Bottom-up vs top-down drivers of eruption style : Petro-geochemical constraints from the holocene explosive activity at La Soufrière de Guadeloupe (Metcalfe et al., 2022)

M. Courcelles[1] M. Soares Correia [1] E. Vincent [1]

[1]University Paris Cité, IPGP, Paris, France

Geological Context

La Soufrière de Guadeloupe is an active andesitic volcano which belongs to the Lesser Antilles arc, resulting from the eastward subduction of the Atlantic plate beneath the Caribbean plate. It is located on the Basse-Terre and included in the Grande-Découverte–Soufrière volcanic complex, which has been active throughout the Holocene and generated a wide range of eruptive styles, from effusive dome-building events to Vulcanian, sub-Plinian, and Plinian explosions.

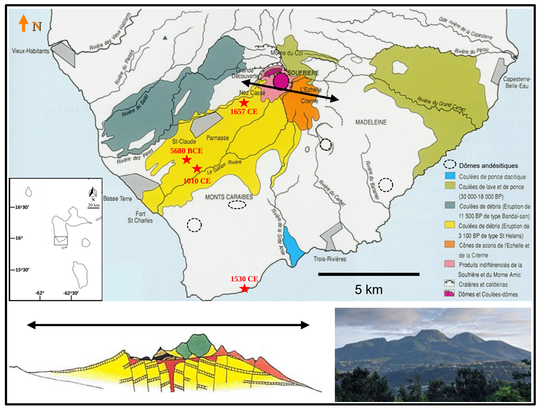

Figure 1. Simplified map of southern Basse-Terre showing La Soufrière and nearby Holocene vents. Red stars show sampling locations. Inset : regional setting of Guadeloupe. Photo: view of La Soufrière from the southwest (Metcalfe et al., 2021)

Motivations

The factors controlling the eruptive variations of La Soufrière remain poorly constrained. In particular, it is unclear whether eruptive style is primarily governed by:

- *Bottom-up* processes : internal to magma dynamic response ;
- *Top-down* processes : with a cause external to the magma.

This study aims to untangle these controls from four Holocene eruptions of different magnitudes (VEI 2 to 4) by trying to identify the dominant parameters that modulate explosivity at La Soufrière. Constraining these drivers is essential for refining future eruptive scenarios and improving monitoring strategies.

Methods

Sample selection

- Four Holocene eruptions (VEI 2-4)
- Melt inclusions (MI) inside plagioclases & orthopyroxenes
- Groundmass (GM) glass from corresponding deposits

Geochemical analyses

- Major elements (EPMA)
- Volatiles : H_2O, CO_2, S, Cl, F (SIMS)
- Used to reconstruct pre-eruptive melt composition & volatile budget

Physical parameters

- Thermobarometry → storage depth & temperature (Putirka, 2008)
- Microlite textures → ascent behaviour in conduit

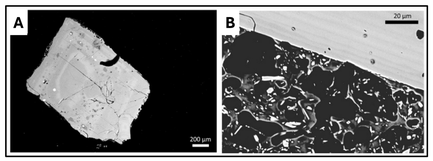

Figure 2. (A) Plagioclase hosted inclusions. (B) Groundmass glass (modified from Metcalfe et al., 2022)

Results

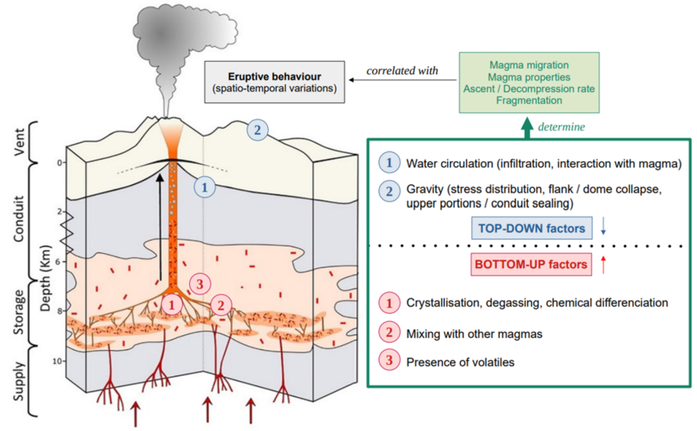

Figure 3. Bottom-up & Top-Down factors plotted on a La Soufrière reservoir schematic diagram

- Homogeneous MI (63–79 wt % SiO_2 ; constant volatile contents) over 7000 years → stable and evolved reservoir.

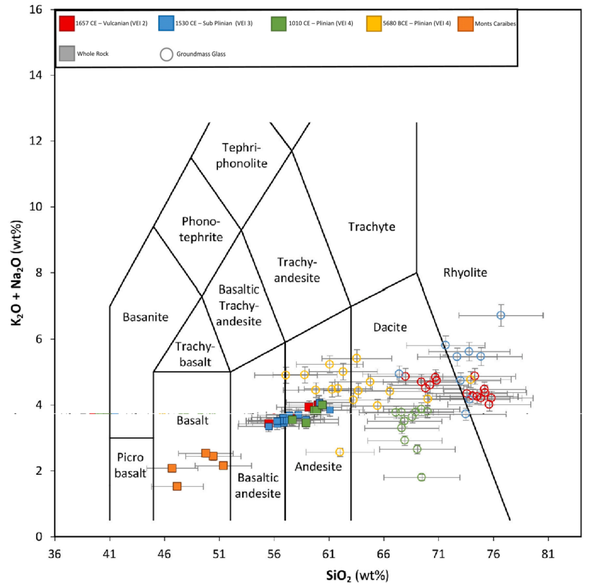

Figure 4. Total Alkali-Silica whole rock dataset for the La Soufrière eruptions and parental Monts Caraïbes magma

- Narrow source depth range for all eruptions : 7–9 km (190–220 MPa).
- MIs more evolved than GM → crystals entrained from a colder mush, confirming a long-lived mush system.

Results

- GM composition controlled by syn-eruptive crystallization (8–47 % microlites) → directly linked to magma ascent rate.

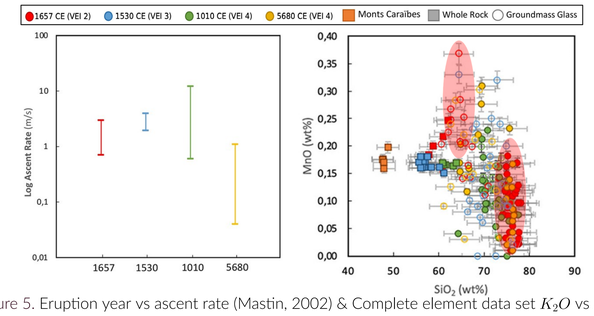

Figure 5. Eruption year vs ascent rate (Mastin, 2002) & Complete element data set K_2O vs SiO_2

- No significant differences in volatile contents between eruptions → volatiles do not control explosivity at this system.

Figure 6. Volatile contents for melt inclusion H_20 & CO_2 vs K_2O

Conclusions

- Major and volatile elements of melt inclusions from the eruption series show **stable properties of the mush storage** (homogeneous composition, 7-9 km, 1000 °C). It could indicate a **global predominance of top-down factors** in the control of the explosive activity intensity.
- Top-down factors such as **sealing by a capping dome** or **flank collapse** could lead to different eruption style than those expected considering only bottom-up factors.
- **Rapid ascent rate** combined with **limited gas exsolution** and **important microlites growth** ease **explosive** activity.
- The multiple controls on explosive eruption style render La Soufrière volcanic system particularly **hazardous**. **Monitoring** on tracking ascent and shallow-depth conduit processes should be made to develop efficient prevention.

References

[1] Abigail Metcalfe, Séverine Moune, Jean-Christophe Komorowski, Geoff Kilgour, David E Jessop, Roberto Moretti, and Yoann Legendre. Magmatic processes at la soufrière de guadeloupe: insights from crystal studies and diffusion timescales for eruption onset. *Frontiers in Earth Science*, 9:617294, 2021.

[2] Abigail Metcalfe, Séverine Moune, Jean-Christophe Komorowski, and Roberto Moretti. Bottom-up vs top-down drivers of eruption style: Petro-geochemical constraints from the holocene explosive activity at la soufrière de guadeloupe. *Journal of Volcanology and Geothermal Research*, 424:107488, 2022.

[3] Keith D Putirka. Thermometers and barometers for volcanic systems. *Reviews in mineralogy and geochemistry*, 69(1):61–120, 2008.

vincent@ipgp.fr courcelles@ipgp.fr soarescorreia@ipgp.fr