Metamorphic-Tectonic Interactions in Large Hot Orogens: Lower Crustal Flow in the Central Gneiss Belt, Western Grenville Province

R.A. Jamieson[1], C. Beaumont[2], M.H. Nguyen[1,2] and N.G. Culshaw[1]

[1]Department of Earth Sciences, Dalhousie University, Halifax, N.S. B3H 3J5
[2]Department of Oceanography, Dalhousie University, Halifax, N.S. B3H 4J1
E-mail: beckyj@dal.ca, christopher.beaumont@dal.ca, mhnguyen@dal.ca, culshaw@dal.ca

Among the many ways in which metamorphic and tectonic processes interact during orogenesis, partial melting and associated rheological weakening are particularly important. Thermal-mechanical models for large hot orogens that incorporate a viscosity reduction over the temperature range associated with incipient partial melting show a diachronous 3-phase evolution. Phase 1 is associated with crustal thickening and phase 2 with thermal relaxation; a minimum 20-25 My "incubation time" separates these phases. Phase 3 is associated with lateral flow of weak middle to lower crust, which may driven by a topographically-induced pressure gradient or by collision with a strong lower crustal indentor. In laterally homogeneous crust, outward flow takes the form of a low-viscosity channel bounded by thrust-sense and normal-sense shear zones (Beaumont et al., 2001, 2004). Where lower crust is laterally heterogeneous, crustal thickening can lead to the formation and stacking of thrust nappes that may be expelled over a colliding strong lower crustal block. An intermediate flow regime may arise where lower crustal nappes become disrupted by and/or partly incorporated into heterogeneous channel flow at mid-crustal levels (Beaumont *et al*., this volume).

The Mesoproterozoic Grenville Province represents a Himalayan-scale convergent orogen formed on the southeastern margin of Laurentia at ca. 1200-1000 Ma. In the Central Gneiss Belt (CGB) of Ontario, Laurentian rocks were reworked at synorogenic depths of 25-35 km, mainly during the Ottawan phase of the Grenvillian orogeny (ca. 1090-1040 Ma). Deformation propagated from dominantly juvenile continental arc rocks in the southeast towards older polycyclic rocks in the northwest. Widespread migmatite and granulite record peak metamorphic conditions of 750-900°C at 10-12 kb, probably beneath an orogenic plateau (Culshaw *et al.*, 1997). These features suggest that conditions within this part of the Grenville orogen may have been favourable for channel flow and/or the formation of hot lower crustal nappes.

Based on a combination of Lithoprobe seismic profiles (White *et al.*, 2000) and a wide range of geological, structural, petrological, and geochronological data, we propose that the Georgian Bay-Muskoka region, at the western end of the CGB, may represent the exhumed remnants of a hot nappe-channel system active at the peak of the Ottawan orogeny. Evidence for a low-viscosity channel comes mainly from the Muskoka domain, which comprises mainly shallow-dipping, highly migmatitic orthogneisses that form thin, laterally extensive, lobate sheets. Voluminous syn-tectonic leucosome formed at 1065 Ma (Timmermann *et al.*, 1997; Slagstad *et al.*, in press); the high-strain zone at the base of the Muskoka domain is cut by ca. 1047 Ma granite (Slagstad *et al*., in press). Underlying rocks of the Rosseau and Algonquin domains, in contrast, are much less migmatitic and contain significant volumes of mafic to intermediate granulite. On the crustal scale, however, the structural style of the CGB and the adjacent Central Metasedimentary Belt Boundary Zone (CMBBZ) comprises moderately dipping reflective zones more in keeping with a "hot nappe" style of deformation. Allochthonous granulites of the Parry

Sound Domain preserve steep, pre-Ottawan structures that could be the remnants of an early Grenvillian (Elzevirian) lower crustal nappe. Fragmental anorthosite and retrogressed eclogite bodies are widespread within the CGB, particularly along domain boundaries (e.g., Ketchum & Davidson, 2000); their petrology indicates that they must have originated at a much deeper crustal level than is currently exposed. These features suggest that "hot nappes" played a role in the tectonic evolution of the CGB and adjacent regions, and that pre- or early Ottawan lower crustal nappes may have been disrupted by and locally incorporated into a low-viscosity channel that operated during the Ottawan orogeny. This study shows how geological and seismic data (parameters) can be used in combination with numerical modelling (processes) to provide more insight into orogenic evolution than is offered by any one technique on its own.

References: Beaumont, Jamieson, Nguyen & Lee (2001) *Nature* **414**, 738-42; Beaumont, Jamieson, Nguyen & Medvedev (2004) *J. Geophys. Res.* **109**, B06406, doi:10.1029/ 2003JB002809; Beaumont, Nguyen, Jamieson & Lee (2004; this volume); Culshaw, Jamieson, Ketchum, Wodicka, Corrigan & Reynolds (1997) *Tectonics* **16**, 966-82; Ketchum & Davidson (2000) *Can. J. Earth Sci.* **37**, 217-34; Slagstad, Hamilton, Jamieson & Culshaw (in press) *Can. J. Earth Sci.*; Timmermann, Parrish, Jamieson & Culshaw (1997) *Can. J. Earth Sci.* **34**, 1023-29; White, Forsyth, Asudeh, Carr, Wu, Easton & Mereu (2000) *Can. J. Earth Sci.* **37**, 183-92.

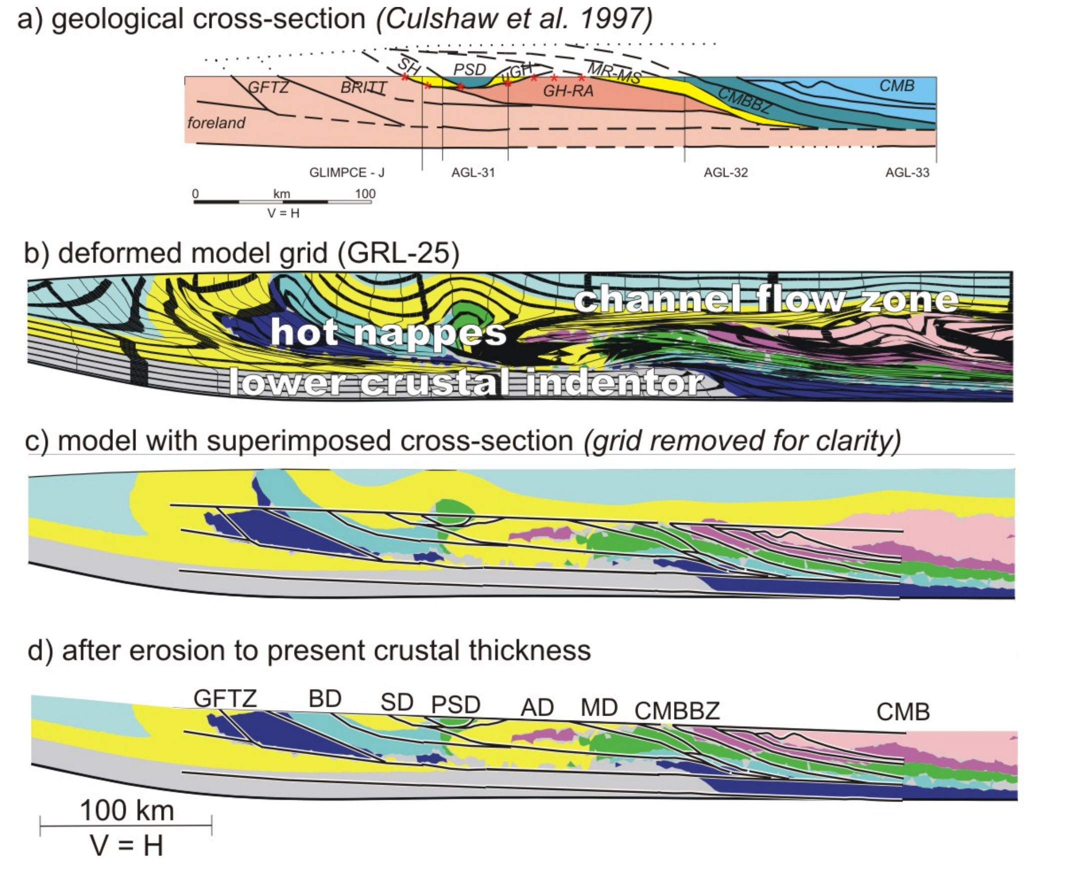

Fig.1. "Hot nappe" model (GRL-25) with Georgian Bay cross-section (Culshaw *et al.*, 1997) superimposed, showing how crustal architecture of western Grenville orogen may represent a combination of lower crustal flow modes (hot nappes + channel).
GFTZ = Grenville Front Tectonic Zone; BD = Britt Domain; SD = Shawanaga Domain; PSD = Parry Sound Domain; AD = Algonquin Domain; MD = Muskoka Domain; CMBBZ = Central Metasedimentary Belt Boundary Zone; CMB = Central Metasedimentary Belt