EGU21-2786
https://doi.org/10.5194/egusphere-egu21-2786
EGU General Assembly 2021

Melt migration by reactive porosity waves

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The formation of alkaline magmas observed worldwide requires that low degree-melts, potentially formed in the asthenosphere, were able to cross the overlying lithosphere. Fracturing in the upper, brittle part of the lithosphere may help to extract this melt to the surface. However, the mechanism of extraction in the lower, ductile part of the lithosphere is still contentious. Metasomatic enrichment of the lithospheric mantle demonstrates that such low-degree melts interact with the lithosphere, but the physical aspect of this process remains unclear.

Here, we aim to better understand, first, the percolation of magma in a porous viscous medium at pressure (P) and temperature (T) conditions relevant for the base of the lithosphere, and second, the impact of chemical differentiation on melt migration. We investigate theoretically the process of melt migration employing the fundamental laws of physics and thermodynamics. We simulate melt percolation numerically with a one-dimensional (1-D) Thermo-Hydro-Mechanical-Chemical (THMC) model of porosity waves coupled with thermodynamic results obtained from numerical Gibbs energy minimisation calculations. We perform THMC modelling and Gibbs energy minimisations with self-developed numerical algorithms using MATLAB and linear programming routines. We employ a simple ternary system of Forsterite/Fayalite/Enstatite for the solid and melt. Model variables, such as solid and melt densities or mass concentrations of MgO and SiO in solid and melt, are a function of pressure (P), temperature (T) and total silica concentration of the system (X). These variables are pre-computed with Gibbs energy minimisation and implemented in the THMC porosity wave transport code via parameterized equations, determining the T-P-X dependence of the model variables.

First results show that the total silica concentration and the temperature gradient are important parameters to consider in melt migration by reactive porosity waves. We discuss results of a systematic series of 1-D simulations and we present preliminary results form a 2-D reactive porosity wave model.