Subject offered for a contract starting october 2015

SUBJECT TITTLE: Spatial and temporal distribution of strain in Afar

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Financing: Doctoral contract with or without assignment

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Presentation of the subject: (1 or 2 pages)

The Afar depression in East Africa presents unique geodynamic features, as it comprises the main zone of deformation related to tectonic divergence across the Arabia-Nubia plate boundary. The region is situated above sea level, making it possible to study extensional processes at crustal and lithospheric scales, as well as within a context of ocean spreading, with a variety of geological, geophysical and geochemical tools, both in the field and using remote sensing.

Previous studies have recognised the primary role of volcanism in localising strain along the diffuse plate boundary of Afar. Several volcanic-tectonic segments, such as the Asal rift (Djibouti), the Manda Hararo rift and the Erta Ale segment (Ethiopia) show morphological and geochemical features typical of an advanced stage of oceanisation. These segments have already experienced major episodes of magma intrusion along their axial volcanic zone in the last decades, which illustrates the way tectonic strain can be accommodated efficiently by magmatism. At the scale of several tens of thousands of years, episodes of volcanic construction within these segments seem to be followed by a dismantlement of volcanic edifices, likely as a result of the temporal variability of magma supply. On the contrary, the central part of the Afar depression has been devoid of volcanism for several million years at least. In Central Afar, deformation appears to be distributed within a series of rift systems including normal faults with vertical throws exceeding several hundred meters.

However, the Afar depression presents three additional singularities that make it difficult to interpret the entanglement of faults and volcanic edifices that prevails in this region. First, the area has been under the influence of a mantle plume since 30 million years. Furthermore, the Afar depression lies at the triple junction between the East-African rift system to the South, the Red Sea Ridge to the North, and the Aden Ridge to the East. Finally, the region has experienced several episodes of marine transgression in the past,

which have led to deposition of thick layers of evaporitic material, alternating with sporadic infill by volcanic material, the last episode of lava flooding dating back from 4 to 1 Ma (the so-called “stratoid series”). Although these features certainly affect the ongoing process of lithospheric rupture through the geometrical and thermomechanical conditions they impose (inherent instability of R-R-R triple junctions, relatively high heat flow, stacking of layers with contrasting rheologies), it is difficult to identify how they feature in today's strain field.

Nevertheless, many pieces of evidence indicate that processes of strain are intrinsically transient by nature, not only over time scales greater than 1–10 kyr, but also on durations of several years or decades. Analysing the strain field at different spatial and temporal scales is therefore an essential step to understand the main thermomechanical processes involved.

The launch of the Sentinel-1A spacecraft in 2014 by the European Space Agency (ESA), which will be soon followed by the launch of its twin, Sentinel-1B, provides a tool suited for the study of tectonic deformation in this region, where techniques such as radar interferometry (InSAR) are particularly adapted as shown by many previous studies led in particular by researchers of the Tectonics Team of IPGP. The swath of the images (250 km) combined with a short revisit frequency (once every 12 days) will allow for quickly building a dense archive of SAR images. It will then be possible to measure strain localisation, both within the volcano-tectonic segments themselves, as well as at the scale of the depression. In order to fully exploit the potential of these data, it will be necessary to tailor specific processing methods that are adapted to the massive influx of SAR data.

In addition, a remarkably rich geodetic data set gained over the last 40 years is already available in the area :

- a number of GPS sites were surveyed thanks to the ANR project DoRA since 2010, and permanent stations were installed;
- a fruitful scientific collaboration has been established with researchers of the University of Addis Ababa (Ethiopia) in the fields of seismology and geodesy;
- the Geophysical Observatory of Arta (Centre d'Etudes et de Recherche de Djibouti-IPGP) has been operating a permanent seismic network and has provided support to scientific projects for several decades, including geodetic surveys in the field and through space borne campaigns.

This exceptional data set, gathered by the team since the 1970s, is available for the thesis to provide means of validation and comparison with “Sentinel” data in order to characterise the distribution of strain within and across the Afar depression. It will be possible to isolate syn- and inter-dyking signals within rift zones by analysing transient deformation, and to understand relations with essentially “non-magmatic” transfer zones. Measurements of strain accumulation in dormant segments (magmatic or non-magmatic) will provide a quantification of the along-axis elastic thickness. Geodetic observations of syn-rifting and post-rifting deformation in the Asal and Manda Hararo rifts for the crises of 2005–2010 (10 years) and 1978 (30 years), will be reinterpreted in view of the new measurements of inter-rifting deformation provided by Sentinel-1. The ultimate goal is to shed light on the evolution of extensional deformation during periods of magmatic activity, as well as during phases of magmatic quiescence, in order to better understand the functioning of this complex plate boundary.