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Ridge Melting Revisited: Melting of a wet multi-component mantle and its implications for the formation of MORB and a compositional lithosphere

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We explore several simple scenarios for wet melting of a heterogeneous multi- component mantle. In our melting formulation the mantle is viewed as a mixture consisting of a heterogeneously depleted peridotite matrix with embedded veins of fertile peridotite and/or geochemically enriched pyroxenite. These lithological units differ in their mineral composition but are assumed to have diffusively equilibrated both their water/hydrogen content and temperature over the hundreds of millions to billions of years prior to entering a melting region. During the melting process, however, only thermal but not chemical (water) equilibrium is assumed between the lithologies, which is a reasonable assumption for veins with thicknesses on the order of few tens to few hundreds of meters, a thermal diffusivity of 10-6 m2/s and a diffusivity of hydrogen of less than 3*10-9 m2/s.

We present results from 1-D model calculations, which represent the idealized decompression of a multi-component mantle rising underneath a mid-ocean ridge. We find that the initial water content in the mantle rocks has a very small effect on total melt production: While the onset of melting of a wet lithology is shifted to greater depths, the melting rates in this wet melting regime remain low because water efficiently partitions into the melt. High melt productivities are observed only after the dry solidus has been crossed; these findings are similar to those of Asimow and coworkers using PMELTs with a peridotite lithology. Since the hydrogen diffusion rate is too low to equilibrate the water contents of veins and surrounding matrix within the melting zone, dry and wet lithologies can coexist next to each other. Considering the dehydration related increase in viscosity for each lithology, the aggregate viscosity remains low until the last (most depleted) major lithology starts to melt — e.g. until the most refractory harzburgites cross their wet solidus.

We have also extended the formulation to examine the effects of rising melts on “flux-melting” the wall-rock through which they migrate. To do so we assume a certain volume-fraction of wall-rack that reacts with the rising melts. This effect is likely to be the reason why ridge melts almost always have major element chemistries in equilibrium with a peridotitic mantle. We hypothesize that rising melt will cause rapid and limited flux-melting in adjacent wall-rock as long as the melt+wall-rock system generates a larger equilibrium melt volume than the initial local melt volume, and that the preferred amount of local flux-melting is equal to the maximum amount of potential flux-melting: The volume fraction of wall-rock that interacts with melt is the fraction that maximizes the productivity of flux-melting. Since local flux-melting consumes latent-heat, this effect also reduces shallower melt-productivity.