Title of the thesis: Lithophile elements (Si, Al, Ca, O, Mg) in the Earth's core: Implications for the chemical composition of the silicate Earth and the core

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Summary :

The last stages of the formation of the Earth's core took place under extreme conditions, at temperatures of around 3500 K and pressures of more than 50 GPa. The chemical exchanges that took place between the metallic and silicate phases constrained the chemical compositions of the core and mantle. Recently, it has been proposed that the metallic liquid dissolved a significant amount of lithophile elements, MgO and SiO2 in particular, before being sequestered into the core (Badro et al., 2016; Hirose et al., 2017). This would have led to a major chemical imbalance at the core-mantle boundary just after the crystallization of the magma ocean. The progressive return of excess lithophile elements from the core to the deep mantle could be responsible for some mantle plumes. This phenomenon could also have contributed to the start of the magnetic field very early in the Earth's history (O'Rourke and Stevenson, 2016).

In this project we propose to experimentally study the equilibria between metallic and silicate liquids at high pressures and temperatures using the laser-heated diamond anvil cell technique. The novelty in this project is the use of hydrated silicate compositions (containing variable concentrations of H2O). Indeed, most studies to date have been limited to anhydrous compositions which do not necessarily reflect the late stages of core formation.

We will focus on the dissolution reactions of the lithophile elements in the metal liquid via the following reactions (for Ca and Mg, for example):

$MgO^{silicate} \leftrightarrow Mg^{metal} + O^{metal}$ (1)

$CaO^{silicate} \leftrightarrow Ca^{metal} + O^{metal}$ (2)

The experimental study will allow us to determine the equilibrium constants K_{Mg}, K_{Ca}, K_{Si}, K_O, et K_{Al} which can be written empirically in the following form where the parameters ai, bi and ci are obtained by smoothing the experimental data as a function of pressure (*P*) and temperature (*T*):

$$\log K_i = a_i + b_i/T + c_i P/T \quad (3)$$

These equilibrium constants will allow us to model the dissolution of Mg, Ca, Si, O and Al in the core during its formation as a function of pressure and temperature conditions. Also, we will be able to determine the ratios of Mg/Si, Al/Si, Ca/Al or Al/Mg and the amount of oxygen incorporated into the core, and compare these values to geochemical models that provide constraints on the chemical composition of the core (e.g. McDonough and Sun, 1995). The nature of our experiments will allow us to constrain the concentration of hydrogen present in the bulk silicate Earth as well as in the core, and will contribute to better constrain the internal water cycle. The results will also allow us to quantitatively discuss different models of core formation and chemical composition of the Earth.

Finally, this thesis work will allow obtaining a very good expertise in diamond anvil cell technique; Scanning Electron Microscope coupled to a focused ion probe (SEM-FIB), and Electron Microprobe.

References:

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