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Isotopic mapping of the Allochthon Boundary Thrust in the Grenville Province of Ontario, Canada

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ABSTRACT

Nd isotope analyses of orthogneissic rocks were conducted in the vicinity of the Allochthon Boundary Thrust (ABT) in the Central Gneiss Belt of Ontario, Canada. Gneisses from the parautochthonous belt have relatively homogeneous Nd isotope signatures with an average TDM model age of 1.91 Ga, consistent with an origin as an accreted Paleoproterozoic arc terrane (Barilia). Orthogneissic rocks from the overlying allochthonous belt have a wider range of model ages from 1.46 to 1.79 Ga, consistent with a more complex geological history that may involve reworking of sedimentary material in a long-lived ensialic arc (Algonquia). The isotopic boundary between these terranes, represented by the ABT, is consistent with the distribution of distinct types of metabasic rock, previously used as a criterion for recognising rocks of the allochthonous and parautochthonous belts of the Grenville Province. However, the location of the ABT proposed on the basis of isotopic analysis has been modified from that of other workers, because Nd isotopes provide a much more detailed tool for mapping the original zone of convergence (thrusting) between allochthonous and parautochthonous terranes with distinct crustal formation ages. The isotopic boundary is also supported by field-based mapping of high-strain zones in critical areas. Other mapped shear zones may represent later extensional structures with lesser geological significance.

1. Introduction

The Allochthon Boundary Thrust (ABT) is one of the most important tectonic boundaries in the Grenville Province because it defines the northwesterly limit of major terrane displacement during the 1080–1020 Ottawan phase of the Grenville Orogenic Cycle (Rivers et al., 1989). Hence it separates parautochthonous crust to the northwest from allochthonous nappes and thrust sheets to the southeast (Fig. 1). The ABT may also be a crustal scale ramp (Rivers et al., 1993), and therefore the locus of major uplift, separating deeply exhumed crust in the hanging-wall from less exhumed crust in the footwall.

The recognition of the allochthonous segment as a high pressure belt (Rivers et al., 2002) might imply that the ABT should correspond to a well-defined metamorphic isograd. However, despite its tectonic significance, the ABT has proven surprisingly hard to locate in much of the Central Gneiss Belt of Ontario and western Quebec, where it juxtaposes poly-metamorphosed Proterozoic grey gneisses on each side. Nevertheless, the shoreline of Georgian Bay south of Pointe au Baril represents one area where the ABT is relatively well-defined, since the excellent distribution of outcrop has allowed detailed geological mapping.

A zone of intense shearing in the Pointe au Baril area was first mapped by Davidson et al. (1982), running through a lithotectonic terrane then referred to as the Britt domain. More detailed fieldwork was carried out by Culshaw et al. (1994, 1997), who referred to the shear zone as the Central Britt shear zone and later the Shawanaga Shear Zone (SSZ). The SSZ was subsequently recognised by Davidson (1998) as the local expression of the ABT.

Although the ABT is regarded as a major thrust, Culshaw et al. (1994, 1997) recognised that the majority of movement indicators identified in the field were actually extensional, so that this extensional movement must have largely overprinted the original thrust boundary. Hence they termed the boundary a 'cryptic Grenvillian thrust', and argued that the location of the original convergent boundary must be based on the recognition of distinct geological histories in the lithotectonic terranes on either side of the thrust, rather than just the mapping of shear zones.

The different evolutionary history identified by Culshaw et al. (1994) includes an older protolith age in the parautochthonous rocks north of the boundary, a pre-Grenvillian metamorphic event only identified north of the boundary, and a suite of 1.35 Ga plutons only observed south of the boundary. In addition, distinct suites of metabasic rocks were seen on opposite sides of the boundary. Both terranes also share several common features, including the occurrence of supracrustal rocks, pervasive intrusive activity at 1.45 Ga, and more than one episode of intense Grenvillian metamorphism.

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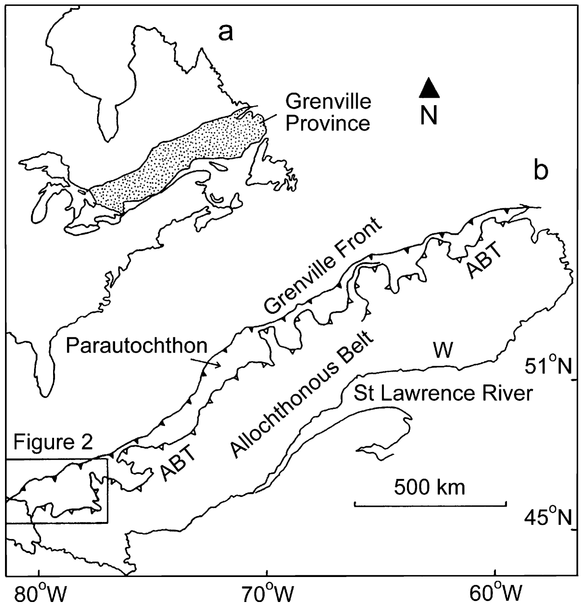

Fig. 1. General views of the Grenville Province showing (a) its location in eastern Canada; and (b) its division into major tectonic belts after Rivers et al. (1989). Box shows the area of Fig. 2. ABT, Allochthon Boundary Thrust.

Based on detailed U-Pb geochronological work (Culshaw et al., 1994), it was possible to distinguish between the parautochthonous and allochthonous terranes on the shores of Georgian Bay, and hence to pin-point the Shawanaga Shear Zone (=ABT) in this area. However, inland to the east, poor outcrop exposure hinders identification of the boundary.

To simplify the problem of delineating the trace of the ABT across Ontario and western Quebec, Ketchum and Davidson (2000) focussed only on the suites of metabasic rocks identified by Culshaw et al. (1994). The parautochthonous belt was found to contain fragmented bodies of metadiabase which could be correlated by age dating and geochemical tracers with the 1.24 Ga Sudbury Diabase suite. On the other hand, the allochthonous belt was found to contain bodies of coronitic olivine metagabbro with a distinctly younger age of 1.16 Ga. A third suite of metabasic rocks, consisting of retrogressed eclogites, was found to be locally associated with the boundary zone itself.

The asymmetric distribution of these metabasic suites on either side of the ABT was used by Ketchum and Davidson (2000) to infer that the ABT was a zone of major tectonic convergence during the Grenville orogeny. They also attempted to use the distribution of these rock types to map the location of the ABT from Georgian Bay to western Quebec. However, the distribution of metabasic rock suites in the Central Gneiss Belt is rather sporadic, requiring wide interpolation between outcrops. For example, in a 50 km gap between mapped metabasic outcrops at Burk's Falls and North Bay (Fig. 2), the only evidence for the location of the ABT was an aeromagnetic low following the eastern side of the Powassan batholith.

An alternative approach to mapping the ABT, using Nd isotope analysis, was proposed by Dickin (2000). The ABT normally separates terranes with significantly different Nd model ages, interpreted to represent distinct crustal formation ages. The difference in protolith ages across the ABT was already identified by Culshaw et al. (1994) as an indicator of the boundary on the Georgian Bay shoreline, but work by Dickin and Guo (2001), Dickin and McNutt (2003) and Herrell et al. (2006) showed that model age differences across the ABT could also be used to delineate its location in eastern Ontario and western Quebec, where high-grade polycyclic gneisses were found on both sides of the boundary.

In the North Bay and Mattawa areas, the ABT was found to separate crust with Nd model ages over 1.8 Ga in the parautochthonous belt from Nd model ages less than 1.8 Ga in the allochthonous belt. Because the method can be applied to any granitoid orthogneiss, it allows more detailed localization of the ABT than the sampling of metabasic rocks. Nevertheless, where metabasic rock suites were identified by Ketchum and Davidson (2000), the results from Nd isotope mapping were fully consistent with their data. Hence, the combination of these methods was used to establish an approximate trajectory of the ABT in Ontario and western Quebec (Fig. 2, Herrell et al., 2006).

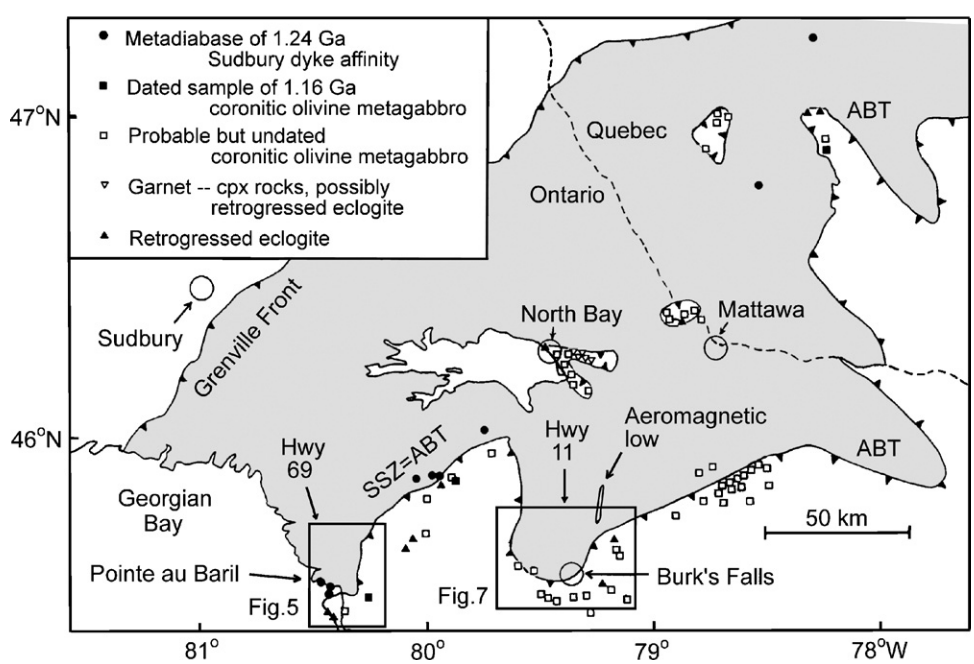

Fig. 2. Map of the southwest Grenville Province showing metabasic outcrops classified by Ketchum and Davidson (2000) relative to the location of the ABT based on Nd isotope mapping (Herrell et al., 2006). SSZ, Shawanaga Shear Zone; pale grey shading, parautochthonous belt. Inset boxes show locations of Figs. 5 and 7.