Geoscience Canada

Early Proterozoic orogenic activity adjacent to the Hopedale block of southern Nain Province

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Volume 17, Number 4, December 1990

URI: https://id.erudit.org/iderudit/geocan17_4art18

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Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

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Cite this article

Ermanovics, I. & Ryan, B. (1990). Early Proterozoic orogenic activity adjacent to the Hopedale block of southern Nain Province. *Geoscience Canada*, *17*(4), 293–297.

Article abstract

The Hopedale block of the southern ArcheanNain Province forms a wedge between the Early Proterozoic Makkovik and Churchill provinces. Lower Proterozoic supracrustal rocks, deposited on the Hopedale block following intrusion of tholeiitic dykes ca. 2200Ma, were reworked at amphibolite faciès, and thrust westward against undeformed portions of the block during orogeny in theMakkovik Province. The Makkovik/Hopedaleblock structural boundary Is marked by alate, greenschist-facies dextral shear. By contrast, the boundary between the Hope-dale block and the Churchill Province to the west is a fault zone that separates lower Proterozoic supracrustal rocks, deposited on a protocontinent of Churchill Provincerocks, from fundamentally different rocks ofthe Nain Province. The intensity of Early Proterozoic deformation and metamorphismrises progressively from sub-greenschist fades In the Hopedale block to granulite fades in the interior of the Churchill Province.

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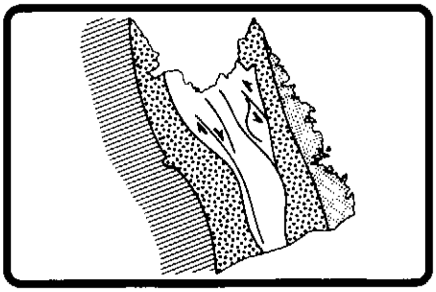

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Summary

The Hopedale block of the southern Archean Nain Province forms a wedge between the Early Proterozoic Makkovik and Churchill provinces. Lower Proterozoic supracrustal rocks, deposited on the Hopedale block following intrusion of tholeiitic dykes *ca.* 2200 Ma, were reworked at amphibolite facies, and thrust westward against undeformed portions of the block during orogeny in the Makkovik Province. The Makkovik/Hopedale block structural boundary is marked by a late, greenschist-facies dextral shear. By contrast, the boundary between the Hopedale block and the Churchill Province to the west is a fault zone that separates lower Proterozoic supracrustal rocks, deposited on a protocontinent of Churchill Province rocks, from fundamentally different rocks of the Nain Province. The intensity of Early Proterozoic deformation and metamorphism rises progressively from sub-greenschist facies in the Hopedale block to granulite facies in the interior of the Churchill Province.

Introduction

The Archean Hopedale block of the southern Nain Province (Figure 1)(Taylor, 1971) is part of the pre-Phanerozoic North Atlantic craton (Bridgwater *et al.*, 1976). In the Early Proterozoic, widespread intrusion of tholeiitic dykes preceded deposition of lower Proterozoic supracrustal rocks and Early Proterozoic deformation. These dykes are referred to as the Kikkertavak dykes (*ca.* 2200 Ma) in the

Hopedale block (see also Napaktok and Domes dykes *in* Ermanovics and Van Kranendonk, 1990; Ryan, 1990). The presence of deformed equivalents of these dykes identifies Archean rocks reworked in adjacent Proterozoic mobile belts such as the Nagssugtoqidian and Ketilidian of Greenland (Bridgwater *et al.*, 1976). They have been utilized as similar lithological markers in the tectonic forelands of the Makkovik and Churchill provinces of Labrador (Ermanovics *et al.*, 1982; Ryan, 1984).

In this contribution, we summarize some of the recent work on the Makkovik and Churchill provinces adjacent to the Hopedale block. We feel that a good case can be made for correlation of the geological history of the Hopedale block, in which the *ca.* 2200 Ma dykes are a key element, into the Makkovik Province, but conclude that the rocks of the Churchill Province adjacent to the Hopedale block are exotic with respect to the Hopedale block.

Hopedale block of Nain Province

Rocks of the Hopedale block record two distinct Archean volcano-plutonic episodes, each of which was succeeded by periods of deformation and metamorphism *ca.* 3150 Ma

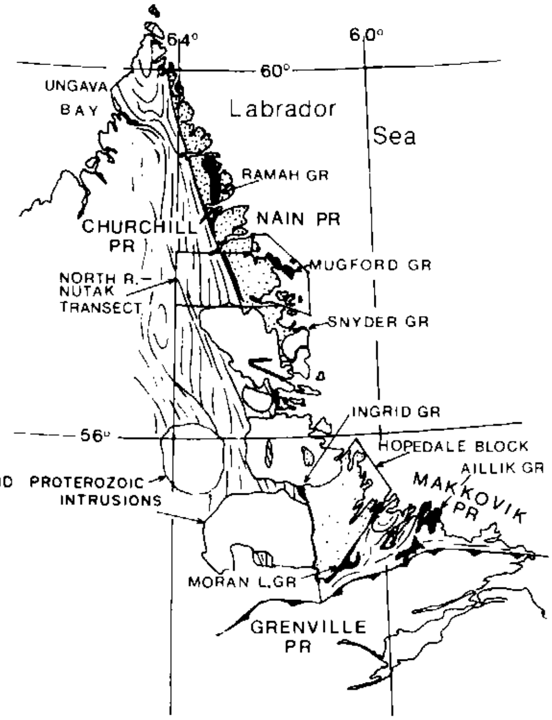

Figure 1 *Location of the Hopedale block of the southern Nain Province.*

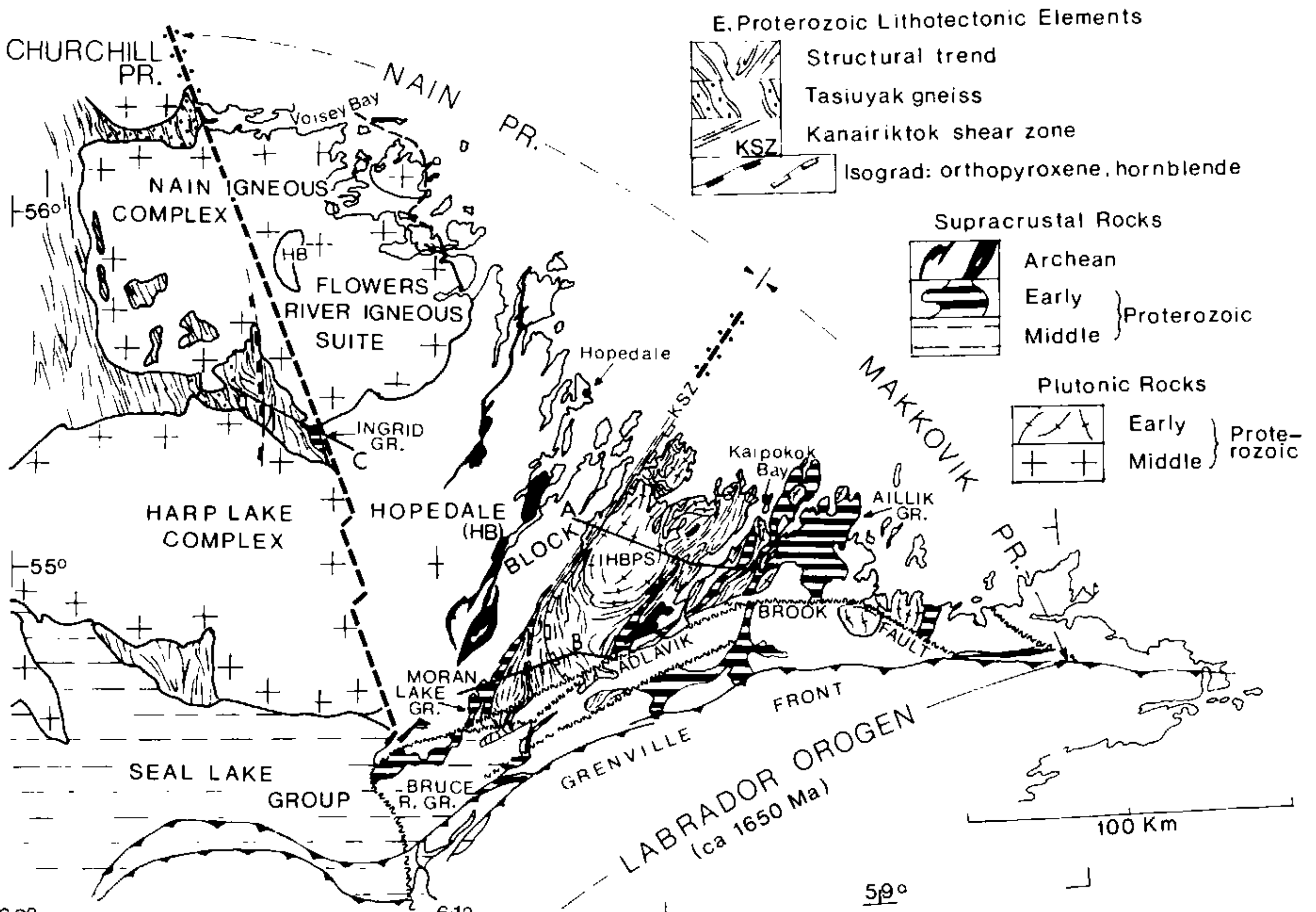

Figure 2 *The Archean Hopedale block and adjacent Proterozoic provinces. Map from Ermanovics (in press) and from unpublished compilations of staff of the Newfoundland Geological Survey Branch. The Kanairiktok shear zone underlies, and is exposed on the SE side of, Kanairiktok Bay.* ***A, B*** *and* ***C*** *indicate locations of sections of Figures 3 and 4. The hornblende isograd in the Makkovik Province follows the Kanairiktok shear zone, then swings south. Abbreviations:* ***E****, Early (older than 1760 Ma);* ***IHBPS****, Island Harbour Bay Plutonic Suite.*

and 2850 Ma (Ermanovics *et al.*, 1982; Finn, 1989; Loveridge *et al.* and Grant *et al.* *in* Ermanovics, in press). Rocks of the older episode were deformed and metamorphosed at amphibolite and granulite facies and overprinted by structures of the younger period at greenschist facies. An earlier episode, *ca.* 3258–3305 Ma (Schiøtte *et al.*, 1989; Finn, 1989), is inferred from dating of other polydeformed gneisses, but its significance remains largely unknown.

Proterozoic imprint on the Kikkertavak dykes. Epeirogenesis and stabilization of the Hopedale block is indicated by Rb-Sr biotite, and K-Ar biotite and hornblende ages in the range 2665–2265 Ma (Ermanovics, in press). Intrusion of the tholeiitic Kikkertavak dykes into this stable crust occurred *ca.* 2200 Ma (Fryer, *in* Ermanovics, in press). Dyke orientations tend to be subparallel to the Archean structural trends, with the result that NNE- and SE-trending dykes are common. However, Kikkertavak dykes adjacent to the Makkovik and Churchill provinces generally trend parallel to the Proterozoic structural fabrics, implying NW-SE and E-W extension across the Hopedale block in Early Proterozoic time.

In the southeastern Hopedale block, the dykes are generally statically altered to saussurite, chlorite and actinolite and are locally bordered by fractured, epidotized wall rock. These minerals form a schistosity in dykes less than a kilometre from the Kanairiktok shear zone that forms the structural boundary between the Hopedale block and the Makkovik Province (Figure 2). In the northwestern Hopedale block, the dykes are generally fresh, but develop a chlorite-actinolite schistosity parallel to dyke walls 2–3 km from the fault-boundary with the Churchill Province. The Kikkertavak dykes are recognized as discordant amphibolites in the Makkovik Province (reworked rocks of the Hopedale block), but do not occur west of the boundary faults in the Churchill Province (rocks exotic to the Hopedale block).

Makkovik Province

The Makkovik Province was formed largely during the Makkovikian (*ca.* 1800 Ma) Orogeny, which includes deformation and metamorphism of the Archean Nain Province rocks, its dykes, and Early Proterozoic cover rocks of the Aillik and Moran Lake groups. The province is a triangular area extending from the unreworked Hopedale block to the Labrador Orogen/Grenville Front (Figure 2). For the purpose of this paper, we restrict our discussion to a terrane 120 by 50 km, bounded in the NW by the unreworked Hopedale block, in the SE by Kaipokok Bay (Aillik Group), and in the south by the Grenvillian Adlavik Brook fault.

The boundary between the unreworked Hopedale block (Nain Province) and the Makkovik Province is defined by the SW-trending Kanairiktok shear zone located along Kanairiktok Bay. Southwest of the bay, the boundary is marked by the Moran Lake Group/Hopedale block unconformity (Figure 2). A composite west to east section across the northeastern part of the province (Figure 3a; section A, Figure 2) includes the following lithotectonic elements (Ermanovics *et al.*, 1982; Ryan and Kay, 1982): (1) Proterozoic sub-greenschist-facies Hopedale block; (2) the Kanairiktok dextral shear zone, a 1–2 km wide tract of protomylonite and mylonite in upper greenschist facies; (3) reworked Hopedale block lithologies, including Kikkertavak dykes, with subvertical mineral (predominantly hornblende) stretching lineation, at amphibolite facies, but generally lacking significant migmatization; (4) Island Harbour Bay Plutonic Suite — mainly post-kinematic granitoid rocks; (5) strongly migmatized and refoliated Hopedale block lithologies, in which peak metamorphism occurred *ca.* 1794–1761 Ma (Schärer *et al.*, 1988); and (6) upright, NNE-trending folds that deform early mylonitic imbrications of basement and cover rocks (*e.g.*, lower Proterozoic Aillik Group and Postville mylonite in Kaipokok Bay). The subvertical mineral lineation in the northern part of the Makkovik Province (3, above) occurs marginal to plutonic rocks of the Island Harbour Bay Plutonic Suite and may be related to diapiric emplacement of early foliated phases of the suite (Korstgård and Ermanovics, 1984). Massive, unmetamorphosed granite of the suite, dated at 1805 Ma (U-Pb zircon, Loveridge *et al.*, *in* Ermanovics, in press) postdates amphibolite-facies metamorphism, but predates the Kanairiktok shear zone, indicating that amphibolite-facies metamorphism may be younger in the internal parts of the Makkovik Province.

A composite section west to east across the southwestern part of the Makkovik Province (Figure 3b; section B, Figure 2) shows the following lithotectonic elements (Ryan, 1984): (1) outliers of steeply bedded, well-sorted siltstone and argillite of the lower Proterozoic Moran Lake Group lying unconformably on undeformed Hopedale block; (2) the main outcrop area of the Moran Lake Group, consisting of coarse basal clastic rocks succeeded by sandstone, siltstone, mudstone, and pillowed basalt at greenschist facies; (3) NE-trending, mylonitic, interleaved Moran Lake Group and reworked Hopedale block lithologies (this mylonite appears to represent the early imbrication of cover and basement observed in folds in 6 of section A); (4) reworked Hopedale block lithologies, including amphibolite-facies supracrustal rocks; (5) granodioritic rocks of problematical age; and (6) the Grenville Front (Adlavik Brook fault).

The Moran Lake Group was deposited on Hopedale block basement. Clastic rocks were deposited in an initially southward-deepening basin that became flooded with (turbidite?) detritus derived from uplifted basement blocks that pierced the deeper and central parts of the basin (Ryan, 1984). Subsequently, the basin deepened and extended northward over the Hopedale block, initiating uninterrupted submarine lava extrusion that marked the end of basin forma-

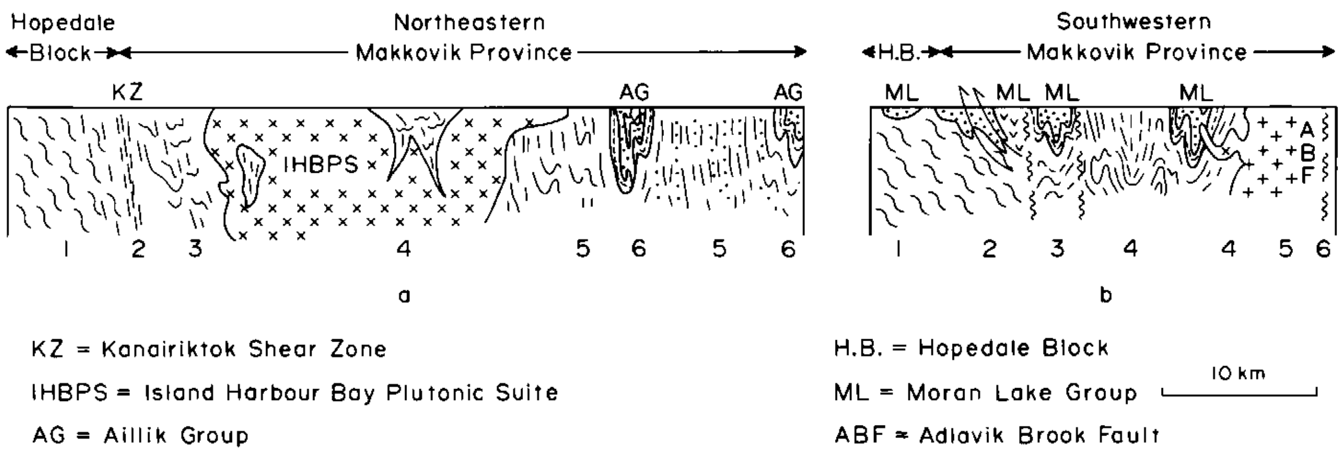

Figure 3 *Schematic west to east cross-sections of the Hopedale block and the Makkovik Province (Sections A and B, Figure 2). Numbers refer to zones described in text. Supracrustal rocks (dots) of the interior Makkovik Province are separated from reworked basement by mylonite zones (short dashes).*

tion. The basement-cover interfaces are lower Proterozoic mylonites (thrusts?) that were subsequently deformed into upright folds. This deformation is part of the Makkovikian Orogeny.

The Kanairiktok shear zone and its significance. This zone is characterized by a steep, SE-dipping planar fabric and by a subhorizontal, mineral aggregate lineation. The shear zone developed at greenschist facies and, in the Kanairiktok Bay area, deforms Proterozoic Makkovikian amphibolite-facies structures. The zone thus separates Archean rocks of the Hopedale block, essentially unaffected by Proterozoic events, from their reworked amphibolite-facies equivalents in the Makkovik Province. Horizontal displacement across the NE-striking zone due to dextral transcurrent shear is estimated to be at least 16 km (Korstgård and Ermanovics, 1984). This seemingly transcurrent displacement may have had a scissor-fault component of movement that excised the greenschist-facies rocks of the Proterozoic Moran Lake Group that occur along strike of the shear zone SW of Kanairiktok Bay (see hornblende isograd, Figure 2). Alternatively, and more likely, the greenschist-facies rocks may have been thrust westward over the Hopedale block during early mylonitic imbrication of basement and cover prior to the late shearing, but have subsequently been eroded. Deformation in the northern Makkovik Province thus had a component of late simple shear in response to E-W maximum horizontal stresses (NW-SE shortening direction)(Korstgård and Ermanovics, 1984). Southwest of Kanairiktok Bay, the Kanairiktok shear zone is lost under glacial cover.

Churchill Province and boundary area

Most of the boundary between the Nain Province and the Churchill Province to the west is obscured by large sheets of younger Proterozoic (1450–1270 Ma) intrusions. However, the boundary can be traced from the north by means of roof pendants, or inliers, within these intrusions and is exposed as a fault zone for 15 km at 55°22'N (Figure 2). The lower Proterozoic Ingrid Group, lying within this fault zone, is in fault contact with the Hopedale block to the east, and is mylonitized and imbricated with mylonitized rocks of the Churchill Province in a zone to the west. A SE-NW cross-section (Figure 4; section C, Figure 2) across the boundary fault zone shows the following lithotectonic elements: (1) Hopedale block lithologies in which Kikkertavak dykes 2–3 km east of the boundary fault show faint Early Proterozoic chlorite-epidote-actinolite cleavage; (2) Early Proterozoic N-S cross-cutting cleavage in NE-striking Hopedale block layered gneisses; (3) the boundary fault zone, in which steep-dipping faults of unknown displacement sense are superimposed on rocks showing ductile deformation; (4) the Ingrid Group, in lower greenschist facies, consisting of subaerial, alkaline-subalkaline basalt and porphyritic andesite overlain(?) by massive, coarse, heterolithic, proximal conglomerates; (4a) granodioritic orthogneiss and layered quartzofeldspathic rocks of Churchill Province south of the Ingrid Group, which are imbricated with rocks of the Hopedale block in a one km wide ductile to brittle fault zone in Proterozoic greenschist facies (Kikkertavak dykes, diagnostic of the Hopedale block, do not occur west of this zone, nor do they intrude the Ingrid Group); (5) steeply west-dipping basement-cover, upper-greenschist-facies mylonitic imbrication of the Ingrid Group with quartzofeldspathic rocks of the Churchill Province; (6) amphibolite-facies, straight-layered gneisses that grade into 5 above; (7) a zone in which metamorphic grade, degree of migmatization, and intensity of flattening and shear-related straightening increase to granulite facies 15–20 km west of the Ingrid Group; and (8) a one km wide mylonite zone, bordered to the west by Tasiuyak-type gneiss at granulite facies (Thomas and Morrison, 1989) typical of the Nain-Churchill boundary zone north of the Hopedale block (see Ermanovics and Van Kranendonk (1990) for description of the Tasiuyak gneiss).

The low-grade brittle fault and ductily deformed rocks of elements 3 and 4a (Figure 4) separate lithologies of the Hopedale block from the Churchill Province. The two provinces are linked by continuity of deformation and metamorphism, which increase westward in intensity. Considerable undetected shortening may have occurred across the greenschist-facies fault and mylonite zones (3, 4a and 5, above).

The Ingrid Group and its relationship to boundary rocks. Ingrid Group lavas comprise alkaline-subalkaline basalt, porphyritic andesite and minor dacite. These massive lavas have transitional tholeiitic to calc-alkaline affinities, suggestive of magmas that may have had contributions from sialic crustal sources. The composition of such rocks is normally bimodal (Baragar, 1981), but major element variation diagrams for the Ingrid Group (Ermanovics, in press) show a number of compositional groupings that suggest accumulation of lavas from discrete fractionation centres, or magma contamination. Ingrid Group conglomerates (Ermanovics and Korstgård, 1981, figure 12.4) overlying the lavas comprise heterolithic angular boulders of: (i) adjacent volcanic rocks, (ii) layered gneisses that could be derived from either the Hopedale block or from protocrust of the Churchill Province, and (iii) massive diorites and gabbros of unknown affinity. Other conglomerate units of uncertain stratigraphic position contain boulders and pebbles of black and red shale, mudstone, siltstone, chert, aphanitic volcanic rock, carbonate and metaplutonic rock. Rare discontinuous beds of sandy, gravelly and silty units, with lenses of dacitic porphyry, contain graded beds, cross-bedding, and slump and scour structures. The group records erosion of a pre-existing supracrustal succession, probably due to faulting that was accompanied by volcanism. The sediments of the Ingrid Group thus reflect a high-energy and tectonically unstable depositional environment that rapidly eroded the emerging basinal deposits to their sialic basement.

The Ingrid Group is a small remnant of what must have been more extensive deposits located on the eastern edge of a Churchill Province protocontinent. These supracrustal rocks and the underlying quartzofeldspathic gneiss cannot be correlated with the Hopedale block. The original relationship of the Ingrid Group to either the Hopedale block or the Churchill Province is masked by Early Proterozoic deformation. This has produced a subvertical metamorphic foliation subparallel to moderately dipping, isoclinally folded Ingrid Group beds that are overturned to the east. Steep west-dipping reverse faults and recumbent fold planes can be inferred from a reconstruction of the stratigraphy (Ermanovics, in press). The fabric in the Ingrid Group is the same as that in bounding units of the Hopedale block and the Churchill Province. From this, it is inferred that the Ingrid Group was deposited on layered metaplutonic and plutonic rocks of Early Proterozoic or Archean age of a protocontinent of the Churchill Province.

Discussion

The Archean crust of the southern Nain Province was subjected to NW-SE and E-W extension *ca.* 2200 Ma, and subsequent WNW-ESE and E-W compression (1800-1900 Ma) along its western and eastern margin during orogenic activity in the Makkovik and Churchill provinces, respectively. Tectonic activity in the Makkovik Province included extensive reworking of Nain Province rocks, which, together with their Early Proterozoic

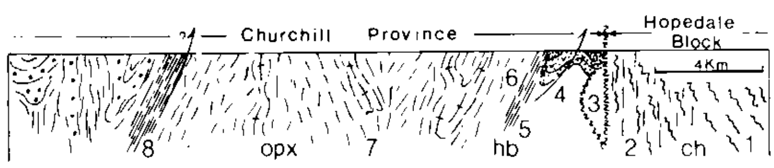

Figure 4 *Schematic SE to NW cross-section of the Hopedale block and the eastern Churchill Province (Section C, Figure 2). Isograds:* ***ch****, chlorite (and epidote) in cross-cutting schistosity;* ***hb****, hornblende (and diopside + garnet);* ***opx****, orthopyroxene. Numbers refer to zones described in text.*

cover, were subsequently thrust over unaffected parts of the Nain Province, represented by the Hopedale block. Tectonic activity in the Churchill Province, on the other hand, is represented by tectonic fabrics that wane progressively from granulite-facies in the internides of the Churchill Province to sub-greenschist-facies at its contact with the Hopedale block.

Moran Lake Group rocks of the Makkovik Province represent Early Proterozoic, ensialic or continental margin deposits, whereas Ingrid Group rocks were derived from a succession of undeformed Archean or earlier Proterozoic metasedimentary rocks and their highly deformed basement rocks. Deposition of Ingrid Group sediments preceded, or was accompanied by, continental volcanism in a tectonically unstable environment.

The relative age of orogenic activity of the Proterozoic provinces adjacent to the Hopedale block is not precisely dated, but the activity may generally relate to collision of the Nain Province with a protocontinent of the Churchill Province. In this model, southeasterly deepening basin deposits (Moran Lake Group) on the Nain Province were transported, during deformation, westerly toward the Churchill protocontinent. The unaffected portion of the Nain Province (Hopedale block) collided directly against the Churchill Province protocontinent. The Ingrid Group may have formed during the early phases of this collisional episode on the Churchill protocontinent.

The relatively low intensity of deformation and grade of metamorphism along the Nain–Churchill boundary zone are in marked contrast to fabrics in the boundary zone farther north, where sinistral shear, co-extensive with the Torngat Orogen, overprinted Nain Province rocks in upper amphibolite to granulite facies (*e.g.*, Ermanovics and Van Kranendonk, 1990). At the latitude of the Hopedale block, however, such high-grade structures are present 20 km west of the Ingrid Group (zone 8, Figure 4). The difference between the northern part of the Churchill–Nain boundary and the area discussed here may be the result of shallower crustal levels exposed to the south, or the more southerly area may simply reflect a less intensely deformed foreland of the high-grade Churchill Province internides.

Acknowledgements
We acknowledge the interest of our colleagues in our work in the southern Nain Province and adjacent areas. Some of their ideas, expressed at the recent Wakefield workshop, are incorporated in this paper. We thank John B. Henderson for a critical and thoughtful review.

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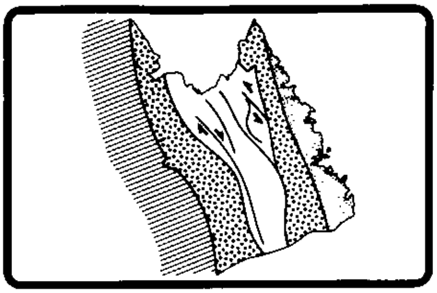

Structural and metamorphic geochronology of the Torngat Orogen in the North River–Nutak transect area, Labrador: Preliminary results of U-Pb dating

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Summary
Preliminary precise age determinations of tectonic and metamorphic events across a transect of the Torngat Orogen have shown a time-span of 80 million years between the oldest synmetamorphic intrusions and the latest uplift of the orogen. Two tectonothermal peaks have been determined at 1844 Ma (eastern and central part of the transect) and at 1826 Ma (western part of the transect).

Resumé
Les premiers résultats d'une étude géochronologique de l'orogène de Torngat, axée sur la datation précise d'événements tectoniques et métamorphiques, ont montré qu'une durée de 80 millions années (entre 1860 Ma et 1780 Ma) separe les premières intrusions synmétamorphes de la surrection finale de la chaîne. Deux "pics" de déformation et de métamorphisme ont été déterminés à 1844 Ma (au centre et à l'est de la chaîne) et à 1826 Ma (à l'ouest).