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Predicted transit times of melt extraction at a mid-ocean ridge compared with observed U-series disequilibria

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Beneath mid-ocean ridges, magma is thought to rise through a network of high porosity channels that form by reactive flow. Through these channels, partial melts travel rapidly to the surface and retain the geochemical signature of their source rock. Global analyses of these melts indicate that the mantle is chemically heterogeneous, but the consequences of this heterogeneity for reactive porous flow remain unclear. Using numerical models of coupled magma/mantle dynamics, we investigate the relationships between mantle heterogeneity, melting, and magmatic channelization. The models are based on conservation statements for mass, momentum, energy, and composition in a system with two phases and two thermodynamics components in local thermodynamic equilibrium. One of these components is more fusible than the other. In this context, we find that heterogeneities enriched in the more fusible component can nucleate a network of magmatic channels. Some of these channels feed magma directly to the ridge axis, whilst others focus it to off-axis ponds of melt. To understand the predictions that our model makes for magma extraction and mixing, we seed the domain with tracer particles that are perfectly incompatible. Using these tracers we investigate the contribution of different portions of the melting region for magma focused to the ridge axis. We calculate the distribution of model transit-times for magma to reach the ridge axis and compare these results with the U-series geochemistry of mid-ocean ridge basalts. Furthermore, we question which regions and properties of the channel network and heterogeneous mantle structure, if any, can be mapped onto the geochemistry of mid-ocean ridge basalts.