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Morphology of melt-rich channels formed during reaction infiltration experiments on partially molten mantle rocks

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Geochemical, geophysical and geological observations suggest that melt extraction from the partially molten mantle occurs by some sort of channelized flow. Melt-solid reactions can lead to melt channelization due to a positive feedback between melt flow and reaction. If a melt-solid reaction increases local permeability, subsequent flow is increased as well and promotes further reaction. This process can lead to the development of high-permeability channels which emerge from background flow.

In nature, anastomozing tabular dunite bodies within peridotitic massifs are thought to represent fossilized channels that formed by reactive flow. The conditions under which such channels can emerge are treated by the reaction infiltration instability (RII) theory (e.g. *Szymczak and Ladd 2014)*.

In this contribution, we report the results of a series of Darcy type experiments designed to study the development of channels due to RII in mantle lithologies *(Pec et al. 2015)*. We sandwiched a partially molten rock between a melt source and a porous sink and annealed it at high-pressures (P = 300 MPa) and high-temperatures (T = 1200° or 1250°C) under a controlled pressure gradient (∇P = 0-100 MPa/mm) for up to 5 hours. The partially molten rock is formed by 50:50 mixtures of San Carlos olivine (Ol, Fo $\sim$ 88) and clinopyroxene (Cpx) with either 4, 10 or 20 vol% of alkali basalt added. The source and sink are disks of alkali basalt and porous alumina, respectively.

During the experiments, silica undersaturated melt from the melt source dissolves Cpx and precipitates an iron rich Ol (Fo $\sim$ 82) thereby forming a Cpx-free reaction layer at the melt source – partially molten rock interface. The melt fraction in the reaction layer increases significantly (40% melt) compared to the protolith, confirming that the reaction increases the permeability of the partially molten rock. In experiments annealed under a low pressure gradient (and hence slow melt flow velocity) the reaction layer is planar and no channels develop. However, if the melt migration velocity exceeds $\sim$5 μm/s the reaction layer locally protrudes into the partially molten rock forming finger-like melt-rich channels. The morphology and spacing of the channels depends on the initial melt fraction. With 20 vol% melt, multiple and voluminous channels with an elliptical core formed of pure melt develop. At lower melt contents, fewer and thinner channels develop.

Our experiments demonstrate that melt-rock reactions can lead to melt channelization in mantle lithologies. The morphology of the channels seems to depend on the initial permeability perturbations present in the starting material. The observed lithological transformations are in broad agreement with natural observations. However, the resulting channels lack the tabular anastomozing shapes which are likely caused by shear deformation in nature. Therefore, both reaction-driven as well as stress-driven melt segregation have to interact in nature to form the observed dunite channels.

Szymczak, P., and A. J. C. Ladd (2014), Reactive-infiltration instabilities in rocks. Part 2. Dissolution of a porous matrix, *J. Fluid Mech.*, 738, 591–630.

Pec, M., B. K. Holtzman, M. Zimmerman, and D. L. Kohlstedt (2015), Reaction infiltration instabilities in experiments on partially molten mantle rocks, *Geology*, 43(7), 575–578, doi:10.1130/G36611.1.