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Proterozoic southward accretion and Grenvillian orogenesis in the interior Grenville Province in eastern Labrador: Evidence from U–Pb geochronological investigations

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ABSTRACT

This study is a fascinating example, from the eastern Grenville Province, of unraveling the triple challenges inherent in the geochronological investigation of any multi-orogenic region, namely inheritance, emplacement and subsequent metamorphism. The existence of hitherto unknown pre-Labradorian crust within allochthonous Grenvillian terranes is demonstrated; formerly unrecognized spatial relations between Labradorian and Pinwarian crust are outlined; and a new perception of mid-Grenvillian magmatic and metamorphic events is presented.

The pre-Labradorian crust has an age range of 1800–1770 Ma and consists of calc-alkaline plutonic rocks intruding earlier supracrustal assemblages containing Archean and early Paleoproterozoic inherited zircons. Evidence is provided from dated enclaves and inheritance in younger rocks that similar-aged pre-Labradorian crust once existed farther south. The geochronologically defined geographic extent of early Labradorian crust having a 1680–1655 Ma age range is expanded. This crust is intruded by the mid-Labradorian Mealy Mountains Intrusive Suite, for which new results confirm its 1650–1630 Ma time of emplacement. Pinwarian orthogneiss, dated between 1513 and 1496 Ma and previously unknown in the region, is now recognized to be common. Sufficient data exist to define, for the first time, a boundary between Labradorian and Pinwarian orthogneiss (cryptic in the field), establishing the presence of Pinwarian-aged crust to the southwest, lacking Labradorian inheritance except close to the boundary. A belt of layered mafic, anorthositic and monzogranitic intrusions is situated close to the boundary. Current data favour a Pinwarian age for emplacement of these rocks.

Mid-Grenvillian plutonism is demonstrated by 1043 Ma ages from two K-feldspar megacrystic granodiorite bodies. They are situated on either flank of a crustal-scale, northeast-trending, northeast-closing fold. The fold, which is 40 km wide and at least 160-km long and exposes Pinwarian orthogneiss in its core, post-dates emplacement of the 1043 Ma intrusions. The fold probably formed at the peak of Grenvillian tectonism in the region, between 1030 and 1015 Ma, and certainly before intrusion of weakly deformed granitoid rocks at 992 Ma. Final activity included the emplacement of late- to post-Grenvillian granitoid plutons between 964 and 951 Ma. A pluton having a 951 Ma age is the youngest known in the eastern Grenville Province. Cooling and stabilization was completed by ca. 940 Ma.

Broader implications of the results, in conjunction with existing data, are that: (i) the northeasternmost part of the eastern Grenville Province was only peripherally affected by Grenvillian orogenesis, (ii) an east–northeast offshore extrapolation of the Grenville front as a major tectonic feature does not exist, (iii) high-grade metamorphic mineral assemblages in the Groswater Bay and Hawke River terranes are pre-Grenvillian, rather than an eastward expression of a Grenvillian high-pressure belt, and (iv) the north shore of the eastern St. Lawrence estuary represents across-orogen exposure, rather than orogen-parallel as previously supposed.

1. Introduction

From previous studies (Gower and Krogh, 2002, 2003 and references therein), it is now known that the Grenville Province in eastern Labrador experienced several well-defined events, namely

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(i) supracrustal deposition before 1780 Ma, (ii) an early geon 17 magmatic event, (iii) Labradorian orogenesis (1710–1600 Ma), (iv) Pinwarian orogenesis (1520–1460 Ma), (v) Grenvillian orogenesis (1085–985 Ma), and (vi) late- to post-Grenvillian magmatism (985–950 Ma). The purpose of this study is to present new U–Pb data for 39 samples from eastern Labrador and to discuss the implications of these results in conjunction with further interpretation of existing age data. In particular, details are given for the first time of the early geon 17 magmatic event, of formerly unrecognized spatial relations between Labradorian and Pinwarian crust, and of a new perception on mid-Grenvillian magmatic and metamorphic events. Advances in understanding Grenvillian events leads to an important breakthrough, we believe, in understanding the tectonic configuration of the eastern Grenville Province.

It is our normal practice to collect multiple samples from a given locality, choosing outcrops where unequivocal field relations are exposed among several different rock types. A critical advantage in doing so is to provide an independent control on timing between various metamorphic or deformational events. This, in turn, can provide information to interpret more rigorously the primary ages of the rocks involved. In the text that follows, the data are presented in order of the oldest (pre-Labradorian) to youngest (post-Grenvillian) *host* rock at a given locality. Interpretation of the host-rock age commonly requires knowledge of the timing of later Pb-loss events (and vice versa), so all samples investigated from one locality are addressed together, although this leads to chronological inconsistency. Inevitably, due to the complex geological history through which most of the samples have passed, residual ambiguities remain regarding interpretation of specific samples. Nevertheless, we feel that the geochronological conclusions of this study are clear and that, although further work might refine some results, the conclusions are robust.

2. Regional geological outline

The region addressed here straddles the ill-defined boundary between the Mealy Mountains and Pinware terranes in the eastern, interior part of the eastern Grenville Province. It is also astride the boundary (also ill-defined) between the Exterior Thrust Belt and Interior Magmatic Belt (Fig. 1). This region was the target of 1:100,000-scale reconnaissance geological mapping projects by the Geological Survey of Newfoundland and Labrador between 1995 and 2001 (Gower and van Nostrand, 1996; Nunn and van Nostrand, 1996; Gower, 1998, 1999, 2000, 2001). Reports from those projects deliver the field context and provide photographs of many of the geochronological sample sites for which data are reported here. The reports may be accessed at http://www.nr.gov.nl.ca/mines&en/geosurvey/publications/current.stm.

The main geological features are shown in Fig. 2. The dominant rock type, particularly in the central and southern parts of the region, is granitic and granodioritic quartzofeldspathic gneiss, interpreted to have been derived from igneous protoliths. As is demonstrated in this study, formation of this gneiss occurred at various times over an 800-million year period, from about 1800 Ma onward. Although the gneisses are not readily amenable to field subdivision, it has been possible to separate some K-feldspar megacrystic areas (augen gneiss), as well as small bodies of contrasting composition, such as tonalite or amphibolite. Geological mapping and aeromagnetic data indicate that these gneisses have been deformed into a huge fold structure having a northeast-trending axial trace and closing at its northeast end, where the plunge is steep northeast or vertical. The northern part is clearly evident on aeromagnetic maps, where magnetic fabrics are strongly enhanced by concordant, narrow (ca. 1-km wide), mafic bodies within quartzofeldspathic gneiss. The regional extent of the structure farther southwest has only been identified through mapping (Gower, 1998, 1999, 2000, 2001).

In the core of the fold, in the south, quartz-rich psammitic gneisses occur and are lithologically distinct from metasedimentary gneisses found in the northeast corner of the region, which are pelitic and have an inadequately constrained age of protolith deposition thought to be pre-1770 Ma (Gower and Krogh, 2003). Similar pelitic gneisses are found underlying large areas in other parts of the northern half of the eastern Grenville Province. In the study area, the pelitic gneisses show a well-established metamorphic facies gradation from garnet–sillimanite–biotite assemblages in the east to anhydrous cordierite–hypersthene assemblages in the west on approaching, and a consequence of emplacement of, the Mealy Mountains AMCG (anorthosite–monzonite–charnockite–granite) Intrusive Suite. The Mealy Mountains Intrusive Suite (MMIS) has been previously dated between 1650 and 1625 Ma (details below). A large layered mafic body occurs south of the MMIS in the west-central part of the area and smaller mafic bodies are found farther northeast. The geological affiliation and age of these rocks remains inadequately established. A separate AMCG suite occurs in the southeast quadrant (the 1505–1495 Ma Upper Paradise River suite). Before the completion of this study, it was the only known Pinwarian body in the region. The southern half of the region is punctured by numerous late- to post-Grenvillian plutons, generally readily distinguished from the rocks they intrude. Not indicated in Fig. 2 are mafic-dyke suites, the most notable being the east–northeast-trending 1250 Ma Mealy dykes in the north and the north–northeast-trending 615 Ma Long Range dykes, a representative of which crosses the southeastern part of the region. Further descriptive and chronological information and references are given by Gower (1996) and Gower and Krogh (2002, 2003).

3. Analytical procedures

U–Pb data collection for this study began in the mid-1990s and procedural and instrumental changes have occurred since then. However, the general description that follows applies to the majority of the data. Zircon and other accessory minerals were separated from rock samples using standard heavy liquid and magnetic separation techniques. All zircon fractions have had an air-abrasion treatment (Krogh, 1982); titanite and monazite have not. U–Pb data were obtained using isotope dilution thermal ionization mass spectrometry methods (ID-TIMS). Mineral dissolution and isolation of U and Pb from zircon follow the procedure of Krogh (1973), modified by using miniaturized anion exchange columns (0.05 ml of resin). In some cases, zircons that weighed less than 5 μg had no chemical separation procedure, and the bulk dissolved sample was evaporated and then re-equilibrated in 3.1N HCl. Monazite was dissolved in 6N HCl; titanite in a mixture of HF and HNO_3 at ~80 °C. For monazite, U and Pb were isolated using the same procedure as for zircon, and for titanite a HBr chemical procedure was followed.

Pb and U were loaded, together with silica gel, onto outgassed rhenium filaments. The isotopic compositions of Pb and U were measured using a single collector with a Daly pulse counting detector in a solid source VG354 mass spectrometer. Data are corrected for a mass discrimination of 0.07%/AMU and a dead time correction of 21.5 ns. The thermal source mass discrimination correction is 0.1%/AMU. The laboratory blanks for Pb and U are usually less than 1 and 0.1 pg, respectively. Total common Pb less than 10 pg was considered laboratory Pb, and that in excess of 10 pg was corrected using Stacey and Kramers (1975) Pb evolution model. Error estimates were calculated by propagating known sources of