ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

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Titre du sujet : Evolution of the hydrothermal system of La Soufrière de Guadeloupe volcano : insights from stable isotopes

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Financement : **Contrat doctoral avec ou sans mission d'enseignement**

State of the art

Volcano monitoring relies primarily on monitoring seismicity, ground deformation, and the chemical composition of emitted volcanic fluids. On open-conduit volcanoes, monitoring the concentrations and fluxes of major volatile species (sulfur dioxide SO_2, carbon dioxide CO_2, hydrochloric acid HCl) in volcanic gases can provide information on magma storage and ascent conditions, enabling the detection of a future eruption. However, variations in the chemical composition of volcanic gases emitted at the surface — and, more broadly, geophysical signals — are much more difficult to interpret in the presence of a hydrothermal system. At la Soufrière de Guadeloupe volcano, where nearly 7 meters of rain falls annually at the summit, the gases escaping from deep magma reservoirs interact with the hydrothermal system — a mixing zone where ascending magmatic fluids and surface fluids (rainwater or seawater) infiltrate through the fracture network. This process, known as "scrubbing," therefore alters the original composition of the gases, particularly for water-soluble species such as SO_2 or HCl. To isolate and characterize the evolution of purely magmatic inputs over time, geochemical tracers are needed to decipher these interactions, which are still difficult to identify and quantify and represent a major obstacle for the monitoring of hydrothermal volcanoes.

A multi-disciplinary team of IPGP's researchers has recently unraveled that chlorine stable isotopic compositions ($\delta^{37}Cl$) can be used as such a tracer, as its pioneer application clearly demonstrated the ^{35}Cl lost through partial dissolution of gaseous HCl as it circulates in liquid water in the dome, likely during its ascent toward the surface at la Soufriere de Guadeloupe (Le Glas et al., 2025). These $\delta^{37}Cl$ data constituted the first strong evidence, now reinforced by many other observations (e.g., rising temperatures: close to 100°C before January 2021, and exceeding 150°C starting in 2023) of the progressive drying, between mid-2019 and mid-2021, of the gas pathway from the main fumarolic site of la Soufriere de Guadeloupe.

Objectives and strategy

This thesis aims at extending this knowledge to other fumarolic zones at the summit, and thermal springs at the flank, of the volcano to track the spatial- and time- evolutions (before and after the 2019-2021 period) of liquid-gas interactions within the dome of la Soufrière de Guadleoupe. New measurements of $\delta^{37}Cl$ will be compared, if needed, to more traditional stable isotopic tracers of other main volcanic volatiles ($\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$) that can be analyzed in the IPGP's stable isotope team. Isotopic data will be compared to geochemical data routinely obtained by the Observatory (or OVSG - Observatoire Volcanologique et Sismologique de la Soufrière de Guadeloupe) such as elementar composition of gas collected from fumeroles or gas plume compositions (e.g., SO_2/H_2S and C/S ratios), in collaboration with OVSG and Laboratoire Magma et Volcans. Finally, the isotopic data will be compared to geophysical data (seismology and deformation) in collaboration with OVSG and the team of Systèmes Volcaniques de l'IPGP.

This approach is crucial to determine whether the hydrothermal system is evolving locally, with a simple shift in activity, or whether the entire system is evolving in response to deeper magmatic forcing.

More broadly, this thesis aims at bringing important constraints to characterize time- and spatial-evolution of the hydrothermal system at la Soufrière de Guadeloupe volcano as well as the evolution of fluid connections (ie., sealing and/or opening of pores and/or fractures) within the dome. This is crucial for a better evaluation of hazards related to phreatic eruptions and flank destabilization – a timely challenge for the study of hydrothermal volcanoes.

Candidate skills : The ideal candidate should have strong training in isotope geochemistry and/or volcanology and/or hydrogeology and strong interest for labwork. Skills in modelling gas-liquid interactions will be appreciated.

Supervision : This work will be supervised by Magali Bonifacie (CNRS senior scientist at team Géochimie des Isotopes Stables, IPGP), in close collaboration with colleagues from team Systèmes volcaniques, the Soufrière de Guadeloupe Observatory (OVSG) and international institutions. For more information, please contact : bonifaci@ipgp.fr