Subject offered for a contract starting October 2017

SUBJECT TITTLE: South Atlantic hotspots and deep mantle geodynamic modeling

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Host lab/ Team : **Laboratoire de Dynamique des Fluides Géologiques -UMR7154 - IPGP**

Financing: Doctoral contract with or without teaching assignment

Presentation of the subject: (1 or 2 pages)

The overarching goal of this research project is to quantitatively understand how deep-seated mantle heterogeneities, of compositional and/or isotopic origin, can be dynamically entrained by mantle plumes and how/if they might cause the spatio-temporal geochemical variability of hotspot lavas. For this project the candidate must have good skills in numerical computation, since he/she will conduct simulations with three-dimensional thermo-chemical convection codes. Moreover, he/she needs to have a real interest in mantle geodynamics and fluid dynamics, as well as in using geophysical-geochemical observations.

The project will focus on the South-Atlantic intraplate volcanism, which has been active for the last 130 Ma and shows a complex geochemical spatio-temporal evolution. Clearly, the understanding gained by modeling the South-Atlantic volcanism will be of interest to other hotspots with a long-lasting "geochemical zonation". For example, at Hawaii the two parallel volcanic chains (i.e., Kea- and Loa-trend) have been geochemically distinct over the last 5 Ma. Similarly, at Galapagos the geochemical zonation lasted 14 Ma, at Marquesas 5.5 Ma, and at Society 4 Ma *[see for example . Abouchami at al., 2005; Chauvel et al., 2012; Huang et al., 2011; Weis et al., 2011; Hoernle at al., 2000; and references therein]*. Several authors have explained these observations by invoking the entrainment of geochemically distinct material from the Large Low Shear Velocity Province (LLSVP). Yet, existing models do not predict the time-scales and length-scales and physical conditions leading to such an entrainment.

In the South-Atlantic, the Tristan hotspot is considered as the classical example of a mantle plume, with its plume-head-fed Paranà-Etendeka Continental Flood Basalt province (formed ~130 Ma ago), followed by a long-lasting, plume-tail-fed magmatism forming the age progressive volcanic chain. Today we know that this model is acceptable only from 130 to 70 Ma ago, because over the last 70 Ma the intraplate volcanic chain is "diffuse" and organized into two tracks (Tristan and Gough) which are age progressive but not parallel. Over time (i.e., 70 Ma-present) the two volcanic tracks spatially diverged and are now 500 km far. **A first key question** will be to understand under which conditions progressively divergent volcanic chains can form.

The geochemistry is also interesting, since Tristan and Gough lavas are geochemically distinct *[e.g., Hoernle et al., 2015; and references therein].* Tristan's depleted geochemical fingerprint appeared only 70 Ma ago, rising the question of which mantle reservoir is sampled by Tristan. In contrast, Gough's enriched isotopic fingerprint has been present since 130 Ma ago and it characterizes also two hotspots, Discovery and Shona, situated further South. **The second key question** is thus to model how LLSVP-geochemically enriched material can upwell and feed several hotspots (Gough-Discovery-Shona) over a distance of a few thousand kilometers.

Note that the candidate will have the opportunity to collaborate with C. Class *(Lamont Doherty Earth Observatory of Columbia University, USA)* for geochemical aspects and new unpublished data from recent cruises. Another relevant observation is that South-Atlantic hotspots are relatively close to the spreading ridge, so **the third question** that will be addressed by modeling, concerns to which extent the young oceanic lithosphere affects plume melting and the flow of plume material in the uppermost mantle *[for recent results on this topic see Gassmoller et al., 2016]*.

I have experience with the convection code Stag-3D (by Paul Tackley) in Cartesian geometry, where millions of tracers are used to simulate compositionally distinct material. The code runs on IPGP parallel machine S-CAPAD. Moreover, by the time the Ph.D. student will start, we plan to have the three-dimensional code ASPECT running on S-CAPAD. Installing and learning how to use ASPECT is an ongoing project with John Armitage. ASPECT offers the advantage of having an adaptive mesh and it can run in spherical geometry. The Ph.D. student will probably work with both codes, gaining experience and constructing his/her model set-ups.

By systematically exploring key parameters, such as mantle viscosity and the intrinsic excess density of "LLSVP-like" material in the deep mantle, we will be able to study the shape and dynamics of thermo-chemical plumes and to quantify the entrainment of "LLSVP-like" material up to the surface. We will also pay attention at carefully modeling of shallow processes, such as partial melting and sub-lithospheric flow.

The resulting plume temperature and velocity fields will be used to calculate heat, mass and energy fluxes at different mantle depth. This will lead us to address **another key question**: which fraction of a plume mass/heat flux actually reaches the shallow mantle? Since *Sleep [1990]* the plume buoyancy flux has been estimated from the topographic swell observed at the surface. But we can ask “Is this buoyancy flux representative of the whole plume from “tip to toe”, or does it represent only the “tip” (i.e., the plume at sublithospheric depth)?

Hopefully, this research project will also give us a geodynamically consistent mechanism to explain a key seismological observation by *French and Romanowicz [2015],* concerning the dramatic change in plume shape at 1000 km depth. **An intersting result would be to explain** the apparent contradiction between hot-spots that have a relatively weak surface signature (i.e., magmatic activity, topographic swell) but show a major seismic velocity anomaly below 1000 km depth.

Finally, if the Ph.D. student is interested in conducting laboratory experiments, he/she will have the opportunity to do it. The experimental part will be under the supervision of Angela Limare and in collaboration with me. Limare recently developed an innovative and technically chellenging methodology which uses microwave radiations to explore the dynamics of an internally heated fluid. Laboratory experiments conducted with the microwave oven will enable the Ph.D. student to tackle the **key problem of thermo-chemical mixing** in fluids with a heterogeneous distribution of radioactive elements (e.g., U, Th, K).

If you are interested in this project, please write to: cinzia@ipgp.fr

Sincerely,
Cinzia Farnetani