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

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Titre du sujet : The dynamics of partial column collapse during explosive volcanic eruptions

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Presentation of the subject:

Volcanic plumes produced by explosive eruptions commonly reach, at some stage, a collapse regime with associated pyroclastic density currents (PDCs) propagating on the ground. Column collapse is often partial and the controls on the mass partitioning between the buoyant rising jet and the dense collapsing flow remain to be elucidated. Understanding the key mechanisms that govern the column behavior is crucial for the rapid assessment of the predominant risk, which may pass from one of ash injection into the atmosphere to one of ground-level hazard with complete destruction of infrastructures. This thesis addresses this issue by using an integrated approach, which combines direct observations in the field, laboratory analogue experiments, and 3D numerical modelling.

The partial collapse regime has been observed during several historical eruptions (e.g., 1977 Ukinrek, 1979 St Vincent, 1980 Mt St Helens, 1982 El Chichon, 1984 Mayon, 1991 Pinatubo, 2009 Sarychev, 2010 Eyjafjallajökull, 2015 Calbuco) and inferred from the deposit architectures of prehistorical and less recent events (e.g., Bishop Tuff 0.76 Ma, Fogo A 4.6 ka, Mt Pelée 2 ka, Taupo 1.8 ka, Vesuvius 79 CE, 1150 Quilotoa, 1815 Tambora, 1912 Katmai, 1937 Rabaul, 1963 Agung) [1,2]. However, the number of eruptions for which field observations are sufficient for a detailed reconstruction of the eruptive history is relatively limited, making it difficult to interpret the deposits in terms of eruptive dynamics. Theoretical models yield valuable insights on the threshold conditions for the entrance into the partial collapse regime, shedding light on the importance of the mass eruption rate and exsolved gas content at the vent [1]. Laboratory analogue experiments provide additional constraints and highlight the crucial role of magma temperature [2], particle concentration [3], and total grain-size distribution [4] on the intensity of column collapse. These preliminary results are not included yet in numerical models used for hazard assessment, most likely due to the lack of a robust framework to tackle the partial collapse regime.

The aim of this thesis is build such a quantitative framework in order to better understand the behavior of this peculiar eruptive regime, and to constrain its impacts on the environment, from the ground level to the high atmosphere. For this, the PhD candidate will (i) perform fieldwork to collect new data at two different volcanoes: Mt Pelée (Martinique) and Fogo (Azores), (ii) run laboratory experiments simulating an eruptive column in the partial collapse regime, and (iii) model the tephra dispersion in the atmosphere and on the ground.

i) Fieldwork will be performed in order to collect detailed data on deposits thickness, grain size, type and shape. Isopach and isopleth map of airfall and PDC deposits will be built and used to infer the eruption source parameters (volume, mass eruption rate, column height). We will build on previous field work on the 2 ka P3 eruption of Mt Pelée volcano [5], and explore the 4.6 ka Fogo A eruption deposits [6] in order to provide a unprecedented data set that will be used to constrain the models.

ii) Analogue experiments will be designed and performed in the laboratory under controlled conditions to reproduce a hot particle-laden jet in the partial collapse regime [2,3]. The set-up will be calibrated using appropriate scaling analysis, and will allow to vary all the physical parameters: mass flow rate, vent size, exit velocity, particle content and size, source temperature, and ambient fluid properties. High-speed camera measurements will help to determine the mass partitioning between the buoyant rising part and the dense collapsing part of the flow, as a function of the source and environmental conditions.

iii) Finally, 3D numerical models of ash dispersion (Fall3D [7]) and PDC propagation (VolcFlow [8]) will be applied to the two different volcanic sites in order to interpret the field measurements in terms of flow dynamics. The models will then be used to assess associated volcanic hazards on infrastructures.

This work will provide critical constraints to better understand the dynamics of partial column collapse during explosive eruptions. The new laboratory results will provide a stringent test to fully validate the physical models, which will be used in turn to interpret the field data. The results will be of great interest for volcanological observatories worldwide and constitute a robust tool for hazard assessment at active volcanoes, including those under the monitoring of IPGP Volcanological Observatories.

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