

# THE MESOPROTEROZOIC NAIN PLUTONIC SUITE AND ITS COUNTRY ROCKS IN THE KINGURUTIK LAKE–FRASER RIVER AREA, LABRADOR (NTS 14D/9 AND 16)

B. Ryan and D. James  
Regional Geology Section

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## ABSTRACT

*The Kingurutik Lake–Fraser River area was mapped during the summer of 2003. The region is dominated by plutonic rocks of the Mesoproterozoic Nain Plutonic Suite (NPS), which here comprises mostly anorthosite and leuconorite. Variations in texture, layering, and intrusive contacts have been employed to subdivide these rocks into more than two dozen geological units, many of which represent separate plutons. Granitoid rocks comprise two major units, and both are intrusions that post-date and predate some of the abutting leuconoritic rocks. There is one significant ferrodiorite intrusion. Troctolitic rocks are rare, being present only as a couple of zones of mottled leucotroctolite that may be variants of the anorthositic rocks. A diverse group of older rocks borders the NPS plutons. Among these rocks are massive, but recrystallized, anorthosite and leucogabbro of presumed Paleoproterozoic age. More extensive are gneissose anorthositic to leucogabbroic rocks and associated granulite-facies, quartzofeldspathic migmatites and mesocratic rocks that appear to be both Archean and Paleoproterozoic. Geochronological studies are underway to determine the absolute age of several NPS intrusions, as well as some of the enigmatic anorthositic and gneissic rocks marginal to them. Both the NPS and the older rocks have small base-metal showings.*

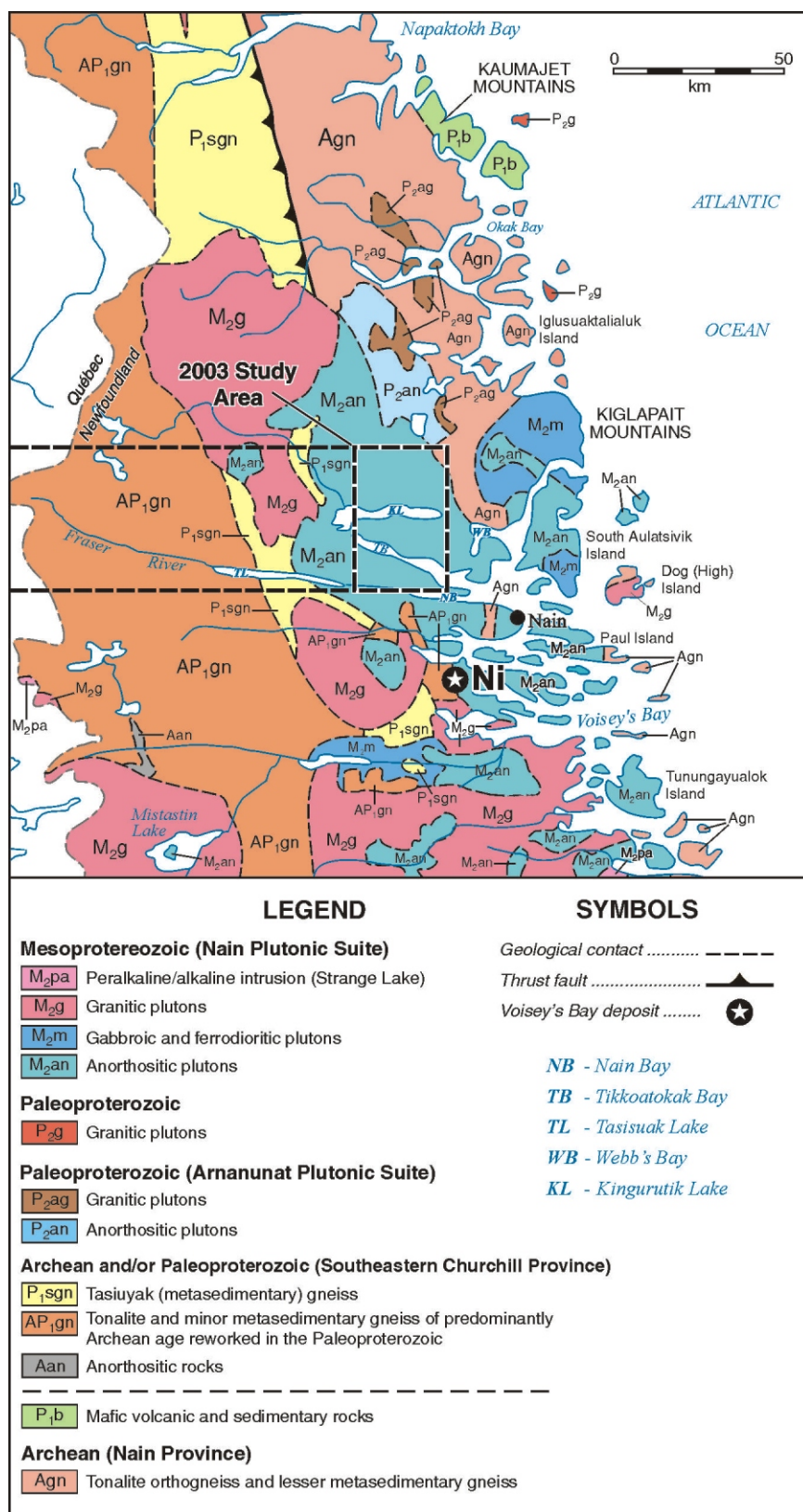
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## INTRODUCTION

The Mesoproterozoic Nain Plutonic Suite (NPS) of northern Labrador is an amalgamation of plutons displaying a spectrum of rock compositions – from troctolite to granite. These aggregated plutons cover a north–south elongate area of nearly 20 000 km<sup>2</sup>, straddling a Paleoproterozoic continental collisional suture between the Archean Nain Province and the Archean to Paleoproterozoic Churchill Province (Figure 1). The NPS can be confidently classed as a batholith using the accepted definition (Bates and Jackson, 1987, p. 59). The predominant plutons within the batholith are (a) leuconorite and anorthosite and (b) quartz monzonite and granite. Subordinate to these are plutons of gabbro and troctolite, as well as lesser Fe-rich diorite and associated monzonite. Initial attempts at a broad-scale subdivision of the NPS were made by Wheeler (1960, 1969), arising from many years of field work in the Nain area. Investigators such as Berg (1974) and Wiebe (1978) went a long way to establishing reliable local relationships between various intrusions, but Morse (1983a), using a geographically limited data base, was the first to undertake the onerous task of establishing a region-wide relative temporal sequence for pluton emplacement within the NPS. Morse (*op. cit.*) restricted most of his discussion to the basic rocks that had been his main research focus for over a decade.

Few precise radiometric ages were available from rocks of the NPS prior to the early 1990s. The data that were available up to that time – mostly Rb–Sr and <sup>40</sup>Ar/<sup>39</sup>Ar isotopic ages – were used to postulate that the formation of this batholith likely took no more than 20 to 30 million years (*cf.* Snyder and Simmons, 1992; Yu and Morse, 1993). The subsequent recognition of zircon within the anorthositic and leuconoritic rocks of the NPS, along with its abundance in many of the felsic and intermediate rocks, allowed for application of U–Pb geochronology to a wide spatial and compositional array of NPS intrusions (*cf.* Hamilton *et al.*, 1994). By the mid-1990s, the U–Pb dates being determined made it apparent that magmatism responsible for the formation of the batholith was more protracted than previously proposed, probably in excess of 60 million years – occurring from 1350 Ma to 1290 Ma. (*cf.* Ryan and Emslie, 1994).

Systematic mapping by the Geological Survey of Newfoundland and Labrador (GSNL) and the Geological Survey of Canada (GSC) since the mid-1990s has considerably clarified the picture of the internal architecture of the NPS. The mapping has shown the interfering and nested form of the intrusions, given insights into the geometry of some of the intrusions, and documented the distribution of deformed and recrystallized rocks within the batholith. Age determinations have unequivocally demonstrated the longevity of the NPS



**Figure 1.** Regional geology of north-central Labrador, showing the distribution of the Nain Plutonic Suite and its surrounding rocks. Outlined area is the northern half of NTS sheet 14D corridor to be mapped at 1:50 000 scale over the life of the project; 2003 map area (14D/9, 16) is highlighted.

magmatism, and have shown that plutons of widely contrasting compositions within the batholith were emplaced contemporaneously in differing areas (Hamilton *et al.*, 1994).

The need to better define the spatial and temporal distribution of the plutons comprising the NPS became critical after the discovery of a major deposit of Ni–Cu–Co sulphide in a troctolitic intrusion near Voisey’s Bay (*cf.* special issue of Economic Geology, Volume 95, 2000). This deposit occurs in one of the oldest (ca. 1333 Ma) mafic intrusions of the NPS, it has a discrete spatial relationship to the intrusion, and it is seemingly the product of interaction between the troctolitic magma and sulphurous metasedimentary country-rock gneisses. The exploration frenzy precipitated by the discovery led a plethora of companies to undertake both limited and extensive exploration programs within other parts of the NPS and its envelope rocks. Numerous uneconomic sulphide prospects were discovered during the exploration in the interior of the NPS, but the lack of regional knowledge at that time inhibited any “stratigraphic” or “genetic” classification (*viz-à-viz* the Voisey’s Bay deposit) of the mineralization.

The GSNL, in a joint venture with the GSC, undertook a regional mapping program in 1996 to survey the northernmost part of the NPS, in sufficient detail, to place the newly discovered prospects there, as well as any heretofore undiscovered mineralization, in the context of their regional surroundings (Ryan *et al.*, 1997; Ermanovics *et al.*, 1997). That program, and others conducted by the GSNL in the next few years, were successful in demonstrating several ages, hosts and styles of mineralization (*cf.* Ryan *et al.*, 1997; Kerr, 1998; Kerr and Ryan, 2000).

The GSNL has now shifted its investigative focus to the north-central interior part of the NPS. The current program is aimed at 1:50 000-scale mapping of the northern half of the 1:250 000-scale NTS

map-sheet 14D, covering an area from the coast of Nain Bay west to the Québec border (Figure 1; Ryan and James, 2003). It will provide a transect across the NPS and its bordering gneisses. The 2003 field season was devoted to the eastern part of the transect, an area dominated by rocks of the NPS (Figure 1). NTS map-sheets 14D/9 and 14D/16 had been slated for examination; the whole of the latter sheet was examined, but only about half of the former. The field work was conducted between July 12 and September 12 from an operations base in Nain, and was accomplished by helicopter-support for positioning the ground traversing crews and for supplementary spot-checking of outcrops.

### PHYSIOGRAPHY OF SURVEY AREA

The surveyed region is mostly rugged and barren. It is dominated by smooth-topped mountains and elongate ridges separated by steep-walled valleys. Numerous topographic linears crisscross the landscape, in some cases reflecting the presence of ice-plucked basic dykes. Mountainous terrain, having local relief on the order of 3000 feet (ca. 1000 m), comprises most of the region north of Tikkoatokak Bay, the imposing Mount Lister rising from the ocean at the entrance to the bay being an example. Spectacular undercut or overhanging cliffs about 2000 feet (ca. 700 m) high form the southern walls of two valleys west of “Iviangiuyakh<sup>1</sup> east flank big lakes” in the northwest corner of the area (Plate 1).

Significant stands of coniferous trees occur only in low-lying areas, especially south of Tikkoatokak Bay. The higher country supports a diminutive Alpine flora, clinging to cracks in bare or lichen-encrusted bedrock and rooted in a veneer of glacial gravels; willows and dwarf birch abound along the banks of some brooks.

### PREVIOUS WORK

Geological investigations in the Kingurutik Lake region began with the initial and pioneering reconnaissance study of Wheeler (1942). Christie (1952) subsequently integrated some of Wheeler’s data with his own regional mapping of the interior and north coast of Labrador. A small area south



**Plate 1.** *Rugged and barren landscape that typifies the 14D/16 map area. View is southwest across “Iviangiuyakh east flank, southeast lake”. Overhanging cliff in centre is about 2000 ft (700 m) high. Brown rocks to right are leuconorite and anorthosite (Unit 33) that are younger than the massive pale-grey to white anorthosite (Unit 13) underlying the ridge beyond the lake.*

of Tikkoatokak Bay was briefly examined, in a more focussed manner, by British Newfoundland Exploration (BRINEX) during a Labrador-wide search for base metals and uranium in the 1950s (*cf.* Grimley, 1955). Apart from E.P. Wheeler’s continuing mapping, the Nain Bay–Kingurutik Lake area received very little geological attention during the next decade. A concerted effort to understand the origin of anorthositic rocks began in the Nain region in 1970 (Morse, 1970), and over the next ten years the “Nain Anorthosite Project” (NAP) contributed substantially to unraveling some of the complexities of the NPS. As part of the NAP, Morse and Wheeler (1974) presented preliminary observations on layered and deformed anorthositic rocks bordering Tikkoatokak Bay, building on a foundation of Wheeler’s earlier work. They introduced the names “Bird Lake massif”, “Susie Brook slab” and “Lister massif” for three large anorthositic bodies located there; these subdivisions are herein referred to by a modified nomenclature (*see* subsequent sections on the anorthositic rocks and on stratigraphic problems). Morse (1983b) traversed part of the “Bird Lake massif” south of Tikkoatokak Bay, mostly to the west of the present study area. Small intrusions, such as the one on Ukpaume Island, were subjected to more rigorous study (Deuring, 1977). By the time it was terminated, the NAP had assembled a remarkable and invaluable archive of information (*cf.* Morse, 1983c).

<sup>1</sup> “Iviangiuyakh” is an Inuit term meaning “the breast-like one”, and refers here to a 2800 foot (700 m) mountain 4 km west of the study area (56°58’N, 62°36’W), having twin, rounded summits (*see* Wheeler, 1953, p. 28). The lake reference is adapted from an unpublished report by Wheeler.

One of the writers (B.R.), as well as R.F. Emslie of the Geological Survey of Canada, briefly visited the Tikkoatokak Bay–Kingurutik Lake area in the early 1990s (*cf.* Ryan, 1992, 1993); some of the rocks were sampled, but no systematic investigations were made at that time. Following the discovery of the Voisey’s Bay deposit in 1993, the whole NPS, as noted above, became an exploration target, and the Nain Bay–Kingurutik Lake area received its share of attention for a few years thereafter. Several uneconomic base-metal prospects were discovered and reported in exploration-company press releases, but few such discoveries went beyond the surface sampling stage nor did many warrant significant follow-up work.

## RESULTS

The general attributes of the geology of the 2003 survey region had been established by previous workers, namely, gneisses of Archean and Paleoproterozoic age intruded by the Mesoproterozoic NPS. The 2003 project was aimed at refining the known distribution of these main rock units, at addressing finer subdivisions within these broad units, and at tackling local stratigraphic problems that had become obvious from previous work here and in neighboring areas. The geological field information (Figure 2) is presented below in the following order: (i) gneissic rocks considered to be Archean and Paleoproterozoic, (ii) plutonic rocks considered to be Paleoproterozoic, and (iii) Mesoproterozoic intrusions of the NPS.

### GNEISSIC COUNTRY ROCKS ABUTTING THE NPS

Gneissic rocks are exposed as the eastern envelope to the NPS northeast of Kingurutik Lake, and as septa between plutons north of Kingurutik Lake and crossing Tikkoatokak Bay. Each area has a slightly differing assemblage of rocks, and even within each of the three assemblages there is great diversity. The ages of these rocks have not yet been determined – they could range from Archean to Mesoproterozoic – but as a first-pass correlation, those northeast of Kingurutik Lake are assigned to the Nain Province and those to the north of Kingurutik Lake and crossing Tikkoatokak Bay are assigned to the Churchill Province.

The deformed layered rocks abutting the NPS northeast of Kingurutik Lake are dominated by compositions of gabbro-norite, leucogabbro-norite, and anorthosite. These are bordered to the east by quartzofeldspathic gneisses. The unit north of central Kingurutik Lake comprises mostly mesocratic gneisses, but also includes a series of rocks derived from a layered melagabbro-noritic to anorthositic intrusion. Most of the gneisses in the Tikkoatokak Bay septum are diffusely layered, mesocratic, gabbro-noritic rocks, but also present are quartzofeldspathic migmatites and metasedi-

mentary gneisses. The granulite-facies metamorphism exhibited by all the rocks seems to be a regional event, but some rocks have the granular aspect that may signify an overprint of pyroxene hornfels contact metamorphism from the proximal intrusions.

### GNEISSES NORTHEAST OF KINGURUTIK LAKE (UNITS 1 AND 2)

#### Leucogabbro-noritic and Associated Rocks (Unit 1)

This group of rocks directly abuts the NPS from Iglusuataliksiak Lake southeastward to the eastern end of Kingurutik Lake. These deformed metabasic rocks have been, since their recognition by Wheeler (1942), somewhat of an enigma in the regional picture. In overall field aspect and composition they are similar to basic members of the NPS, as well as to a Paleoproterozoic-aged group of basic igneous rocks west of Iglusuataliksiak Lake (*see* following descriptions of Paleoproterozoic intrusions and discussion of regional stratigraphic problems). Wheeler (1942, p. 630) initially included them with the “marginal facies of the [NPS] anorthositic intrusive .....because of the spatial relations and the resemblances in mineral compositions”, but later he (Wheeler, unpublished) opted to refer to them as “granulites of uncertain origin”. Ryan (1993) briefly examined these rocks between Iglusuataliksiak Lake and Webb’s Bay (east of the current study area, Figure 1), and proposed, on the basis of field and petrographic criteria, that they were significantly older than the NPS. This pre-NPS stratigraphic position was verified by a U–Pb crystallization age of ca. 1873 Ma for zircon separated from a foliated, pink, aplitic, granitic dyke that has intruded the deformed basic rocks just to the east of the area shown in Figure 2 (Connelly and Ryan, 1999).

The field character of the rocks within this metaplutonic unit is quite diverse, even in individual outcrops (*cf.* Ryan, 1993, Plates 3, 4). The rocks are mainly white-weathering, but are more of a pale, maple-sugar brown at the southernmost extent of the unit northeast of Kingurutik Lake. Compositions range from anorthosite to melagabbro-norite; in places, these two rock types form alternating layers in association with leucogabbro-norite. The rocks are regionally deformed and recrystallized (Plate 2), but to varying degrees, and hornblende and biotite are widespread. The heterogeneity of the superposed deformation and metamorphism allows for local preservation of primary igneous characteristics at one extreme and a distinctly gneissic rock at the other. Melanocratic lenses and layers are locally present, in some cases clearly derived from mafic dykes, and several generations of white to pink leucogranitic veins and dykes are evident.

### **Quartzofeldspathic Gneisses (Unit 2)**

Quartzofeldspathic rocks in the Iglusuataliksiak Lake area are not as well exposed as the anorthositic unit described in the previous section. They are evident only in a few outcrops on a ridge just west of the lake, and are assumed to continue southeastward beneath a thick blanket of sand and swamp, to appear again outside the present study area on the east side of the Webb's Brook valley and near Webb's Bay (Ryan, 1993). The main rock type within this subdivision, in the survey area, is a granulite-facies migmatitic gneiss of enderbitic to charnockitic composition, having lenses and layers of mafic rock. A narrow screen of gneissic rocks, having numerous sills of white leucogranite, is also exposed north of the east end of Kingurutik Lake. These, however, lack the migmatitic features of the ones near Iglusuataliksiak Lake, and a sample examined petrographically is a deformed rock of mangeritic composition that has an abundance of opaque oxide, apatite and zircon, mineralogical attributes in common with NPS ferrodioritic rocks. Inclusions of anorthositic and leucogabbroitic rocks similar to those of Unit 1 to the west are present both in the Iglusuataliksiak Lake outcrops and in the unit north-east of Kingurutik Lake. Foliations in the rocks assigned to this unit vary from chaotic to laminar, the latter style in the screen near Kingurutik Lake.

### **GNEISSES NORTH OF KINGURUTIK LAKE AND CROSSING TIKKOATOKAK BAY (UNITS 3 to 7)**

#### **Mesocratic Gneisses (Unit 3)**

The predominant gneissic rocks to the north of Kingurutik Lake are quartz-poor, grey-green-weathering, diffusely layered ones, locally having abundant "ribs" of subparallel granitic veinlets. These mesocratic rocks seem to be of gabbroitic composition, but may range through to two-pyroxene enderbite. Leucocratic layers of overall anorthositic composition are locally present. Also part of this septum are folded to laminar-layered quartzofeldspathic migmatites, having massive mafic layers derived from basic dykes (Plate 3). Metasedimentary rocks, perhaps equivalent to the Tasiuyak gneiss to the west (Figure 1), are volumetrically minor components within this group of gneisses, but are easily recognizable by their generally orange-brown-weathering and/or their abundance of blue cordierite replacing original garnet and sillimanite. The cordierite is subordinate to aggregates of dark-brown hypersthene in the paragneisses directly adjacent to anorthositic plutons.

### **Layered Olivine Gabbroite and Leucogabbroite (Unit 4)**

A well-layered succession of brown-weathering, olivine-bearing, melagabbroite and pale-grey to white leucogabbroite was outlined north of Kingurutik by Wheeler (unpublished), who designated it as another belt of "granulites of uncertain origin". One of the writers (B.R.) visited it in 1991 (Ryan, 1992), noting its derivation from a layered igneous intrusion, and recording that it predated an NPS leucogabbroite to the east of it. This layered sequence was subsequently examined in 2002, and was assigned to the NPS (Ryan and James, 2003). Traverses of its surroundings during the 2003 field season indicate that, in spite of its well-preserved character and lack of migmatization, and its possible genetic link to the NPS, it seems to be an integral part of the pre-NPS gneissic envelope of this area. If that is indeed the case, it has no extensive counterpart elsewhere in this septum of gneisses, although an outcrop of olivine-bearing melagabbroitic rocks immediately east of Seal Bay on the south side of Kingurutik Lake (Unit 18) may be another fortuitously preserved example. The main group of layered rocks comprises alternating and strike-variable, brown, variably serpentinized, olivine-bearing melagabbroite and pale-grey, olivine-free, leucogabbroite. Layering of the leucocratic and melanocratic components is on the order of centimetres to metres, and narrow (<20 cm wide) meta-anorthosite sheets intrude it. Layer-parallel lenses and screens of cordierite-bearing (Tasiuyak?) paragneiss (interpreted to be a pyroxene-hornfels) are locally enclosed by the gabbroitic-layered rocks, perhaps an indication that the sequence was emplaced into the gneisses as a series of sills.

#### **Gabbroitic, Metasedimentary, and Quartzofeldspathic Gneisses (Units 5 to 7)**

The belt of gneissic rocks crossing Tikkoatokak Bay comprises, on its eastern side, metaplutonic rocks of gabbroitic to anorthositic composition (Unit 5), and, on its western side, quartzofeldspathic gneisses (Unit 6). Interspersed with these are metasedimentary rocks, the largest belt of which occurs on the south side of Tikkoatokak Bay (Unit 7).

The gabbroitic and anorthositic rocks (Unit 5) are pale-brown- to white-weathering, are generally granular, and locally have a well-developed, streaky, foliation defined by combinations of pyroxenes, hornblende, and biotite in a feldspar matrix. Layers or lenses of melanocratic composi-

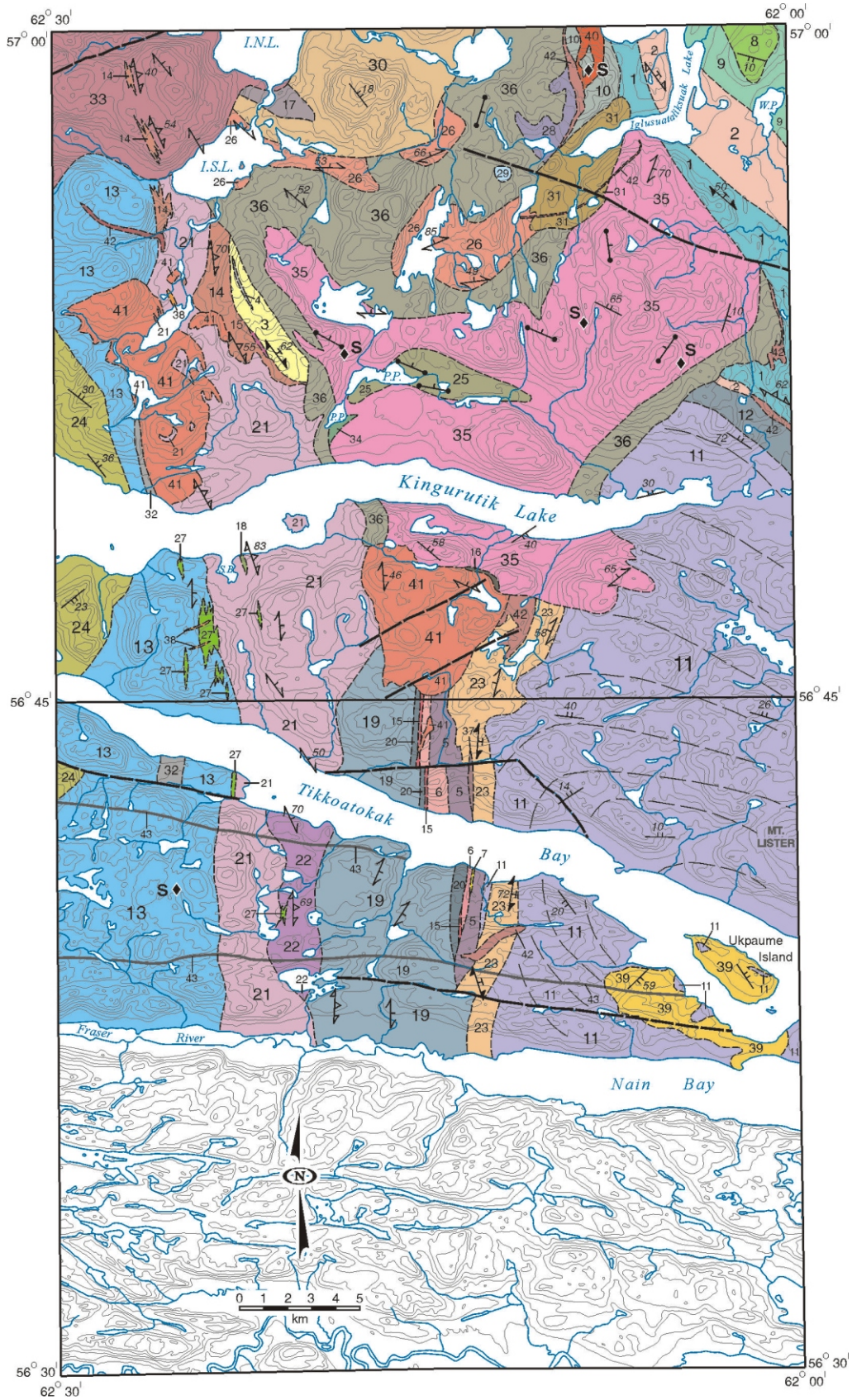


Figure 2. Caption and legend on page 241.



**Figure 2.** Geological map of the Kingurutik Lake–Tikkoatokak Bay area, based on investigations in 2003. Abbreviations: S.B = Seal Bay, P.P. = Polygon ponds, W.P = Webb’s Pond, I.S.L = Iviangiuyakh east flank, southeast lake, I.N.L = Iviangiuyakh east flank, northeast lake. Numbering of units in legend does not necessarily reflect relative age of the units.

tion, on the scale of several tens of centimetres in width and seeming to be peridotite, have been observed within these rocks north of Tikkoatokak Bay. Intrafolial isoclinal folds are present locally. South of the bay, these rocks are diffusely to sharply layered, and retain clear textural relicts of their plutonic parentage.

The quartzofeldspathic gneisses north of Tikkoatokak Bay (Unit 6) are rocks that exhibit a layering varying from folded and chaotic to finely laminated and mylonitic-like. A migmatitic aspect is locally prevalent, as are veins of bluish-grey quartz. Lenses and layers of mafic, ultramafic, and metasedimentary rocks are dispersed throughout the quartzofeldspathic gneisses.

Garnet–cordierite semipelitic and quartzitic (Tasiuyak?) paragneisses form narrow layers within the quartzofeldspathic gneisses at several localities north of Tikkoatokak Bay, but they have their greatest extent directly south of the bay (Unit 7). Here, they are bordered on their western side by foliated, garnetiferous, enderbitic rocks.

#### **PALEOPROTEROZOIC INTRUSIONS (ARNANUNAT PLUTONIC SUITE, UNITS 8 to 10)**

Three types of basic intrusive rocks in the Iglusuataliksuak region are assigned a Paleoproterozoic age. These are (i) layered melanocratic rocks (Unit 8) and (ii) leucogabbro (Unit 9) east of Iglusuataliksuak Lake and (iii) anorthositic to leucogabbroanorthitic rocks (Unit 10) to the west of the lake. The leucocratic rocks superficially resemble basic members of the NPS, but a Paleoproterozoic age is advanced for them because they are interpreted to be the southward continuations of plutons to the north that are known to be Paleoproterozoic (*cf.* Hamilton *et al.*, 1998). The name Arnanunat plutonic suite (APS) has been proposed for this older, NPS-like, plutonic terrane (*cf.*, Ryan *et al.*, 2003).

##### **Well-layered Melanocratic Rocks (Unit 8)**

This unit outcrops on several adjacent hills north of Webb's Pond, and is another example of rocks that Wheeler (unpublished) had assigned to "granulites of uncertain origin". It is the southern continuation of a belt of layered gabbroanorthite ("mafic granulite") and associated melanocratic to ultramafic rocks in the vicinity of Iglusuataliksuak Lake that was initially outlined by Ryan *et al.* (1997). Similar rocks crop out sporadically on the adjoining map-sheet to the east–southeast of Webb's Pond and north of Ado's Brook (Ryan, 1993). In the present study area, they comprise variably recrystallized gabbroanorthite to leucogabbroanorthite. Outcrops typically display a well-developed to indistinct layering defined by varying percentages of mafic minerals. Locally, rocks have a weak foliation defined by the align-

ment of mafic minerals. Many outcrops contain pink- to white-weathering granitoid veins having abundant bluish-grey quartz; some veins also contain coarse clinopyroxene. The layered rocks are intruded by the adjacent leucogabbro (Unit 9) and by a swarm of south- to southeast-striking mafic dykes, and all exhibit a greenschist-facies metamorphism.

The assignment of this unit of layered rocks to the APS is tenuous because the age of magmatism represented by these layered rocks is not firmly established. It is certainly Paleoproterozoic or earlier because the rocks are intruded by the adjacent leucogabbro (Unit 9), which itself is intruded by ca. 2044 Ma metadiabase dykes (Hamilton *et al.*, 1998). The rocks differ from the regional Archean gneisses by their lack of migmatization and structural complexity, but they could still be Archean and simply postdate the major tectonic events of the other Archean rocks.

##### **Leucogabbro (Unit 9)**

The APS leucogabbro pluton (Unit 9) to the east of Iglusuataliksuak Lake is, as noted above, intruded into the proximal layered melanocratic rocks (Unit 8). This pluton is locally weakly deformed, is mildly metamorphosed, is hardly recrystallized, and is the southward continuation of an intrusion provisionally named the Iglusuataliksuak Lake pluton that continues northward about 10 km onto map sheet 14E/1 (Ryan *et al.*, 1997). Primary gabbroic texture is well preserved, the main manifestation of a metamorphic overprint being replacement of the original clinopyroxene by actinolite. Metagabbro and metadiabase dykes intruded into the leucogabbro exhibit the same metamorphism as the host.

##### **Leucogabbroanorthitic to Anorthositic Rocks (Unit 10)**

Leucogabbroanorthitic to anorthositic rocks (Unit 10) to the west of Iglusuataliksuak Lake are identical to a Paleoproterozoic assemblage to the north that has been assigned to the Aupalukitak Mountain pluton (B. Ryan, unpublished data). Grain morphology is usually granular, and on the order of a few millimetres, but the preservation of primary medium-grained to pegmatoidal textures is widespread (Plate 4). The latter have relicts of feldspars on the order of tens of centimetres, whereas the associated pyroxene (originally pigeonite?) has recrystallized to granular aggregates of clino- and orthopyroxene having associated hornblende and biotite. Characteristic of this pluton are deformed mafic dykes varying from granular, black, homogeneous melagabbroanorthite ("mafic granulite") to grey- and brown-weathering, fine-grained, "biotite granulites". The latter type of dyke locally has compositional and textural variations that can be attributed to interaction and hybridization with contemporaneous granitic magma, features akin to some ferro-



diorite rocks within the NPS. Most such dykes within the Aupalukitak Mountain intrusion display a sigmoidal or a wall-parallel foliation, and they are assumed to have been emplaced while the host was still hot and at a crustal level where the “granulite” assemblage was stable. It is of interest to note that no greenschist-facies metadiabase dykes, like those found in the leucogabbro pluton to the east of the lake, are evident in this intrusion, nor are there “granulite” dykes in the latter pluton.

It is worthy of note that the APS pluton to the west of Iglusuataliksiak Lake bears a strong compositional resemblance to leucogabbroic and anorthositic “gneisses” (Unit 1) that directly border it to the east; the relation between the two units is unclear because the outcrop continuity required to establish whether an intrusive, transitional or faulted contact exists is lacking. However, a folded foliation in the rocks of Unit 1, in contrast to a weak single period of deformation in Unit 10, may be cited to temporally separate the two.

#### **MESOPROTEROZOIC INTRUSIONS (NAIN PLUTONIC SUITE, UNITS 11 to 42)**

The most abundant rocks in the survey area belong to the NPS, and they encompass the whole gamut of compositions that comprise the batholith regionally. Anorthositic and leuconoritic plutons are predominant within the NPS here, followed by monzonitic to quartz monzonitic intrusions; ferrodiorite comprises the third largest component, whereas troctolitic rocks are very minor (Figure 2). Few of the NPS intrusions have been assigned formal stratigraphic names to date.

The anorthositic and leuconoritic components are rather monotonous rock masses on a regional scale. Contacts between them vary from subtle to abrupt. In spite of the monotony, the rocks have been subdivided into their various textural types. Such divisions provide clues to the internal character and/or distribution of different intrusions, but in many cases insufficient “ground truthing” is available to demarcate firm boundaries or establish the relationship between surmised individual intrusions. The task of outlining the general distribution of the other compositional subdivisions (e.g., ferrodiorite, quartz monzonite) of the NPS is a little less daunting because these compositionally distinct rocks occupy less area, they are texturally different from the anorthositic and leuconoritic rocks, and they have very abrupt contacts with their hosts. Rather than address each of the more than thirty NPS units shown in Figure 2, some of their general features are summarized, and a few details on specific subdivisions are provided only as an indicator of the character that allowed the separation of these rocks from those compositionally similar rocks nearby. It should be

emphasized that relative ages have not been established between all of the plutonic subdivisions illustrated on Figure 2. No doubt, many of these subdivisions constitute individual intrusions, but in most cases, as noted above, reliable contacts have not been established. Where relative ages have been documented, these have allowed erecting, locally at least, a plutonic stratigraphy.

#### **Anorthositic and Leuconoritic Rocks**

These rocks vary considerably in their field aspects, having colours that range from white to grey to mauve to pink, grain sizes that vary from millimetres to tens of centimetres, feldspar shapes that range from anhedral granular to euhedral tabular, and overall textures that range from granular (recrystallized and adcumulate) to subophitic to “clotted” (poikilitic). Primary magmatic planar features include feldspar lamination and aligned streaks of orthopyroxene, in some cases in concert with an igneous layering. Some of the aforementioned diversity in field features are found at local scale, where they can be demonstrated as simply variances within a single intrusion. Continuity of one or more of these features at 1:50 000 map-scale provides a field means to separate individual intrusions. Most of the anorthositic and leuconoritic plutons are undeformed and exhibit delicate primary mineral relations, although significant areas display profound modification of these primary textures by deformation and recrystallization. These deformed and recrystallized rocks are demarcated as separate units on Figure 2, although in some cases they are subdivisions of otherwise massive intrusions. The structural modifications were, in most cases, imprinted following crystallization because primary rock textures are preserved among the deformed ones, the latter being a variant of the former. In other cases, however, the fabrics exhibited by the leuconoritic rocks appear to have been imposed prior to full consolidation and without significant recrystallization, e.g., oikocrysts of orthopyroxene having a preferred orientation can be seen in rocks lacking feldspar recrystallization, and these oriented oikocrysts enclose laminated or random feldspar tablets.

Pegmatoidal anorthositic bodies located on the eastern and western sides of the study area are assumed to be the oldest NPS intrusions in the area. The eastern one is the Mount Lister intrusion (Units 11 and 12), a large pluton that extends off the present map-areas to the east (Ryan, 1993, 2001), and originally referred to by Morse and Wheeler (1974) as the “Lister massif”. The western one (Units 13 and 14) is correlated with similar rocks termed the Pearly Gates intrusion to the south of the Fraser River (Ryan, 1993), the “Bird Lake massif” between the Fraser River and Kingurutik Lake (Morse and Wheeler, 1974; Morse, 1983b), and the Ikatsiak Brook intrusion northwest of the present study-area

(Ryan *et al.*, 1998). The name Pearly Gates intrusion is employed in this paper for all of these western rocks.

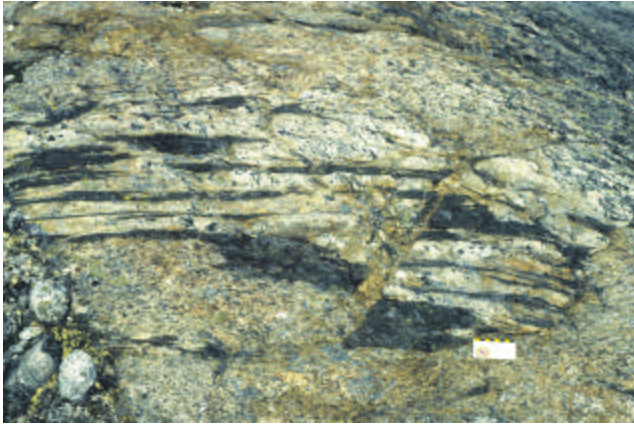
The northeastern margin of the Mount Lister intrusion, abutting a preserved narrow wedge of gneissic country-rock, is a zone comprising deformed, layered, anorthosite and leuconorite (Unit 12). Within this marginal zone, layer-parallel, lenticular aggregates and lozenge-shaped remnants of coarse orthopyroxene define a steeply northeast-dipping fabric. The primary compositional layering in the interior, coarse-grained to pegmatoidal, part of the intrusion (Unit 11) is not masked nor modified by deformation. The layering directly west of the marginal zone has an orientation similar to that of the deformed rocks, but distal from the margin – along Kingurutik Lake and north of Tikkoatokak Bay, for example – the pluton displays a very gently inclined, diffuse, layering. Limited observations of the attitude of this layering to the south indicates that overall it has a domal form, consistent with attitudes measured to the east (Ryan, 2001). Indigenous to the Mount Lister intrusion north, of Ukpaume Island, is a series of gently inclined, foliated, composite ferrodiorite–monzonite dykes.

The northwest extent of the Mount Lister intrusion, in the study area, is defined by its contact with a younger group of anorthositic and leuconoritic rocks (Units 35 and 36), rocks that truncate the Mount Lister planar structures both at outcrop and map scale (Figure 2). The western extent of the Mount Lister intrusion is equivocal. An elongate body of grey to brown, clotted-textured to subophitic leuconorite and anorthosite (Unit 23) is intrusive into it north and south of Tikkoatokak Bay, separating it from gneisses to the west. Insufficient data are available to characterize the full extent of this younger intrusion, so its distribution on Figure 2 must be considered as being suspect because some of the rocks presently assigned to it are superficially similar to those of the Mount Lister itself. The foregoing statement highlights a problem that was addressed last year (Ryan and James, 2003), namely, that the eastern margin of the Mount Lister intrusion displays a clear “structural” contact with adjacent gneisses (i.e., a foliated zone), but its western contact against older rocks seems to either lack this characteristic or it has been exploited by a superficially similar younger intrusion.

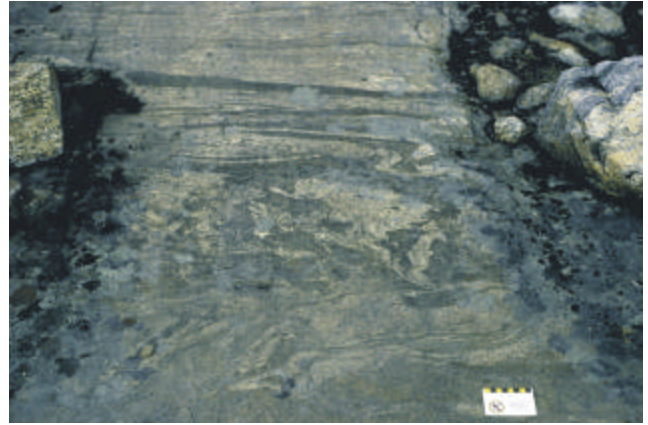
Most of the rocks exposed in the high country along the western side of the study area are massive, coarse-grained to pegmatoidal, mildly recrystallized, white anorthosite (Unit 13). All these rocks are assigned to the interior zone of the Pearly Gates intrusion, although they may, in fact, represent more than just one pluton. A region of foliated and recrystallized leuconorite and anorthosite in excess of a kilometre in width (Unit 14) abutting the gneisses of Unit 3 south of

“Iviangiuyakh east flank, southeast lake” is assigned to a marginal zone of the Pearly Gates intrusion. Like the eastern margin of the Mount Lister intrusion in the Nain area (Ryan, 2000a, 2001), the deformed and recrystallized rocks of the Pearly Gates margin are locally separated from the adjacent gneisses by foliated olivine–clinopyroxene monzonite (Unit 15). The marginal zone rocks are similar to those of the Mount Lister intrusion in comprising recrystallized and foliated leuconorite in which orthopyroxene streaks and lozenges define a foliation, and anorthosite that has a variably recrystallized granular texture. The Pearly Gates marginal zone directly south of “Iviangiuyakh east flank, southeast lake” seems, however, to have been wider than that of the Mount Lister intrusion, but this could be a function of it being pried apart in this area by intrusion of the “giant-pyroxene” anorthosite (Unit 21, *see* following paragraph). The narrow north–south belt of foliated rocks (Unit 20) abutting the western side of the gneisses that cross Tikkoatokak Bay may be a continuation of the Pearly Gates foliated zone. If this is the case, however, the more massive leuconoritic rocks (Unit 19) to the west of it are examples of rocks not seen at the same relative stratigraphic location in the north. A foliated monzonite (Unit 15) locally separates foliated rocks from the gneisses here too, in an analogous setting to that seen north of Kingurutik Lake.

“Giant-pyroxene” anorthosite (Unit 21) constitutes a distinct north–south-trending belt of rocks that can be traced from the south shore of “Iviangiuyakh east flank, southeast lake” to near the Fraser River. The unit comprises pale-grey to mauve, adcumulate-like, recrystallized anorthosite, characterized by the widespread occurrence and local abundance of single crystals, and/or multi-crystal pods, of large, irregular, brown to black, orthopyroxene. Pyroxenes measuring several tens of centimetres on a side are prevalent, and some podiform aggregates reach up to several metres in maximum dimension. At several localities south of “Iviangiuyakh east flank, southeast lake” coarse pyroxene forms interconnecting vein arrays that enclose numerous angular fragments of the surrounding grey anorthosite. The “giant-pyroxene” anorthosite is certainly intruded into, and excises much of, the foliated marginal zone of the Pearly Gates intrusion to the north of Kingurutik Lake, and by inference (contact not examined) must be younger than the pegmatoidal anorthosite of the interior zone to the west as well. Contacts against the foliated marginal zone are marked by rafts of deformed leuconorite within, and having their fabrics truncated by, the “giant-pyroxene” anorthosite (Plate 5). The relationship with other anorthositic rocks south of Kingurutik Lake is yet to be determined, but it is interpreted to be younger than the deformed poikilitic leuconorite (Unit 22) that occurs south of Tikkoatokak Bay.



**Plate 2.** Heterogeneity in grain size, texture, and foliation development in deformed meta-leucogabbro to meta-anorthosite of Unit 1 northeast of Kingurutik Lake. Coarser white rock here seems to have been a raft in the finer brown one.

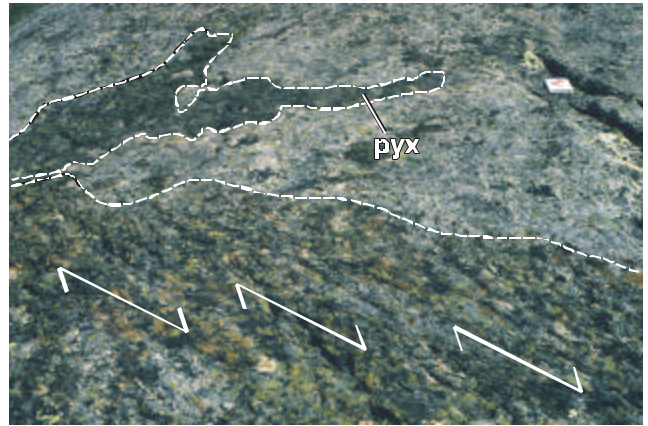


**Plate 3.** Folding of a migmatitic layering intrafolial to a more regular “straightened” layering in quartzofeldspathic gneisses (Unit 3), a component of the septum of more mesocratic rocks north of Kingurutik Lake. Topmost dark layer here may have been a mafic dyke.



**Plate 4.** Recrystallized anorthosite assigned to the Aupaluk-itak Mountain intrusion (Unit 10) west of Iglusuataliksuaq Lake, showing original grain relations between feldspar and pyroxene. The igneous pyroxene has recrystallized to an aggregate of orthopyroxene, clinopyroxene and plagioclase, surrounded here by a darker rim having hornblende and biotite; the plagioclase is partly recrystallized to anhedral grain aggregates.

Two groups of poikilitic leuconoritic rocks having a preferred orientation to the long axes of orthopyroxene oikocrysts are worthy of note. The first (Unit 26) occupies several separate outcrop areas east of “Iviangiuyakh east flank, southeast lake”. Here, the fabric within the individual outcrop areas define an easterly trending, arcuate, though discontinuous, form, likely indicating that these disjointed bodies are remnants of a single pluton preserved within a younger intrusion. The rocks east of Iviangiuyakh lakes are mottled brown- to grey-weathering. They have a “clotted” texture in which the fabric comprises aligned, elliptical,



**Plate 5.** Contact between a fragment of foliated leuconorite from the margin of the Pearly Gates intrusion (Unit 14) and younger pale-grey “giant-pyroxene” anorthosite (Unit 21) south of “Iviangiuyakh east flank, southeast lake”. The contact between the two rocks (dashed line) is plainly transgressive to the fabric trace (barbed lines) in the foliated one. An aggregate of coarse orthopyroxene (pyx) has been outlined in the younger rock.

orthopyroxene oikocrysts up to 20 cm long. Plagioclase is variably recrystallized, and mainly medium grained, although grey-weathering laths up to 8 cm long are locally present. Some rocks have a primary plagioclase lamination that is parallel to the long axes of the elliptical orthopyroxene oikocrysts. The second (Unit 22) occurs south of Tikkoatokak Bay, and here the fabric defined by the oikocrysts is mostly north–south. This rock is white weathering, having brown, lenticular oikocrysts of orthopyroxene defining the fabric.

A cusped outcrop area of layered/laminated rocks (Unit 25) has been outlined north of Polygon ponds<sup>2</sup>. These rocks comprise alternating <1-m-thick sheets of light-brown weathering leuconorite and pale pink- to mauve-weathering anorthosite.

Subophitic leuconorite (Unit 36) is a common associate of the anorthositic rocks (Unit 35) throughout most of the central part of the survey area. It may be fortuitous, but all the contacts that have been observed between major outcrop areas of Units 35 and 36 indicate that the leuconoritic rocks are younger than the anorthosite. Most of these leuconoritic rocks are brown-weathering, and their textures range from uniform subophitic to poikilitic or “clotted-textured” (Plate 6). The tabular to equant, grey to mauve, plagioclase feldspars of these rocks rarely exceed 3 cm in size, but dark-grey to black plagioclase megacrysts (perhaps xenocrysts) up to 10 cm are widely distributed and locally prominent. On Figure 2, the distribution of the leuconoritic rocks is illustrated where they are most extensively developed, but this pattern should not be taken to indicate that these are all part of a single intrusion. In fact, both of the leuconorite and anorthosite units (35 and 36) portrayed in the central Kingurutik Lake to Iglusuataliksiak Lake region likely include several different plutons.

An arcuate north-south-trending intrusion comprising layered brown leuconorite and grey anorthosite (Unit 24) crosses the western part of Kingurutik Lake. This gently east-dipping body has been emplaced into massive white anorthosite belonging to the interior zone of the Pearly Gates intrusion, and is the eastern part of a pluton that, based on the regional work of Wheeler (1960, Plate 1), occupies part of NTS map areas 14D/10 and 14D/15 immediately to the west of the present study area.

There are several discontinuous areas of brown- to grey-weathering, speckled, leuconorite (Unit 27) that occur within other anorthositic rocks between Kingurutik Lake and the Fraser River. This leuconorite is older than the massive anorthosite (Unit 13) and the “giant-pyroxene” anorthosite (Unit 21), both of which intrude, and include rafts of, the speckled rock. The largest area of this leuconorite occurs south of Kingurutik Lake, but outcrop-size inclusions are widespread in the general area. The unit is texturally distinctive, in as much as most outcrops of it have oval orthopyroxene “blotches” that contribute to its speckled appearance. Finer grained and more uniform-textured rocks occur locally, a weak layering may be present, and it

has rare coarse orthopyroxene segregations like those in the “giant-pyroxene” anorthosite. Some outcrops have a diffuse layering, and in many areas a foliation can be detected. No discrete, single, continuous intrusion of the speckled leuconorite can be mapped; rather, all outlined areas (Figure 2) seem to be remnants of previously more extensive rocks that are now merely preserved within or between younger intrusions.

### Granitoid Rocks

Granitoid rocks of the NPS, although regionally widespread as metre-scale dykes, form only two, map-scale intrusions in the study area (Unit 41). These intrusions crop out on the north and south sides of Kingurutik Lake, and comprise olivine-augite quartz monzonite and monzonite. The northern pluton is an elongate one, having several satellite intrusions. It appears to represent just the upper part of a more extensive unexposed body. At its northern end, it occupies low ground adjacent to the massive anorthosite of the Pearly Gates intrusion, and plunges northwest underneath this older anorthosite. The southern half has more of an interfingering and sheeted contact with the surrounding anorthosite rocks, and it supports large rafts or roof pendants of these older rocks. Inclusions of the contiguous rocks are widespread, but also present are granulite-facies gneisses that are exotic.

The monzonitic intrusion south of Kingurutik Lake occupies high rolling country otherwise underlain by anorthositic rocks. This intrusion is fine to medium grained, and displays a variation in content of olivine and clinopyroxene that locally produces a diffuse layering. There is a local alignment of mesoperthitic feldspar grains and streaks of mafic minerals that define a weak fabric. At its northern end there are well-layered rocks, having centimetre-scale sills and dykes of olivine-opaque oxide, that appear to be inclusions within the more massive rocks. Anorthositic and gneissic inclusions occur throughout the monzonite intrusion, and along its northern edge it contains inclusions of the mottled leucroctolite (Unit 16) that it abuts. Zircon separated from this monzonite indicates a crystallization age of 1333 Ma (*see* discussion of geochronology below).

Charnockitic to mangeritic rocks assigned to the NPS also outcrop in lesser amounts west of Iglusuataliksiak Lake (Unit 40). These are medium-grained, pale pink- to white-weathering, displaying on freshly broken surfaces the typical green tinge of olivine-bearing rocks. A weak foliation is locally present throughout this unit.

<sup>2</sup> “Polygon ponds” is the informal name used by E.P. Wheeler (unpublished) for two ponds on the north side of the central part of Kingurutik Lake. They are so-named because they are adjacent to a low-lying area displaying a network of frost-induced polygonal patterns on its surface.

### Ferrodioritic and Troctolitic Rocks

The least abundant components of the NPS are represented in the study area by intrusions such as a layered ferrodiorite to monzonite underlying Ukpaume<sup>3</sup> Island and the adjacent mainland (Unit 39), a dyke-like elongate ferrodiorite intrusion to the west of Ukpaume Island (Unit 42), a dyke-like ferrodiorite body west of Iglusuataliksiak Lake (Unit 42), a curved ferrodiorite dyke south of Iglusuataliksiak Lake (Unit 42), and mottled leucotroctolitic bodies between “Iviangiuyakh east flank big lakes” (Unit 17) and south of Kingurutik Lake (Unit 16).

The Akpaume body (Unit 39) is the largest of these intrusions, and has been mapped and described in some detail by Deuring (1976, 1977) who identified the major components as a layered group ranging from ferrodiorite to ferrosyenite. Coarse-grained rocks of gabbroic or dioritic composition (Unit 42) constitute an elongate body west of Ukpaume Island, intruded into gabbroic gneisses and leuconorite; this intrusion contains abundant ilmenite and coarse zircon, and resembles dykes emplaced into the Mount Lister intrusion on the south side of Nain Bay (Ryan, 2000a). Ferrodiorite west of Iglusuataliksiak Lake (Unit 42) is generally fine grained, is in mingled contact with adjacent charnockitic rocks, and it locally displays a spectacular “porphyritic” texture marked by an abundance of dark-grey to black, xenocrystic(?), plagioclase tablets supported by a dark-brown groundmass. The ferrodiorite dyke (Unit 42) south of Iglusuataliksiak Lake is up to 40 m wide, has an arcuate northeast strike, and is a brown- to grey-weathering, medium-grained, granular rock that contains minor amounts of quartz. The dyke locally has a well-developed compositional layering, and it is locally intruded by thin (<20 cm) pink-weathering granitic dykes.

The leucotroctolite bodies (Units 16 and 17) have only been partly outlined; they appear to be variations of anorthosite intrusions rather than parts of distinct troctolitic plutons. Both the one near “Iviangiuyakh east flank, northeast lake” and the one south of Kingurutik Lake are mottled-textured to crudely layered, medium- to coarse-grained, rocks comprising irregular, rusty-red, olivine-rich zones in a white anorthositic host (Plate 7). The latter body has been intruded, as noted above, by the adjacent monzonite pluton.

### Relative Age Relations Established or Surmised, and Extant Geochronology for NPS Intrusions

Some of the map patterns portrayed by abutting NPS intrusions on Figure 2 are clearly indicative of the relative intrusive ages of plutons, but others are not. Some of the field observations with respect to relative ages are discussed below. The following caveat must be borne in mind: some of the units shown likely comprise more than one individual intrusion, and relative ages between parts of such units that have been documented at a certain outcrop may not apply to all the subdivisions where two such composite units are shown in contact on the map. The relative ages are put in the context of absolute ages where appropriate data exist.

The Mount Lister (anorthosite) intrusion (Units 11 and 12) is older than composite, undivided, bodies of mauve anorthosite and brown leuconorite (Units 35 and 36) north of the east end of Kingurutik Lake. This is evident at map scale from the truncation of the foliation and layering of the Mount Lister by the anorthosite–leuconorite units. The map pattern verifies observations of this intrusive relationship at outcrop scale. The Mount Lister intrusion is also older than a grey to brown subophitic leuconorite (Unit 23) south of Kingurutik Lake, the latter intrusion being a sill-like body intervening between white anorthosite of the Mount Lister and the gabbroic gneisses (Unit 5) to the west. The intrusive contact has been observed at two places along the junction portrayed between the two units on the map (Figure 2), one north of Tikkoatokak Bay and one to the south.

The Pearly Gates (anorthosite) intrusion (Units 13 and 14) north of Kingurutik Lake is older than at least five abutting anorthositic to leuconoritic plutons. It also predates the emplacement of the north-northwest-trending quartz monzonite (Unit 41) in the same area. South of the lake, relations have not been firmly established in the field. The foliated margin (Unit 14) of the Pearly Gates (anorthosite) intrusion is intruded by “giant-pyroxene” anorthosite (Unit 21), and, as noted in a foregoing section, this relation is evident from the numerous rafts of foliated rock in the more massive rock, as well as by outcrop-scale and the map-scale truncations of the marginal fabric of the Pearly Gates intrusion where the two come in contact. Massive anorthosite of the interior zone (Unit 13) must also be intruded by the “giant-

<sup>3</sup> This spelling for the island in Tikkoatokak Bay is used on the NTS topographic map (14D/9). Wheeler (1953, p. 12-13) indicates the spelling as “Akpaume”, derived from *akpaumivok*, meaning “it is lower”, an indication that the island is not as high as the land bordering the bay. The latter spelling is also the one that has been applied to the stratigraphic name of the ferrodiorite intrusion underlying the island, and used herein.

pyroxene" anorthosite, but we have not documented this relation in the field. The interior anorthosite of the Pearly Gates intrusion is certainly intruded by layered brown leuconorite (Unit 24) along the western side of the map area. The younger intrusion dips gently eastward beneath the massive anorthosite and contains inclusions of the older rock near its roof. Massive mauve anorthosite and leuconorite (Unit 33) underlying the mountain directly west of "Iviangiuyakh east flank, big lakes" contain metre- to kilometre-scale rafts of deformed leuconorite that are interpreted as being derived from the foliated margin of the Pearly Gates intrusion (Plate 8). This undeformed pluton is also interpreted to truncate the northern part of the anorthositic interior zone of the Pearly Gates intrusion west of "Iviangiuyakh east flank, southeast lake" but a field contact between the two has not been observed. Relations between these two plutons mirror those to the north where mauve anorthosite has risen passively underneath, and into, the margin of the overlying Pearly Gates pluton (there termed the Ikatsiak Brook pluton; Ryan *et al.*, 1997). Undivided brown leuconorite (Unit 36) to the southeast of "Iviangiuyakh east flank, southeast lake" is portrayed as truncating the foliated margin of the Pearly Gates intrusion and its veneer of gneisses; the northern contact is interpreted from the field distribution of the different rocks, but at the southern contact there are sheets of brown leuconorite intruded into foliated marginal leuconorite and the bordering gneisses. The brown leuconorite also intrudes the "giant-pyroxene" anorthosite north and south of Kingurutik Lake.

An elongate quartz monzonite pluton (Unit 41) north of Kingurutik Lake has been emplaced into both the marginal and interior zones of the Pearly Gates intrusion, as well as the giant-pyroxene anorthosite. This intrusion seems to have a hogback form. For part of its western side, it occupies low country buttressed by a line of high ridges underlain by massive anorthosite of the Pearly Gates intrusion (Unit 13). Here it appears to dip westward beneath the anorthosite. The northwestern terminus seems to plunge gently northwest beneath the anorthosite, but there has been insufficient outcrop examination here to verify this. The field interpretation regarding the subsurface northwestern extension of the body is given credence by the results of geophysical surveys conducted for Noranda Mining and Exploration in 1996 (Squires *et al.*, 1996), which show the aeromagnetic signature of the monzonite extending well into an area occupied by anorthosite. The eastern side of the monzonite is in intrusive contact with "giant-pyroxene" anorthosite (Unit 21). Here, the contact locally manifests itself as an interfingering one of steeply dipping anorthosite and monzonite, yet in other places the contacts are gently inclined. Several irregular smaller intrusions of monzonite in this area likely represent offshoots from the main body. The closure of the southern end of the body on Figure 2 is somewhat conjectural

because there are few outcrops directly north of Kingurutik Lake here. One of the peculiar features of the monzonite is that it has many inclusions of granulite-facies quartzofeldspathic gneiss, yet the monzonite does not intrude such rocks at the present exposure level. A narrow, sill-like, unit of grey subophitic leuconorite (Unit 32) intrudes the western margin of the quartz monzonite just north of Kingurutik Lake. This leuconorite must also be younger than the anorthosite to the west, but the actual distribution of these two basic rocks in this area has not been mapped out.

Anorthositic rocks that both predate and postdate emplacement of abutting granitoid rocks, akin to the relations mentioned in the foregoing paragraph, can also be seen south of Kingurutik Lake. There, a massive to locally layered intrusion of olivine-augite monzonite to quartz monzonite (Unit 41), bordered to the east by contemporaneous(?) ferrodiorite (Unit 42), has been shown from map pattern and field observation to intrude the anorthositic and gneissic rocks that abut it to the east, south, and west. Dyke networks of monzonite locally abound in the older rocks. On its northern side, however, the continuity of the quartz monzonite pluton and the older rocks, is abruptly truncated by pink to grey anorthosite and brown leuconorite (Units 35 and 36), a relation quite clearly evident in the map pattern. A sharp contact of layered monzonite against grey anorthosite has been observed at the northwest margin of the older unit. There is a clear, high-angle discordance between the layering attitude of the monzonite and the distribution of the anorthosite (Plate 9), and a few blocks of layered monzonite are suspended in the anorthosite. In contrast to contacts where monzonite has intruded into anorthosite, at this "reversed" contact there are few dykes of the younger anorthositic rock in the older monzonite. Zircon from the quartz monzonite pluton has yielded a U-Pb isotopic crystallization age of  $1333 \pm 3$  Ma (Kamo, 2003) establishing, therefore, an absolute benchmark age for reference to the older and younger intrusions.

Relationships between differing NPS rocks west of Iglusuatliksuak Lake are not fully resolved, but a few observations are worthy of record. The Paleoproterozoic Aupalukitak Mountain anorthosite (Unit 10) in this area is intruded by large, north-south-trending dyke-like bodies of ferrodiorite (Unit 42) and weakly foliated charnockite to mangerite (Unit 40). Both the ferrodiorite and the charnockite-mangerite are assigned to the NPS; they could, however, be part of the Paleoproterozoic magmatism. The ferrodioritic and charnockitic rocks can be mapped out as distinct units, but the magmas appear to have been emplaced contemporaneously because the two rock-types exhibit a mingled interface where they are in contact. The relationship between the ferrodiorite and the coarse white anorthosite (Unit 28) along its western side has not been categorically



**Plate 6.** Subophitic texture of grey tabular plagioclase and enclosing dark orthopyroxene within brown-weathering leuconorite from the undivided anorthosite–leuconorite intrusion (Unit 36) north of Kingurutik Lake.



**Plate 7.** Mottled leucotroctolite (Unit 17) south of “Iviangiuyakh east flank, northeast lake”. Irregular, reddish-brown-weathering, olivine-rich zones are interspersed with white-weathering anorthositic zones.



**Plate 8.** Large tabular inclusion of foliated leuconorite from the marginal part of the Pearly Gates intrusion (Unit 14) enclosed by pale-brown-weathering massive mauve leuconorite (Unit 33) exposed on a spine south of “Iviangiuyakh east flank, northeast lake”. Person on horizon for scale.

established because no direct contact has been observed. Field contacts between the ferrodiorite and the brown subophitic-textured leuconorite (Unit 36) to the west indicate that the leuconorite is the younger of the two; the leuconorite is also intruded into the massive white anorthosite (Unit 28).

North–south trends characterize the contacts between, and internal fabrics of, rock units bordering Tikkoatokak Bay. The nature of many of these contacts, and thus the relationship of these units to each other, are still unknown because the area has not been ground-traversed in sufficient detail to establish relative ages. Massive pegmatoidal anorthosite (Unit 13) crossing western Tikkoatokak Bay has



**Plate 9.** Monzonite intruded by leuconorite, south of Kingurutik Lake. Brownish-tinged rocks above and to the right of the person are olivine–clinopyroxene monzonite (Unit 41), having a lensoid compositional layering (shown by short dashes) dipping steeply to the left. Pale-grey rocks in foreground and to the right of the person are leuconorite belonging to the undivided leuconorite–anorthosite intrusion of this area (Unit 35); inclusions of monzonite (not visible in photograph) occur in the leuconorite. Dash-dot line across photo is the trace of the contact between the monzonite and the anorthosite.

been correlated with the interior zone of the Pearly Gates intrusion as defined north of Kingurutik Lake. That being the case, the “giant-pyroxene” anorthosite (Unit 21) to the east must be younger. Limited, and non-definitive, field contacts indicate that the “giant-pyroxene” anorthosite also intrudes a streaky-foliated poikilitic leuconorite (Unit 22) south of Tikkoatokak Bay; the latter unit has not been observed on the north side of the bay, perhaps because it has been cut out by intrusion of the former. Intrusive contacts of

massive white anorthosite (Unit 13) emplaced into speckled leuconorite (Unit 27) have been observed at several places north of Tikkoatokak Bay, and the “giant-pyroxene” anorthosite is intrusive into, and cross-cuts fabrics in, a small area of foliated speckled leuconorite to the south of the bay.

### OLIVINE GABBRO DYKES

There are several impressive mafic dykes (Unit 43) intruded into rocks south of Tikkoatokak Bay. Two of these are shown on Figure 2. These are roughly east-striking, steeply dipping intrusions of olivine gabbro, part of the post-NPS “Nain dykes” swarm of the Nain area described by Wiebe (1985). The southern dyke is about 40 m wide and can be traced along strike for over 20 km. It is pale brown-weathering, friable, and occupies a prominent linear in the landscape. The northern one is 20 m wide, and is traceable for 14 km along strike. At its western extent, the aforementioned dyke has a low-angle intersection (relative age not determined) with another one of similar width that is choked with anorthosite inclusions; the distribution of the inclusion-laden dyke has not been traced and it is not portrayed on Figure 2.

## ECONOMIC GEOLOGY

It has been stated in a foregoing section of this report that the Nain Bay–Kingurutik Lake area had been subjected to reconnaissance exploration for base metals during the mid-1950s and again for a couple of years in the mid-1990s following the 1993 discovery of the Voisey’s Bay Ni–Cu–Co deposit. The activity in the area during the most recent exploration was, however, tempered by the fact that much of the territory had been declared “Exempt Mineral Lands” shortly after the exploration rush began, and therefore only limited work was undertaken. Nevertheless, one small prospect north of Kingurutik Lake did cause some excitement.

The limited investigations of the area undertaken in the mid-1950s centred around small ilmenite–pyrrhotite concentrations in coarse anorthosite, herein included with the Pearly Gates intrusion (Unit 13), on the south side of Tikkoatokak Bay. Grimley (1955) provided a short summary of a brief investigation of several small occurrences, but their distribution was found to be limited and no follow-up was undertaken. The showings were subsequently investigated by Absolut Resources (MacGillivray, 1996), but, again, no continuity to the mineralization was found nor were there significant base-metal values derived from assays.

The most “newsworthy” of the new discoveries in the region was one comprising several gossanous zones spread over the sides of a couple of valleys 7.5 km north of Kingurutik Lake, within the undivided anorthosite and leuconorite of Unit 35 on Figure 2. These sulphide occurrences were found by Castle Rock Exploration, were termed the “NBK” showings, and were the focus of ground work in 1995 (O’Sullivan, 1996). The showings comprise disseminated, coarse podiform, and centimetre-scale veins of pyrrhotite, chalcopyrite and pentlandite within massive grey anorthosite. The sulphide mineralization examined at the NBK#3 occurrence is of limited extent, is patchy in exposure and likely the same in the subsurface, and is far less voluminous than the gossans would suggest. The same attributes seem to characterize the other occurrences within the NBK zone (A. Kerr, personal communication, 2003). The gossans and areas of rust-stained anorthosite are mostly found on inclined fracture surfaces, and are a result of direct weathering of exposed sulphide, as well as being due to deposition from iron-enriched water emanating from fractures that have small pockets of sulphide along them. Assays reported by Castle Rock Exploration from several grab samples showed maximum values of 1.9% Cu, 1.7% Ni and 0.23% Co (Castle Rock Exploration press release, July 31, 1995). The initial prospecting was followed by airborne and ground-based geophysical surveys, but no subsequent detailed exploration work was done.

Several small gossanous zones also occur in the same unit of anorthositic to leuconoritic rocks elsewhere in this area. One occurs north of the east end of Kingurutik Lake, on the southeastern flank of a 2600 ft (approximately 850 m) ridge (UTM 556470E, 6303565N). It is similar to the NBK showings in consisting of scattered centimetre-scale pods of coarse pyrrhotite interstitial to the feldspar of the host rock. Another gossanous area occurs at the eastern end of a 2400 ft (750 m) ridge north of the Polygon ponds (UTM 542410E, 6304620N). The gossanous zone here is discontinuous, but covers an area at least 50 m wide and more than 300 m long trending east-southeast. It comprises deeply weathered, mauve anorthosite and leuconorite having a few percent disseminated sulphides. The sulphide minerals are also locally present within east-southeast-striking ferrodiorite dykes, up to 3 m thick, that intrude the anorthosite and leuconorite.

A single sulphide occurrence was observed and briefly examined west of Iglusuataliksiuk Lake (UTM 552330E, 6315930N) during the course of the present mapping. This sulphide occurs in grey recrystallized anorthositic rocks assigned to the Paleoproterozoic Aupalukitak Mountain intrusion (Unit 10), and it is likely that the mineralization is



Paleoproterozoic as well. The showing comprises coarse pyrrhotite and stringers of chalcopyrite, having a vein-like aspect, plastered against a steep outcrop slope. The largest gossanous area and associated mineralization occupies about 30 m<sup>2</sup>. The sulphide body is sheared along its margins. This showing had been examined, sampled and assayed by personnel from Absolut Resources in 1995 and 1996 (MacGillivray, 1996; Theriault, 1996). Best metal values obtained were 1.81% Ni, 1.49% Cu and 0.16% Co from the pyrrhotite-rich parts of the zone and 6.80% Cu, 1.22% Ni and 0.10% Co from the chalcopyrite-rich areas. The restricted surface extent of the showing, coupled with discouraging geophysical evidence for subsurface continuity, led Absolut personnel to conclude there was little possibility of an extensive mineralized zone.

Plagioclase feldspar displaying a labradoresence is widely distributed in the anorthositic to leuconoritic rocks of the region. In some cases, the labradorite is an integral characteristic of the whole rock, but in other cases, the colour is restricted to megacrysts or xenocrysts. Crystal sizes vary from a few centimetres to tens of centimetres. The most prevalent colour shade exhibited by the feldspar is a pale blue, but greenish-blue and orange-brown are also present. The latter colour was observed only in zoned grains, where it forms the partially resorbed core to plagioclase that exhibits further colour changes passing outward through an intermediate zone of green surrounded by a rim of blue.

### **SOME REGIONAL STRATIGRAPHIC PROBLEMS AND A GEOCHRONOLOGICAL PROGRAM TO ADDRESS THEM**

The current mapping program offers an opportunity to address some of the long-standing stratigraphic problems of the region through focussed examination of critical areas. Outcrop examination alone, however, does not always offer the solutions to these problems, so a dedicated geochronology program has been initiated to provide some of the answers. The geochronology will comprise U–Pb age determinations to be undertaken by Dr. Staci Loewy and Dr. James Connelly at the Department of Earth Sciences at the University of Texas in Austin. The program is jointly funded by the Targeted Geoscience Initiative 2 (TGI 2) program of the Geological Survey of Canada and by the Geological Survey of Newfoundland and Labrador. In the 2003 field season, the geochronology program involved field sample collecting and export of the sample suite to Austin. The first age determinations are anticipated before the end of March 2004. Examples of some of the regional problems to be confronted by the age determinations have been discussed elsewhere (e.g., Ryan, 1992, 1993; Connelly and Ryan, 1999), and several are re-iterated below. Following the outline of the geochronological approach, some other problematic

relationships brought to light by the 2003 program are considered.

### **PROBLEMS THAT ARE THE FOCUS OF GEOCHRONOLOGY**

The sampling program in 2003 was designed to address four main themes: 1) the ages of the Archean and/or Paleoproterozoic anorthositic and quartzofeldspathic rocks that form the northeastern envelope to the NPS, 2) the ages of Archean and/or Paleoproterozoic rocks occurring in the septum of gneisses separating NPS intrusions crossing Tikkoatokak Bay, 3) the ages of presumed Paleoproterozoic rocks that are provisionally correlated with the Arnanunat Plutonic Suite, and 4) the ages of selected NPS rocks in the study area.

(1a) Absolute age of the gneissic anorthositic and leucogabbroic rocks (Unit 1): do they represent an Archean or Paleoproterozoic intrusion? All that is known is that one of the aplitic leucogranitic dykes cutting the gabbroic rocks crystallized ca. 1873 Ma, and therefore the latter rocks are older than this. Other samples have been collected from the unit to attempt to better define its true age of crystallization and/or metamorphism. Certainly, there are migmatized rocks of similar composition within the Archean gneisses to the north (Ryan *et al.*, 1997) and southeast (Ryan, 1993) of the present study area, but the unit here is the regionally most extensive found so far. This unit not only differs from the smaller ones by its extent, but also by its preservation of textures that are so closely akin to those of the less deformed Paleoproterozoic and Mesoproterozoic intrusions nearby (*see below*). Such coarse-grained and subophitic textures are rare or completely lacking from the intra-gneiss units, which have, instead, oval (“snow-ball”) plagioclase typical of many Archean metaleucogabbro and anorthosite rocks (*cf.* Ashwal, 1993). As noted above, in view of the lack of an observed relative relationship between Unit 1 and Unit 10, the former could be the deformed equivalent of the latter. If the metamorphosed units are Archean, Paleoproterozoic, or both, then there are implications regarding mantle magmatic processes that periodically produced spatially overlapping anorthositic rocks over more than 1000 Ma. Alternatively, might some of the meta-anorthositic rocks represent deformed and metamorphosed Mesoproterozoic rocks occurring along the margins of slightly younger NPS anorthositic intrusions? A sample of strongly foliated granitic neosome was collected from Unit 1 meta-anorthosite; an age from this sample will help to constrain the ages of emplacement and metamorphism of the anorthosite.

(1b) Absolute age(s) of the quartzofeldspathic rocks along the eastern edge of the survey area (Unit 2): are they

Archean or Paleoproterozoic? This question follows from the foregoing quandary, and is predicated on the observation that anorthositic inclusions mesoscopically comparable to Unit 1 are found within Unit 2. If the quartzofeldspathic granulites are Archean and part of the Nain Province, as presently assumed (Figure 2), they are derived from a plutonic precursor that was intruded into anorthositic and leucogabbroic rocks. Then, by default, Unit 1 is likewise Archean. Alternatively, if Unit 1 is Paleoproterozoic, and represents, for example, a foliated variant of the Aupalukitak Mountain pluton, then the granulite-facies quartzofeldspathic rocks could represent Paleoproterozoic intrusions emplaced into these basic rocks. In the latter situation, the quartzofeldspathic gneiss represents a granitoid rock injected into the border of the Aupalukitak Mountain pluton (Unit 10), giving rise to a “border facies” for that pluton that differs radically from the margins of the other Paleoproterozoic and NPS plutons. Either of the foregoing surmised relationships could be completely revamped should one or both of the units be Mesoproterozoic! To provide some answers to the ages of crystallization and metamorphism (Archean, Paleoproterozoic, Mesoproterozoic?) samples have been collected from the granulite-facies quartzofeldspathic orthogneiss (Unit 2) just north of the study area. These rocks contain several phases of granitic neosome and pre-metamorphic xenoliths of anorthosite.

(2) Granulite-facies gneissic rocks, including meta-anorthositic ones, occur as septa dividing NPS plutons across Tikkoatokak Bay: what is the age and “provincial” affinity of these rocks, and are the anorthositic components related in any way to the NPS? The gneissic rocks that separate anorthositic and leucogabbroic plutons of the NPS across Tikkoatokak Bay are, like the eastern envelope of the NPS, somewhat enigmatic by the amount of meta-anorthosite and leucogabbroic rocks within them. Wheeler (1969, Figure 1) initially portrayed the belt as part of the “basement gneiss complex”, but subsequently he (Wheeler, unpublished) assigned it to “granulites of uncertain origin”. On a regional compilation map of the NPS and its surroundings, which included Wheeler's published and unpublished work, Ryan (1990) interpreted the Tikkoatokak Bay septum as a preserved remnant of the Churchill Province gneisses. As a result of the 2003 survey the septum has been divided into its two main components (Figure 2) – metaplutonic quartzofeldspathic gneisses to the west (Unit 6) and anorthositic–leucogabbroic rocks to the east (Unit 5). The ages of protolith emplacement and metamorphism for these units are unknown, but a Paleoproterozoic age is permissible for these rocks, and thus an assignment to the Churchill Province is warranted. Even though it is unusual to find such volumes of metamorphosed leucocratic basic rocks along the eastern edge of the Churchill Province, metamorphosed intrusions of this composition may belong

to a quartz-poor suite identified east of, and intercalated with, Tasiuyak gneiss in the Okak Bay area (Ermanovics and Van Kranendonk, 1998). Similar quartz-poor rocks, having associated anorthositic and leucogabbroic compositions (B. Ryan, unpublished data), are also found east of Tasiuyak gneiss near Anaktalik Brook (Ryan and Lee, 1989). In the Anaktalik Brook area, the tonalitic (enderbitic) orthogneisses have yielded a crystallization age of  $1909 \pm 33 / -21$  Ma, and are likely part of a calc-alkaline suite emplaced into Tasiuyak gneiss and older rocks between 1910 and 1860 Ma (*cf.* Ryan, 2000b). Ryan and Lee (1989) had considered anorthositic and quartzofeldspathic orthogneisses directly north of Voisey's Bay to be Archean, but data presented by Rawlings-Hinchey *et al.* (2003) allow for the interpretation of the anorthositic components here, too, as part of a Paleoproterozoic calc-alkaline assemblage (*see also*, Ryan, 2000b, page 716). To test the age and affinity of the Tikkoatokak Bay belt, samples were collected from well-layered granulite-facies quartzofeldspathic gneiss (Unit 6) as well as from a narrow unit of metamorphosed leucogabbroic to anorthositic gneiss within it, north of the bay. A sample of banded leucogabbroic rock and a garnetiferous enderbite rock were collected south of the bay. In an attempt to test the detrital and metamorphic ages of the zircon in the metasedimentary rocks in this belt, a garnet–cordierite gneiss (Unit 7) was also collected south of Tikkoatokak Bay. The derived age data may help to elucidate the tectonic affinity of all these rocks – are they part of the Nain or Southeastern Churchill provinces? As with the rocks discussed in the preceding sections, this septum of gneisses may have a history of Archean, Paleoproterozoic and Mesoproterozoic metamorphism.

(3) In addition to the meta-anorthositic rocks addressed in the preceding two paragraphs, granular meta-anorthosite (Unit 10) occurs west of Iglusuataliksiak Lake. This group of rocks is far less deformed than those that are associated with the gneisses. Because of their similarity to the Paleoproterozoic Aupalukitak Mountain intrusion of the APS to the north (Ryan *et al.*, 2003) they are considered to be a southward extension of that intrusion. Characteristic of the Aupalukitak Mountain intrusion directly to the north, is a swarm of deformed basic dykes of overall gabbroic (“mafic granulite”) composition, a trait also shared by the anorthositic rocks of Unit 10. In order to determine a crystallization and/or metamorphic age from this anorthosite, a sample was collected from its northern end. At the sampled location, the meta-anorthosite is intruded by light brown-weathering granulite-facies (“biotite–granulite”; diorite?) dykes. At a nearby location to the south, the meta-anorthosite and its dyke network are cut by charnockite (Unit 40) correlated with the NPS. A foliated granulite-facies “biotite–granulite” dyke and the charnockite have been sampled from that outcrop. The ages derived from all

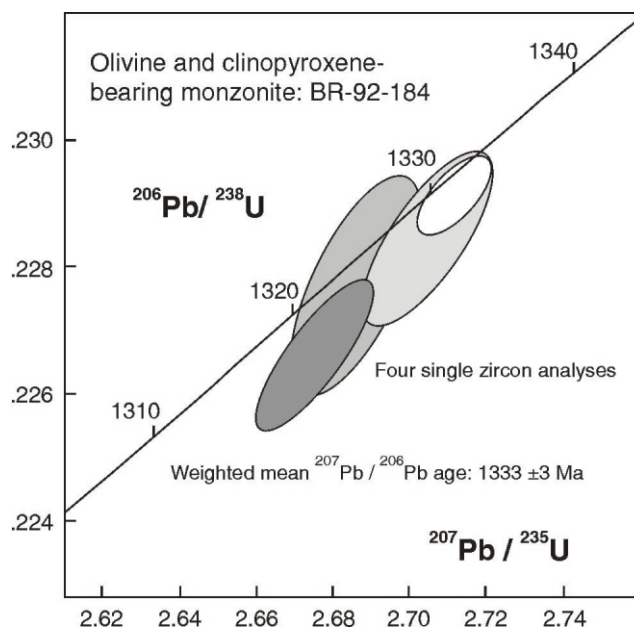
these rocks will hopefully provide insights into the timing of pre-NPS and NPS magmatism in the northeastern part of the study area.

(4) The final stratigraphic element to be addressed by the geochronology program is the age of NPS magmatism: what is the time-frame for generation of the NPS rocks in the Kingurutik Lake area? To date, there are only two absolute ages from rocks of the map-area – the monzonite south of Kingurutik Lake and the ferrodiorite–monzonite intrusion on Ukpaume Island.

The olivine–clinopyroxene-bearing monzonite (Unit 41) south of Kingurutik Lake was briefly examined in 1992 (Ryan, unpublished data). Samples of medium-grained monzonite having abundant zircon were collected at that time. One of these samples, from the western part of the intrusion, was submitted for geochronological study to the Jack Satterly Laboratory at the Royal Ontario Museum prior to the 2003 field season. Kamo (2003) reported that the submitted sample contained dark to pale brown fragments of euhedral to somewhat rounded zircon. From the zircons collected, four flawless grains were individually analyzed for uranium. Data from the four grains give overlapping ages that are concordant and nearly concordant (Figure 3). The weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1333 \pm 3$  Ma is considered the best possible crystallization age for the monzonite. This age is identical to the crystallization age of the Akpaume Intrusion (Unit 39), determined by Hamilton *et al.* (1994) to be  $1333 \pm 2$  Ma based on U–Pb dating of zircon.

The U–Pb age of the monzonite pluton provides an absolute geological “pin” for the local igneous stratigraphy. Field relations indicate that, with the exception of the leuconorite and anorthosite along its northern edge, all the rocks that abut this monzonite are older than 1333 Ma. These include the giant-pyroxene anorthosite (Unit 21) to the west, “foliated margin” leuconorite and anorthosite (Units 20 and 19) to the south, and the elongate leuconorite (Unit 23) to the east. Because the latter is intruded into the Mount Lister anorthosite, the age of the monzonite corroborates data derived from the Akpaume intrusion indicating the Mount Lister intrusion is pre-1333 Ma. Taking the Akpaume intrusion into account in another context, the nearly identical age from the monzonite points again to the diversity of contemporaneous magmatism within the NPS.

To test other episodes of magmatism, several samples have been collected from rocks assigned to the post-monzonite intrusions north and south of Kingurutik Lake. Specifically, sampling has concentrated on fresh rocks within the composite anorthosite-leuconorite intrusions encompassed by Units 35 and 36. Unit 36 leuconorite, as well as a granite dyke that cuts it, were sampled near the northeast-



**Figure 3.** U–Pb data derived from zircon extracted from the monzonite south of Kingurutik Lake, indicating a crystallization age of  $1333 \pm 3$  Ma.

trending lake approximately 8 km north of the central part of Kingurutik Lake. Another sample of subophitic brown leuconorite was collected from Unit 36 east of the island in the central part of Kingurutik Lake. This leuconorite has intruded “giant-pyroxene” anorthosite and the 1333 Ma monzonite. In addition, a granitic pod between feldspars in Unit 35 anorthosite, interpreted to be the last crystallizing component of the intrusion, was sampled along the eastern margin of the unit north of the east end of Kingurutik Lake. The granitic pod contains abundant and spectacular, amber-brown zircon needles up to 8 cm long. Ages from all these NPS rocks will help to place absolute limits on the age of emplacement of several of the NPS basic plutons.

## SOME OTHER OBSERVATIONS REGARDING UNIT RELATIONSHIPS IN THE MAP-AREA

### Susie Brook Slab

One of the intriguing problems to be addressed in the future is the significance and affinity of a group of rocks south of Tikkoatokak Bay that had been termed the “Susie Brook slab” by Morse and Wheeler (1974). The surmised extent of the “slab”, which Morse and Wheeler (*ibid.*) had outlined chiefly on the basis of a dataset limited mostly to coastal exposures, corresponds approximately to Units 19, 20 and 22 and parts of Units 21 and 23 of the present survey (Figure 2). Their coastal work indicated that the “Susie Brook slab” comprised a “monoclinial slab, some 10 km thick and dipping  $75^\circ\text{E}$ , of foliated, weakly layered leu-

conorite to anorthosite.” They noted that the anorthosite contains “giant orthopyroxene with regular lamellae of plagioclase”; this variant likely corresponds to the “giant-pyroxene” anorthosite (Unit 21). It appears from the present limited field work south of Tikkoatokak Bay that most of the “slab” is, however, free of such pyroxenes, being composed of a massive to foliated, white-weathering rock of anorthositic composition in the east (may be more than one age of rock in this unit) and a foliated “clotted-textured” leuconoritic one in the west. The more massive rock (Unit 19) does have local concentrations of coarse pyroxene in its western half. Where these rocks have abundant pyroxene throughout, the deformation features exhibited by them are comparable to those found in the foliated marginal zones of intrusions such as the Pearly Gates and Mount Lister. The eastern half of the anorthositic unit is less deformed, and where fabrics are apparent they are best interpreted as primary, i.e., aligned plagioclase tablets overgrown by orthopyroxene oikocrysts. An unusual feature of the anorthosite is the eastward swing of the foliation in the northern half of the body. Only at its eastern margin, where it abuts gneisses, does it have a pronounced deformational fabric. The foliated “clotted-textured” leuconorite (Unit 22) that occupies the western part of the “slab” is a very distinctive rock, being composed of north-oriented, brownish-weathering, ellipsoidal orthopyroxene oikocrysts averaging 10 cm in length, set in a groundmass of white feldspar.

It is clear that two, and possibly more, phases of the same intrusion, or even completely different intrusions, are encompassed by the “Susie Brook slab”. Consequently, the aforementioned informal, nonstratigraphic, designation for these rocks should be abandoned, and the rocks be subsequently referred to by a name or names more in keeping with stratigraphic nomenclature. The lack of ground traversing to establish the nature of contacts between the different units defined south of Tikkoatokak Bay precludes firm statements about relative relations between any of the rocks here. The map-scale truncation of the foliated oikocrystic leuconorite (Unit 22) by the massive “giant-pyroxene” anorthosite (Unit 21) just north of the Fraser River suggests that the latter intrudes the former. Outcrops of the massive anorthosite in close proximity to deformed leuconorite along the contact between the two support this interpretation, as does the local presence of foliated leuconorite inclusions in the massive rock. The relationship between the foliated leuconorite (Unit 22) and the foliated anorthositic rock (Unit 19) to the east has not been determined, nor is there sufficient field evidence to advocate one. It is possible that the two units represent completely different intrusions, but a gradational contact between them is also plausible. If the two are gradational, and the eastern anorthosite itself passes into the “foliated margin” type leuconorite against the gneisses, then the whole may be a subdivision of the Pearly

Gates intrusion. Like the foliated “clotted-textured” unit to the west, the massive white anorthosite north of the Fraser River is also interpreted to be intruded by the “giant-pyroxene” anorthosite.

### **Gneissic Inclusions in Monzonites**

It has been stated in foregoing parts of this report that gneissic inclusions are locally present in the monzonitic intrusions (Unit 41) north and south of Kingurutik Lake. No such rocks occur in the immediate surroundings to the northern intrusion, and the inclusions occur far from the narrow strip of gneisses that abuts the south margin of the southern intrusion. Two explanations are possible for this distribution of gneissic xenoliths. First, they are derived from gneisses such as those that constitute the septa in each area, and have been transported laterally or from depth within the magma. They thus tap the unseen floor or sidewalls of the intrusions. Second, they are representatives of country-rock gneisses that originally capped the monzonitic magma chambers, and have collapsed into the chamber from above during ascent or once the magma has come to rest. In this case, they are pieces that have been stoped and spalled from the eroded roofs of each intrusion. The latter explanation seems untenable for the northern intrusion because it is totally encased by anorthositic rocks, and it is not unreasonable to assume that the roof was likewise anorthosite. Therefore, the xenolithic gneissic blocks must have been transported within the magma from an outside source area. For the southern intrusion, founder cap-rock may be justified in accounting for the gneissic rafts because several hilltops here are crowned by numerous gneissic inclusions that can be cited as evidence of proximity to a gneissic roof.

### **Outline of the Mount Lister Intrusion**

If a simple form-line exercise is performed on the layering trend within the Mount Lister intrusion (Figure 2), the available data highlight an interesting problem. That problem is one involving the trend of the internal layering and the trace of the contact with the gneisses crossing Tikkoatokak Bay. It is apparent from the map that layering attitudes in the Mount Lister intrusion northeast of Kingurutik Lake conform approximately to the outline of its contact with the gneisses. This relation is also seen along the contact between this intrusion and its bounding gneisses outside the map-area. If, however, the layering attitudes of the Mount Lister intrusion between Kingurutik Lake and Tikkoatokak Bay are projected westward, and the younger elongate leuconorite unit is ignored, it seems that the Mount Lister layering is truncated quite abruptly by, or takes a very sharp southward bend against, the belt of gneisses that occurs there. An explanation for this apparent map-scale cut-off is not readily apparent. If it is a true truncation then it implies

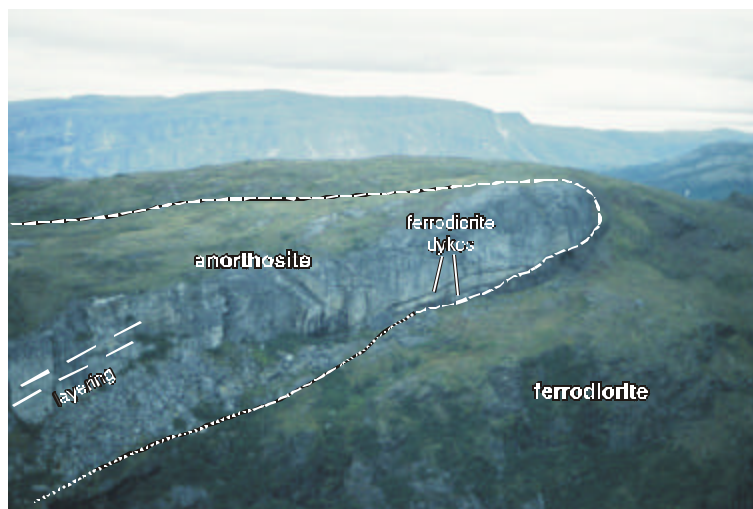
a faulted contact between the gneisses and the Mount Lister intrusion existed here prior to the emplacement of the younger leuconorite. If there was no fault, which seems to be the case south of Tikkoatokak Bay where there is a steep foliated contact between possible Mount Lister anorthosite and gneisses, then the layering is drawn into conformity with the trace of the margin over a very short distance.

### Inclusions in the Akpaume Intrusion

The Akpaume (ferrodiorite) intrusion was not traversed nor examined in any systematic manner during the 2003 survey, and its distribution shown on Figure 2 is taken from the work of Deuring (1976, 1977). However, a helicopter reconnaissance was conducted of the rocks on Ukaume Island, during which a large slab of anorthosite enclosed by ferrodiorite was examined at the northeast side of the island (Plate 10). That slab is clearly a large inclusion that was engulfed by the ferrodioritic magma. Although on Figure 2 this slab is shown as being correlative with the Mount Lister intrusion, the limited examination of the inclusion and that of the proximal Mount Lister intrusion on the north and south sides of Tikkoatokak Bay, suggests that the slab may not be locally derived. Whereas it is tempting to associate all the inclusions in the Akpaume intrusion with the local anorthosite of the Mount Lister intrusion, the textures and unrecrystallized aspect of the slab in relation to the surrounding anorthosite can be interpreted to indicate that its provenance is not local. This, like the gneissic inclusions in the monzonites addressed above, may mean that either this slab was transported from elsewhere within the ascending magma, or else it represents a giant block that has descended from an otherwise unrecognized intrusion that was the roof above the present erosional level.

### SUMMARY

Field work conducted upon the Mesoproterozoic NPS as part of the 2003 summer mapping project in the Kingurutik Lake–Fraser River has indicated that the NPS here exhibits the same attributes that it does elsewhere in the batholith: many coalesced plutons, variable compositions but with anorthosite and leuconorite predominant, a diversity of primary textures, differences in pluton geometry, and varying degrees of deformation and recrystallization. Monzonitic plutons that predate some of the adjacent anorthositic rocks have been recognized, demonstrating for the first time an age relationship from local field exposures that has been indicated by the regional geochronology. Anorthositic rocks that may be part of the Paleoproterozoic



**Plate 10.** Pale rocks forming the cliff in the centre of the view and exposed on the step above are grey leuconorite to anorthosite that constitute a large tabular slab in the Akpaume (ferrodioritic) intrusion (Unit 39), the latter being the brown-weathering rocks above and below the slab. The slab may be a foundered block of the nearby Mount Lister intrusion (Unit 11) but this is uncertain. Ferrodiorite dykes fill brittle fractures at the base of the slab, and a compositional layering is visible in it at the left.

Arnanunat Plutonic Suite are less extensive than in the region to the north, and no granitic nor ferrodioritic rocks belonging to the APS have been found in the 2003 survey area. Attempts to firmly establish, from field relationships, the age of the many gneissose anorthositic and leucogabbro-noritic units proximal to the NPS – are they Archean, Paleoproterozoic or Mesoproterozoic? – proved frustrating, and U–Pb geochronology will be used to investigate their age(s) of crystallization and metamorphism. Several occurrences of sulphide mineralization were investigated in the anorthositic and leuconoritic rocks; their economic significance requires additional evaluation.

### ACKNOWLEDGMENTS

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## REFERENCES

- Ashwal, L.  
1993: Anorthosites. Springer-Verlag, Berlin, 422 pages.
- Bates, R.L. and Jackson, J.A.  
1987: Glossary of Geology, 3rd Edition. American Geological Institute, Alexandria, Virginia, 788 pages.
- Berg, J.H.  
1974: Further study of the Hettasch Intrusion and associated rocks. *In* The Nain Anorthosite Project: Field Report, 1973. *Edited by* S.A. Morse. Geology Department, University of Massachusetts, Contribution No. 13, pages 107-119.
- Christie, A.M.  
1952: Geology of the northern coast of Labrador, from Grenfell Sound to Port Manvers, Newfoundland (maps plus notes). Geological Survey of Canada, Paper 52-22, 16 pages.
- Connelly, J.N. and Ryan, B.  
1999: Age and tectonic implications of Paleoproterozoic granitoid intrusions within the Nain Province near Nain, Labrador. *Canadian Journal of Earth Sciences*, Volume 36, pages 833-853.
- Deuring, D.E.  
1976: Akpaume layered intrusion: field aspects. *In* The Nain Anorthosite Project, Labrador: Field Report, 1975. *Edited by* S.A. Morse. Geology Department, University of Massachusetts, Contribution No. 26, pages 45-50.  
  
1977: The Akpaume layered intrusion: further investigations. *In* The Nain Anorthosite Project, Labrador: Field Report, 1976. *Edited by* S.A. Morse. Geology Department, University of Massachusetts, Contribution No. 29, pages 35-40.
- Ermanovics, I.F., Emslie, R.F. and Ryan, A.B.  
1997: Geological map of the Umiakovik Lake-Kiglapait Mountains sector, Labrador, Newfoundland. Geological Survey of Canada, Open File 3451, Scale 1:100 000.
- Ermanovics, I.F. and van Kranendonk, M.J.  
1998: Geology of the Archean Nain Province and Paleoproterozoic Torngat Orogen in a transect of the North River-Nutak map areas, Newfoundland (Labrador) and Quebec. Geological Survey of Canada, Bulletin 497, 156 pages.
- Grimley, P.H.  
1955: Showings in Nain and Tikkoatokak Bay areas, Labrador. Unpublished BRINEX report. Geological Survey, Department of Mines and Energy, File 14D/9 (12).
- Hamilton, M.A., Emslie, R.F. and Roddick, J.C.  
1994: Detailed emplacement chronology of basic magmas of the Mid-Proterozoic Nain Plutonic Suite, Labrador: insights from U-Pb systematics in zircon and baddeleyite. Eighth International Conference on Cosmochronology and Isotope Geology. United States Geological Survey, Circular 1107, page 124.
- Hamilton, M.A., Ryan, A.B., Emslie, R.F. and Ermanovics, I.F.  
1998: Identification of Paleoproterozoic anorthositic and monzonitic rocks in the vicinity of the Mesoproterozoic Nain Plutonic Suite, Labrador; U-Pb evidence. Radiogenic Age and Isotopic Studies: Report 11, Current Research 1998-F, Geological Survey of Canada, pages 23-40.
- Kamo, S.  
2003: U-Pb ages of late Grenvillian intrusions from the eastern Grenville Province, and from the Nain Plutonic Suite, Labrador. Unpublished report submitted to the Geological Survey of Newfoundland and Labrador, from the Geochronology Laboratory, Royal Ontario Museum, Toronto. May 2003, 6 pages.
- Kerr, A.  
1998: Petrology of magmatic sulphide mineralization in northern Labrador: preliminary results. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 98-1, pages 53-75.
- Kerr, A and Ryan, B.  
2000: Threading the eye of the needle: lessons from the search for another Voisey's Bay in Labrador. *Economic Geology*, Volume 95, pages 725-748.
- MacGillivray, G.  
1996: Voisey's Bay area, northeast Labrador, province of Newfoundland, summary report on 1995 exploration activities. Absolut Resources Corporation, Geological Survey, Department of Mines and Energy, 61 pages plus Appendices, LAB1156.
- Morse, S.A.  
1970: Introduction. *In* Nain Anorthosite Project,

- Labrador: Field Report, 1970. *Edited by S.A. Morse.* Department of Geology, University of Massachusetts, Amherst, Contribution 9, pages 1-7.
- 1983a: Emplacement history of the Nain Complex. *In* Nain Anorthosite Project, Labrador: Field Report, 1981. *Edited by S.A. Morse.* Department of Geology, University of Massachusetts, Amherst, Contribution 40, pages 9-15.
- 1983b: Reconnaissance geology of the Bird Lake anorthositic massif, Labrador. *In* Nain Anorthosite Project, Labrador: Field Report, 1981. *Edited by S.A. Morse.* Department of Geology, University of Massachusetts, Amherst, Contribution 40, pages 37-41.
- 1983c: Recent Abstracts and Nain bibliography. *In* Nain Anorthosite Project, Labrador: Field Report, 1981. *Edited by S.A. Morse.* Department of Geology, University of Massachusetts, Amherst, Contribution 40, pages 126-138
- Morse, S.A. and Wheeler, E.P.  
1974: Layered anorthosite massifs along Tikkoatokhakh Bay. *In* The Nain Anorthosite Project, Labrador: Field Report, 1973. *Edited by S.A. Morse.* Geology Department, University of Massachusetts, Contribution No. 13, pages 129-132.
- O'Sullivan, J.  
1996: First year assessment report on prospecting, airborne geophysical, and ground geophysical surveys carried out July 7 to September 30, 1995, licences 1471M - NBK group, NTS 14D/16, Labrador. Castle Rock Exploration, Geological Survey, Department of Mines and Energy, 11 pages plus Appendices, File 14D/19(0274).
- Rawlings-Hinchey, A.W., Sylvester, P.J., Myers, J.S., Dunning, G.R. and Kosler, J.  
2003: Paleoproterozoic crustal genesis: calc-alkaline magmatism of the Torngat Orogen, Voisey's Bay area, Labrador. *Precambrian Research*, Volume 125, pages 55-85.
- Ryan, B.  
1990: Geological map of the Nain Plutonic Suite and surrounding rocks (Nain-Nutak, NTS 14SW). Newfoundland Department of Mines and Energy, Geological Survey Branch, Map 90-44, scale 1:500 000.  
  
1992: Nain area geology: observations on selected islands, and the area south of Nain Bay (NTS 14C/6, 14; 14D/9). *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 92-1, pages 381-398.
- 1993: Further results of mapping gneissic and plutonic rocks of the Nain area, Labrador. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 93-1, pages 61-75.
- 2000a: Geological investigations in the type locality of the Nain Plutonic Suite (NTS4C/12). *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 2000-1, pages 251-277.
- 2000b: The Nain-Churchill boundary and the Nain Plutonic Suite: a regional perspective on the geologic setting of the Voisey's Bay Ni-Cu-Co deposit. *Economic Geology*, Volume 95, pages 703-724.
- 2001: A provisional subdivision of the Nain Plutonic Suite in its type-area, Nain, Labrador (NTS map-area 14C/12). *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 01-1, pages 127-157.
- Ryan, B. and Emslie, R.F.  
1994: Pre-Elsonian mafic magmatism in the Nain Igneous complex, Labrador: the Bridges layered intrusion - comment. *Precambrian Research*, Volume 68, pages 179-181.
- Ryan, B., Hynes, A. and Ermanovics, I.F.  
1997: Geology of the Nain Plutonic Suite and its country-rock envelope, Alliger Lake area (NTS 14E/1), Labrador. *In* Current Research. Geological Survey Branch, Department of Mines and Energy, Report 97-1, pages 29-47.
- Ryan, B., Hamilton, M.A., Emslie, R.F. and Connelly, J.N.  
2003: Two, spatially coincident but temporally disparate, Proterozoic anorogenic-type granitic (and anorthositic) suites in Northern Labrador, Canada. *In* Granitic Systems - State of the Art and Future Avenues, A Symposium in Honor of Professor Ilmari Haapala. Extended Abstracts, *Edited by* O.T. Rämö, P.J. Kosunen, L.S. Lauri, and J.A. Karhu, Department of Geology, University of Helsinki, Helsinki University Press, pages 79-83.
- Ryan, B. and James, D.  
2003: The geology of Labrador between Tikkoatokak Bay and the Quebec border (NTS 14D, north half): a reconnaissance examination. *In* Current Research. Newfoundland and Labrador Department of Mines and

- Energy, Geological Survey, Report 03-1, pages 137-165.
- Ryan, B. and Lee, D.  
1989: Geological map of the Makhavinekh Mountain area (14D/1). Newfoundland Department of Mines and Energy, Geological Survey Branch, Open File 89-17. Scale 1:50 000.
- Ryan, B., Phillips, E., Schwetz, J. and Machado, G.  
1998: A tale of more than ten plutons (geology of the region between Okak Bay and Staghorn Lake, Labrador, parts of NTS maps 14E/2, 7, 8). *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 98-1, pages 143-171.
- Snyder, G.A. and Simmons, E.C.  
1992: Intrusion of the Elsonian (C. 1303 Ma) Nain Anorthosite Complex over a contracted time interval: current geochronologic evidence. Geological Society of America, Annual General Meeting, Cincinnati, Ohio, Abstracts, page A94.
- Squires, G., Mitton, B., Kendel, F. and Schwarz, S.  
1996: First year Assessment Report (geology, geochemistry, geophysics) on licences 735M-741M, 766M-782M, 901M-915M, 1033M-1037M, 1322M-1325M, 3749M-3754M and 3978M-3980M: Cu, Ni, Co Exploration in the area between Hebron Fiord and Shapio Lake, Labrador. Noranda Mining and Exploration. Geological Survey, Department of Mines and Energy, 127 pages plus Appendices, File LAB1194.
- Thériault, R.  
1996: Report of exploration activities for 1996, Voisey's Bay area, Labrador, Province of Newfoundland, Canada. Absolut Resources Corporation. Geological Survey, Department of Mines and Energy, 27 pages plus Appendices, File LAB1288.
- Wheeler, E.P.  
1942: Anorthosite and related rocks about Nain, Labrador. *Journal of Geology*, Volume 50, pages 611-642.
- 1953: List of Labrador Eskimo Place Names. Department of Resources and Development, National Museum of Canada, Bulletin 131, 105 pages.
- 1960: Anorthosite-adamellite complex of Nain, Labrador. *Geological Society of America, Bulletin* 71, pages 1755-1762.
- 1969: Minor intrusives associated with the Nain anorthosite. *In* Origin of Anorthosite and Related Rocks. *Edited by* Y.W. Isachsen. New York State Museum Science Service, Memoir 18, Albany, New York, pages 189-206.
- Unpublished: Geology of the Anorthositic Nain Complex, Labrador. Geological Survey, Department of Mines and Energy, File LAB370, 123 pages.
- Wiebe, R.A.  
1978: Anorthosite and associated plutons, southern Nain complex, Labrador. *Canadian Journal of Earth Sciences*, Volume 15, pages 1326-1340.
- 1985: Proterozoic basalt dykes in the Nain anorthosite complex, Labrador. *Canadian Journal of Earth Sciences*, Volume 22, pages 1149-1157.
- Yu, Y. and Morse, S.A.  
1993:  $^{40}\text{Ar}/^{39}\text{Ar}$  chronology of the Nain anorthosites, Canada. *Canadian Journal of Earth Sciences*, Volume 30, pages 1166-1178.