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Three-dimensional structure of the Torngat Orogen (NE Canada) from active seismic tomography

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Abstract. The crustal velocity structure and the Moho depth of the Proterozoic Torngat Orogen, NE Canada, is determined by active seismic tomography using travel times of crustal turning rays and Moho reflections. The orogen developed during oblique convergence of the Archean Superior and Nain Provinces, which trapped an interior belt of Archean crust (Core Zone) between them, with the Torngat Orogen evolving between the Core Zone and the Nain Province. Beneath the central orogen a crustal root is found with a preserved depth of >52 km and a width of ~100 km. To the north, the root shallows to <44 km and narrows to a width of ~45 km. The root correlates with a set of major, late orogenic shear zones that accommodated oblique convergence of the Superior and Nain Provinces. This correlation suggests that the transpressional shearing focused strain in the region of the root and contributed to the crustal thickening. Absence of postorogenic magmatic activity prevented reworking or thermal relaxation of the root. The lack of late magmatism is probably related to the depleted and refractory nature of the Archean lithosphere underlying the orogen. Upper crustal velocities are lowest in the Core Zone (~5.7 km/s at the surface) and are compatible with laboratory measurements carried out on gneissic rock samples from that area. Higher velocities in the Nain Province (~5.9 km/s) correlate with felsic gneiss and anorthosite rock samples. A high-velocity region immediately to the north of the crustal root is associated with a Moho uplift (~34 km). This is explained by extension along the Ungava transform fault, and possibly in Hudson Strait, at ~55 Ma when rifting in the Labrador Sea was transferred into Baffin Bay.

1. Introduction

Seismic studies have revealed a number of preserved crustal roots in the closely related Paleoproterozoic orogenic belts of Laurentia [*Lucas et al.*, 1993; *Funck and Louden*, 1999] and Baltica [*Grad and Luosto*, 1987; *BABEL Working Group*, 1990]. While the preservation of these roots for >1.5 Gyr is commonly related to the absence of postorogenic heating, there is a range of explanations for their creation. Some are thought to represent frozen subducted slabs [*BABEL Working Group*, 1990], and others are interpreted to result from ductile reworking of thickened crust during postcollisional transpression [*Németh et al.*, 1996] or from delamination of lithosphere and subsequent thickening of the crust by underplating [*Nironen*, 1997].

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The Torngat Orogen has been studied as part of Lithoprobe's Eastern Canadian Shield Onshore-Offshore Transect (ECSOOT). A previous refraction/wide-angle reflection (R/WAR) seismic transect across the Torngat Orogen (ECSOOT96 line 5W-E, Figure 1) found evidence for the existence of a crustal root beneath the orogen [*Funck and Louden*, 1999]. However, the experiment could not provide a definitive answer as to how the root was formed because of the lack of information about the three-dimensional (3-D) geometry of the root. It is clear that the root does not have a simple 2-D shape since an earlier reflection seismic line (ECSOOT92, Figure 1) shows no evidence for a root 200 km to the north of the R/WAR seismic transect [*Hall et al.*, 1995]. The seismic tomography study presented in this paper was designed to obtain more detailed information about the crustal thickness and structure for large parts of the orogen and to allow for a correlation with the complex geology in the area. The results from the tomography are compared with velocities obtained from rock samples from the study area and with potential field data. Together with geological data, an integrated interpretation for the orogenic development of the Torngat Mountains will be given.

2. Geological Setting

The southeastern Churchill Province in northeastern Canada (Figure 1) has a basic tripartite subdivision consisting of an interior belt of Archean crust, known as the Core Zone, and the bordering Archean cratons of the Nain and Superior Provinces [*Wardle*, 1998]. The Core Zone is linked to the