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Exploring new frontiers in fluids processes in subduction zones

Physical factors that control fluid migration pathways in the mantle wedge

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Arc volcanism is mainly generated by the addition of hydrous fluids that trigger flux melting in the hot region of the mantle wedge. While thermo-petrological models predict the release of aqueous fluids from the subducting slab over a wide depth range, arc volcanoes are observed only in a relatively narrow region which lies $\sim$100$\pm$30 km above the top of the slab, suggesting the existence of some mechanism that focuses fluids and/or melts beneath the arcs. To assess the physical factors that exert a first-order control on fluid migration (FM) pathways through the mantle wedge, we use numerical 2D Darcy's-Stokes flow models (TerraFERMA and SubFUSc).
Recent FM models have suggested that spatial variations in mantle shear viscosity and permeability are critical factors that control FM pathways in the mantle wedge [Wilson et al., 2014; Cerpa et al., 2017]. In particular, the relatively small grain size predicted by the models near the tip of the corner flow leads to the trap of fluids released beneath the forearc and their down-dip drag towards by mantle solid flow. Once they reach the sub-arc region, the fluids start to migrate upwards [Wada and Behn, 2015; Cerpa et al., 2017]. Using such models we have explored the effects of the magnitude of fluid influx from the slab, the fluid viscosity and the density of the fluid on FM pathways. By applying uniform fluid properties in the model, we find that fluid influx and fluid viscosity may play a key role in defining fluid pathways while fluid density plays a secondary role. When a temperature-dependent fluid viscosity is applied, models predict greater entrapment of shallow and relatively cool fluids by the down-going mantle, promoting their arc-ward transport. On another hand, we observe that some of the fluids released at post-arc depths are also focused towards the sub-arc region by the mantle incoming flow. Yet, most of those fluids tend to focus beneath the back-arc and may trigger melting of distal parts of the mantle wedge.
Whether such distal melts form rear-arc volcanoes or are also focused towards the arc cannot be addressed by current models, as they do not account for mantle melting. Indeed, variations in water and silica content, affect fluid properties; the large jumps in fluid composition expected in the partial melting region may affect the paths of melts. To quantify this effect, we plan to use the Subduction Framework Utilising Scientific Computing (SubFUSc) code. This new code uses a fully-coupled mathematical framework in which melting is computed assuming local thermodynamic equilibrium and a parameterized, three-components phase diagram.