Subject offered for a contract starting October 2017

PROJECT TITLE:
Stability and Evolution of Continental Lithosphere : Theory and Analogue Experiments with Microwave Induced Internal Heating

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Financing: Doctoral contract with or without teaching assignment

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Presentation of the subject: (1 or 2 pages)

The thermal evolution of telluric planets is characterized by the secular cooling of their silicate mantle. The slow convective motions of the planet interior depend on the mantle transport properties and on the amount and spatial distribution of long-lived radioactive isotopes (238U, 235U, 232Th and 40K). The composition of the bulk silicate mantle can be estimated from chondritic material, although there is a lively debate on the type of chondrites that formed the Earth [1, 2]. The distribution of radioactive elements in the mantle depends on internal differentiation processes subsequent to planet formation. For example, the multi-stage formation of the core [3] or the solidification of the primordial magma ocean [4] have probably led to a non-uniform radial distribution of heat producing elements. Partial melting efficiently concentrates incompatible elements, such as U, Th and K, in magmas that form the crust, thereby leaving a depleted residual mantle.

There are no experimental studies of convection in fluids with variations of chemical composition and intrinsic density on the one hand and variations of heat production on the other hand. To investigate the behavior of such systems, we have devised a new technique based on microwave heating that has been validated in previous studies [5, 6, 7]. Our microwave-based method offers the new perspective, out of experimental reach until now, to selectively heat different regions of a convecting liquid, analogue to heterogeneous convection in the presence of chemical reservoirs with different concentration of radioactive isotopes.

The main issue addressed by this thesis will deal with the continental lithosphere. Lithospheric material is the solid residue of past partial melting events, such that it is less dense and more viscous than the underlying convecting mantle. As it is cooled from above, continental lithosphere may become unstable depending on its thickness and density contrast with the mantle [8,9]. Partial melting also leads to enriched magmas that form continental crust with large amounts of heat producing elements. According to present estimates, the Earth's mantle may have lost as much as half of its radioactive elements to the continental crust and this induced stratification has two main effects [10]. First, mantle convection vigor decreases and becomes increasingly sensitive to heat supply from the core. Second, localized heat production at the top surface increases the continental insulating effect and competes against lithosphere instabilities. We aim to determine which amount of internal heating is required to keep the lithosphere stable for a given rate of cooling from the top.

The PhD student will perform a systematic experimental study of convection of an initially stable two-layer analogue characterized by different fluid properties: amount of internal heating, density, viscosity, and thickness. Based on these experimental results, the PhD student will determine the stability conditions and the scaling laws allowing their transposition to the Earth's and possibly other telluric planets' lithosphere.

We seek for a candidate with interests in Geodynamics, Fluid mechanics, Experimental physics.

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