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Geodynamic control on melting in 3D mantle convection models

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Noble gases provide major constraints on Earth's mantle dynamics and thermal evolution that are not currently satisfied within our understanding of the mantle (i.e. whole-mantle convection supported by seismic tomography models[1]). Helium and argon are of particular interest since the source of the high $^{3}He/^{4}He$ ratios in OIBs and the global budget of ^{40}Ar are still debated, but are consistent with the preservation of primordial or unprocessed material within the convecting mantle. Additionally, helium and argon radiogenic isotopes are produced by the main heat-producing elements (HPEs) of the mantle, and are therefore intrinsic to geodynamic processes.

In this context, one crucial process is partial melting, observed by the presence of volcanic structures on the surface of terrestrial bodies in the Solar System. Melting creates compositional heterogeneity, segregates incompatible elements and allows the transfer of elements from the solid mantle to the atmosphere. We focus on the geodynamic controls over melting, considering melting depends on the composition and temperature of the material that is being processed.

Using the 3D mantle convection code, TERRA[2,3], we vary mantle temperature by implementing different initial amounts of HPEs to promote melting of less fertile compositions and greater melt production. We explore the influence of different viscosity parameters and imposed surface velocities on the renewal rate of material within the melting zone. Also, we investigate the effect of the buoyancy of recycled oceanic crust (and associated residence time in the deep mantle) on preferentially processed compositions within the melting zone.

Melting regimes can be defined based on the volume of melt and the type of compositions processed. A melting regime that favours preservation of enriched materials could potentially generate noble gases signatures which more closely resemble observations. We investigate the feasibility of such a regime within our models, specifically the preferred melting regime of the most Earth-like simulations.

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