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.

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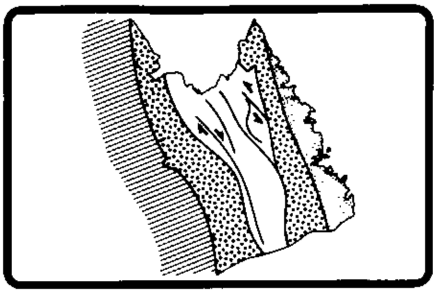

Structural and metamorphic geochronology of the Torngat Orogen in the North River–Nutak transect area, Labrador: Preliminary results of U-Pb dating

Jean-Michel Bertrand
Geological Survey of Canada
588 Booth Street
Ottawa, Ontario K1A OE4

Present Address
Centre de Recherche Pétrographiques et Géochimiques
BP 20, 54501 Vandoeuvre-les-Nancy, France

Martin Van Kranendonk
Department of Geological Sciences
Queen's University
Kingston, Ontario K7L 3N6

Simon Hanmer, J. Christopher Roddick
and Ingo Ermanovics
Geological Survey of Canada
588 Booth Street
Ottawa, Ontario K1A OE4

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).

Introduction

Any geotectonic modelling must be constrained by precise geochronological data, the significance of which depends on: (1) selection of samples which have an unequivocal kinematic interpretation; and (2) the separation of all possible zircon types and careful checking of their internal structure as a record of the zircon history. However, correlations between "crystallographic" events defined at the mineral scale, and tectonic or igneous events defined in the field, are difficult to assess, especially in the case of regions which have experienced long-lived progressive deformation under high-grade conditions.

The Early Proterozoic Torngat Orogen separates the Archean Nain and Rae provinces of the eastern Canadian Shield. The aim of this study is to establish a chronology of tectonic and metamorphic events in the North River–Nutak transect of the orogen (latitude 57°30′–58°N) and to address the duration of the regional shear regime. This paper presents the preliminary results of U-Pb dating of zircons and monazites. Analytical methods are summarized in Parrish *et al.* (1987).

Geology, sample description and preliminary results

The Torngat Orogen (Figure 1; see Ermanovics and Van Kranendonk, 1990, for regional location) comprises from east to west: (i) reworked Archean gneiss of the Nain Province and unconformably overlying supracrustal rocks of the Early Proterozoic Ramah and Mugford groups; (ii) the Abloviak shear zone; and (iii) a central zone comprising the Tasiuyak domain and the western Lac Lomier complex (Ermanovics and Van Kranendonk, 1990). Early Proterozoic tectonism involved initial amphibolite- to granulite-facies sinistral shearing, which was concentrated along the Abloviak shear zone, followed by east-directed thrusting on steep ultramylonite zones associated with uplift (Van Kranendonk and Ermanovics, 1990). Samples from the main units were analyzed (Figure 1 for location). Comparative sketches of zircon microstructures studied so far are shown in Figure 2, and U-Pb ages are presented in Figure 3.

Eastern margin of the Torngat Orogen. Samples are from veins of granite and pegmatite that occur close to or within mylonitic zones associated with the late thrusting-uplift event.

Sample **RAL88 17** (see Figure 1 for location) is a pre- to syntectonic granite at amphibolite-facies and contains a down-dip lineation associated with the late thrusting event. The zircon age of 1805±5 Ma (Figure 3) on two concordant fractions defines a maximum age for this late orogenic activity. A single grain with a minimum $^{207}Pb/^{206}Pb$ age of 2560 Ma indicates the presence of an inherited Archean component, which supports the interpretation that the strip of orthogneiss separating the Ramah Group and the Tasiuyak domain represents reworked Archean rocks.

Another sample, **EES89 22B** (Figure 1) is a sillimanite-bearing granite, strongly deformed and containing a down-dip lineation. Two fractions of zoned zircons have yielded an almost concordant date of 1786±2 Ma (0.4–0.8% discordancy); concordant monazite gives an age of 1782±1 Ma.

Tasiuyak domain. This contains a wide zone of the Tasiuyak gneiss, a garnet-rich granulite-facies migmatite derived from a metasedimentary protolith (Ryan *et al.*, 1984; Wardle, 1984). On both margins, the Tasiuyak gneiss is intercalated with thick bands of foliated and lineated charnockite. Large areas of Tasiuyak domain are also underlain by garnetiferous, white megacrystic granite (S-type granite) and diatexitic migmatite (sample EES89 G1 on Figure 1).

Zircons from a weakly foliated, garnet-biotite granite (sample **EES89 G1**) yielded a poorly defined discordia age of 1847+7/-5 Ma (Figure 3) corresponding to rounded grains with various core/overgrowth ratios. However, an almost concordant fraction of two grains devoid of cores (0.4% discordancy) constrains the age of the last melting event at 1844±1 Ma (Figure 3). A less-constrained age for the cores of needles (Figure 2, F to I) is given by two discordant fractions (1.7% and 4% discordancy), including a single grain, that show the same $^{207}Pb/^{206}Pb$ age of 1859 Ma. This may correspond with either some kind of detrital or magmatic protolith, or the onset of granulite-facies conditions and zircon growth. Discordant monazite (1.7% discordancy) yields a $^{207}Pb/^{206}Pb$ age of 1849 Ma, slightly older than the zircon discordia age, suggesting that the generation and early (*in situ*?) emplacement of the S-type granite, obvious from field evidence, was outlasted by metamorphic and/or anatectic growth of zircons.

An undeformed cross-cutting vein of garnet-bearing leucogranite and pegmatite (**EES89 G2**) has yielded a younger age. Multifacetted grains with minor, small cores correspond to almost concordant points (0.4– 0.8% discordancy) with a small age difference between the cores and finely zoned outer parts of grains (1790±2 Ma and 1788±2 Ma, respectively); the cores of euhedral needles are slightly older at 1792±2 Ma. Such an age pattern suggests continuous growth of zircon over a short period.

Lac Lomier complex. The contact between the Lac Lomier complex and the Tasiuyak domain is a 5–10 km wide zone consisting of a kilometre-scale intercalation of Tasiuyak gneiss and brown, homogeneous charnockitic gneiss. The Lac Lomier complex comprises brown charnockite as well as leucocratic to mesocratic quartzofeldspathic layered gneiss, mafic gneiss and paragneiss. Two samples have been analyzed — EE89 023 and EE89 019.

EE89 023 is a brown, hypersthene-hornblende-plagioclase-quartz charnockite showing a strong, subhorizontal L-S fabric formed under granulite-facies conditions. At least nine different populations of zircons (four morphological types and varying colours) were observed in this sample. From morphological comparisons, the following relative zircon chronology, from oldest to youngest, is pro-

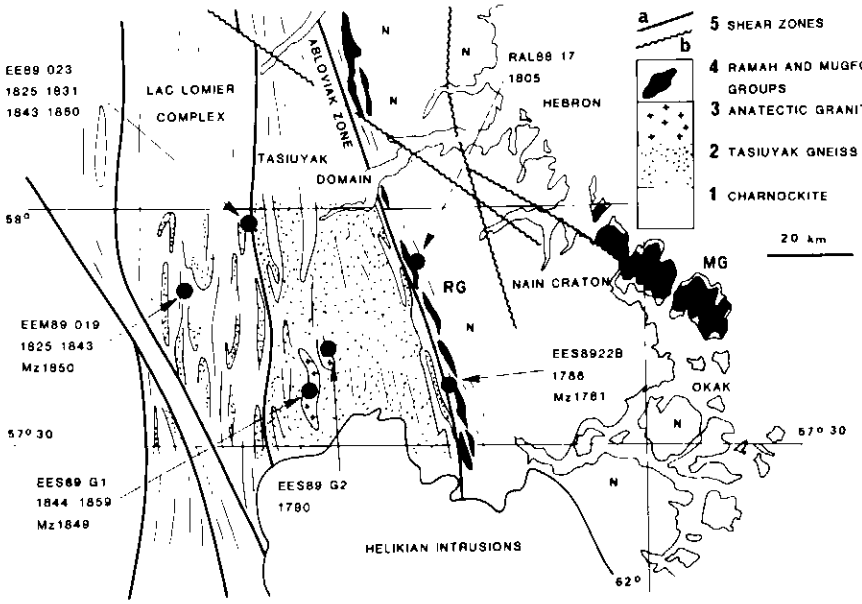

Figure 1 *Geology of the Torngat Orogen and sample locations. Zircon and monazite (**Mz**) ages are indicated. Legend units include: **1**, Charnockites and orthopyroxene-bearing gneiss; **N**, Archean banded gneiss of the Nain craton; **2**, Tasiuyak garnet-sillimanite gneiss of Tasiuyak domain and metasedimentary rocks of the Lac Lomier complex; **3**, Anatectic granite; **4**, Early Proterozoic Ramah (**RG**) and Mugford (**MG**) groups; **5**, Ductile (**a**) and brittle (**b**) shear zones.*

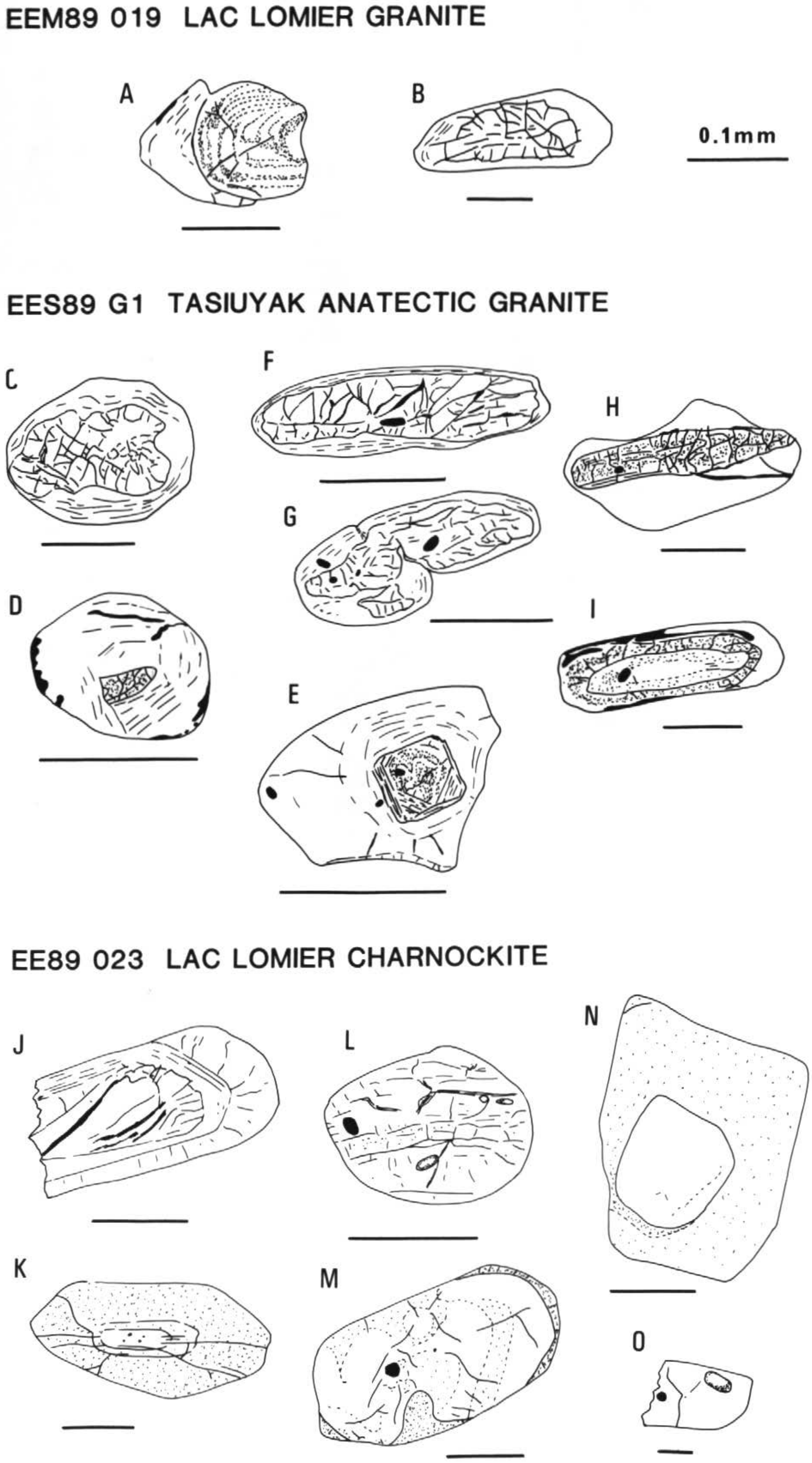

Figure 2 *Morphology of zircon grains.*
***Sample EEM89 019**, granitic vein cross-cutting banded gneiss of the Lac Lomier complex.*
(A) *Round, honey-coloured zircon grain with regular zoning in the core and overgrowth (drawing from SEM photograph);*
(B) *Honey-coloured short prism showing broken, lighter core and overgrowth; drawing from transmitted light (TL) photograph.*
***Sample EES89 G1**, Tasiuyak anatectic granite.*
(C) *Round, brown zircon grain with broken, lighter core and finely zoned overgrowth (from TL photo);*
(D) *Round, brown zircon grain with minute core; late metamictization is shown in black (from SEM photo);*
(E) *same as D, with small, zoned core and overgrowth (from SEM photo);*
(F) *Long, colourless prism with broken core (from TL photo);*
(G) *same as F, showing resorption predating the overgrowth (from TL photo);*
(H) *Irregularly rounded zircon grain with a prismatic broken core (from SEM photo);*
(I) *Complex zoning of a long, colourless prism with a core and two distinct overgrowths; late metamictization is shown in black (from SEM photo).*
***Sample EE89 023**, charnockitic gneiss of the Lac Lomier complex.*
(J) *Long, yellow prism with broken core and two successive overgrowths (from TL photo);*
(K) *Short, yellow prism with a small, light core and large subhedral overgrowth (from SEM photo);*
(L) *"Flat" zircon with numerous cracks and minute inclusions, including fluid inclusions (from TL photo);*
(M) *"Flat" zircon showing a resorbed nebulitic core and a narrow, discontinuous overgrowth (from SEM photo);*
(N) *Subhedral, rounded zircon grain with little difference between a colourless core and pink overgrowth (from SEM photo);*
(O) *Fragment of large, pink, euhedral grain with a large (fluid?) inclusion (from TL photo).*

posed: (i) "flat" zircons (Figures 2L and 2M) and possibly some round, dark brown grains; (ii) yellow and colourless needles (Figure 2J); (iii) round, yellow, pink and colourless, multifacetted grains, often with colourless, limpid cores (Figures 2K and 2N); and (iv) pink fragments of large euhedral grains (Figure 2O).

Concordant or almost concordant zircon fractions are arrayed along concordia between *ca.* 1860 Ma ($^{207}Pb/^{206}Pb$ age of a 0.8% discordant "flat" zircon fraction) and 1825±2 Ma (concordant age of a pink euhedral zircon fraction). A major grouping of yellow needles and multifacetted zircon fractions, all representing cores, occurs at 1843 Ma (average of $^{207}Pb/^{206}Pb$ ages of four concordant and almost concordant fractions) and may indicate the peak metamorphic age of a long-lived, lower crustal tectonothermal regime. An 1832 Ma, concordant, multifacetted zircon fraction may represent either a step in a continuous crystallization history, a discrete event, or a point situated on a mixing line between 1843 Ma and 1825 Ma.

The "flat" zircon morphology is believed to represent growth under high strain conditions in a magmatic environment (Figure 2M). Therefore, the ill-defined age of the "flat" zircons at *ca.* 1860 Ma may date the syntectonic emplacement of the charnockite.

EEM89 019 is a pink, microcline-bearing granitic vein that cross-cuts the regional foliation of the Lac Lomier complex, but contains a vertical foliation and a shallow N-plunging lineation that is parallel to the regional shear fabric. This granite vein is therefore interpreted as late kinematic, and constrains the age of the latest deformation in the western Lac Lomier complex. Three types of zircon have been defined: brown balls and prisms with obvious cores (Figures 2A and 2B), and fragments of colourless, euhedral zircon.

Zircon fractions are scattered on the concordia diagram and define an array of points

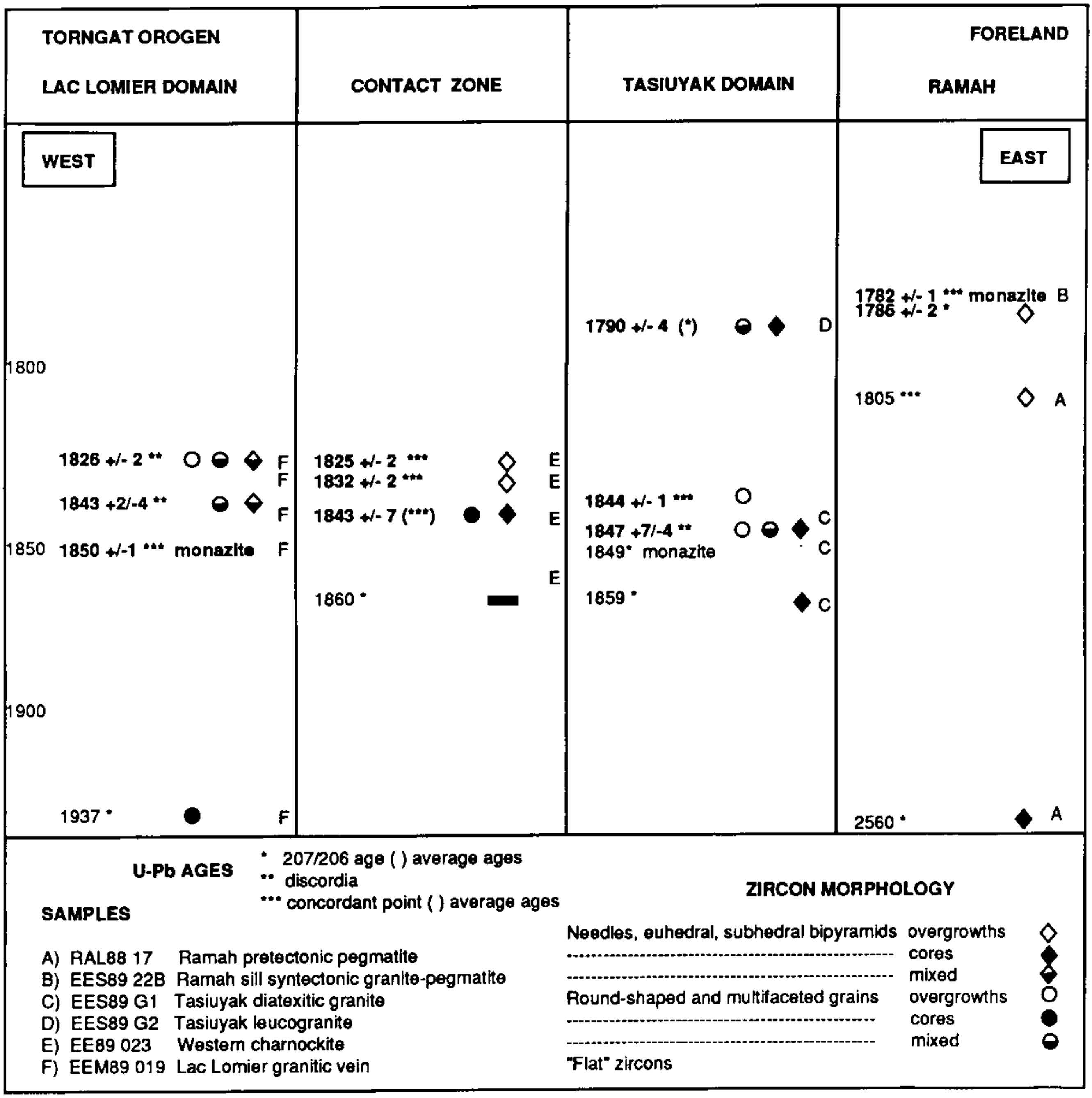

Figure 3 *Time and space chart showing isotopic results and morphology of the analyzed samples. All ages are given with a 2σ error.*

rather than a well-defined discordia line. The best-defined regression line is calculated at 1826±2 Ma from four single grains representing exclusively or dominantly overgrowths and one concordant fraction comprising fragments of euhedral grains. The oldest possible discordia yields an age of 1843+2/-4 Ma. Monazite is slightly older and overlaps the concordia at 1850±1 Ma. One large, brown, cloudy, highly discordant (20%) core yields a minimum age ($^{207}Pb/^{206}Pb$) of 1937 Ma, proving the existence of inherited zircons.

The minimum age for syntectonic emplacement of the pink granitic veins may be thus estimated at 1826±2 Ma, but the significance of the monazite age is ambiguous; it may represent a xenocryst.

Preliminary conclusions

Our data suggest that the Torngat Orogen experienced high-grade, lower crustal conditions for at least 80 million years. Discrete tectonothermal events may have occurred within this range, but the observed spread of concordant ages in the charnockite probably implies a progressive crystallization of zircon around "peak" ages which may or may not correspond to "peak" metamorphic conditions or to discrete magmatic events. Age results are shown in Figures 1 and 3. The following preliminary conclusions are drawn.

Brown, U-rich overgrowths have given two distinct ages — 1844 Ma and 1826 Ma. The 1844 Ma age of the anatectic granite from the Tasiuyak domain obviously corresponds to a melting event closely associated with granulite-facies metamorphism (Mengel and Rivers, 1989). This age is also represented by a group of concordant zircons from the charnockite, by $^{207}Pb/^{206}Pb$ minimum ages for zircon cores from the Lac Lomier complex, and by a concordant zircon from an orthopyroxene-bearing mobilizate sampled by T. Krogh from the eastern margin of the Torngat Orogen (T. Krogh, personal communication, 1990). The younger age of 1826 Ma corresponds to euhedral zircon overgrowths in both the charnockite and syntectonic granite vein of the Lac Lomier complex. It is interpreted as dating the waning of granulite-facies conditions and the late-stage shear-related straightening of the Lac Lomier complex. Surprisingly, this age has not been found in the Tasiuyak domain (EES89 G1): such a difference tends to support a polyphase metamorphic evolution of the orogen and a time-dependent displacement of tectonothermal activity from east to west.

S-type granite generation in the Tasiuyak domain occurred before the end of granulite-facies metamorphism, as suggested by the age difference between inherited monazite and zircon growth; similar cases of inherited monazite are reviewed by Parrish (in press).

An age of 1860 Ma may be defined from $^{207}Pb/^{206}Pb$ ages of fractions representing cores. Concordant xenocrystic zircons of that age have been analyzed recently from an orthopyroxene-bearing mobilizate (see above, T. Krogh, personal communication, 1990) from the eastern margin of the Torngat Orogen. In our samples, this age is recorded in the "flat" zircons from the charnockite and in broken cores of needle-shaped zircons from the anatectic Tasiuyak granite. These may date syn-tectonic intrusion of charnockitic magmas during the crustal thickening that initiated granulite-facies metamorphism.

Two inherited zircons are significantly older. The oldest, at 2563 Ma ($^{207}Pb/^{206}Pb$ age) from the Abloviak shear zone, confirms field evidence for reworked Archean rocks. It must be emphasized that our data may be biased toward young ages, since most of the studied samples are pegmatites, or highly differentiated granites, and older inheritance is therefore not excluded.

The age of uplift of the orogen is given by a maximum age of 1805 Ma and by a syn-tectonic age of 1786 Ma obtained from pegmatites emplaced within mylonite of the eastern Abloviak shear zone. In the Tasiuyak domain, leucogranitic veins that postdate transcurrent shearing have yielded a similar age of *ca.* 1790 Ma, implying that the Torngat Orogen remained in deep crustal conditions for at least 80 million years. This period extended from 1860 Ma, the age of the oldest syntectonic magmatic precursors, to 1780 Ma.

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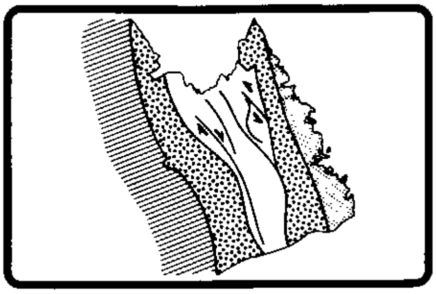

Les cisaillements latéraux dans l'arrière-pays des orogènes du Nouveau-Québec et de Torngat: Une revue

Réjean Girard
Module des Sciences de la Terre
Université du Québec à Chicoutimi
555 Boul. de l'Université
Chicoutimi, Québec G7H 2B1

Résumé

Le segment est de l'orogène Trans-Hudson se compose d'un terrain gneissique polycyclique coincé entre les orogènes hudsoniens du Nouveau-Québec et de Torngat. L'interface entre ce terrain gneissique et les cratons de Nain à l'est et Supérieur à l'ouest est marqué par les failles de Komaktorvik à l'est et du Lac Tudor à l'ouest, lesquelles montrent des directions de transport opposées. Similairement, le terrain interorogénique est disséqué de cisaillements à déplacements latéraux montrant une direction de mouvement cohérente avec celles des failles limitrophes, soit senestre à l'est dans les cisaillements d'Abloviak, Falcoz et Moonbase Lake, et dextre à l'ouest pour le cisaillement de la rivière George. La relation temporelle entre ces différents systèmes de failles est incertaine.

Summary

The eastern part of the Trans-Hudson Orogen is composed of a gneissic polycyclic terrain caught between the Torngat and New Québec orogens. Its boundaries with the adjacent Archean Nain and Superior cratons are expressed by the sinistral Komaktorvik shear in the east and the dextral Lac Tudor fault in the west. Their common gneissic hinterland is dissected by two networks of transcurrent faults, the sinistral Abloviak–Falcoz–Moonbase Lake shear system in the east and the dextral George River shear in the west. Timing relationships between these fault systems is still unclear and is essential to the unravelling of the link between both orogens.

Introduction

Les orogènes du Nouveau-Québec (ONQ) et de Torngat (OT) définissent un patron grossièrement symétrique (Hoffman, 1988),