Schmidt, M.W., Connolly, J.A.D., Solferino, G., Bagdassarov, N.

Experimental Determination of the Permeability of Asthenospheric Mantle and an Acceleration of Melt Extraction Velocities by 1-2 Orders of Magnitude

Eos Trans. AGU, 90(52), Fall Meet. Suppl.

ABSTRACT:

Magmatic production on Earth is dominated by asthenospheric melts of basaltic composition erupted at mid-ocean ridges, at hotspots, or being mostly differentiated at the base off or within arc crust. The time scale for segregation and transport of these melts is critically dependent on the permeability of the partially molten asthenospheric mantle. We employed a centrifuging piston cylinder at accelerations of 400-700 g, P = 1 GPa, and T = 1270-1300 oC, to measure the rate of basalt melt flow in olivine aggregates with porosities of 5-12 %. After annealing and textural equilibration at ambient acceleration but identical P-T conditions, centrifuging of samples with an initially homogeneous melt distribution for 21-24 h yields melt gradients along the sample axis (parallel to the gravity acceleration) of up to 12 vol% melt/mm. From this gradient, we determine melt velocities at the barycenter of the capsule which in turn lead to permeabilities of our samples. With the experimentally known porosities we have then determined the constant C in the permeability-porosity relationship κ = d2 φ3 / C to 3-27 with a preferred value of 10. The resulting permeabilities are consistent with a microscopic model in which melt is completely connected and are 1-2 orders of magnitude larger than currently predicted employing a C of 200-300. As a direct consequence melt extraction speeds become proportionally faster. Taken at face value, extrapolation of the measurements to conditions characteristic of sub mid-ocean ridge (MOR) asthenosphere yield extraction speeds of 2-130 m/yr for uniform flow assuming plausible upper asthenospheric parameters (d~10-2 m, μ~10 Pa s, ρ=500 kg/m3) and porosities on the order of 10-2 as indicated by sub-MOR geophysical observations. Application of these results in a model for porous media channelling instabilities yields melt transport times of ~ 1-2.5 kyr across the entire asthenosphere, sufficient to preserve the observed 230Th and 231Pa excesses of MOR basalts and the mantle signature of even shorter-lived isotopes such as 226Ra.