Geophysical Research Abstracts
Vol. 15, EGU2013-3455, 2013
EGU General Assembly 2013

Testing and refining a tectonic model for the Grenville orogen

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Numerical modelling of large, hot, long-duration orogens (LHOs) has become an important conceptual driver in the quest to better understand the tectonic evolution of the late Mesoproterozoic to early Neoproterozoic Grenville orogen, in terms of both interpreting the tectonic style and assessing the roles of individual variables. However, since the appropriate values for many variables in the models are unknown (and perhaps unknowable) in ancient orogens, model results can vary widely and must be critically tested against empirical data. Maps of the hinterland of the Grenville orogen showing the distribution of pressure (depth) of the Ottawan (∼1090-1020 Ma) peak metamorphism, coupled with representative P-T-t paths and structural / kinematic data for each crustal level, have proven useful in distinguishing between two alternative tectonic scenarios, i.e. whether the present distribution of metamorphic rocks primarily developed during compression by processes such as thrusting, tectonic extrusion or channel flow, or whether the compressional architecture was significantly modified by extension during later orogenic collapse. The hinterland is principally composed of gneissic granulite-facies mid crust (Ottawan P ∼1000 MPa) and HP granulite- to eclogite-facies lower crust (Ottawan P $\geq$ 1500 MPa) in which peak metamorphism took place at ∼1090-1050 Ma, that is tectonically juxtaposed against the amphibolite-facies upper crust (Ottawan P ∼400-1000 MPa, metamorphic peak at ∼1050-1020 Ma), and uppermost crust (Ottawan Orogenic Lid, OOL; Ottawan P $\leq$ 400 MPa) that lacks penetrative Ottawan deformation and was heated to < 500 °C after ∼1020 Ma. Lithoprobe crustal-scale seismic studies show that the orogenic mid and lower crust presently forms regional domal structures resembling core complexes, whereas the OOL occupies adjacent basin-shaped graben. It is argued that the progressive younging of peak Ottawan metamorphism with height in the orogenic crust over ∼70 Ma was a result of conductive heating as exhumation of the hot mid crust brought it into contact with successively higher crustal levels. A range of kinematic data indicate that exhumation was associated with extension and crustal thinning, supporting an origin by orogenic collapse due to gravity-driven lateral flow rooted in the ductile mid crust.

The long-duration (∼70 Ma) Ottawan phase of the Grenvillian orogeny in the orogenic hinterland was followed by the short-duration (∼20 Ma) Rigolet orogenic phase from ∼1000-980 Ma that was focussed in a structurally-underlying, narrow belt in the foreland and gave rise to the Grenville Front and Parautochthonous Belt. The grade of Rigolet metamorphism also ranges from greenschist to HP granulite facies, but its Barrovian character and the narrow width of the Parautochthonous Belt suggest an evolution more similar to a short-duration, cold orogen (SCO) than a LHO.

The temporal and spatial evolution from a LHO metamorphic regime beneath a plateau in the hinterland that underwent significant orogenic collapse before the development of a SCO metamorphic regime in the orogenic foreland has not yet been satisfactorily simulated in numerical models. It is argued that the spatial and temporal features of the Rigolet phase imply it evolved after significant cooling and stiffening of the lower crust in the Ottawan hinterland, possibly due to crystallization of leucosomes, and the two orogenic phases together imply the Grenvillian compressional regime lasted ∼100 Ma.