Characterizing convective mixing efficiency from the early magma ocean to long-term solid-state convective stage

Institut de Physique du Globe de Paris

<u>Project summary</u>

The diversity of geochemical signatures in lava samples collected on Earth suggests that its silicate mantle is heterogeneous at various scales. However, such an interpretation of the geochemical data requires a consistent geodynamic frame to explain the possible survival or the disappearance of mantle heterogeneities. These heterogeneities are directly related to the ability of convective motions to deform and to progressively reduce the size of compositional variations that may eventually be homogenized by diffusion on small length scales.

Due to its progressive cooling, the convective dynamics of the Earth's mantle has evolved considerably throughout its entire history. During the earliest stages of its evolution, the Earth most likely experienced a brief, but intense, stage in which the mantle was entirely molten. This was followed by a long-term period lasting until the present, during which the mantle convected in a solid-state stage (with negligible inertia). The convective dynamic processes during these two distinct stages are very different and are therefore expected to impact the efficiency of mixing in very different ways.

The aim of this PhD project will be to quantify the efficiency of convective mixing during both the early magma ocean stage and the subsequent long-term solid-state convective stage using numerical modelling. To achieve this goal, the successful candidate will conduct a systematic parameter exploration (*e.g.*, *Rayleigh* number, *Prandtl* number, and viscous rheology) in 2–3D Cartesian geometry, along with the fine tracking of fluid particle trajectories in a spherical geometry. The experiments will rely on the use of pre-existing finite-volume (*StreamV [1,2]*) and finite-element (*ASPECT [3]*) codes. These experiments will serve as a basis to develop scaling laws to describe the convective mixing efficiency in the Earth's mantle during the two aforementioned end-member stages, along with the transitional period during which the mantle was largely partially molten. The results will be applied to interpret the isotopic signatures measured in collected samples both at regional (*i.e.*, plume) and global mantle scales.

This three-year PhD will be conducted in a dynamic, international, and multidisciplinary environment provided at the *Institut de Physique du Globe de Paris* (www.ipgp.fr), whose primary mission is to study processes shaping the Earth and planetary bodies. This project is financially supported by the *SHRED* ERC grant #833632 awarded to Catherine Chauvel (chauvel@ipgp.fr) and will be supervised by Henri Samuel (samuel@ipgp.fr) and Cinzia Farnetani (cinzia@ipgp.fr) in collaboration with Catherine Chauvel and Alessandro Forte (forte@ufl.edu).

Programming skills in at least one scientific language, along with a good knowledge of numerical methods and fluid mechanics, are required for this project.

To apply, send the following items to samuel@ipgp.fr :

- A one-page statement of interest for this project;
- A brief CV;
- The contact information of up to three references; and
- A copy of the highest relevant diploma obtained and the corresponding grade transcripts.

[1] H. Samuel, M. Evonuk, *Modeling Advection in Geophysical Flows with Particle Level Sets*, G^3, **11**, doi:10.1029/2010GC003081 (2010)
[2] H. Samuel, *A re-evaluation of metal diapir breakup and equilibration in terrestrial magma oceans*, EPSL, **313**, 105-114 (2012)

[3] Code maintained by the U.S. CIG consortium (https://geodynamics.org/cig/software/aspect/)