

## GEOLOGICAL MAPPING IN THE TORNGAT OROGEN, NORTHERNMOST LABRADOR: PRELIMINARY RESULTS

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### ABSTRACT

Northernmost Labrador contains the boundary between the Archean Nain Province and the enigmatic Burwell Terrane of the Early Proterozoic Torngat Orogen. The Nain Province crust consists predominantly of granulite-facies tonalitic to granodioritic gneisses that were extensively migmatized prior to intrusion of an Early Proterozoic mafic dyke swarm and subsequent reworking within the Torngat Orogen. A major feature of the western part of the Nain crust is an approximately 70-km-long Archean anorthosite that strikes north-south, parallel to the main Proterozoic trends in the area. In contrast, the Burwell Terrane consists largely of Early Proterozoic metaplutonic rocks, ranging in composition from diorite to hypersthene-granodiorite and granite, interspersed with belts of metasedimentary gneiss. Metaplutonic rocks of Burwell Terrane are largely in sheared contact with the western limit of Nain crust, but some are seen to have also intruded this crust. The Burwell Terrane is therefore interpreted to represent the deep levels of a magmatic arc that was, in part, constructed upon the western edge of Nain Province, and/or accreted late in the arc's magmatic history.

Proterozoic ductile deformation was associated with amphibolite-facies reworking of the Archean crust and amphibolite- to granulite-facies metamorphism of the Burwell Terrane. Ductile shearing was concentrated in the Nain crust along the margins of the anorthosite body and along the Nain-Burwell contact. Early shearing and folding occurred at granulite to amphibolite facies in an oblique collisional environment, through sinistral shear associated with east-side-up motion. This was followed by a separate phase of ductile shearing and ultramylonite formation in response to west-side-up thrusting. The shear zones located along the boundary of the Nain crust and Burwell Terrane do not represent the type of fundamental plate boundary predicted by previous interpretations.

Concordant zones of sulphide (predominantly pyrite) mineralization have been discovered within Archean anorthosite and at the contact of metasedimentary gneiss with hypersthene-granodiorite in the interior of the Burwell Terrane. These may provide new exploration targets in northern Labrador and adjacent Northwest Territories.

### INTRODUCTION

The Early Proterozoic Torngat Orogen (1.86–1.79 Ga) forms the collision zone between the Archean blocks of the Rae Province, in the west, and the Nain Province to the east (Hoffman, 1988, 1990a, b; Wardle *et al.*, 1990a, b) (Figure 1). The Rae Province was extensively metamorphosed and deformed during this collision whereas only the western edge of the Nain Province was similarly affected. Along much of its length in northern Labrador, the core of the collision zone is represented by a belt of intensely deformed and migmatized metasedimentary gneiss known as the Tasiuyak gneiss, which

is approximately coincident with the Abloviak shear zone (Van Kranendonk, 1990; Ermanovics and Van Kranendonk, 1990; Van Kranendonk and Ermanovics, 1990; Mengel *et al.*, 1991) (Figure 1). Evolution of the suture was dominated by early oblique collision ca. 1.86 Ga followed by transcurrent, sinistral shearing and late cross-orogen shortening in the interval 1.84–1.79 Ga (Bertrand *et al.*, 1990). The Abloviak shear zone and associated Tasiuyak gneiss can be traced aeromagnetically across Hudson Strait where they establish continuity of the Torngat Orogen into southern Baffin Island (Hoffman, 1990a). In northernmost Labrador, the picture is

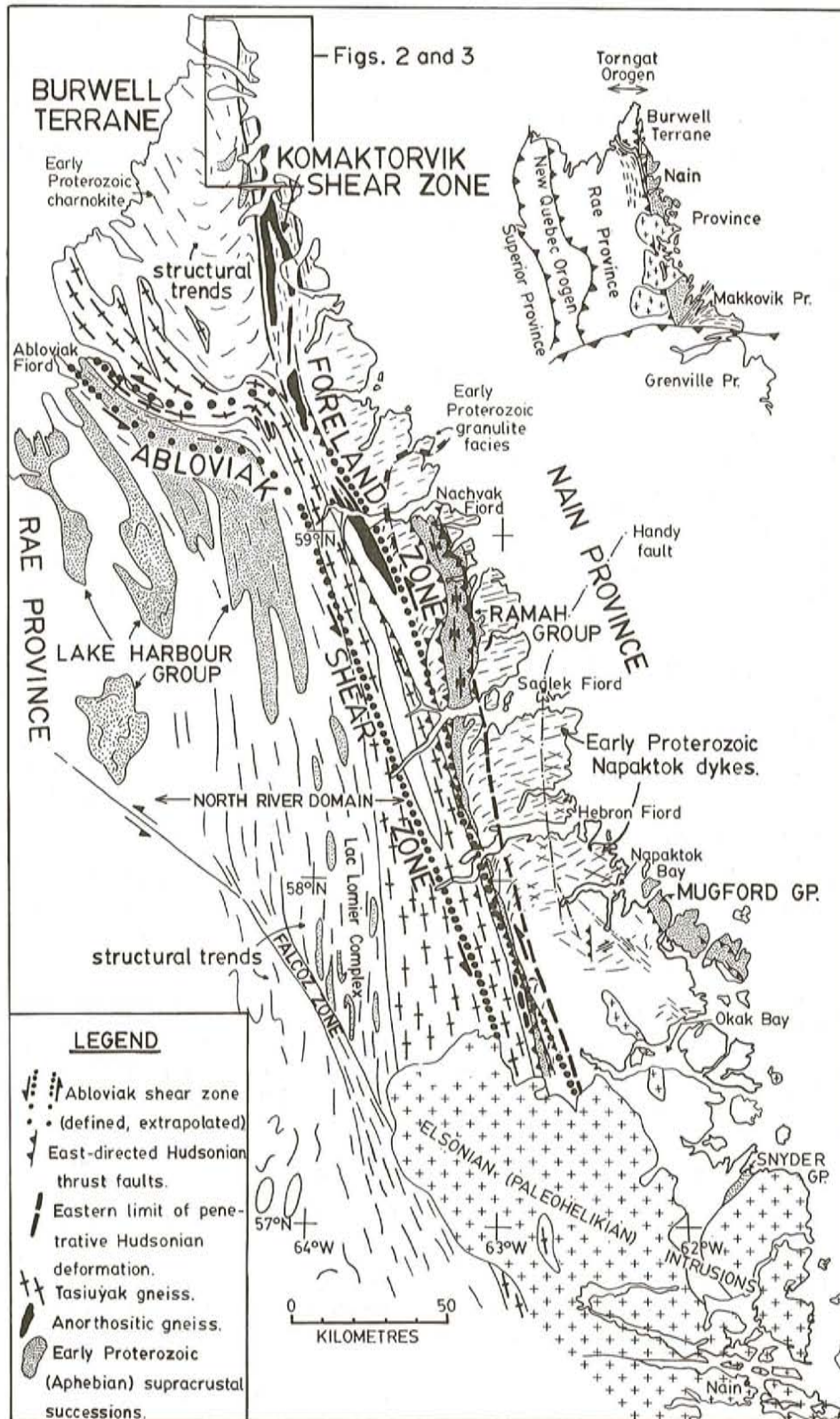
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**Figure 1.** Generalized geological map of Torngat Orogen in northern Labrador, northeastern Québec and Northwest Territories (Van Kranendonk, 1990). Map area discussed in this report is outlined by box labelled Figures 2 and 3.



complicated by a second aeromagnetic lineament, termed the Komaktorvik zone by Korstgaard *et al.* (1987), or Komaktorvik shear zone (Wardle *et al.*, 1990b), which diverges from the Abloviak zone and isolates an intervening crustal wedge referred to as the Burwell Terrane (Figure 1). Korstgaard *et al.* (1987) noted the lack of information concerning this terrane, but suggested that it was a detached segment of Nain crust on the basis of its aeromagnetic pattern. Hoffman (1990a, b) has more recently proposed the Burwell Terrane as an independent plate with extensions into south Baffin Island and West Greenland. Further interpretation has been hindered by the lack of reliable dates and paucity of geological information for Burwell Terrane; the terrane having been last described during reconnaissance mapping in the early nineteen seventies (Taylor, 1977).

In addition to its scientific importance the region contains Archean anorthosite intrusions that may have potential for mineralization (Wilton and Wardle, 1990; Swinden *et al.*, 1991) and has recently become accessible through a program of northern radar site construction. Studies of the Burwell Terrane, and its boundaries with the Nain and Rae provinces, are therefore a priority target for renewed mapping in northernmost Labrador.

A joint project between the Newfoundland Geological Survey Branch and the Geological Survey of Canada will eventually map all of Labrador north of 59°15'. This report covers mapping in parts of NTS 25 A/1, 2, 7 and 8 (Figure 2); associated mapping to the south in NTS 24/P16 has been reported separately by Van Kranendonk and Scott (1992). Field work for 1991 was entirely boat-supported and restricted to areas accessible from the sea. Inland areas shown as unmapped on the accompanying map (Figure 2) will be completed in 1992 when extensive helicopter support becomes available.

Northernmost Labrador has received cursory visits by geologists engaged in coastal reconnaissance since the last century, e.g., Low (1896), Coleman (1917) and Forbes and Odell (1938). Early mineral-exploration programs by BRINEX (Piloski, 1959) led to a broader understanding, but complete geological coverage (at 1:250 000 scale) was not achieved until the early nineteen seventies (Taylor, 1977, 1979). The current study was preceded by a brief reconnaissance visit in 1990 (Wilton and Wardle, 1990).

The map area, which lies at the northern end of the Torngat Mountain chain, is rugged, mountainous and indented by spectacular fiords. Relief becomes progressively subdued to the west where the land slopes down to the tundra plain surrounding Ungava Bay.

## GENERAL GEOLOGY

The area comprises two principal groups of rocks (Figures 2 and 3). In the east, is an Archean gneiss complex, intruded by Early Proterozoic mafic dykes, and variably affected by Early Proterozoic deformation. These rocks are clearly correlative with those of the Nain Province and

establish the continuity of Archean crust to the northern tip of Labrador, contrary to previous mapping (Taylor, 1977) that assigned an Early Proterozoic age to all of the area dealt with in this report. The dykes serve as an important chronological marker for distinguishing the effects of Archean versus Proterozoic tectonism. In the western part of the area, metaplutonic rocks and associated metasedimentary gneisses of inferred Early Proterozoic age form the Burwell Terrane.

The map area has been further subdivided into five lithotectonic zones (Figure 3). Extrapolation of these zones through unmapped or water-covered areas has been greatly facilitated by the use of unpublished, colour-shaded-relief aeromagnetic maps produced by G. Kilfoil of the Geological Survey Branch.

*Zone 1* comprises Archean, granulite-facies granitoid gneisses interspersed with narrow belts of supracrustal gneiss and mafic granulite, and intruded by a northeast-trending swarm of Early Proterozoic metadiabase dykes. This zone has substantially escaped significant penetrative Proterozoic deformation.

*Zone 2* is underlain by Archean gneisses and Proterozoic dykes of similar origin to those in Zone 1, but transected by belts of Early Proterozoic, amphibolite-facies ductile shearing.

*Zone 3* consists entirely of Archean anorthosite and related rocks, which are overprinted by Early Proterozoic amphibolite-facies fabrics.

*Zone 4* consists of Archean gneisses that preserve widespread Archean granulite-facies assemblages but have been partially retrogressed to Proterozoic amphibolite facies. In contrast to Zone 2, these have not been significantly affected by shearing, except along the boundaries of the zone.

*Zone 5* represents the eastern part of the Burwell Terrane and is composed of a western hypersthene-granodiorite batholith and an eastern metaplutonic suite of diorite-quartz diorite-tonalite and granodiorite composition, interspersed with belts of supracrustal gneiss.

Late intrusions of metaplutonic rocks have been found in Zones 2 to 5 with the greatest concentration being in Zone 5 (Burwell Terrane). Van Kranendonk and Scott (1992) have also identified similar rocks in the equivalents of Zone 1 to the south. The metaplutonic rocks are probably largely or entirely of Early Proterozoic age; however, in the absence of geochronological data a Late Archean age cannot be ruled out for some of them.

As defined by Stockwell (1982) the term 'Nain Province' refers only to Archean crust unaffected by Proterozoic tectonism, and would exclude most of the Archean rocks of the map area. In this report, the term 'Nain crust' is used to refer to such rocks of Nain Province affinity, regardless of the degree to which they have been affected by Proterozoic deformation.



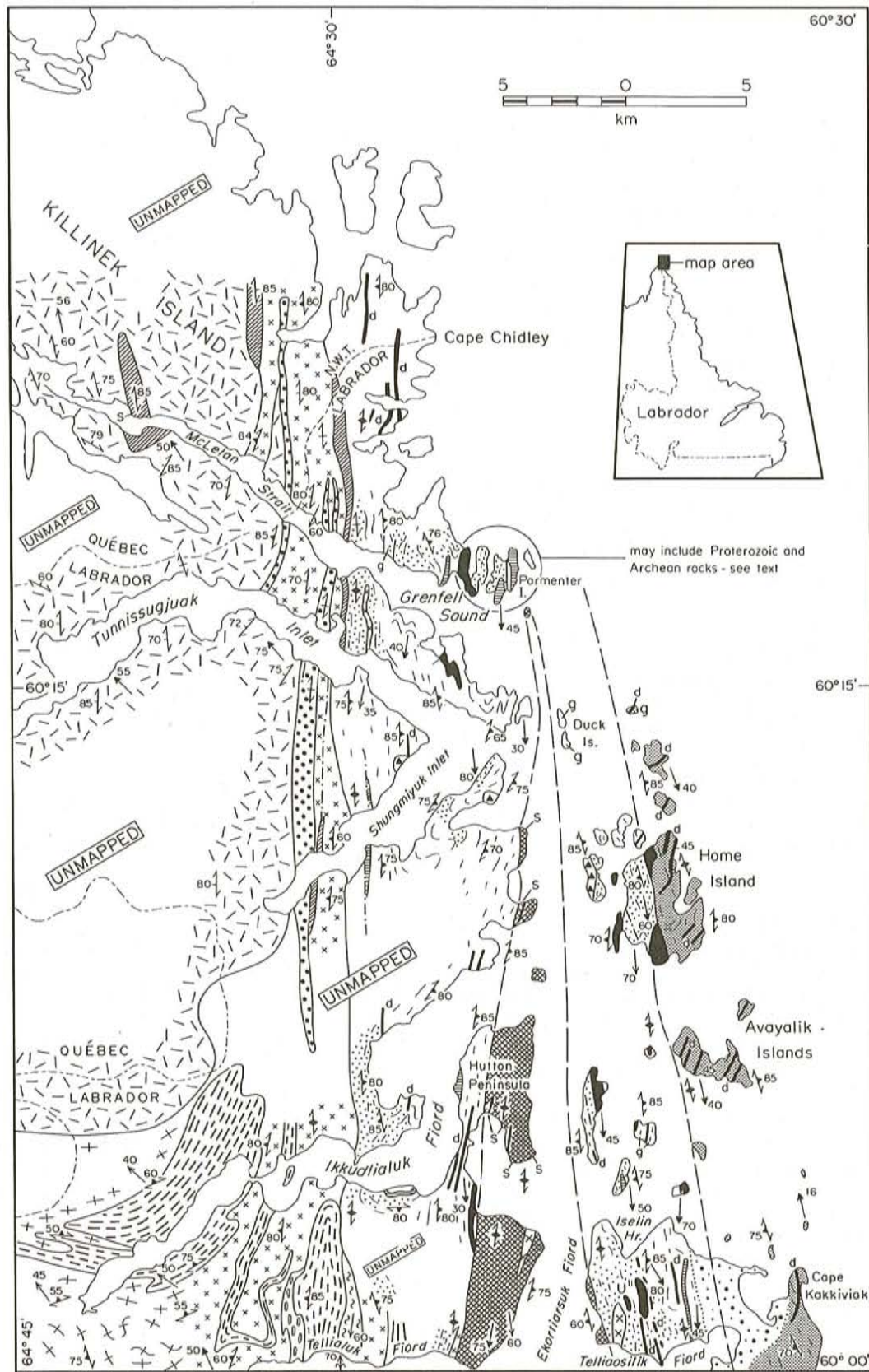


Figure 2. Geology of the field area. Areas shown as unmapped will be completed in the 1992 field season.


**LEGEND (for Figure 2)**

 Fluvioglacial drift

**LOWER PROTEROZOIC****BURWELL TERRANE METAIGNEOUS ROCKS**


 Pink megacrystic granite: *foliated to mylonitic*


 Buff hypersthene-granodiorite: *weakly foliated to gneissic*


 Grey diorite-quartz-diorite-tonalite (DQT suite): *moderately to strongly foliated and gneissic*


 Grey to buff hypersthene-bearing tonalite gneiss


**BURWELL TERRANE METASEDIMENTARY ROCKS**

 Granitic migmatite: *derived from quartzofeldspathic metasedimentary gneiss*

 Grey, banded, quartzofeldspathic psammitic gneiss: *including minor mafic (volcaniclastic?) and pelitic bands*

 Rusty-weathering garnet-biotite pelitic and psammitic gneiss,  $\pm$  sillimanite and graphite: *generally strongly migmatitic. Contains minor interlayers of green quartzite and banded clinopyroxene-amphibolite (metavolcanic/volcaniclastic?)*


 Tasiuyak gneiss: *interbanded white garnet-granite and rusty biotite-garnet-sillimanite-graphite pelitic gneiss*

 Metadiabase to amphibolite dykes

**LOWER PROTEROZOIC and/or ARCHEAN**

 Grey diorite-metagabbro plutons: *locally gneissic and migmatitic*


**ARCHEAN (Nain Crust)**

 Metagabbro: *weakly to moderately deformed, locally migmatitic; may include younger rocks on Home Island*


 Pink granite: *moderately to strongly foliated*


**NAIN GRANITOID GNEISSES:**


 Buff tonalitic-granodioritic gneisses at granulite facies

 Grey to buff, tonalitic-granodioritic gneisses at granulite facies, partially retrograded to amphibolite facies: *locally straightened and mylonitic*

 Grey tonalitic-granodioritic gneisses at amphibolite-facies gneisses: *contain abundant pink granite, granite gneiss and pegmatite; locally straightened and mylonitic*

 Anorthosite, anorthositic gabbro and anorthositic gneiss: *minor layered amphibolite/metagabbro and ultramafic rock: strongly foliated to gneissic*

 Ultramafic rocks: *generally altered to anthophyllite-actinolite assemblages*

 Layered to massive amphibolite-mafic granulite: *generally migmatitic and includes rocks of probable plutonic and supracrustal origin*

 Rusty garnet, biotite,  $\pm$  sillimanite and graphite pelitic to psammitic gneiss, interlayered with garnet-clinopyroxene,  $\pm$  hypersthene, amphibolite/mafic granulite gneiss

**SYMBOLS**

— Geological contact

- - - Inferred or extrapolated contact

- · - Ultramylonite-mylonite shear zone

↔ Gneissic layering and foliation

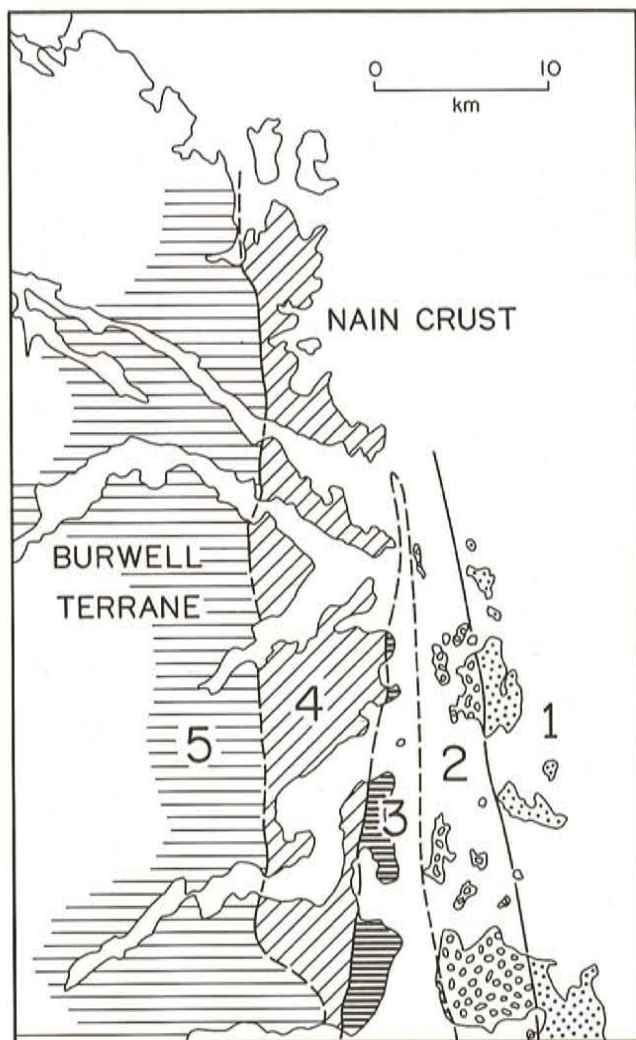
↔ Foliation

→ Lineation

→ Minor fold plunge

s Rusty sulphide zone





**Figure 3.** Structural zonation of the area shown in Figure 2.

#### ARCHEAN GNEISSES (ZONES 1, 2 AND 4)

The composition of the Archean crust does not differ significantly across the area, with the exception of the anorthosite in Zone 3. There are systematic variations in structural and metamorphic character but these are discussed in a later section.

The prevalent rock type throughout the gneiss complex is a buff- to grey-weathering, strongly migmatitic granitoid gneiss of overall tonalite–granodiorite composition (Plate 1). This appears to have been uniformly metamorphosed and migmatized in an Archean (pre-dyke) granulite-facies event and then heterogeneously retrogressed to amphibolite facies during Early Proterozoic deformation. Relict Archean gneissic texture is characterized by a profusion of disrupted enclaves of mafic and ultramafic rock enclosed within a tonalite–granodiorite leucosome (Plate 1). Strongly disrupted, so-called ‘exploded’ textures are common in these migmatites. Narrow screens of rusty metasedimentary gneiss are commonly associated with bands of mafic granulite and ultramafic rock. The mafic rocks comprise massive to weakly



**Plate 1.** Migmatitic, tonalitic, granulite-facies Archean gneiss containing disrupted mafic layers; from Zone 4. Straightening fabric at left and right of plate is due to superimposed Proterozoic strain and is associated with partial retrogression to amphibolite facies.

layered amphibolite or mafic granulite, probably derived from a plutonic protolith; and more irregularly layered rocks that may have originated as metavolcanic rocks. The ultramafic enclaves are commonly podiform and range in size from centimetres to kilometres in length. They consist of two general types: a yellow-weathering, heavily serpentinized rock, probably derived from peridotite; and a brown-weathering, metapyroxenite variety that is altered to anthophyllite–actinolite assemblages.

The original Archean character of the gneisses is best preserved in Zone 1, where the gneisses are uniformly at granulite facies, and where hypersthene porphyroblasts are preserved in the leucosome fraction. The thorough granulite-facies migmatization is probably correlative with the ca. 2.8 Ga event defined in the Saglek Fiord area (Collerson *et al.*, 1982), which was responsible for the Late Archean metamorphism of much of the northern Nain crust. Migmatization has obscured evidence of any earlier crustal history in the Archean gneisses, although Van Kranendonk and Scott (1992) have reported possible indications of relict Early Archean crust in the area to the south.

The area around Parmenter Island (outlined on Figure 2) requires special comment. Although shown as Archean, this area contains supracrustal rocks similar to the Tasiuyak gneiss (see below) and also some mesocratic to melanocratic, locally megacrystic, tonalites that are cut by unusual green mafic dykes. Relationships between these rocks and the typical Early Proterozoic dykes have not been observed and it is possible that the Parmenter Island area includes a mixture of Archean and Early Proterozoic rocks.

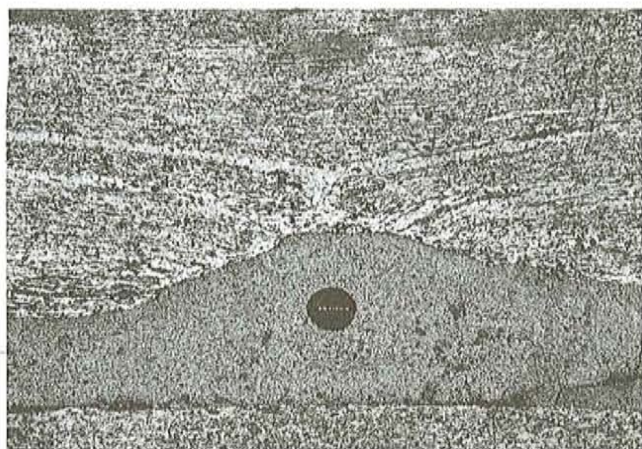
#### ARCHEAN ANORTHOSITE (ZONE 3)

Previous work by Taylor (1977) indicated a series of anorthosite lenses along the western margin of the Archean gneiss complex. Mapping in 1991 has shown that the northern



lenses are likely connected as a single pluton that underlies Zone 3 as a north-tapering wedge, and that also extends well to the south (Van Kranendonk and Scott, 1992). Although Taylor (1977, 1979) inferred an Early Proterozoic age for the anorthositic rocks, the fact that they are cut by deformed mafic dykes requires an Archean age.

The unit consists of variably foliated anorthosite, leuconorite and their gneissic equivalents, characterized by a thoroughly recrystallized, granoblastic texture containing hornblende and garnet as the principal mafic minerals (Plate 2). Relict, primary, coarse-grained texture is locally recognizable in the form of large hypersthene crystals rimmed by hornblende, and also as aggregates of granoblastic plagioclase evidently derived from the recrystallization of larger primary crystals. Thin (1 to 30 m) bands of layered amphibolite—mafic granulite, locally containing disrupted ultramafic layers, form a minor component within the unit. Another variety of anorthosite—leuconorite is a streaky, white gneiss that is injected by diffuse veins of white, garnet—hypersthene-bearing tonalite or trondhjemite. The quartz-rich composition and granulite-facies character of the tonalite—trondhjemite veins suggest that they were injected into the anorthosite gneiss during Late Archean granulite-facies melting of the host gneisses. The hypersthene migmatite fabric is cut by Early Proterozoic dykes (Plate 3) and hence of Archean age.



**Plate 2.** Archean metanorthosite of Zone 3. Dark areas are aggregates of hornblende after primary orthopyroxene.

The contacts of the anorthosite pluton are marked partly by shear zones, and partly by a 20- to 200-m-wide border sequence consisting of layered, mafic metaplutonic rocks, interlayered with anorthosite. This border sequence also includes screens of granulite-facies granitoid gneiss, mafic granulites, ultramafic rocks and minor metasedimentary gneisses, all of which are likely part of the Archean gneiss complex. The prevalence of supracrustal rocks in these border zones suggests that the anorthosite may have been preferentially intruded into such rocks, a feature that has also been noted from other Archean anorthosites (e.g., Myers, 1985).



**Plate 3.** Early Proterozoic amphibolite dyke cutting granulite-facies migmatite texture in anorthositic gneiss of Zone 3.

### LATE ARCHEAN INTRUSIONS

Crosscutting units of pink to white granite and pegmatite are locally abundant and are presumed to be of Late Archean age. These crosscut granulite-facies gneissic banding but are affected by amphibolite-facies fabrics. Larger, more homogeneous, masses of Late Archean, foliated granite have been recognized on the Duck Islands (Figure 2) where they are cut by Early Proterozoic dykes. Other Late Archean intrusions are represented by small units of ophitic gabbro on Home Island and on the north shore of Shungmiyuk Inlet. These postdate most of the migmatization in the gneiss complex but have been variably deformed and locally migmatized prior to Early Proterozoic dyke injection. Gabbro on Home Island, although similar in texture to other gabbros, is not seen to be cut by dykes and could be Early Proterozoic in age.

### GRANITOID PLUTONS OF UNCERTAIN AGE

The Archean gneisses are intruded by several small, lenticular plutons ranging from hornblende gabbro—diorite to tonalite in composition. These plutons crosscut gneissic fabrics in their host rocks and locally contain xenoliths of gneiss (Plate 4). They generally contain a single amphibolite-facies foliation that grades locally into a migmatitic texture. These rocks resemble plutonic rocks of the Burwell Terrane (Zone 5); however, relationships with the Early Proterozoic dykes have not been determined and their age is uncertain.

### THE EARLY PROTEROZOIC DYKE SWARM (ZONES 1 TO 4)

Dykes are found throughout the Nain crust (Zones 1 to 4 inclusive), except in the very west where they die out within a distance of 2 km to 200 m of the Burwell Terrane. The dykes consist of two principal types: 1) undeformed metadiabase dykes in Zone 1 termed Avayalik-type (after Avayalik Islands), and 2) amphibolite dykes that are found throughout Zones 2, 3 and 4.





**Plate 4.** *Amphibolite and anorthositic gneiss inclusions in tonalitic pluton of uncertain Late Archean or Early Proterozoic age (Zone 3).*

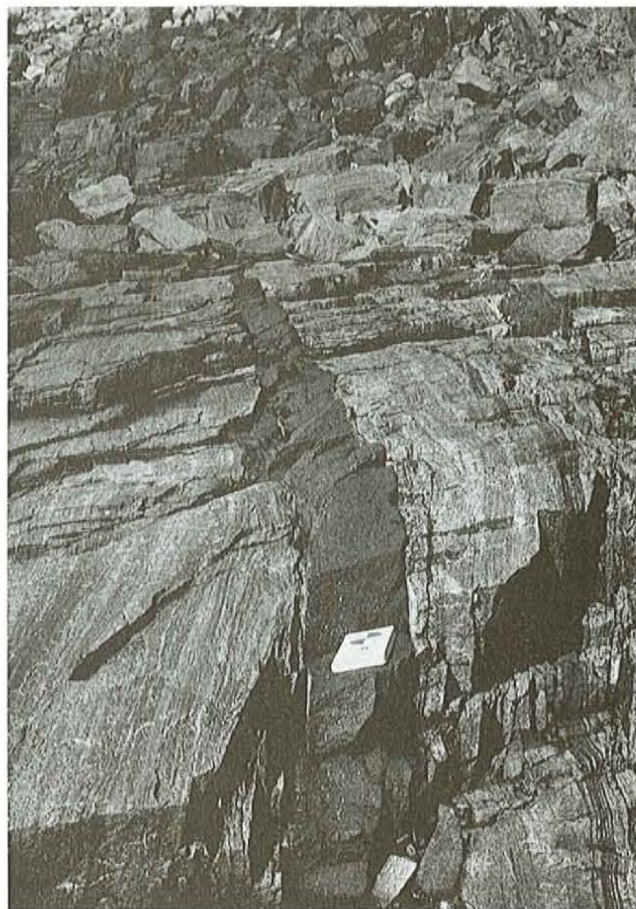
The Avayalik-type dykes are typically dark brown but vary to black or dark green, have well-preserved chilled margins, and contain scattered phenocrysts of black plagioclase. Some of the thin dykes are affected by marginal cleavage development, but the majority are straight and undeformed (Plate 5). In detail, they possess a fine, granoblastic texture composed of hornblende and plagioclase intergrown with scattered clusters or strings of garnet and local hypersthene porphyroblasts. The dykes have a consistent northeast strike and moderate southeasterly dip that is aberrant in comparison with the east-west trends and vertical attitudes of dykes in Nain Province farther to the south (Taylor, 1979). However, equivalent areas of West Greenland (allowing for pre-drift reconstruction) contain abundant northeast-trending dykes, (Nielsen, 1987), though with vertical dips.



**Plate 5.** *Avayalik-type Early Proterozoic dykes crosscutting Archean granulite-facies gneiss in Zone 1. Notebook for scale on left-hand dyke.*

The amphibolite dykes are generally black or green and are commonly, but not invariably, porphyritic, with individual dykes containing up to 20 percent white plagioclase crystals

or grain aggregates. The dykes have been pervasively recrystallized to granoblastic or foliate textures defined by hornblende-clinopyroxene  $\pm$  garnet assemblages, but lack migmatitic textures. Additional varieties, seen mostly within the anorthosite unit, are garnetiferous dykes, distinguished by large garnet-plagioclase  $\pm$  hornblende symplectites, and dykes containing large, rounded plagioclase phenocrysts up to 3 cm across. North-south trends predominate in all dykes and are the result of straightening, folding and shearing during Proterozoic deformation (Plate 6). Transitional stages have been observed between the porphyritic amphibolite dykes and Avayalik-type dykes, but the equivalence of the two types will have to be further tested through geochemical studies. Although all mafic dykes are assumed to be Early Proterozoic, there may have been more than one age of injection, as is the case in the Nachvak Fiord area to the south, where two sets of dykes have been recognized (Wardle, 1983).



**Plate 6.** *Early Proterozoic amphibolite dyke cutting retrogressed, granulite-facies Archean gneiss has been partially transposed into the north-south structural trend of Zone 2.*

## **BURWELL TERRANE, GRANITOID ROCKS (ZONE 5)**

The Burwell Terrane is dominated by granitoid rocks and their gneissic derivatives. These are grouped into two principal suites: 1) a large, relatively homogeneous



hypersthene—granodiorite batholith that occupies most of the northern part of Zone 5, and extends well to the west, and 2) a more varied suite of dioritic, quartz dioritic and tonalitic rocks of broadly calc-alkaline character, referred to as the DQT suite, that occurs in the east and south.

### Hypersthene—Granodiorite

This is typically a buff- to brown-weathering rock of predominantly granodioritic composition but varying locally to tonalite. A K-feldspar megacrystic phase is also present in a small area around central Tunnissugjuak Fiord. Where retrogressed within shear zones, this rock type looks remarkably similar to the megacrystic granite sheets that intrude the DQT suite (see below). The hypersthene—granodiorite varies from strongly foliated to gneissic, but in low strain areas, primary features such as melanocratic (cognate?) xenoliths in various stages of assimilation (Plate 7), and convolute syn-plutonic mafic dykes are preserved. Partially assimilated, slab-like inclusions of mafic granulite gneiss are also abundant and contain a fabric that at least locally can be demonstrated to predate their incorporation in the granodiorite. The eastern contact of the granodiorite with the DQT suite is mostly occupied by younger, megacrystic granite sheets. Its southern contact has not been mapped but is extrapolated (Figure 2) on the basis of the unit's distinctive aeromagnetic expression.



**Plate 7.** *Hypersthene—granodiorite of Burwell Terrane (Zone 5) showing relict igneous texture and also cognate xenoliths in various stages of assimilation.*

### The DQT Suite

The easternmost part of this suite is seen as irregular dykes of dark diorite to tonalite that are intruded across migmatite fabrics in the Archean gneisses (Plate 8). The dykes do not extend more than 200 m into the Nain crust; however, the plutons of uncertain age described above may represent more easterly examples of the suite. The DQT suite immediately west of the Nain crust consists of strongly foliated to banded, grey, dioritic—tonalitic gneisses. These grade westward into more massive hypersthene-bearing, augen gneiss variants that retain relict plagioclase-porphyritic



**Plate 8.** *Metatonalite dyke of DQT suite cutting Archean migmatite gneiss fabric; western boundary of Zone 4.*

texture. Orthopyroxene-bearing varieties of the DQT suite predominate north of Tunnissugjuak Inlet, whereas hornblende-bearing varieties are more common to the south.

Relict plutonic textures are best preserved in more southerly parts of the DQT suite, notably between Shungmiyuk Inlet and Tellialuk Fiord. Multiple intrusive phases are present consisting of early enclaves of dark, plagioclase-porphyritic hornblende gabbro or diorite cut by many different phases of quartz diorite and tonalite. The youngest phases are generally leucotonalite and pegmatite dykes (Plate 9). The DQT suite plutonic rocks, which generally contain only a single foliation, pass gradationally into zones of banded, migmatitic gneiss that locally preserve orthopyroxene porphyroblasts in their leucosome. Similar rocks have been described by Van Kranendonk and Scott (1992) from the area to the south.

In the northern part of the area, the DQT suite is intruded by numerous thin sheets of pink, megacrystic granite and derived augen gneiss, of which only the larger examples are shown on Figure 2. These have localized much of the Proterozoic strain and are generally strongly sheared, and locally converted to a distinctive pink and black ultramylonite containing relict K-feldspar porphyroclasts.





**Plate 9.** Multiple intrusive phases in DQT suite, Burwell Terrane (Zone 5). Dark inclusions of diorite are set in a polyphase matrix of paler quartz diorite-tonalite and are intruded by leucotonalite and pegmatite dykes.

Southwest of Ikkudlialuk Fiord, the recognizable plutonic rocks of the DQT suite pass westward along strike into strongly foliated, hypersthene-bearing equivalents, and then into a buff, well-banded, granulite-facies gneiss of overall tonalitic composition. The transition is thought to be solely the result of progressive metamorphism and deformation, but further field work is required before this can be confirmed.

The plutonic rocks of Burwell Terrane have yet to be dated. The westernmost parts of the DQT suite clearly postdate migmatization in the Archean gneisses but relationships have not been observed with the Proterozoic dyke swarm, which does not extend into the area intruded by DQT rocks. However, by comparison with the observations of Van Kranendonk and Scott (1992), who have described analogues of the DQT suite crosscutting Early Proterozoic mafic dykes, an Early Proterozoic age for the DQT suite is inferred. As well, indications of a Proterozoic age are provided by preliminary Nd model (depleted mantle) ages of 2.9–2.1 Ga (Jackson and Hegner, 1991), which have been interpreted as mixing of juvenile Proterozoic igneous material and remelted Archean crust. The samples analyzed by Jackson and Hegner (1991) came from the archived collection of Taylor (1979), but their field locations are unknown.

#### **BURWELL TERRANE METASEDIMENTARY GNEISSES (ZONE 5)**

Zone 5 contains a variety of metasedimentary gneisses, all of presumed Early Proterozoic age, and distinct from the Archean metasedimentary gneisses lying to the east.

Metasedimentary gneiss north of Shungmiyuk Inlet occurs as a discontinuous strip along, or near, the contact with the Archean gneisses, and as a folded belt within the hypersthene-granodiorite of Killinek Island. The gneiss is a well-layered rock consisting of alternating white, garnetiferous granite and rusty, biotite-garnet-graphite  $\pm$  sillimanite pelitic gneiss, correlated with the Tasiuyak gneiss described from areas to the south (Wardle, 1983; Goulet and Ciesielski, 1990). The contact between the Archean gneiss

complex and Tasiuyak gneiss is straightened but not mylonitized.

Metasedimentary gneisses south of Shungmiyuk Inlet are of rather different aspect. The most prominent are extensive belts of rusty-weathering, pelitic-semipelitic gneiss containing biotite-garnet-graphite  $\pm$  sillimanite assemblages and found around Ikkudlialuk Fiord. These are generally strongly migmatitic with 20 to 50 percent granite and pegmatitic veins, and contain layers of garnetiferous amphibolite and distinctive green, garnetiferous quartzite. Some outcrops also contain thin bands of a plagioclase-porphyrific amphibolite (Plate 10) that locally preserves relict grading and may have originated as volcanic layers in the gneiss protolith.



**Plate 10.** Well-layered supracrustal gneiss composed of alternating dark amphibolite bands (locally plagioclase-porphyrific) and pale quartzofeldspathic gneiss from Burwell Terrane (Zone 5), north shore of Ikkudlialuk Fiord.

A metasedimentary rock type exposed on the north shore of Tellialuk Fiord consists of grey, well-banded, quartzofeldspathic gneiss and its migmatitic equivalents (Plate 11). Plagioclase-porphyrific amphibolite layers, resembling those described above, are also present within this unit. Mapping in the area between Ikkudlialuk and Tellialuk fiords



**Plate 11.** Layered quartzofeldspathic gneiss of psammitic origin from Burwell Terrane (Zone 5), south shore of Ikkudlialuk Fiord. Hammer is 50 cm long.



is incomplete, and the distribution of metasedimentary gneisses shown on Figure 2 is speculative.

## POST-OROGENIC ROCKS

Several lamprophyric dykes were found at the western end of Tunnissugjuak Inlet, and around the entrance to Ikkudlialuk Fiord. Scattered northeast-trending diabase dykes occur west of Ikkudlialuk Fiord. All of these dykes are posttectonic but their age is otherwise unknown.

## TECTONIC EVOLUTION

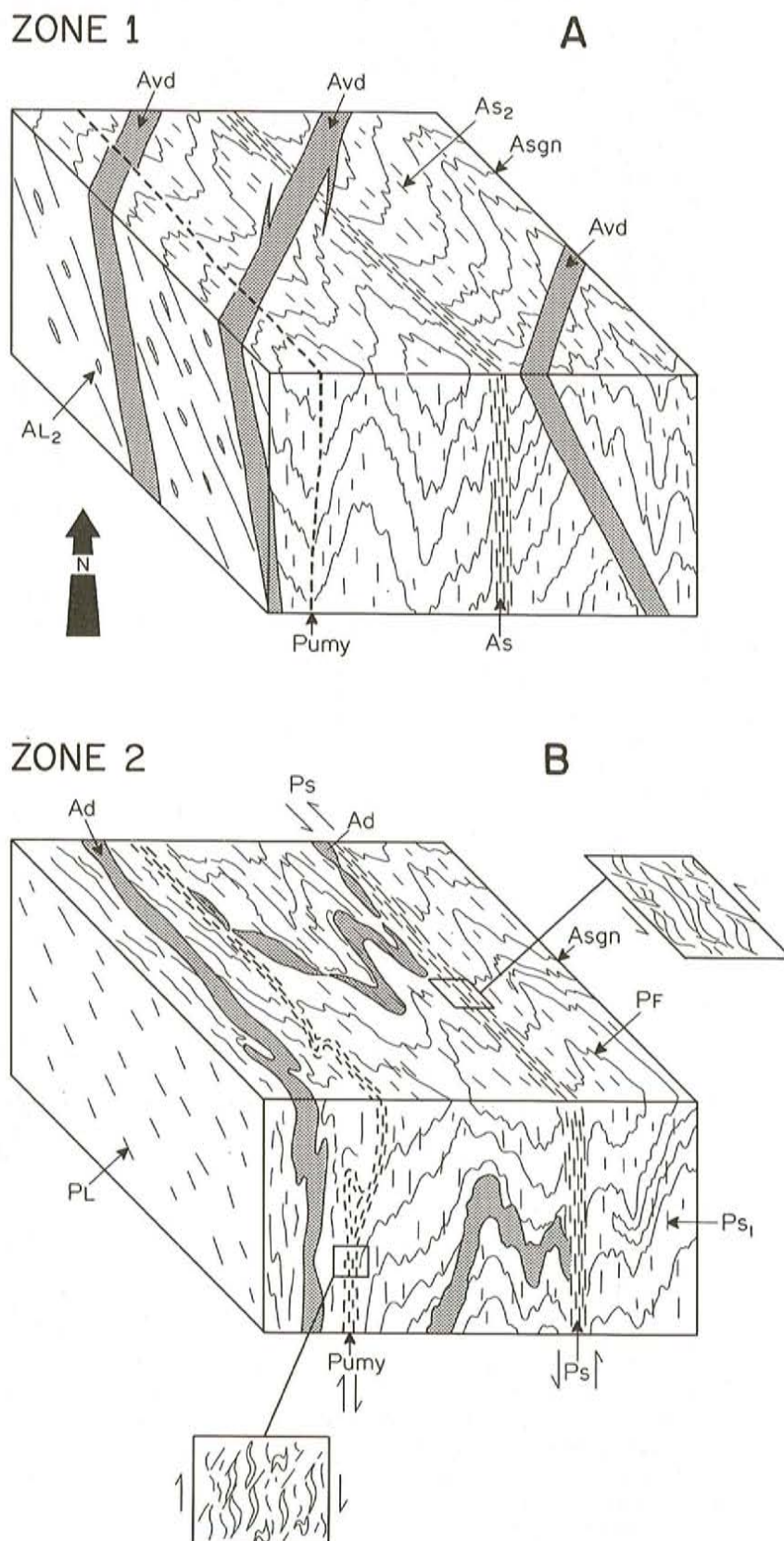
The structure of the area is described from east to west in terms of the lithotectonic zones established in Figure 3.

### Zone 1

The crosscutting nature of the dykes (Plate 5) in this zone indicates that virtually all major fabric development is of Archean age. The earliest fabric is an irregular gneissic layering that is disrupted and injected by a granulite-facies leucosome, which commonly contains orthopyroxene porphyroblasts partially rimmed by hornblende. Gneissic fabrics are affected by a set of southeast-plunging, tight to isoclinal folds, associated with the development of a weak axial-planar biotite–orthopyroxene fabric and an orthopyroxene lineation, indicating that this event also occurred at granulite facies (Figure 4a). The second set of folds appears geometrically related to north-south-trending mylonitic shear zones, defined by amphibolite-facies assemblages, that are crosscut by the Early Proterozoic dykes (Figure 4a). The only Proterozoic fabrics identified within Zone 1 are weak, hornblende fabrics on dyke margins and thin (< 20 cm) ultramylonite zones with 340° trends.

### Zone 2

The transition from Zone 1 to 2 takes place over less than 100 m and is defined by the appearance of retrogressed, straightened, grey gneisses and mylonitic, ductile shear zones that affect both gneisses and dykes (Figure 4b; Plate 6). Most of



**Figure 4.** Schematic summaries of structural geometry and deformation kinematics in structural Zones 1 (A) and 2 (B) (see Figure 3). Insets show shear sense of kinematic indicators. ASgn—Archean gneissosity; As—Archean shear zone; Avd—Avalik-type dyke; AS<sub>2</sub>—Archean second fabric; AL<sub>2</sub>—Archean (second) linear fabric; Ad—amphibolite dyke; P<sub>umy</sub>—Proterozoic ultramylonite zone; Ps—Proterozoic shear zone; PF—Proterozoic fold; PS<sub>1</sub>—Proterozoic axial-planar fabric; PL—Proterozoic linear fabric.



Zone 2 is dominated by Early Proterozoic straightening and ductile shearing associated with folding and reorientation of the Proterozoic dyke swarm into north-south trends. Proterozoic folding of Archean gneissosity is widespread. The folds generally show S-sense asymmetry and typically plunge steeply to the south (Figure 4b), and more locally to the north. The Proterozoic structures can be seen locally to refold earlier folds that are presumably Archean F2 structures (Figure 4b). The axial-planar fabric to the Proterozoic folds, which is typically defined by biotite and/or hornblende alignment, trends  $350^\circ$  and is subvertical. Proterozoic mylonite zones, developed synchronously with folding, are characterized by fine-grained, grey, mylonitic gneiss that passes into thin zones ( $< 3$  m) of black, glassy ultramylonite containing porphyroclasts of plagioclase and locally hornblende and garnet. A strong mineral lineation associated with the mylonite zones plunges steeply south to southeast, coaxial with Proterozoic fold hinges. The shear zones range up to 100 m in width and probably form a braided system isolating islands of less-deformed rock. This is best seen in the area south of Iselin Harbour (Figure 2) where a large, strain augen of Archean granulite with S-sense asymmetry is bounded by mylonitic shear zones.

Kinematic indicators suggest a complex movement history. Shear bands and rotated porphyroblasts seen in plan view (normal to lineation) invariably reveal a sinistral sense of motion (Plate 12), locally coupled with evidence in vertical section for a component of east-side-up motion. This is similar to the observations of Van Kranendonk and Scott (1992) in the area to the south. Rotated feldspars and shear bands seen in vertical sections of the glassy ultramylonite zones, parallel to lineation, usually demonstrate a west-side-up sense of motion (Plate 13). The ultramylonites locally crosscut other structures and are provisionally considered to represent a later period of shearing developed at higher crustal levels.

The mylonite zones and intervening gneisses have been locally affected by a late set of Proterozoic north-south-trending folds characterized by gentle plunges and lack of penetrative axial-planar fabrics.

### Zone 3

The anorthosite of this zone locally preserves evidence of an Archean (pre-dyke) granulite-facies migmatization (Plate 3), but has been pervasively refoliated by amphibolite-facies Proterozoic deformation. Proterozoic fabrics trend north-south and are associated with south-plunging folds and mineral lineations, which are generally collinear with those in Zone 2. A pervasive sense of sinistral shear is revealed by folds having a consistent S-sense of asymmetry and by rotated garnet-hornblende-plagioclase symplectic aggregates (Plate 14). Development of mylonite is a minor feature that is limited to thin zones at the margins of the anorthosite, and thin bands ( $< 1$  m) of black, glassy ultramylonite that form local conjugate sets trending  $065^\circ$  and  $120^\circ$ . The discordant nature of the ultramylonites is unique to Zone 3 and illustrates the late nature of this style of deformation, and the relative competency of the anorthosite.



**Plate 12.** Sinistral shear bands seen in mylonitic gneiss; Zone 2. View is of horizontal surface; lineation plunges steeply to south.

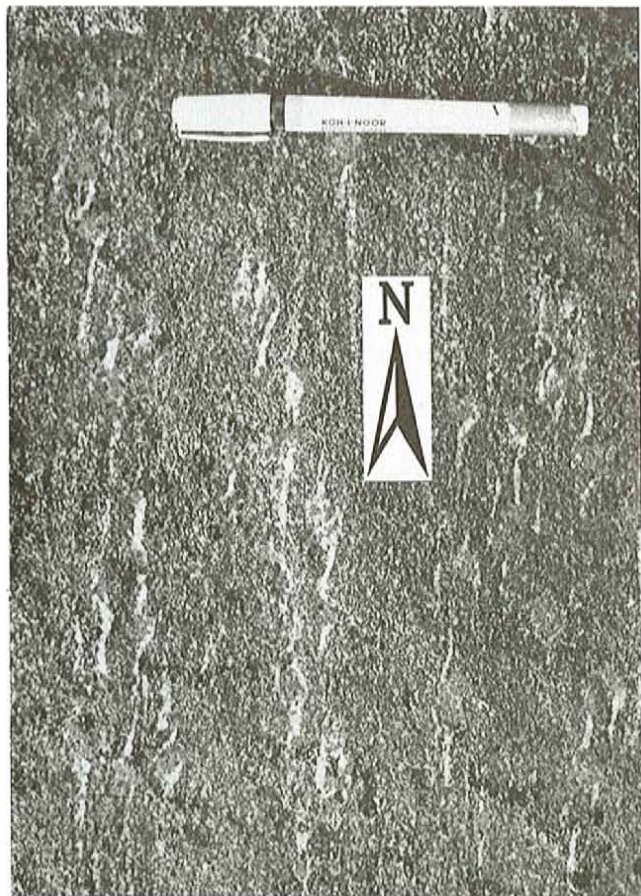


**Plate 13.** Ultramylonite seen in vertical section (parallel to lineation), looking north in Zone 2. Fine shear bands dip to left of plate and indicate west-side-up displacement.

### Zone 4

The structure of this broad zone is characterized by a large component of well-preserved, Archean granulite-facies gneiss, which has been locally retrogressed in zones of





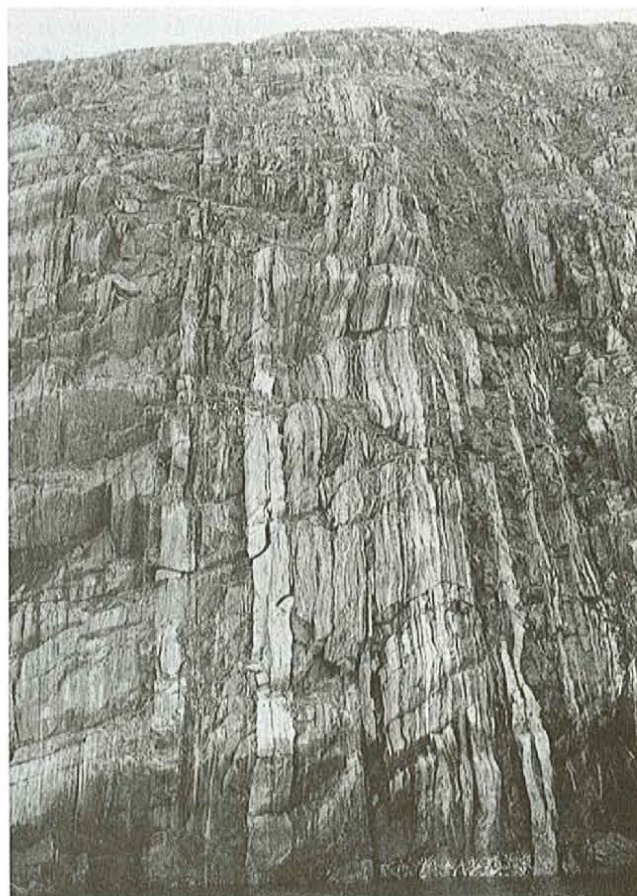
**Plate 14.** Sinistral rotational textures in garnet-plagioclase-hornblende symplectites, Zone 4. View is of horizontal surface; lineation plunges steeply to south.

Proterozoic straightening (Plate 1). Archean gneissic fabrics are folded into a series of major, south-plunging folds associated with a weak to strong mineral lineation collinear with those in zones to the east. Ductile shearing and ultramylonite development is only strongly developed on the western boundary of the zone (Plate 15). Amphibolite-facies retrogression in the Archean gneisses also becomes pronounced in the west, within 500 m of Zone 5.

Amphibolites in Zones 2, 3 and 4, including layers in the Archean gneisses, and the Proterozoic dykes, have developed garnet-plagioclase-hornblende symplectites. These may reflect decompressional effects during Proterozoic metamorphism.

### Zone 5

The boundary of Zones 4 and 5 is generally, but not invariably, marked by thin, discontinuous shear zones. North of Shungmiyuk Inlet these are preferentially located within screens of megacrystic granite, where they are seen as pink and black, feldspar-porphyroclastic ultramylonite zones texturally similar to those of Zone 2. The Archean Tasiuyak gneiss contact is straightened but only weakly affected by



**Plate 15.** Straightened, granulite-facies Archean gneisses, partially retrogressed to amphibolite facies, from Tunnissugjuak Inlet, western end of Zone 4. Height of cliff is about 100 m.

mylonitization. This contrasts with areas to the south where it is the locus of the major Abloviak shear zone (Wardle, 1983). Mylonitization south of Shungmiyuk Inlet is restricted to thin (< 50 m) zones localized along the Zone 5–Zone 4 boundary. Lineation in these mylonite zones is poorly developed but, where present, has a steep down-dip plunge. Sparse kinematic indicators suggest a west-side-up sense of movement.

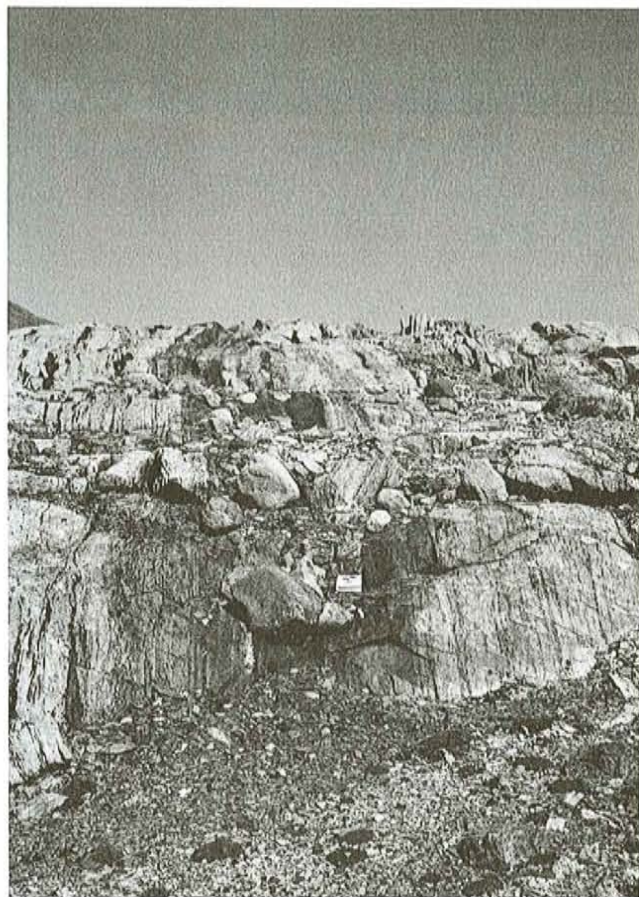
The narrow mylonite zones give way westward to a 4-km-wide, north-south-trending belt of straightened gneiss that dips steeply to the west. These straightened gneisses die in the interior of Zone 5, which is dominated by irregular, folded-fabric trends that appear, on the basis of incomplete mapping, to be related to a set of late, northwest-plunging folds associated with a moderate northwest-plunging orthopyroxene-hornblende lineation. To the south, in the vicinity of Ikkudlialuk Fiord, there is a major swing in strike to east-west trends, accompanied by the development of complex interference fold patterns. As the east-west trends are traced toward the coast they swing into alignment with the regional north-south trends. This deflection is interpreted to be the result of the sinistral deformation seen east of Zone 5.



Ubiquitous, stable hypersthene attests to the attainment of Proterozoic granulite-facies conditions in the interior of Zone 5. Amphibolite-facies assemblages prevail throughout the eastern part of Zone 5; however, the presence of relict hypersthene in rocks of the DQT suite indicates that the amphibolite-facies assemblages may be of retrograde origin, possibly associated with ductile shearing. Hypersthene-bearing assemblages are also locally retrograded to amphibolite facies along thin shear zones in the interior of the hypersthene–granodiorite batholith.

## MINERALIZATION

Several pyritiferous gossan zones have been discovered within and along the margins of the Archean anorthosite of Zone 3. The mineralized zones vary from centimetres to several metres in width and follow compositional layering in both anorthosite (Plate 16) and layered metagabbro–ultramafic rocks. Their strike length locally attains several hundred metres but in most cases has not been established beyond the coastal strip. Six selected grab samples analyzed for PGE, Au, Ni and Cr yielded disappointing results, although it should be noted that the deep gossan weathering of the sulphide zones made it difficult to obtain fresh samples. A more thorough sampling program will be undertaken in 1992.



**Plate 16.** Rusty, pyritiferous zone (dark layer on which notebook rests) in metanorthosite of Zone 3.

A large area of gossan was also discovered on the north shore of McLellan Strait (NWT) along the boundary between hypersthene–granodiorite and Tasiuyak gneiss. Analytical work is in progress and will be reported at a later date (M. Van Kranendonk, personal communication, 1991). Small gossan zones, generally less than a few metres in width, were also discovered within the hypersthene–granodiorite of Burwell Terrane; however, analysis of grab samples for Au and related elements yielded negative results.

D. Wilton (personal communication, 1991) has also reported concentrations of Cr in an ultramafic component of the anorthosite suite south of Ekortarsuk Fiord.

## DISCUSSION

The results of the 1991 field work require that considerable modification be made to previous ideas regarding the nature of the Burwell Terrane and its boundary with the Nain Province. The most significant is the finding that the Burwell Terrane is composed predominantly of plutonic rocks. These are presumed to be of Early Proterozoic age and, according to the Nd work of Jackson and Hegner (1991), must be at least in part of juvenile origin. The calc-alkaline (diorite–quartz diorite–tonalite–granodiorite–granite) composition of these rocks suggests an affinity with subduction-related plutonism and an origin in the deep levels of a magmatic arc. This arc magmatism affected only the western part of the Nain crust within the map area; however, to the south Van Kranendonk and Scott (1992) have reported intrusive activity spread across the breadth of the Nain crust. For at least the later part of its history, therefore, the Early Proterozoic Burwell 'arc' must have been founded upon a substrate of Nain crust. This requires that the idea of the Komaktorvik shear zone as a fundamental suture separating the Nain Province from the Burwell Terrane must be questioned. The shear zone was originally postulated on the basis of strong aeromagnetic and airphoto lineaments but it now appears that these result largely from regional fabric straightening, rather than mylonitization. Intense ductile shearing is therefore not as important as previously suspected and clearly postdates Burwell intrusive activity. The possibility remains, however, that early components of Burwell Terrane may represent tectonically accreted crust. In order to resolve this issue it will be necessary to determine the extent, if any, of Nain crust under Burwell Terrane; and to establish the chronology of Burwell plutonism, in particular the timing of its links with the Nain crust. Delineation of the western extent of Nain crust will depend upon future Nd studies. A U–Pb dating program, presently being undertaken by D. Scott, will establish the age range of Burwell plutonism.

Apart from the Nain–Burwell boundary, the major shear system within the area is that represented by Zone 2, well within the Archean crust. In regional terms, both shear zones can probably be considered part of the Komaktorvik shear zone; indeed they may merge in areas to the south. In a provisional kinematic interpretation, it is suggested that Early Proterozoic deformation was a two-stage event. Initial folding, shearing and lineation development, concentrated within Zone



2 but also affecting Zones 3 and 4, took place in an oblique, collisional environment by sinistral shear associated with east-side-up vertical movement. This probably occurred in response to northward motion of the Nain Province, with respect to the Rae Province, following collision of the two cratons along the Abloviak shear zone (Van Kranendonk and Ermanovics, 1990; Van Kranendonk and Scott, 1992). Sinistral shear was followed by a phase of west-side-up motion and production of glassy ultramylonites in response to late cross-orogen shortening. These late ultramylonite zones generally appear to have reactivated pre-existing sinistral structures, except within the Zone 3 anorthosite, where a conjugate set of discordant ultramylonites is developed. The formation of glassy ultramylonites in response to late shortening is thought to be comparable to more southerly parts of Torngat Orogen, where similar rocks along the eastern margin of the Abloviak shear zone represent the latest events dated between 1805 and 1782 Ma (Bertrand *et al.*, 1990).

Early Proterozoic metamorphism within Zone 1 appears to have been minimal, possibly apart from the garnet–hornblende  $\pm$  hypersthene assemblages developed in the Avayalik-type dykes. These require some discussion, particularly since identical dykes have been described by Morgan and Taylor (1972) from an area of Nain crust, 60 km to the south, suggesting that Avayalik-type dykes are a regional phenomenon. The assemblage may result simply from a regional, granulite-facies metamorphism; however, if this is the case, it is remarkable that the dykes show none of the boudinage, marginal shearing or pervasive foliation that would be expected in an environment of high-grade regional metamorphism and deformation. An alternative explanation is that the dykes were intruded into deep, hot crust and developed their metamorphic assemblages through a process of slow, static cooling at elevated temperatures; a process of auto-recrystallization. In this respect, there appears to be an analogy with the Early Proterozoic Kangamiut dykes of west Greenland (Windley, 1970; Bridgwater *et al.*, 1976), which have developed garnet–hornblende assemblages through a process of static recrystallization in areas of Archean granulite crust unaffected by subsequent tectonism. Although the Avayalik and Kangamiut dykes differ significantly in many aspects, and a correlation is not suggested, the process of auto-recrystallization may have been similar. The implications of both explanations, regional metamorphism and auto-recrystallization, are the same; Zone 1 must have been deeply buried and hot at the time of dyke emplacement. This is consistent with the model suggested by Van Kranendonk and Scott (1992), in which the northern parts of the Nain crust are proposed to represent deep structural levels that have been exhumed by ramping and progressive east-side-up uplift along the Komaktorvik shear system.

Early Proterozoic metamorphism in the remainder of the area appears to have increased from amphibolite facies in the east (Zone 2) to granulite facies in the interior of the Burwell Terrane. Exposure of granulite-facies rocks in the Burwell Terrane may have been aided by exhumation along the west-dipping shear zones located at the eastern edge of the terrane.

Another major revelation of 1991 field work is the unexpectedly large size of the anorthosite pluton represented by Zone 3. This is now seen as a single pluton at least 50 km long (including areas described by Van Kranendonk and Scott, 1992, to the south) whose southern limit is as yet undefined. A chain of similar anorthosite units extends a farther 120 km to the south (Taylor, 1979) indicating that these rocks are a fundamental feature of the western Nain crust. Archean anorthosites have generally been strongly dismembered by subsequent tectonism and granitic intrusions. An example is the well known Fiskenaeset complex of West Greenland (Bridgwater *et al.*, 1976; Myers, 1985) which, despite its large original size, is now preserved as a multitude of small segments, rarely more than 10 km in length. This feature is also true of most of the Nain Province anorthosites, which occur as small podiform masses rarely larger than a few km in diameter (e.g., Wiener, 1981). The size and integrity of the Zone 3 anorthosite is therefore surprising. Discussion of the origin of these anorthosites is beyond the scope of this paper, however, the idea that they represent the vestiges of early oceanic terranes appears to be the favoured model (e.g., Myers, 1981).

In the context of the map area, the most important problem posed by the anorthosite is its restriction to the western margin of the Nain crust. It is possible that this location is a fortuitous result of Archean tectonism, but it is tempting to compare it with the Kapuskasing structure of the Superior Province (Percival *et al.*, 1989) where Proterozoic thrusting has exposed an anorthosite-rich layer in the lower levels of the Archean crust. The anorthosite of Zone 3, together with the gneisses of Zone 4, may similarly have been dragged up from depth by ductile shearing within the Zone 2 shear system and along the Nain–Burwell boundary. If this model is correct there should be a systematic increase in both Archean and Proterozoic paleo-pressure conditions from Zone 2 into Zone 4. The field evidence does not offer any convincing support in this direction, since both Archean and Proterozoic assemblages are similar in all of these zones. Thermobarometric work in progress by F. Mengel may, however, shed additional light on the problem.

Finally the discoveries of pyrite-rich mineralization within both the anorthosite, and the interior of Burwell Terrane, have revealed an unexpected mineral potential, particularly for Ni and PGE, that requires follow-up. The greater than expected extent of anorthosite, coupled with the recognition that it belongs to a single pluton, is believed to enhance its potential as a new exploration target in northern Labrador.

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