UNIVERSITÉ Clermont Auvergne

Chimie Mathématiques Sciences de l'Univers Physique

Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Multi-parametric study of the evolution of hydrothermal systems: contributions to the understanding of volcanic systems in the process of reactivation.

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Summary : Active volcanoes often include a hydrothermal system due to the interaction of heat rising from the deep magmatic system with the water table, inducing fluid movements in the edifice. Acting as a buffer for the signals emanating from the deep magma and complicating their interpretation, the hydrothermal system is nonetheless undergoing the effects of a magmatic reactivation (unrest). The evolution of the state of the magma and the hydrothermal system is quickly reflected in the variations in the degassing flows, thermal anomalies, fluid circulation, gas and water chemistry, micro-seismicity, measurable in routine on the surface. Further geophysical changes are gradually appearing in the conductivity, magnetization and permeability of the surface areas of the building. **La Soufrière de Guadeloupe**, one of the most studied and monitored volcanoes in the world, has been experiencing an unrest phase since 1992, with an increase in activity since 2018. This volcano will therefore be at the heart of the thesis work.

The thesis project focuses on a **multi-parameter study** of the **evolution of hydrothermal systems**, in particular the measurement of degassing, in order to improve our understanding of volcanic systems being reactivated.

The first part will consist in improving the methods of **measuring the degassing of active fumaroles, to better constrain the state of the system at depth**. Empirical methods exist to determine the flow of hot, toxic and turbulent gases, but many poorly constrained factors (size and shape of the plume, wind, quantity of water) are still significant sources of error. The doctoral student will develop a numerical methodology for estimating flows based on field data (already acquired and to be acquired during the thesis) and on an existing plume model. This work will consist of:

i. The analysis of thermal images, using an existing Python code base, in order to extract shape, orientation, trajectory, and temperature parameters of gas plumes.
ii. The development of a module for the inversion of the physical model of a wind-bent plume (*Aubry et al., 2017*), including a radiative model. The model and the inversions will be validated by synthetic data and analogue experiments (*Carazzo et al., 2014*).

iii. The application at La Soufrière de Guadeloupe. Flux estimates from thermal images dating back to 2017 will be compared with estimates by other methods (*Jessop et al., 2021; Moune et al., in prep.*), in order to refine the parametrisation of the models.

In second component we will seek to **better understand the workings of the hydrothermal system**. For this, it will be necessary to carry out and reiterate **high-resolution thermal mapping** by drone of the active areas at Soufrière of Guadeloupe (D. Jessop, DGAC professional drone pilot's licence). The comparison with the maps from previous years (*Gaudin et al., 2016; Jessop et al., 2021*) will make it possible to **trace the spatio-temporal evolution** of the thermal fluxes within the edifice and therefore to **identify areas of reactivation**. These zones of thermal activity (either active degassing by active fumaroles; or passive / diffuse by the ground) being associated with movements of fluids in the building and with gradual changes in the physical properties of the ground (electrical conductivity, magnetisation, permeability), we will seek to physically connect them to geophysical measurements (magnetism, electrical tomography, Spontaneous Polarisation, SP) which capture these changes (*e.g. Brothelande et al., 2014; Gailler et al., in prep.*). These measurements will be carried out in the most active areas identified by the student alongside a team from LMV-OPGC.

The combination of the gas flows determined from the 1st part and the multi-disciplinary data that will be acquired in this 2nd part will make it possible to establish a conceptual model of the functioning of the hydrothermal system, as well as its temporal evolution, connecting the fluids circulating in subsurface, external forcings (rainfall) and surface fumes. This thesis project will ultimately aim to establish a **global interpretative (4D) model of a hydrothermal system in a context of reactivation**.

The study context is very favourable since the doctoral student will have many thermal images already at his disposal as well as an existing code. He will be able to benefit from numerous monitoring data (geophysics, geochemistry, geodesy and thermal) acquired during this unrest and from the four years of experience of D. Jessop at the Soufrière Observatory. The doctoral student will also have the opportunity to work in an active observatory. Regarding the data to be carried out in the field, the doctoral student will focus on thermal data (infrared camera on drone, temperature probe), gas flows (Pitot probe) as well as on SP mapping. The other geophysical measurements will be carried out by a group of researchers from LMV-OPGC, the doctoral student will therefore be integrated into a larger project on La Soufrière, including many experts in geophysics and geochemistry from whom he will gain a lot of experience. These field measurements can be backed up by D. Jessop's regular field campaigns for his observation tasks. It is important to note that this work could also be directly applicable to La Montagne Pelée in Martinique, a volcano that has also been undergoing unrest since 2019.

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