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Petrological and two-phase flow modelling of deep arc crust: insights on continental crust formation

Nicolas Riel (1), Pierre Bouilhol (2), Jeroen van Hunen (3), and Julien Cornet (3)

(1) Department of Earth Science, University of Bergen, Norway, (2) Laboratoire Magmas et Volcans, University of Blaise Pascal, Clermont-Ferrand, France, (3) Department of Earth Sciences, Durham, United Kingdom

The genesis of felsic crust is generally attributed to two main processes: the differentiation of primary magmas by crystallization within the crust or uppermost mantle and the partial melting of older crustal rocks. The Mixing/Assimilation/Hybridization of these magmas in the deep crust (MASH zone) and their subsequent segregation constitutes the principal process by which continents have become differentiated into a more mafic, residual lower crust and a more felsic and hydrated upper crust. Although this model describes qualitatively how continental crust forms, little is known on the physical and chemical mechanisms occurring at the root of volcanic arcs.
To assess the dynamics of partial melting, melt injection and hybridization in the deep crust, a new 2-D two-phase flow code using finite volume method has been developed. The formulation takes into account: (i) melt flow through porosity waves/channels, (ii) heat transfer, assuming local thermal equilibrium between solid and liquid, (iii) thermodynamic modelling of stable phases and (iv) injection of mantle-derived melt at the Moho.
Our parametric study shows that pressure, heat influx and melt:rock ratio are the main parameters controlling the volume and composition of differentiated magma. Overall the composition of segregated products scatters in two groups: felsic (80-68% SiO_2) and intermediate (60-52% SiO_2), with an average andesitic composition. The bimodal distribution is controlled by amphibole which buffer the composition of segregated products to high SiO_2-content when stable. As the amphibole-out melting reaction is crossed segregated products become intermediate.
When compared to available geological evidence, the liquid line of descent of mantle-derived magma do not fit the Mg# versus silica trends of exposed volcanic arcs. Instead our modelling results show that reactive flow of those same magma through a mafic crust is able to reproduce such trends.