

Abstract

Olivine is a common mineral phase in basaltic rocks from terrestrial magmas. Consequently, olivine's textures and chemical characteristics represent an important information-source on their origin, crystallization and differentiation of the solidifying system. The partitioning of major and trace elements between olivine and melt, as well as the evolutionary behavior of the partition coefficient are widely considered by petrologists investigating terrestrial rocks through the studies of mineral-mineral or mineral-melt element exchange reactions. However, for natural crystallization conditions, total equilibrium is rarely the rule, because one of the most important criteria of the solidification process which defines the final rock texture and mineralogy, is the cooling kinetics (Hammer, 2006; Iezzi et al., 2011; Mollo et al., 2010; 2011). The use of laboratory-determined crystal and/or melt equilibrium to model magma generation and differentiation is very important to understand the evolutionary behavior of minerals and coexisting melt (Mollo et al., 2013a, 2013b; Mollo and Hammer, 2017). When crystal-growth shifts from interface-controlled to diffusion-controlled, chemical elements transport in the melt is not fast enough to supply nutrients in the same proportion as exists in the far-field melt. One of the consequences is that the partition coefficient measured between the crystal-rim and the diffusive boundary layer interface changes substantially with the effect of the chemical gradient in the melt.

Undercooling and crystallisation kinetics are increasingly recognised as important processes controlling the final textures and compositions of minerals as well as the physicochemical state of magmas during ascent and emplacement. Understanding these kinetic aspects over the temporal and spatial scales at which volcanic and plutonic processes occur is therefore essential to correctly interpret the time-varying environmental conditions recorded in igneous minerals and host rocks. This project aims to quantitatively determine the partitioning of major and trace elements between olivine and melt through the study of magma crystallisation along kinetic or time-dependent pathways, where solidification is driven by changes in temperature. Cooling experiments from this project will have the ultimate aim to decode the textural geochemical information within crystalline phases. The aim is to place quantitative constraints on the crustal transport, ascent, and emplacement histories of erupted and intrusive terrestrial magmas, specifically of mid-ocean ridge and of hot-spot magmas. Deviations from chemical equilibrium develops in response to kinetically-controlled cation redistributions related to the partitioning of major and trace elements between a rapidly growing crystal and melt. The incorporation into the crystal lattice of chemical components in non-stoichiometric or non-equilibrium proportions is important to understand the conditions under which magmas crystallise and for the development of new thermometric and geospeedometer models.

To answer these questions I will effectate many high-pressure / high-temperature experiments that will be performed in a piston cylinder. The platinum capsules used will be Fe-saturated and loaded with glassy

powders from Mid-Ocean Ridge Basalt and from hot-spot magma to track the compositional effect on partition coefficients. The first step will be equilibrium experiments and the second step will be disequilibrium experiments. Some parameters will be changed (temperature, redox condition, H₂O content, undercooling rate, etc.) during experiments to observe the variation of elements partitioning between olivines and melt. Importantly, Iezzi et al. (2011) and Vetere et al. (2015) have experimentally demonstrated that superliquidus heat treatments does not alter the chemical and textural features of natural basaltic melts.

The analytical strategy will consist of chemical profiles conducted along the crystal surface and in the melt next to the crystal-rim with the microprobe technique to evidence the core-rim crystal zoning and the diffusive boundary layer formed at the crystal-melt interface. The laser ablation point analyses will be close to the microprobe pits with the aim to have guarantee of an internal standard calibration. The microprobe and laser ablation analytical traverses will be also integrated with chemical maps in order to highlight the areal distribution of chemical species in the crystal and coexisting melt.

My P.h.D time will be shared between INGV (Istituto Nazionale di Geofisica e Vulcanologia) in Rome and CRPG (Centre de Recherche Pétrographique et Géochemique) in Nancy (France). All the experiments will be effectuated in INGV laboratory and the analyses will be effectuated in CRPG laboratory. My P.h.D director in Rome is Silvio Mollo and my P.h.D co-director is Lyderic France in Nancy.