Characterizing convective mixing efficiency in planetary magma oceans

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Project summary:

The diversity of geochemical signatures in lava samples collected on Earth suggests that its silicate mantle is heterogeneous at various scales. A similar indication for Mars' mantle holds through the analysis of meteorites. However, such interpretations of geochemical data require a consistent geodynamic frame to explain the possible survival or the disappearance of mantle heterogeneities. These 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.

Throughout most of their histories, planetary mantles convect at solid-state stage, where rocks deform without inertia over billions of years. However, during the earliest stages of terrestrial planet evolution, intense heating due to energetic impacts, amplified by core-mantle segregation, and radioactive heating of short-lived nuclides led to a temperature increase above the silicates melting point. These events imply that most differentiated terrestrial planets and large moons experienced at least one early global magma ocean stage that lasted for a few thousands to a few tens of millions of years. During this relatively short time window, the convecting style was very different from the subsequent long-term solid-state mantle motions. Indeed, the low viscosity of molten silicates implies that inertia becomes important, and may considerably affect the dynamics of convective motions.

While most of the past geodynamic studies have focused on the long-term solid-state mantle dynamics, the efficiency of mixing in a fully molten, vigorously convecting mantle has not drawn a lot of attention.

Therefore, the aim of this internship is to focus on the characterization of convective mixing in a silicate magma ocean, using numerical modeling of Rayleigh-Bénard convection in the presence of inertial effects. The study will essentially consist in conducting a systematic exploration of the parameter space (Rayleigh number, Prandtl number, rheological parameters...). This exploration will serve as a basis to develop scaling laws to describe the convective mixing efficiency within a variety of differentiated terrestrial bodies such as the Earth, Mars, Mercury, or the Earth's Moon.

The experiments will rely on the use of a pre-existing finite-volume Fortran code (*StreamV* [Samuel, 2012a; Samuel, 2012b]), which may require minor modifications. For these reasons, programming skills, along with good knowledge of numerical methods and fluid dynamics are required for this project.

H. Samuel, *A re-evaluation of metal diapir breakup and equilibration in terrestrial magma oceans*, EPSL, **313**, 105-114 (2012)

H. Samuel, *Time domain parallelization for computational geodynamics*, G-cubed, **13**, doi:10.1029/2011GC003905 (2012)