

Reactive Melt Channelization in the Earth's Mantle

*Matej Pec¹, Benjamin Holtzman³, Mark Zimmerman², David Kohlstedt²

1. Massachusetts Institute of Technology, 2. University of Minnesota, 3. Lamont-Doherty Earth Observatory, Columbia University

The formation of oceanic plates requires extraction of large volumes of melt from the mantle. Several lines of evidence suggest that melt extraction is rapid and, therefore, necessitates high-permeability pathways. Such pathways may form as a result of melt-rock reactions.

We report the results of a series of Darcy-type experiments designed to study the development of channels due to melt-solid reactions in mantle lithologies. We sandwiched a partially molten rock between a melt source and a porous sink and annealed it at high pressure ($P = 300$ MPa) and high temperatures ($T = 1200^\circ$ or 1250°C) with a controlled pressure gradient ($\partial P/\partial z = 0$ -100 MPa/mm). To study the influence of lithology on the channel formation, we synthesized partially molten rocks of harzburgitic (40:40:20 OI -Opx -basalt), wherlitic (40:40:20 OI -Cpx -basalt) and lherzolitic (65:25:10 OI -Opx -Cpx) composition. The melt source was a disk of alkali basalt.

In all experiments, irrespective of the exact mineralogy, melt - undersaturated in silica - from the source dissolved pyroxene in the partially molten rock and precipitated olivine ($\sim\text{Fo}_{82}$), thereby forming a dunite reaction layer at the interface between the source and the partially molten rock. In samples annealed under a small pressure gradient, the reaction layer was roughly planar. However, if the velocity of melt due to porous flow exceeded $\sim 0.1 \mu\text{m/s}$, the reaction layer locally protruded into the partially molten rock forming finger-like, melt-rich channels in rocks of wherlitic and harzburgitic composition. The lherzolitic rocks were generally impermeable to the melt except at highest pressure gradients where a narrow fracture developed, forming a dyke which drained the melt reservoir. Three-dimensional reconstructions using micro-CT images revealed clear differences between the dyke (narrow, through-going planar feature) and the channels formed by reactive infiltration (multiple sinuous finger-like features). Apparently, the fraction of soluble minerals together with the melt fraction in the partially molten rock control whether dykes or reactive channels develop. Our experiments demonstrate that melt-rock reactions can lead to channelization in mantle lithologies, and the observed lithological transformations broadly agree with those observed in nature.

Keywords: melt - rock reaction, mantle, melt migration

