Subject title: Mechanical coupling between seismotectonic and volcanic activity at lithosphere scale.

Advisor: Feuillet Nathalie, IPGP, feuillet@ipgp.fr (Seismotectonics/geology/volcanology)

Co-Advisors:
Isabelle Thinon, BRGM, i.thinon@brgm.fr (Tectonics/ geology/geodynamics)
Luc Sholtes, ENSG, Univ. Lorraine, luc.scholtes@univ-lorraine.fr (Geomechanics / numerical modeling)

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On May 2018, the Island of Mayotte (Comoros, Indian Ocean) was struck by several Magnitude 5+ earthquakes as a result of a magmatic intrusion across the whole lithosphere (Lemoine et al., 2020, Cesca et al., 2020, Feuillet et al., 2019). This magmatic activity gave birth to a large deep-sea volcanic edifice (Feuillet et al., 2019). Such deep magmatic sources and diking in the brittle mantle were never documented by geophysical data before. High-resolution marine data were acquired offshore Mayotte Island during several marine cruises in 2019 and 2020 ((Mayobs cruises, Feuillet et al., 2019). Those data revealed that the new volcanic edifice of Mayotte was built at the tip of a NW-SE trending volcanic ridge (Mayotte ridge). This ridge is composed by dozens of volcanic edifices as a result of multiple magmatic intrusions along a NW-SE extensional tectonic structure (Feuillet et al., 2019). This structure opens at the scale of the whole lithosphere to transfer the strain between the East african rift offshore branches and the Madagascar graben, and serves as pathways for the magma straddling at the lithosphere asthenosphere boundary.
The objective of this thesis is to better constrain the processes that led to the building of the Mayotte ridge and many other volcano-tectonics structures at the scale of the whole Comoros archipelago by combining marine geophysical data analysis and numerical modeling based on the discrete element method (Jiao et al., 2018). In addition to the exploitation of the MAYOBS cruise data set, the student will participate to the acquisition and processing of high-resolution marine data that will be acquired during the SISMAORE 2020 cruise (scheduled on the RV Marion Dufresne by the end of 2020*). On the basis of the whole dataset of bathymetry, backscatter, HR seismic and sub-bottom profiles, the student will identify, map and characterize all the volcanic and tectonic structures at different spatial scales. By combining the information she/he will obtain at the subsurface to other information that will be gathered by the other work-packages of the COYOTES project*, the student will be able to built discrete element models**. These models will bring constraints on the origin of such structures by investigating the mechanical coupling between volcanism and tectonics at plate scale. We aim to understand better the complex interactions between magmatism and tectonics in complex faulted media of different rheologies, to reproduce magma pathways, the conditions leading to failure of deep reservoirs and vertical or lateral transfer of the magma between the base of the lithosphere and the seafloor.

Competencies required: Mechanics, physics, computing, modeling. Strong background in geophysics and geology

*More information on the ANR COYOTES project and SISMAORE cruise here:
http://www.geocean.net/coyotes/doku.php?id=start

**Additional information on the discrete element method (DEM): Deformation characterized by large discontinuous (i.e. fault- or fracture-related) strains is typical of many volcano-tectonic processes. Continuum-based numerical modeling approaches have an inherent difficulty in simulating fracture or fault system development which are nonetheless ubiquitous in nature. Here we propose to develop numerical models of volcano-tectonic deformation based on the DEM, a numerical approach that can simulate in an emergent fashion the nucleation, propagation and coalescence of fractures within elastic bodies (Scholtès et al., 2012). DEM models represent the medium as an assembly of rigid particles that interact one with another through predefined cohesive-frictional interaction laws. These interaction laws can be tuned to simulate different rheologies (e.g., elastic-brittle, elastic-plastic, visco-plastic). The particle movements are ruled by Newton's second law of motion. Fractures result from the breakage of the bonds binding up the particles as a consequence of their relative displacement. Once a fracture is generated, the formerly bonded particles can interact in an elastic-frictional manner to simulate the closure and/or shearing of the fracture. Faults can form from the coalescence of fractures. They can grow and propagate within the simulated medium as a function of the deformation process, giving an explicit representation of the mechanisms at stake in many volcano-tectonic systems.

References

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