3D quantification of olivine growth rates

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Olivine has greatly fashioned our understanding of basalt magma formation and evolution through the crust. Surprisingly, however, the rates at which olivine grows in magma are still poorly constrained.

We performed crystallization experiments at 1-atm using a parental Kīlauea tholeiitic composition. Our starting material consists in 1820 CE glassy, weakly olivine-phyric (<4 vol.%) pyroclasts with a relatively primitive composition (11.4 wt.% MgO, with an equilibrium olivine composition $Fo_{85.5}$). In this basalt, olivine is the only crystallizing phase for an undercooling up to ΔT~130°C. Our experiments are first superheated for 24 hours, then rapidly cooled to different final temperatures (undercoolings ΔT=10, 25, 40 and 60°C), and left to crystallize at the final conditions for 20 minutes to 96 hours. We estimate the rates at which olivine grows in natural basalt as a function of undercooling in three different ways: (1) by 2D measurement; this method has the disadvantage that the variety of crystal sizes and intersection effects in the charges induces important variations in the growth rates obtained; (2) using mass-balance calculations from chemical analysis of the glass and assuming a single ideal (spherical) crystal; Chemical analyses show that olivine growth rates follow the same decreasing trend with time regardless of undercooling; (3) in 3D using X-ray micro-computed tomography. 3D olivine morphologies show a prefered cristallographic orientation, with faster growth along the *a*-axis. Glass analyses and 3D morphologies are in agreement with high growth rates of ~10^{-7} m/s at ΔT=60°C, which equates to crystallizing a phenocryst-size skeletal olivine in 15 minutes. Maturing of the skeletal olivine framework, on the other hand, appears to be a much slower (>4 day) process.