Geophysical Research Abstracts
Vol. 14, EGU2012-1155, 2012
EGU General Assembly 2012

Physical and chemical consequences of crustal melting in fossil mature intra-oceanic arcs

J. Berger (1) and J.-P. Burg (2)

(1) Department of Earth and Environmental Sciences, Université Libre de Bruxelles, Brussels, Belgium (juberger@ulb.ac.be),
(2) Department of Earth Sciences, ETH Zurich, Switzerland (jean-pierre.burg@erdw.ethz.ch)

Seismic velocity models of active intra-oceanic arcs show roots with densities and P-wave velocities intermediate to classical lower oceanic crust (density; ∼3.0, Vp: ∼7.0 km/s) and uppermost harzburgitic mantle (density: 3.2-3.3, Vp: 7.9-8.0 km/s). Most studies on active and fossil exhumed island arcs interpret the petrological nature of this root as ultramafic cumulates crystallized from primitive melts and/or as pyroxenites formed via basalt-peridotite reactions. Igneous cumulates and pyroxenites have densities close to or above that of uppermost mantle rocks; they can consequently undergo gravity-driven delamination, a process thought to drive the bulk composition of the arc toward an andesitic, continental crust-like composition.
Dehydration and melting reactions are reported from exposed arc roots (Jijal complex in Kohistan; Amalaoulaou arc in Mali; Fiordland arc in New-Zealand). Intense influx of mantle-derived basaltic magmas at high pressure in a thickening island arc can enable lower crustal rocks to locally cross the dehydration-melting solidus of hydrous subalkaline basalts. Thermodynamic modeling using Perple_X, geochemical analysis and compilation of experimental and field data have been combined to constrain processes, conditions and consequences of intra-arc melting. The position of the solidus in a P-T grid is strongly dependent of the bulk water content: at 1 GPa, it is as low as 750 °C for water saturated hornblende-gabbros (>1 wt% H_2O) and 830°C for gabbros with 0.1 wt% H_2O. Incipient melting (F <10 %) near the solidus produces trondhjemitic melt and garnet granulites residue. The latter has composition very close to that of igneous precursors but is characterized by contrasted physical properties (density: 3.2-3.3, Vp: 6.9-7.4 km/s). Higher partial melting degrees (F: 10-20 %) lead to the formation of anorthositic melts in equilibrium with garnet-clinopyroxene-rutile residues (density: up to 3.45, Vp: up to 7.7 km/s). These melts are rich in LILE (Rb, Ba, Sr) and LREE but strongly depleted in HREE and Y, while the residues are moderately enriched in Ti, Zr, Nb, HREE and Y but depleted in LREE relative to their igneous precursors. Compared to depleted mantle values, the residues also have low Rb/Sr but high Sm/Nd and Lu/Hf ratios.
Partial melting in the lowermost oceanic arc crust thus produces the conditions to trigger gravity-driven delamination of the root and could lead to introduction of fertile arc garnet pyroxenites within the upper mantle. However, in Kohistan and at Amalaoulaou, the dense garnet-clinopyroxene residues are dispersed in the arc roots; they are intermingled with hornblendite and pyroxenite bodies. The small density contrast between garnet granulites and the harzburgitic mantle, and the low volumes of garnet-clinopyroxene residues preclude massive delamination of the partial melting residues. Further numerical modeling of physical modifications induced by dehydration-melting together with igneous mineral segregation in arc roots will help constraining fundamental parameters (mantle and arc crust rheology and density, composition, P-T conditions, volume and rate of incoming basaltic fluxes…) that control the stability of the lowermost arc crust.