Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.14946

A general model for olivine growth rate and morphology in basaltic melts

YISHEN ZHANG[1], OLIVIER NAMUR[1], BERNARD CHARLIER[2] AND MARIAN HOLNESS[3]

[1]KU Leuven
[2]University of Liège
[3]University of Cambridge

Presenting Author: yishen.zhang@kuleuven.be

The size, morphology and composition of crystals in igneous rocks are an expression of magmatic processes. A quantitative understanding of their evolution during cooling is key to estimate magma residence time and to retrieve the thermal history of magmatic events involving transportation, magma mixing, and emplacement in the plumbing system. Olivine is ubiquitous and is usually the first phase on the liquidus of mantle melts. Its growth and morphology are known to be highly sensitive to the dynamical behavior in volcanic settings [1, 2].

We performed a series of experiments with controlled undercooling (-ΔT = 25-65 °C) and equilibration time (0.3-93.5 h) at atmospheric pressure and QFM (QFM = quartz-fayalite-magnetite buffer) to investigate the kinetics of olivine growth and the effect of melt composition and undercooling on growth rate and morphology. We selected three natural basaltic compositions from Nyiragongo (DR Congo), Osorno (Chile) and Kīlauea (Hawaii). These basalts have distinct NBO/T (= ratio of non-bridging oxygens to tetrahedrally coordinated network-forming cations) and cover melt compositions with SiO_2 39.2-50.2 wt.%, MgO 10.2-11.7 wt.%, FeO 8.5-11.4 wt.% and Na_2O+K_2O 2.3-5.9 wt%. In all three liquid compositions, olivine forms an outer shell in less than an hour: this shell is formed by the crystallization of primary branches, followed by secondary branches that progressively fill the melt-filled space inside the outer shell. The rate of growth and morphological evolution are a function of undercooling and melt chemistry. Olivine grows fastest from melt with the highest NBO/T, lowest SiO_2 and highest alkalis, with a morphology that is strongly elongated along the a or c-axis. The melt composition with the lowest NBO/T, high SiO_2 and relatively low alkalis has the slowest growth rate and olivine remains equant and strongly facetted at all undercooling conditions. Combining our new experimental data with published data, we propose a conceptual model to describe the growth rate of olivine as a function of undercooling and thermodynamic properties of olivine.

[1] Hammer 2008, Rev Mineral Geochem
[2] Mourey and Shea 2019, Front Earth Sci