## Kinetic aspects of major and trace element partitioning between olivine and melt during solidification of terrestrial basaltic materials

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## Résumé

Olivine is an important mineral phase in naturally cooled basaltic rocks. Its morphology and composition is controlled by the cooling kinetics, and the mechanisms controlling the crystal growth impact the partitioning of elements. Major elements composing a mineral usually affect the chemical equilibrium of a system, while trace elements record the chemical reactions occurring in the system. Therefore, cations partitioning between two phases may document on the crystallization conditions of rocks. Disequilibrium experiments were designed to explore i) the partitioning of major and trace elements between olivine and basaltic melt during solidification, and ii) cation substitution and the mechanisms of charge balance controlling their entrance in the crystal lattice. The effect of undercooling  $(-\Delta T)$  and cooling rate (CR) were tested on a Hawaiian tholeiitic basalt melted at 1 atm and QFM-2 oxygen fugacity. Experiments started from a superliquidus temperature of 1250 °C and were cooled at the rates of 4, 20, and 60  $\circ$ C/h to the final temperature of 1175 (- $\Delta T = 35 \circ$ C) and 1125  $\circ$ C (- $\Delta$ T = 85  $\circ$ C). The olivine textures indicate equilibrium at - $\Delta$ T = 35  $\circ$ C and strong disequilibrium at  $-\Delta T = 85$  oC, also verified by the determination of the Fe-Mg exchange between olivine and melt. Low  $-\Delta T$  experiments show bulk chemical equilibrium, while local equilibrium occurs at higher  $-\Delta T$ . The forsterite content decreases as CR increases and a diffusive boundary layer develops in the melt next to the crystal interface. Nonetheless, here is established a local equilibrium highlighted by the near-equilibrium incorporation of Mg, Fe, Mn, and Ca. At the T-site, Ti incorporation is controlled by a homovalent substitution (TSi4+)  $\leftrightarrow$  (TTi4+), while heterovalent substitutions occur for Al and P, following  $(MMg2+, TSi4+) \leftrightarrow (MAl3+, TAl3+)$ , and  $(2 TSi4+) \leftrightarrow (TP5+, TAl3+)$ . Although Cr is an octahedrally coordinated cation, it shows the same behaviour as cations entering in the T-site. In fact, Cr is incorporated in the olivine lattice by forming a coupled substitution with a tetrahedrally coordinated cation  $(MMg2+, TSi4+) \leftrightarrow (MCr3+, TAl3+)$ . To preserve the charge balance, disequilibrium incorporation of minor elements is governed by the same mechanisms that occur under local equilibrium crystallization at the crystal-melt interface.

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