Kinetic aspects of major and trace elements in olivines from variably cooled basaltic melts

Sarah Lang¹, Silvio Mollo¹,², Lyderic France³, Manuela Nazzari², Valeria Misiti², Andrey A. Gurenko³, and Jean-Luc Devidal⁴

¹Dipartimento di Scienze della Terra, Sapienza-Università di Roma, P.le Aldo Moro 5, 00185 Roma, Italy
²Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Rome, Italy
³CRPG, UMR 7358, CNRS, Université de Lorraine, 15 rue Notre Dame des Pauvres, 54501 Vandœuvre-lès-Nancy, France
⁴Laboratoire Magmas et Volcans, CNRS, IRD, OPGC, Université Clermont Auvergne, 63000 Clermont-Ferrand, France

Olivine is an important mineral phase in naturally cooled basaltic rocks. The texture and composition of olivine are strictly related to the interplay between the degree of magma undercooling and crystal growth rate. Crystals formed at low undercoolings and growth rates generally show polyhedral-hopper textures and quite homogeneous compositions, while skeletal-dendritic textures and evident crystal zonations occur at high undercoolings and growth rates. In this context, we have performed equilibrium and disequilibrium (i.e., cooling rate) experiments to better understand, by a comparatively approach, the effects of crystallization kinetics on the incorporation of major and trace cations in olivine lattice. The experiments were carried out in a 1 atm vertical tube CO-CO₂ gas-mixing furnace to perform experiment at atmospheric pressure and oxygen fugacity of QFM-2 using a basaltic glass (i.e., OIB) as starting materials. The equilibrium experiment was performed at 1175 °C. These target temperatures were kept constant for 240 h and then quenched. Conversely, the disequilibrium experiments were performed at the superliquidus temperature of 1250, and 1300 °C, which was kept constant for 2 h before cooling. The final target temperatures of 1150 (undercooling -ΔT = 50 °C), and 1175 °C (-ΔT = 25 °C) were attained by applying cooling rates of 2 °C/h, 20 °C/h, and 60 °C/h. Then the experimental charges were quenched. Results show that the olivine texture shifts from euhedral (i.e., equilibrium) to anhedral (i.e., disequilibrium) under the effect of cooling rate and rapid crystal growth. In equilibrium experiments, the composition of olivine is homogeneous and non chemical gradients are found in the melt next to the crystal surface. In contrast, a diffusive boundary layer develops in the melt surrounding the olivine crystals growing rapidly under the effect of cooling rate and degree of undercooling. The compositional gradient in the melt increases with increasing cooling rate and undercooling, causing the diffusive boundary layer to expand towards the far field melt. Because of the effects of crystallization kinetics, skeletal-dendritic olivines incorporates higher proportions of major and trace elements that are generally incompatible within their crystal lattice under equilibrium conditions.

How to cite: Lang, S., Mollo, S., France, L., Nazzari, M., Misiti, V., Gurenko, A. A., and Devidal, J.-L.: