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GEOLOGICAL MAPPING IN THE TORNGAT OROGEN, NORTHERNMOST LABRADOR: REPORT 2

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ABSTRACT

The map area forms part of the Early Proterozoic Torngat Orogen and consists of three principal tectonic divisions. In the east are Archean gneisses of the Four Peaks domain, correlative with the Nain Province; in the centre is the Komaktorvik shear zone, and in the west the Early Proterozoic plutonic and sedimentary rocks of the Burwell domain. The eastern part of the Komaktorvik shear zone contains variably sheared Archean gneisses, the elongate Hutton anorthositic suite of suspected Archean age and several small tonalitic intrusions of Early Proterozoic age. The western part contains Early Proterozoic plutonic and sedimentary rocks contiguous with those in the Burwell domain.

The Four Peaks domain is intruded by the Early Proterozoic (pre-1.91 Ga) Avayalik dykes, which show (autometamorphic?) garnet + clinopyroxene growth and preserve local evidence of possible syntectonic intrusion. The Komaktorvik shear zone contains amphibolite dykes, some of which are demonstrably continuous with the Avayalik dykes, but others of which intrude Early Proterozoic plutons.

Burwell domain plutonism is thought to represent arc magmatism, for which preliminary U−Pb dating indicates a range of 1.91 to 1.86 Ga. Preliminary Pb−Pb isotopic results indicate that the domain is unlikely to be underlain by Archean basement; mafic granulite gneisses that are exposed as enclaves in plutonic rocks may, however, represent part of an Early Proterozoic (oceanic?) basement.

The structural pattern of the map area is dominated by a major swing in strike from east−west in the interior of the Burwell domain, into the north−south trends that define the sinistral Komaktorvik shear zone. This is proposed to have resulted from oblique, sinistral Burwell−Nain convergence and was accompanied by east-side-up uplift, resulting in exposure of the lower crustal levels of the Nain Province in the form of the granulite-facies gneisses of the Four Peaks domain. A late, west-side-up phase of contractional shear that followed this deformation may have been associated with uplift of Burwell domain.

An age range of 1.79 to 1.72 Ga has been established for amphibolite-facies deformation in the Komaktorvik shear zone. This is younger than the 1.86 to 1.82 Ga Abloviak shear zone, which forms the Nain−Rae province suture to the southwest and suggests that the Komaktorvik shear zone evolved as the result of continued Nain−Burwell interaction following Nain−Rae collision.

Hints of an earlier deformation history, within and adjacent to the Komaktorvik shear zone, are provided by indications of syntectonic behaviour in the pre-1.91 Ga Avayalik dykes and the 1.84 Ga metamorphism in the Burwell domain.

INTRODUCTION

The Torngat project, which is jointly undertaken with the Geological Survey of Canada and several university research groups, is directed at mapping the Labrador peninsula north of latitude 59°15'. Initial field work in 1991 was directed at mapping of areas accessible from the coast and was reported in Wardle *et al.* (1992) and Van Kranendonk and Scott (1992). Field work in 1992 benefited from full-time helicopter support and focussed on completion of areas left unmapped in 1991 (this report), and on extension of mapping

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to the south (Van Kranendonk *et al.*, 1993). This work has been aided by companion programs of U–Pb geochronology (Scott *et al.*, 1993), metamorphic thermobarometry (F. Mengel and T. Rivers) and isotope geochemistry (Bridgwater and Wardle, *in press;* L. Campbell, personal communication, 1993).

The map area (Figures 1 and 2) lies within part of the eastern Churchill Province referred to as the Torngat Orogen and contains three first-order divisions (Figure 2). Proceeding from east to west, these are the Four Peaks domain, the Komaktorvik shear zone and the Burwell domain. These are primarily tectonic divisions but serve as convenient headings under which to discuss the component rock assemblages. The Four Peaks domain consists of granulite-facies Archean gneisses cut by Early Proterozoic dykes. These rocks are inferred to extend into the north–south-trending Komaktorvik shear zone, where they become variably sheared and where they abut Early Proterozoic plutonic and metasedimentary rocks that extend west to form the Burwell domain. This subdivision is simplified from that utilized by Wardle *et al.* (1992) in their preliminary description of the area. The following account emphasizes new information arising from this year's work (1992 field season) and the reader is referred to Wardle *et al.* (1992) for more detailed descriptions of many of the map units. Figure 2 summarizes the completed geology of the Labrador part of the map area and also includes reconnaissance information compiled for adjacent parts of Quebec and Northwest Territories from Taylor (1977).

REGIONAL GEOLOGY

FOUR PEAKS DOMAIN

This occupies the easternmost part of the area from Cape Kakkiviak to Home Island (Figure 2) and is mainly underlain by buff-coloured, granulite-facies Archean gneisses of overall tonalitic composition. These are characterized by a profusion of enclaves including mafic granulite gneiss, local anorthosite, ultramafic and metasedimentary rocks and, more rarely, porphyritic mafic granulite probably representing relict dyke material (Plate 1). Reconnaissance work (DB) indicates that the gneisses can be traced at least as far south as Seven Islands Bay (Figure 1) from where they probably extend south to join with rocks of the Archean Nain Province. The Pb–Pb whole-rock isotope work (Bridgwater and Wardle, *in press*) confirms an Archean age for gneisses in the Seven Islands Bay area and indicates the local presence of very old (>3.7 Ga) crust, thus strengthening the link with the Nain Province.

The gneisses are cut by irregular sheets of foliated pink granite and dykes of pink pegmatite that are in turn crosscut by the northeast-trending Avayalik dykes of presumed Early Proterozoic age.

The Avayalik dykes are distinguished by black, plagioclase phenocrysts set in a finely recrystallized, granoblastic matrix of hornblende, biotite, plagioclase and strongly altered pyroxene, and contain scattered porphyroblasts of garnet intergrown with clinopyroxene. The larger dykes are essentially undeformed but thinner dykes show a weak cleavage. Adjacent to the Komaktorvik shear zone, some dykes both crosscut and are deformed by small-scale shear zones. This was interpreted by Wardle *et al.* (1992) to indicate intrusion of dykes between periods of Late Archean and Early Proterozoic ductile shearing, but it is possible that it could also be taken as evidence for syn-shear emplacement (Plate 2). Further work is needed to confirm this interpretation.

The northeast trend of the Avayalik dykes, their distinctive black plagioclase phenocrysts, garnet–clinopyroxene assemblages and LIL-enriched geochemistry appear to distinguish them from the main swarm of east–west-trending, 2.4 to 2.2 Ga dykes that intrude the Nain Province to the south.

The age of the Avayalik dykes is only broadly constrained and could range between latest Archean and ca. 1.91 Ga, the age of plutons that intrude the dykes south of the map area (Van Kranendonk and Scott, 1992). A potential correlative for the swarm is the 1.95 Ga Kangâmiut swarm of West Greenland (Kalsbeek *et al.*, 1978), which is characterized by northeasterly trends and occupies a similar geographic position, allowing for restoration of Labrador Sea opening, to the Avayalik swarm. Similarities with the Kangâmiut dykes also include; i) internal metamorphic recrystallization (including garnet growth) in the absence of regional deformation in their Archean host rocks, and ii) characteristics of synkinematic intrusion (Nash, 1979; Bridgwater *et al.*, 1985), including evidence for intrusion into active shear zones. Geochemical results from two samples of Avayalik dykes in the Four Peaks domain and two in the Komatorvik shear zone (DB) show them to be LIL and LREE enriched to a comparable degree as the Kangâmiut dykes. This contrasts with results from the ca. 2.4 to 2.2 Ga dyke swarms farther south in both Greenland and Labrador. The Kangâmiut dykes differ from the Avayalik dykes in their general, although not complete, lack of black plagioclase phenocrysts, and the presence of pronounced compositional zoning. Correlation will hopefully be constrained by U–Pb dating currently in progress on the Avayalik dykes.

ARCHEAN AND PROTEROZOIC ROCKS OF THE KOMAKTORVIK SHEAR ZONE

The term Komaktorvik zone was originally used by Korstgård *et al.* (1987) to refer to a distinctive belt of Archean crust, characterized by elongate Archean anorthosite units and intense, high-grade, Early Proterozoic reworking, which was defined in the area of Saglek and Nachvak fiords and proposed, on the basis of aeromagnetic trends, to extend north to separate the Nain Province from the Burwell domain. Since then, it has been shown that much of the high-grade reworking that characterizes the southern part of the zone is a result of deformation related to movement on the Abloviak shear zone (Figure 1) between 1.88 and 1.82 Ga and that the northern part of the Komaktorvik zone, i.e., that part bounding the Burwell domain, has a younger history of 1.79 to 1.72 Ga (Scott *et al.* 1993). Confusion has arisen over recent

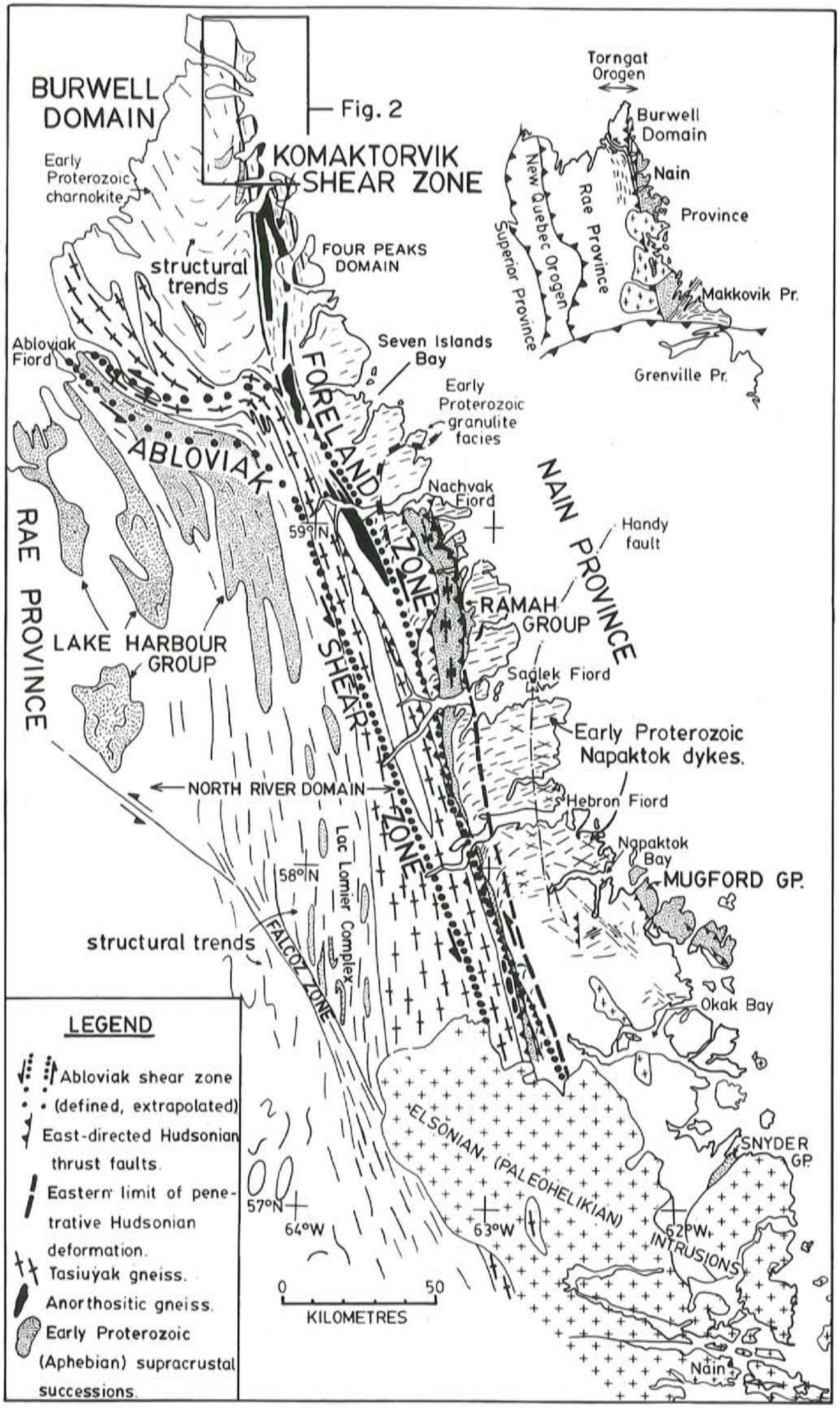

Figure 1. *Generalized map of Torngat Orogen in northern Labrador, northeastern Quebec and Northwest Territories (after Van Kranendonk, 1990). Map area discussed in this report is outlined by box labelled Figure 2.*

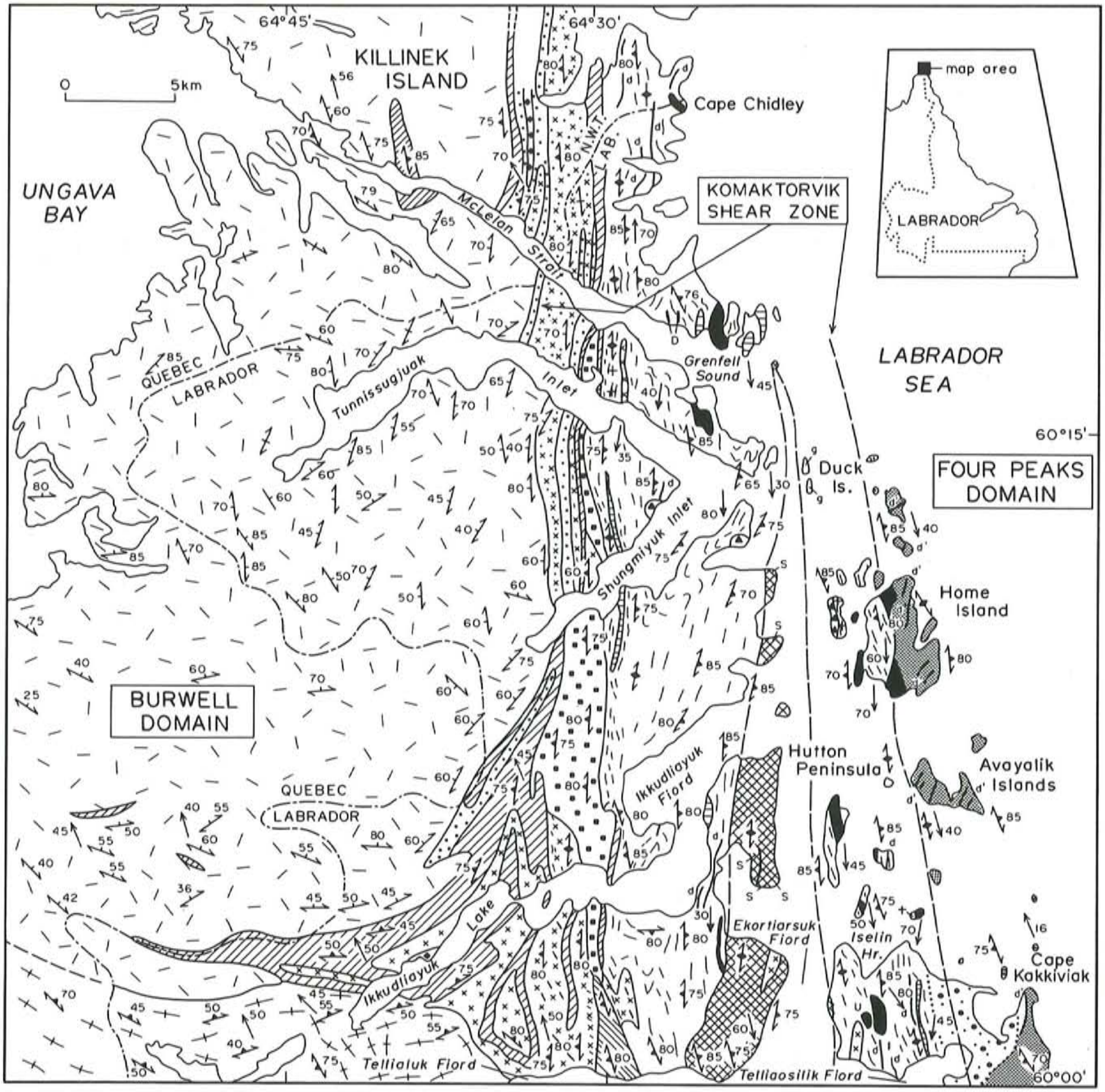

Figure 2. *Geology of the field area north of latitude 60°. Information for western parts of the map area in Quebec has been compiled from Taylor (1977).*

use of the term Komaktorvik zone in a largely structural sense (e.g., Van Kranendonk *et al.*, 1993) and its original definition, which involved a mixture of structural and lithological attributes. Accordingly, it is proposed that the term be revised to Komaktorvik shear zone and redefined as the broad zone of ductile shearing that separates the Burwell domain from the Four Peaks domain and also locally overprints the boundaries of these domains. The definition of the shear zone thus becomes purely structural and is freed from entanglement with lithological features and fabrics of the Abloviak shear zone. It is emphasized that the age range of the zone is open-ended (see below) and that its effects may have extended outside of the presently defined limits. The fact that some of the rocks, which comprise the shear zone, notably the anorthosites, form a distinctive and unique component of the Archean crust is a separate problem. It is proposed that the term Hutton anorthositic suite be used to refer to these rocks but it is possible that an additional term will be necessary to embrace all of the lithological characteristics involved in the Korstgård *et al.* (1987) definition.

The eastern part of the Komaktorvik shear zone consists of Archean gneisses, the Hutton anorthositic suite, and

LEGEND

Fluvioglacial drift

LOWER PROTEROZOIC

BURWELL DOMAIN ROCKS

Pink granitic gneiss and megacrystic granite: *includes screens of grey orthopyroxene-bearing dioritic rocks*

Killinek charnockitic suite: *buff, orthopyroxene-bearing rocks (granite, granodiorite and monzonite)*

Grey diorite–quartz diorite–tonalite (DQT suite): *orthopyroxene-bearing/hornblende-bearing varieties*

Grey foliated to gneissic tonalite of DTG suite containing areas of banded quartzofeldspathic (psammitic?) and rusty semipelitic gneiss

Grey, migmatitic tonalite–quartz diorite gneiss of DTG suite

Grey to buff DTG tonalite–tonalite gneiss, locally orthopyroxene-bearing, containing abundant enclaves of mafic granulite and amphibolite

Amphibolite and amphibolite gneiss, locally well layered, intruded by abundant pink pegmatite sheets

Mafic granulite

Rusty-weathering garnet-biotite pelitic and psammitic gneiss, ± sillimanite and graphite: *generally strongly migmatitic*

PROTEROZOIC DYKES IN ARCHEAN CRUST

D Diorite dykes

d' Metadiabase–gabbro Avayalik dykes

d Amphibolite dykes

LOWER PROTEROZOIC and/or ARCHEAN

Metagabbro: *weakly to moderately deformed*

ARCHEAN (Nain Crust)

g Pink granite: *moderately to strongly foliated to gneissic*

Buff tonalitic–granodioritic gneisses at granulite-facies

Grey tonalitic–granodioritic gneisses, predominantly at amphibolite-facies with relict granulite-facies assemblages. Locally contains abundant pink granite, granite gneiss and pegmatite. Variably straightened and mylonitic

Hutton anorthositic suite; anorthosite, anorthositic gabbro and anorthositic gneiss; minor layered amphibolite/metagabbro and ultramafic rock

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

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

Rusty garnet, biotite, ± sillimanite and graphite pelitic to psammitic gneiss, interlayered with amphibolite/mafic granulite gneiss

SYMBOLS

Geological contact

Inferred or extrapolated contact

Area affected by mylonitic fabric development

Gneissic layering and foliation

Foliation

Lineation

Minor fold plunge

S *Rusty sulphide zone*

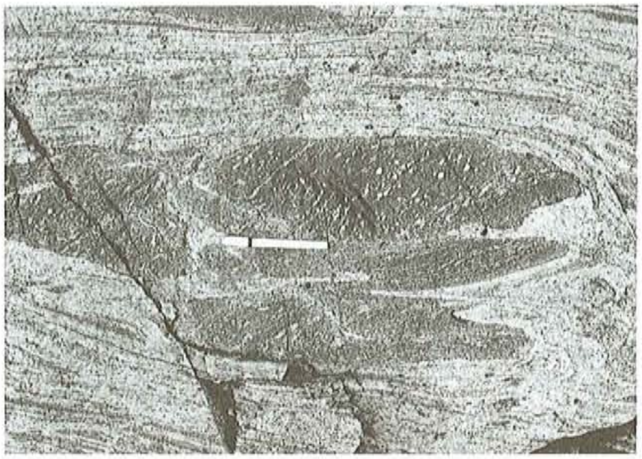

Plate 1. *Pod of plagioclase-porphyritic mafic granulite representing possible relict dyke material in granulite-facies gneiss of Four Peaks domain.*

Plate 2. *An Avayalik dyke that both cuts, and is deformed by, a north–south-trending mylonite zone on the eastern boundary of the Komaktorvik shear zone; relationship indicates possible syn-shear behaviour.*

Proterozoic dykes and tonalite intrusions, all variably straightened and mylonitized by Early Proterozoic deformation. The western part of the shear zone is located within the various Early Proterozoic plutonic and metasedimentary rocks that extend west into the Burwell domain. Straightening into an overall north–south trend is the dominant structural feature of the zone but narrow belts of mylonite and ultramylonite ranging from several metres up to 0.5 km in width are prevalent, probably as braided shear systems, along the eastern margin of the anorthosite and along the contact with the Burwell domain. The eastern contact of the shear zone is abrupt and is marked by the transition of buff, granulite-facies gneisses of the Four Peaks domain into strongly sheared, grey, amphibolite-facies rocks over a distance of less than 100 m (narrow, widely spaced shear zones are, however, found throughout the Four Peaks domain). Low-strain areas within the Komaktorvik shear zone preserve features similar to those seen in the gneisses of the Four Peaks domain, notably relict granulite-facies assemblages and an abundance of mafic enclaves, suggesting that they may be the reworked equivalents of these gneisses. Similarities are also evident in the relative chronologies of the two gneiss complexes, both having been intruded by pink, schlieric granite and pegmatite, prior to injection of Early Proterozoic mafic dykes.

The Hutton anorthositic suite consists mostly of migmatitic, anorthositic gneiss with a *lit-par-lit* layering defined by mobilizate phases of secondary anorthosite and leucotonalite–trondhjemite (Plate 3). Less-deformed parts consist of foliated anorthosite and gabbroic anorthosite containing relict pyroxene (predominantly orthopyroxene), and local primary plagioclase, in a secondary matrix of granoblastic white plagioclase, garnet and hornblende. The anorthosite was deformed, migmatized and intruded by sheets of pink, schlieric granite similar to those forming late phases in the enclosing tonalitic gneisses, prior to amphibolite dyke injection and on this basis was provisionally assigned an Archean age (Wardle *et al.*, 1992). Its texture, however, is unlike that of anorthosites elsewhere in the Nain Province, particularly with respect to the paucity of snowball plagioclase megacrysts (although these are locally seen south of the map area), and is atypical of Archean anorthosites in general. U–Pb dating is currently in progress to establish the age of the pink granites that intrude the anorthosite and thereby place a minimum age on the unit.

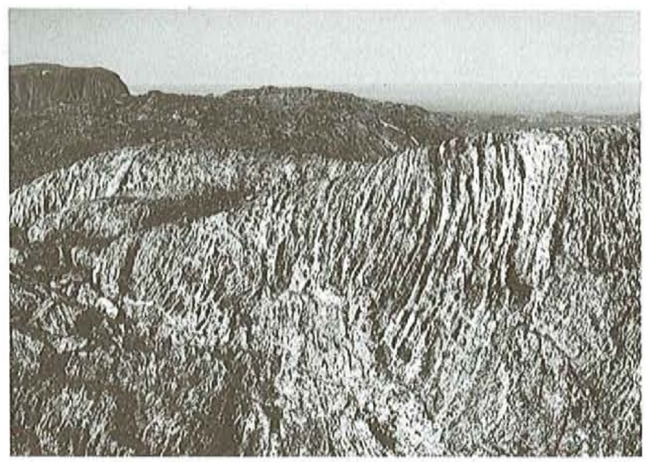

Plate 3. *Anorthositic gneiss of Hutton anorthositic suite, cut by leucotonalitic or trondhjemitic mobilizate.*

Amphibolite dykes, including garnetiferous and non-garnetiferous varieties, are abundant and intrude the gneisses and anorthosite of the Komaktorvik shear zone where they preserve local discordance with earlier migmatitic gneissic fabrics. The dykes have a uniform north–south trend that is, in part at least, a result of transposition into the regional straightening fabric. It is uncertain, however, if all amphibolite dykes in the Komaktorvik shear zone are retrogressed and deformed equivalents of the Avayalik dykes. Some dykes are weakly sheared in comparison with the host rocks and also transgress earlier shear fabrics, suggesting that the dykes may have intruded synchronously with ductile shearing. Whether this shearing is the same age as the 1.79 to 1.72 Ga deformation in the Komaktorvik shear zone or represents an earlier period of deformation (Late Archean or earliest Proterozoic), or whether the dykes represent a different suite from the Avayalik dykes is uncertain. On the islands north of Grenfell Sound, a second set of dykes has been recognized that is younger than, and distinct from, the Avayalik dykes on the basis of a lighter green colour and equigranular groundmass, and because they intrude a small occurrence of Early Proterozoic meta-igneous rocks (not shown on Figure 2). Whether these dykes are the same as those exhibiting possible syntectonic relationships is unclear pending further detailed study.

The Archean gneisses and anorthosite of the Komaktorvik shear zone are cut by small intrusions of diorite–gabbro and tonalite (Wardle *et al.*, 1992). Some of the gabbros are cut by metadiabasic dykes and are of uncertain Archean or Early Proterozoic age. U–Pb dating (Scott *et al.*, 1993) of tonalitic intrusions near Eclipse Harbour, south of the map area, indicates a maximum range in age between 1997 and 1859 Ma, similar to that determined for the Burwell domain intrusive rocks. The Burwell domain rocks that underlie the western part of the Komaktorvik shear zone are included in the descriptions below.

BURWELL DOMAIN

The Burwell domain consists predominantly of Early Proterozoic plutonic rocks interspersed with belts of metasedimentary gneiss.

The plutonic rocks of the domain consist of two major components; an eastern belt of grey diorite, quartz diorite, tonalite and granite, and their derived gneisses, referred to as the DTG suite; and a western association of buff, charnockitic rocks ranging from granite to monzonite and quartz diorite in composition and termed the Killinek charnockite suite. The DTG suite north of Shungmiyuk Inlet contains relict orthopyroxene as a primary igneous phase but south of the inlet, hornblende and biotite are the primary phases. It is perhaps significant that these two groups of the DTG suite are for the most part separated by a thin belt of metasedimentary gneiss that transgresses the Komaktorvik shear zone at a shallow angle and which may mark an internal structural dislocation. The rocks south of Shungmiyuk Inlet also provide the best preservation of igneous textures in the suite (Wardle *et al.*, 1992), including multiple, crosscutting phases of diorite and tonalite (that generally become more leucocratic with relative age) and preservation of porphyry texture in diorite components (Plate 4). A U–Pb age from tonalite of this suite two kilometres south of Tellialuk Fiord yielded an intrusion age of 1910 $\pm$ 2 Ma (Scott *et al.*, 1993).

Separating the DTG suite from the Archean gneisses in the southern part of the area is a wedge-shaped unit of foliated to gneissic amphibolite, intruded by sheets of pink granite and pegmatite. Where least deformed, the amphibolite appears to have been derived from a plutonic protolith of gabbroic or dioritic composition and may represent a mafic end member of the DTG suite. The pink granitoid sheets transgress gneissic foliation in these rocks and appear to have been intruded syntectonically with respect to the development of late straightening fabrics.

Plate 4. *Enclave of dioritic porphyry within tonalite of DTG suite. Dark rim of porphyry may represent a relict chilled margin.*

Restricted to the southern part of the area is a mixed unit of foliated to gneissic tonalite that contains lenses of banded, quartzofeldspathic (psammitic?) gneiss, rusty semipelitic gneiss and (south of the map area) marble–calc-silicate. These metasedimentary components grade into well-banded quartzofeldspathic gneisses of indeterminate origin and also into rocks that are apparently derived from tonalite.

Also associated with the DTG suite is a considerable expanse of grey, migmatitic tonalite–quartz diorite gneiss that is concentrated along the eastern margin of the Burwell domain between Ikkudliayuk Fiord and Grenfell Sound. Whilst some exposures preserve relict igneous textures similar to those seen in the DTG suite, the majority of the unit is strongly gneissic and variably migmatitic with a white leucotonalitic to pegmatitic leucosome. The unit resembles the amphibolite-facies Archean gneisses to the east but can usually be distinguished on the basis of its compositionally more homogeneous nature and by the absence of mafic enclaves and dykes.

The Killinek charnockitic suite forms the bulk of the interior and western parts of the Burwell domain. The predominant rock type is a buff-weathering granodiorite containing small, cognate inclusions, slab-like inclusions of mafic granulite and local synplutonic mafic dykes. Toward its contact with the DTG suite, the unit becomes compositionally more varied and includes significant amounts of dark, fine-grained orthopyroxene-bearing quartz diorite in addition to pegmatite and buff megacrystic granite. The boundary with the DTG suite has generally been mapped at the transition from buff (orthopyroxene-bearing) rocks to grey, hornblende-bearing ones. In many places, this coincides with a genuine compositional change, in others, however, it appears to be a retrograde metamorphic transition that cuts across compositional units. Some of the marginal components of the charnockitic suite may therefore be genetically associated with parts of the DTG suite, particularly the northern part of the suite that contains relict, primary orthopyroxene. A sample of charnockite from the south shore of Killinek island has yielded an age of 1895 ± 3 Ma (Scott *et al.*, 1993).

Both the DTG and Killinek charnockitic suites are intruded by sheets of granite, including megacrystic, aplitic and pegmatitic varieties, and their gneissic equivalents. These appear to be more prevalent in the amphibolite-facies DTG suite, where they stand out as conspicuous pink sheets, but also occur as orthopyroxene-bearing varieties in the charnockitic suite where they are camouflaged by their buff-green colouration. A megacrystic granite from Killinek Island has given a minimum U–Pb age of 1864 ± 2 Ma, and may be as old as 1877 Ma (Scott *et al.*, 1993). Various types of dioritic to tonalitic dykes that cut the Archean gneisses and anorthosite within the Komaktorvik shear zone are probably also related to the DTG suite. As noted above, some of these dykes, including those north of Grenfell Sound, show evidence of syntectonic intrusion.

Reconnaissance Pb–Pb whole-rock isotopic studies (Bridgwater and Wardle, *in press*) have shown that the DTG suite tonalite (ca. 1.91 Ga) in western Tellialuk Fiord lacks a significant component of Pb derived from an Archean lower crustal source such as the Four Peaks domain, suggesting that the DTG suite is essentially a juvenile Proterozoic addition to the crust. In contrast, a single sample from the 1.89 Ga Killinek charnockitic suite contains Pb with an isotopic composition indistinguishable from that of the Tasiuyak metasedimentary gneiss, which forms a major unit separating the Burwell domain from the Rae Province (Figure 1). This suggests that Pb in the charnockites was derived from a source most likely found in the numerous belts of Tasiuyak-like metasedimentary gneiss that occur throughout the Burwell domain, many of which are too small to show on Figure 2.

Metasedimentary rocks of Burwell domain are represented by several belts of rusty-weathering, garnet–biotite pelitic and psammitic gneiss, generally strongly migmatitic and dispersed throughout the domain. The widest and most extensive belt trends east–west through the Ikkudliayuk Lake area then swings north, crossing the strike of the DTG suite at an acute angle and narrowing in places to less than 20 m, to Grenfell Sound where it forms the boundary between the Early Proterozoic plutonic rocks and Archean gneisses within the Komaktorvik shear zone. As noted above, this belt separates orthopyroxene- and hornblende-bearing components of the DTG suite. In the Ikkudliayuk Lake area, the metasedimentary gneisses are complexly interfolded with plutonic rocks of the DTG suite. Smaller units of metasedimentary gneiss also occur interspersed within the interior parts of Burwell domain as noted above.

The metasedimentary gneisses are compositionally similar to the Tasiuyak gneiss but differ in that they contain numerous pods and bands of buff, fine-grained granitoid, interpreted as dykes that have been disrupted by migmatization and deformation (Plate 5). The dykes are probably related to the charnockitic suite and mostly appear to predate the metasedimentary gneiss fabrics, although one exception cutting gneissosity was noted.

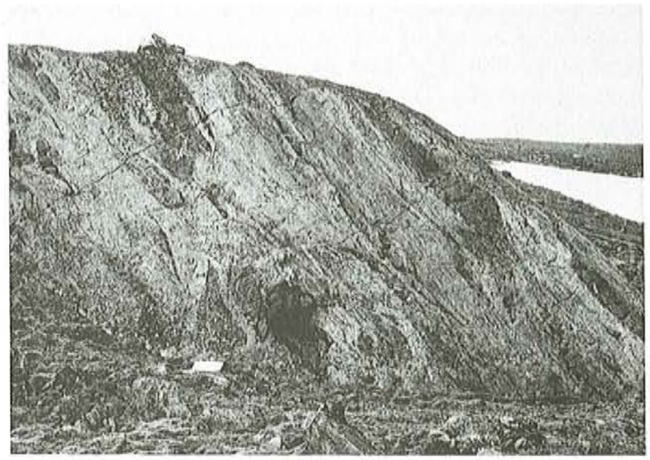

Plate 5. *Strongly migmatitic, metasedimentary gneiss with abundant white granitic leucosome containing charnockitic pods believed to represent relict granitoid dykes.*

Older rocks of Burwell domain are found as a small belt on the north shore of Ikkudliayuk Lake, and as enclaves in the DTG suite south and west of Ikkudliayuk Lake. Rock types comprise finely banded mafic granulite and amphibolite, (probably derived from a mafic supracrustal sequence), massive to gneissic amphibolite, and more locally ultramafic (Plate 6). Areas of tonalite containing more than fifty percent enclave material, have been distinguished as a separate unit on Figure 2. The mafic granulite–amphibolite enclaves were deformed at granulite-facies prior to intrusion of diorite and tonalite (Plate 7) and must be older than ca. 1.91 Ga (the age of nearby DTG tonalite), but could otherwise range from Archean to earliest Proterozoic. U–Pb dating and Nd-isotopic studies are in progress to establish the age of this older sequence. A small unit of mafic granulite also occurs on Killinek Island but may be different in age to that described above. Thin, extensive units of mafic granulite have also been found in the area to the south (Van Kranendonk *et al.*, 1993).

PHANEROZOIC ROCKS

Several east–west-tending dykes of brown gabbro and diabase have been found in the southern and western parts of the area. These appear similar to a 25-km-long dyke that occurs south of the map area and yielded a 524 ± 78 Ma K–Ar date (Taylor, 1979). U–Pb dating of baddelyite from this dyke is in progress at the Geological Survey of Canada in Ottawa.

Several thin, approximately northeast-trending dykes of dark-green to black, biotite–olivine lamprophyre and/or lamproite, have also been discovered in well-exposed coastal regions. These dykes are recessive and therefore difficult to

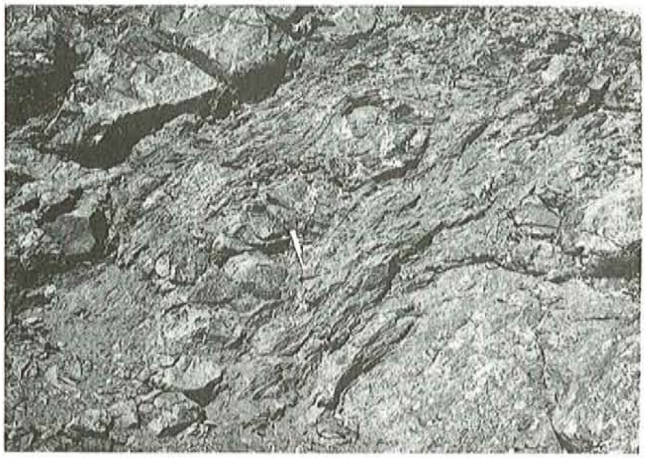

Plate 6. *Tectonized ultramafic enclave, representing early Burwell crust, within tonalite of DTG suite. (Podiform unit next to hammer is a boudan of less-deformed ultramafic in schistose ultramafic matrix.)*

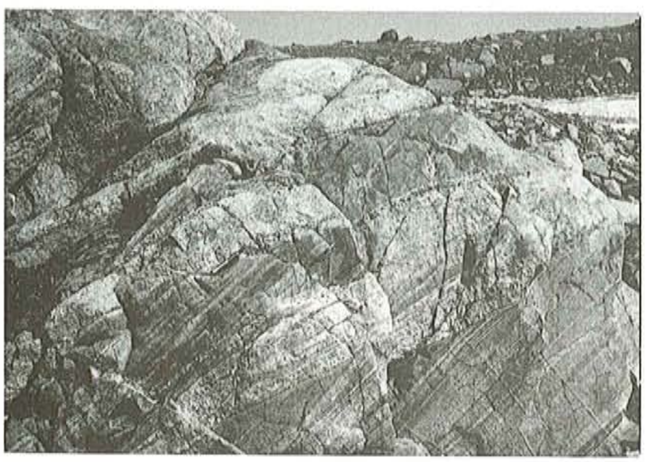

Plate 7. *Early Burwell domain layered (supracrustal?) mafic granulite cut by amphibolite-facies tonalite sheets of DTG suite.*

recognize inland. They are posttectonic, with respect to their host rocks, but otherwise their age is unknown.

STRUCTURE

Structural trends within the Four Peaks domain are dominated by north–south-trending, granulite-facies fabrics refolded by a set of south-plunging second folds that predate emplacement of the Avayalik dykes. The gneissic fabrics are of Archean age, based upon presumed continuity with Archean gneisses of the Nain Province to the south. The age of the second-generation folding is unknown but is bracketed by late, pre-folding pegmatites and the post-folding Avayalik dykes.

The interior of the Burwell domain is characterized by weak to moderate foliations that appear to have had a shallow to moderate dip prior to later refolding (see below). The most prominent feature of the domain is the swing in structural strike from northwest trends in the western part of the domain, into north–south trends toward the Komaktorvik shear zone (Figure 2). Gneissic fabrics and second-generation fold axial planes dip moderately to shallowly to the north around this flexure and are associated with a northwest-plunging mineral lineation defined by orthopyroxene and hornblende. The overall structural style suggests a general vergence to the southeast (see also Van Kranendonk *et al.*, 1993).

Burwell domain units become straightened and attenuated within the Komaktorvik shear zone, a feature that is most clearly demonstrated by the Ikkudliayuk Lake metasedimentary gneiss belt, which is internally mylonitized and has probably acted as a major dislocation that separates northern and southern components of the DTG suite. Other units, for example, some of the megacrystic granite sheets, are excised along the contact with the Archean gneisses and attest to the localization of ductile shearing at this boundary.

The manner in which Burwell domain units are attenuated and excised, coupled with evidence from kinematic indicators (Van Kranendonk and Scott, 1992; Wardle *et al.*, 1992), provides strong evidence that the Komaktorvik shear zone formed within an overall environment of sinistral shear. Lineations and second-generation fold hinges within the shear zone (Plate 8) generally plunge south at steep to moderate attitudes and indicate that sinistral shear must have been associated with a substantial component of oblique, east-side-up motion (Van Kranendonk and Scott, 1992; Van Kranendonk *et al.*, 1993). There are many areas though, particularly in the western part of the shear zone, where lineation is absent—even within strongly mylonitized rocks—thus possibly indicating a substantial component of pure shear. A further problem is posed by the presence of vertical and north-plunging lineations in the northern part of the shear zone on Killinek Island. This may mark a local change in shear sense to west-side-up sinistral motion; alternatively it may indicate rotation of fold hinges by later deformation. There is also evidence for a late phase of west-side-up contractional shearing in association with ultramylonite formation (Plate 9), particularly in the area south of Iselin Harbour (Van Kranendonk and Scott 1992; Wardle *et al.*, 1992), which is being further studied as part of an M.Sc thesis by B. Patey at Memorial University.

Penetrative shearing was succeeded by third-generation folds generally distinguished by their open geometry and lack of axial-planar fabrics. In the interior of Burwell domain, this was associated with open, flexural folding of foliation (and locally lineation) about roughly north-plunging axes, and in the Komaktorvik shear zone with folding of shear fabrics into north- and south-plunging folds, possibly with curvilinear hinge lines. The large infold of DTG tonalite into Archean gneiss south of Ikkudliayuk Fiord is, in part at least, a result of this event. The geometry of the third-generation folds is comparable to that of large, regional folds developed south of the area (Van Kranendonk *et al.*, 1993), including a major bend in the strike of the Tasiuyak gneiss (Figure 1).

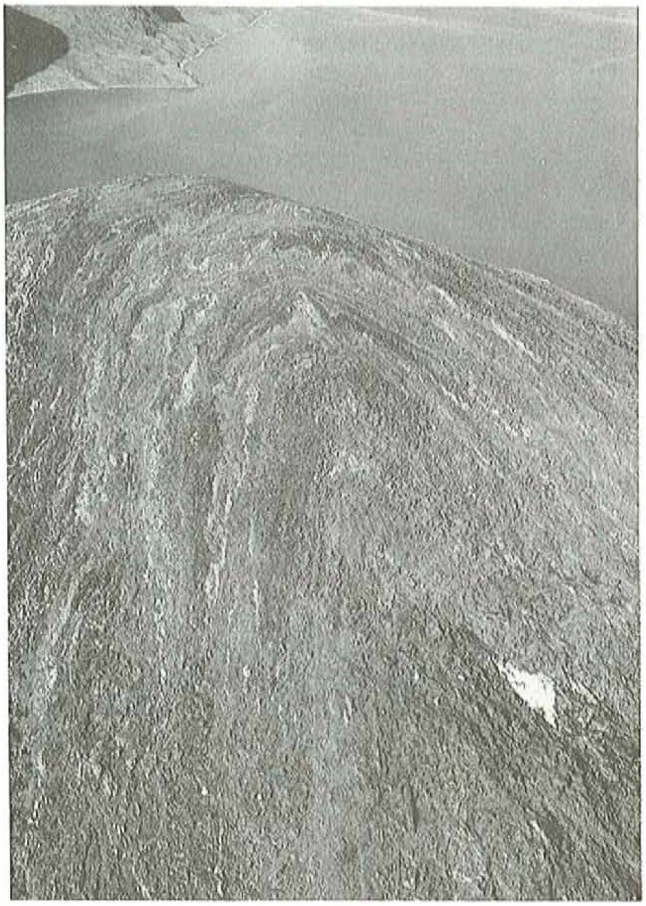

Plate 8. *Part of a large, S-sense, south-plunging second fold of DTG tonalitic gneiss in western part of Komaktorvik shear zone; width of photograph represents about 500 m.*

Plate 9. *Ultramylonite of the Komaktorvik shear zone, Iselin Harbour area, seen in vertical section, parallel to lineation, and showing evidence for west-side-up shear.*

Radiometric dating of metamorphic accessory minerals and syntectonic granitoid sheets (Scott *et al.*, *in press*) has provided preliminary evidence that the Komaktorvik shear zone was active between 1.79 and 1.72 Ga. Field evidence indicates that deformation occurred in association with amphibolite-facies metamorphism.

METAMORPHISM

Metamorphic conditions within the map area are the focus of a separate study (Mengel and Rivers, 1993) from which the following cursory account is summarized. The Four Peaks domain is characterized by granulite-facies gneisses, in which orthopyroxene is developed in both melt and restite fractions, and is presumably of Archean age. The Avayalik dykes exhibit a network of veins containing the assemblage garnet + clinopyroxene + hornblende that appears to have developed under static conditions. The significance of this granulite-facies assemblage is uncertain and could be interpreted as the result of a static burial metamorphism, or the product of slow cooling at lower crustal depths (see discussion in Wardle *et al.*, 1992), the common implication being that the Four Peaks domain was deeply buried for at least part of the Early Proterozoic. The assemblage garnet + clinopyroxene is normally indicative of pressures in excess of 8 kbar at over 700°C (Wells, 1979). However, preliminary observations of calcite in discordant veins with garnet, clinopyroxene, hornblende and plagioclase suggest that a CO_2-rich fluid was present during this thermal event, which would allow the stability of the high-grade assemblage to extend to lower metamorphic grades (500 to 600°C; Mengel and Rivers, *in press*).

Metamorphism within the Komaktorvik shear zone was associated with widespread development of hornblende + garnet ± clinopyroxene assemblages in the Archean gneisses (where it appears to have replaced an earlier orthopyroxene-bearing assemblage) and anorthosite. Hornblende + biotite ± garnet assemblages are typical of the Proterozoic dykes with clinopyroxene appearing as an additional component in the central part of the shear zone.

Interior Burwell domain is dominated by orthopyroxene + clinopyroxene + hornblende assemblages in the charnockitic rocks, and sillimanite + biotite + garnet assemblages in metasedimentary migmatite gneiss. An indication of the timing of this metamorphism may be provided by a ca. 1843 Ma zircon overgrowth age (Scott *et al.*, 1993). The migmatitic DTG suite plutonic rocks in the eastern part of the domain locally preserve relict orthopyroxene in leucosome phases, indicating that the suite was also affected by early, granulite-facies melting. Orthopyroxene-bearing assemblages were retrogressed during later amphibolite-facies metamorphism, possibly in association with 1.79 to 1.72 Ga deformation in the Komaktorvik shear zone. In contrast, the bulk of the DTG suite in the south of the area, around Tellialuk Fiord, appears to have experienced only amphibolite-facies metamorphism in association with partial melting.

Preliminary thermobarometric work (Mengel and Rivers, *in press*) indicates a gentle increase in peak PT conditions from 8 kbar at 600°C in the eastern part of the Komaktorvik shear zone, to 8.9 kbar at 750°C in the western part of the zone, and to 9.2 kbar at 800°C in Burwell domain. At present, it is uncertain to what extent the results from the gneisses in the Komaktorvik shear zone represent Archean as opposed to Early Proterozoic metamorphic effects; additional work is being carried out on the mafic dykes to exclusively constrain Early Proterozoic conditions. The results from Burwell domain, however, seem to indicate that it represents the deepest Proterozoic crustal levels in the area. Coupled with the appearance of the high-pressure assemblage garnet + clinopyroxene in the westernmost mafic dykes, this suggests a general westward increase in Early Proterozoic paleopressures.

SYNTHESIS AND REGIONAL IMPLICATIONS

A previous tectonic model (Van Kranendonk and Scott, 1992; Wardle *et al.* 1992) was based upon correlation of the Early Proterozoic tonalitic intrusions that occur within the Komaktorvik shear zone with the DTG suite of Burwell domain, and suggested that collectively, these represent the roots of a magmatic arc developed upon the western edge of the Nain Province. Based on more recent work, there are two aspects of this model that require further comment. First, the preliminary Pb–Pb isotopic evidence (Bridgwater and Wardle, *in press*) indicates that significant parts of the Burwell domain lack evidence for contamination by Archean crust. It is likely, therefore, that only the easternmost DTG plutons, i.e., those that lie within the Komaktorvik shear zone, were intruded through such crust. The bulk of the Burwell domain is therefore juvenile and possibly allochthonous. Second, some uncertainty has emerged concerning the affinity of the Archean gneisses within the Komaktorvik shear zone. These were previously correlated with those in the Four Peaks domain and by inference, the Nain Province (Wardle *et al.*, 1992; Van Kranendonk and Scott, 1992), a correlation that still appears likely on the basis of the available evidence. The possibility has also been discussed, however, that some or all of the Archean gneisses in the Komaktorvik shear zone may represent exotic crust, perhaps related to Burwell domain rather than the Nain Province. Opinion amongst us is divided on this issue but should be constrained by the radiometric dating and Nd-isotopic studies currently in progress.

Also of significance with respect to the Burwell domain is the discovery of early mafic crust exposed in the southern part of the domain and extending well to the south as inclusions in the DTG suite (Van Kranendonk *et al.*, 1993). As discussed above, there is little reason to suspect an Archean basement to the Burwell domain and the expectation is that this material is Early Proterozoic in age. A hypothesis that will be further investigated is that the mafic rocks represent arc-basement, possibly of oceanic origin.

Further insight is also beginning to emerge concerning the deformation history of the Burwell domain and Komaktorvik shear zone. Evidence for very early (pre-1.91 Ga) deformation may be provided by the Avayalik dykes if the postulated syn-shear interpretation is correct. The tentatively established age of 1.84 Ga for granulite-facies metamorphism in the Burwell domain also indicates an early event in the domain. This may precede, or be linked with, the northeast-plunging lineations and east–west-trending structures seen in the southern Burwell domain that are related to initial southeastward convergence upon the Nain Province. Van Kranendonk *et al.* (1993) have demonstrated that this structural style persists south of the map area but with the added feature that lenticular panels of Archean gneiss have been interleaved with the Early Proterozoic plutonic rocks along ductile shear zones marked by straight gneiss development. The later stages of Burwell domain–Nain Province convergence are probably documented by sinistral deformation and excision of units within the Komaktorvik shear zone in association with east-side-up exhumation of the Nain Province. Later, west-side-up shearing may mark the uplift and exhumation of Burwell domain from deep (ca. 9 kbar) levels in the interior of Torngat Orogen. The latest deformation associated with the Komaktorvik shear zone produced open folding, including the large fold of the Abloviak shear zone on Figure 1, a feature which is consistent with continued sinistral translation along the Komaktorvik shear zone.

Komaktorvik shearing occurred largely within the interval 1.79 to 1.72 Ga, and is thus considerably younger than the 1.86 to 1.82 Ga Abloviak shear zone (Bertrand *et al.*, 1992), which records collision of the Nain and Rae provinces. This suggests a model (see also Van Kranendonk *et al.*, 1993) in which the Komaktorvik shear zone developed as a result of continued northward translation of Nain Province relative to Burwell domain, following the Nain–Rae collision. The model requires further displacement of the Nain relative to the Rae Province but it is proposed that this was accommodated by large-scale folding of the Abloviak shear zone rather than renewed shearing.

The structural history of northernmost Labrador thus appears to have been dominated by prolonged sinistral shear in association with oblique convergence and collision. Dating has revealed the timing of the later stages of this process in some detail but further work is needed to establish the full history of deformation. The presence of shear-related structures possibly as old as 1.91 Ga hints at a considerable longevity for the Komaktorvik shear zone that is perhaps not unexpected given the tendency of magmatic arcs to develop in association with major transcurrent shear structures

(Woodcock, 1986). In addition to providing an explanation for the syn-shear characteristics of the Avayalik dykes, an ancestral Komaktorvik shear zone may have controlled the emplacement of Early Proterozoic tonalite plutons and may thus explain why these rocks have limited extent east of the shear zone. Furthermore, it explains the syn-shear features seen in some of the diorite dykes associated with Early Proterozoic plutonism; shear-controlled emplacement being an increasingly recognized feature of arc-generated plutonic rocks (Hutton and Reavy, 1992; Tikoff and Teyssier, 1992).

MINERALIZATION

Pyritiferous gossan zones were discovered in coastal outcrops of anorthosite in 1991 (Wardle *et al.*, 1992). Analysis of these zones for PGE, Au, Ni and Cr failed to yield any anomalous results and the inland extent of the zones has proved to be limited. Small gossan zones also occur within the charnockitic rocks of interior Burwell domain but have also given negative assay results. The calc-alkaline nature of the Burwell domain plutonic rocks is compatible with a magmatic-arc origin but the level of crustal exposure is probably too deep to retain typical island-arc-type mineral deposits. The discovery of late dykes of lamprophyric or possibly lamproitic character may be significant with respect to the diamond potential of the region, however further work is needed to establish the composition of these rocks.

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