# Time-window into the transcrustal plumbing system dynamics of Dominica (Lesser Antilles)

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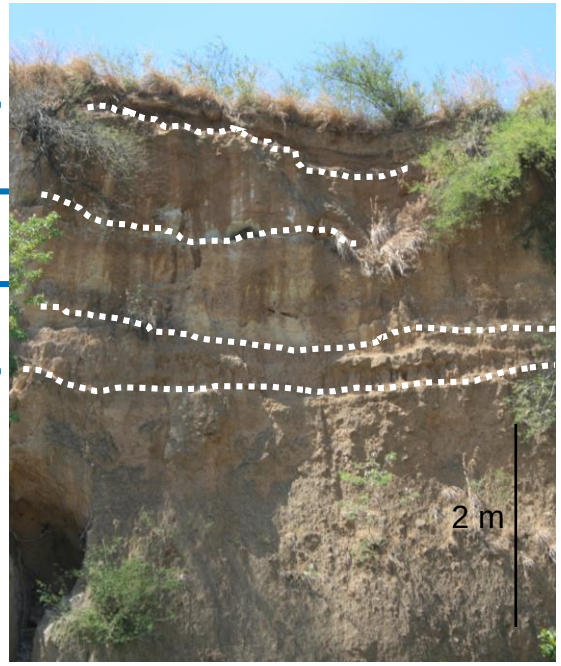
**Display materials for EGU21 – 2797**
**Session GMPV8.1 'The Dynamics of Magmatic Plumbing Systems'**






**Picture of the outcrop of the studied eruptions in Dominica (Lesser Antilles)**

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## Research motivations

- What are the **spatiotemporal dynamics** of the magmas in the plumbing system of Morne Trois Pitons-Micotrin volcano?
- Have the **timescales of magmatic processes** varied prior to the eruptions of the last 24 kyrs?

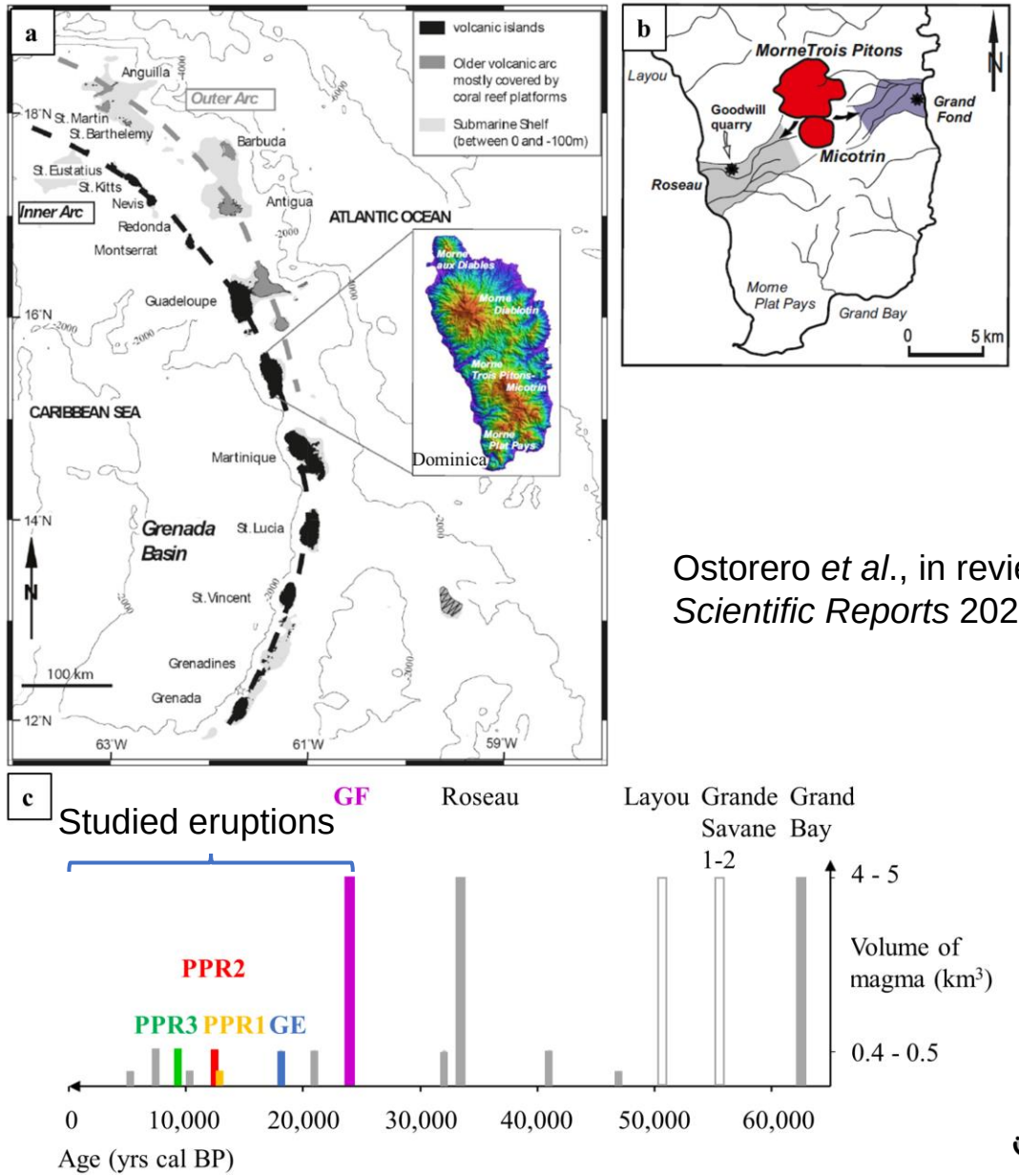


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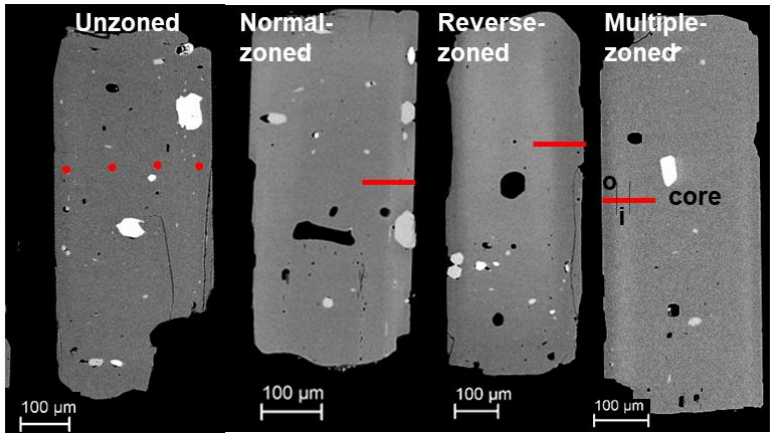
**Figure 1: a. The Lesser Antilles arc. b. Map of southern Dominica and location of the studied deposits: stars (modified from Boudon *et al.*, 2017). c. Chronology of the pumiceous eruptions from Morne Trois Pitons-Micotrin for 70 kyrs.**

# Coupling Crystal System Analysis with timescales modelling

## Step 1: Identification of the zonations in the orthopyroxenes

Red lines: Electron Probe Microanalyzer profiles

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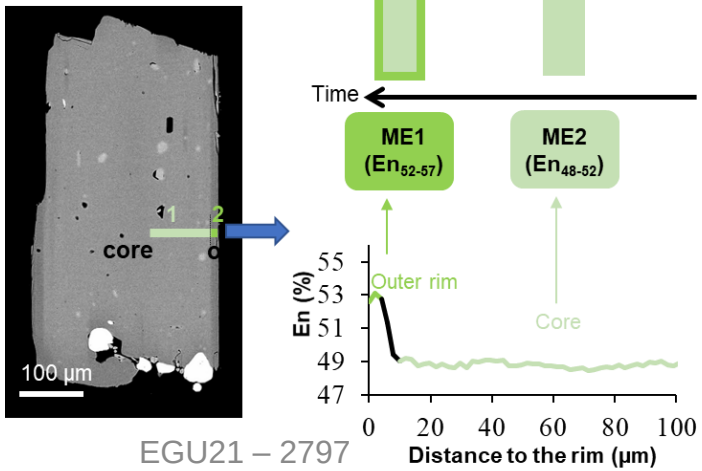
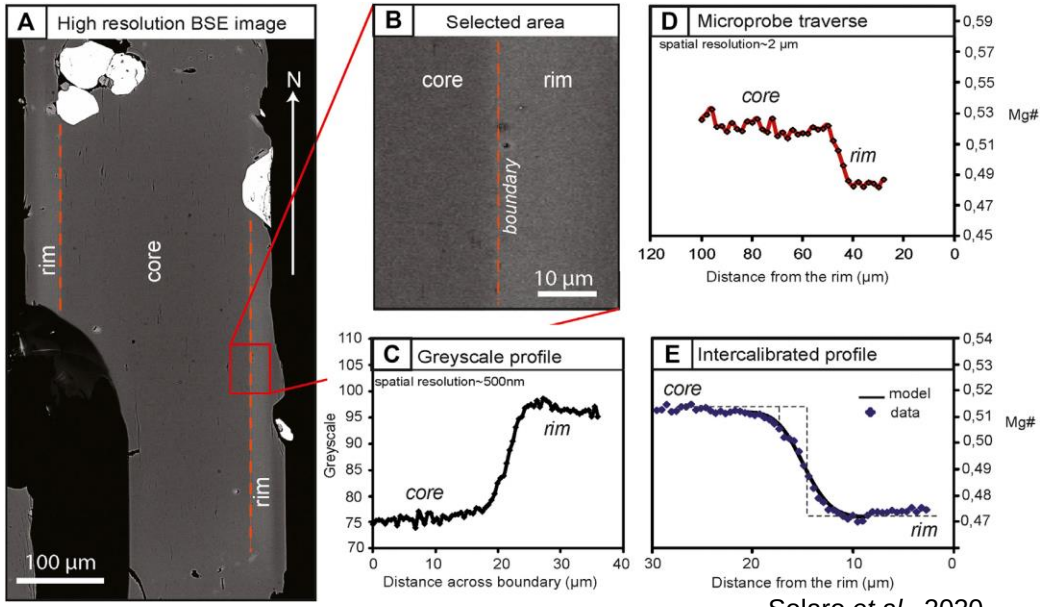
## Step 2: En content of the cores and rims and identification of magmatic environments




**Magmatic environments:** defined by constant set of intensive thermodynamic variables such as pressure (P), temperature (T), composition and fugacities of volatile species

## Step 3: Crystal System Analysis (Kahl *et al.*, 2011, 2013, 2015, 2017) and timescales modelling




Solaro *et al.*, 2020

- **Fe-Mg interdiffusion coefficient**

$$D = D_0 \exp\left(\alpha X_i + \frac{-E_a + PV}{RT}\right) \times (fO_2)^m \times (fH_2O)^n$$

Chemical composition | Temperature and pressure | $O_2$ fugacity | $H_2O$ fugacity

- **Ganguly and Tazzoli (1994) parametrization**
- **1D modelling**

## Step 1: Identification of the zonations in the orthopyroxenes (opx) of PPR3

- **For the last explosive eruption studied PRR3**: 36% Unzoned opx, 64% zoned opx (majority of multiple-zoned opx)

## Step 2: En content of the cores and rims and identification of magmatic environments (ME) of PPR3

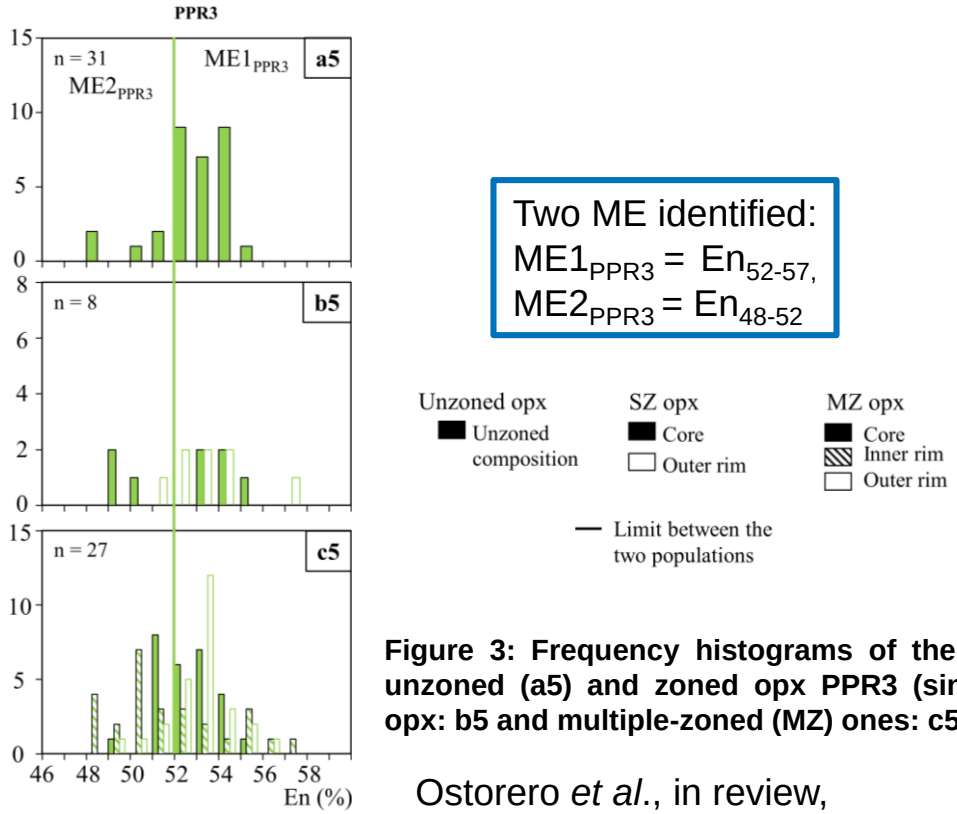



**Figure 3: Frequency histograms of the En content of unzoned (a5) and zoned opx PPR3 (single-zoned (SZ) opx: b5 and multiple-zoned (MZ) ones: c5).**

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## Step 3: Timescales modelling of PPR3

- **Fe-Mg interdiffusion timescales modelling**

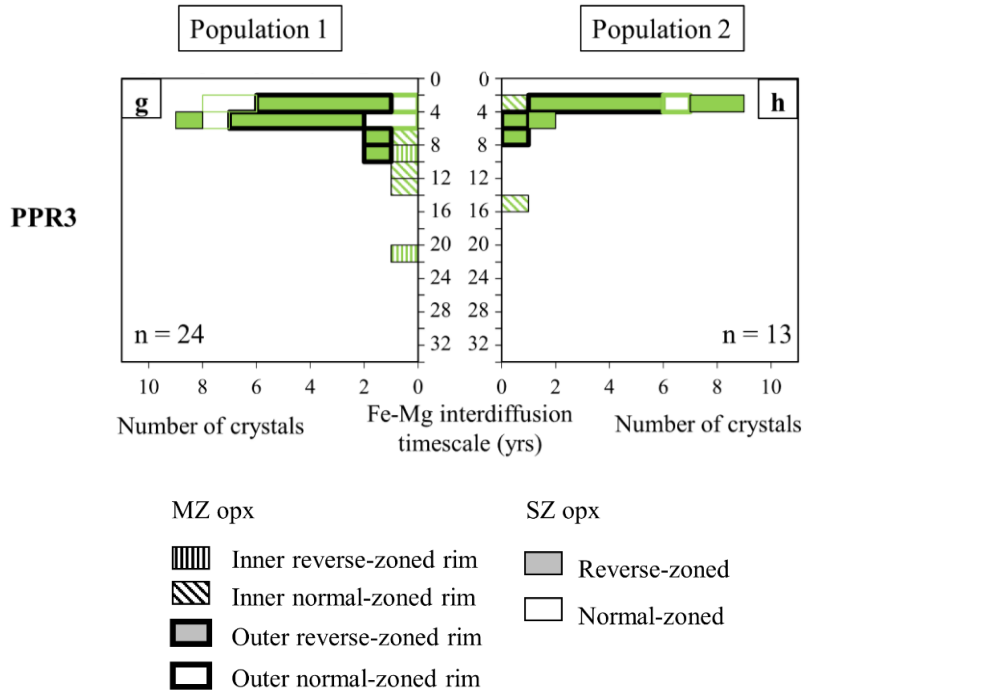



**Figure 5: Frequency histograms of Fe-Mg interdiffusion timescales modelled at 890 ± 9°C for core-rim and inner-outer rim boundaries of SZ and MZ opx of the two opx populations**

Timescales of inner and outer rims in the same order of magnitude

## 1) Crystal System Analysis

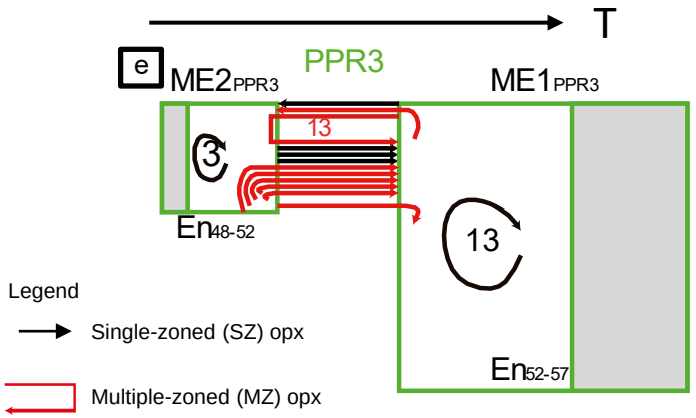
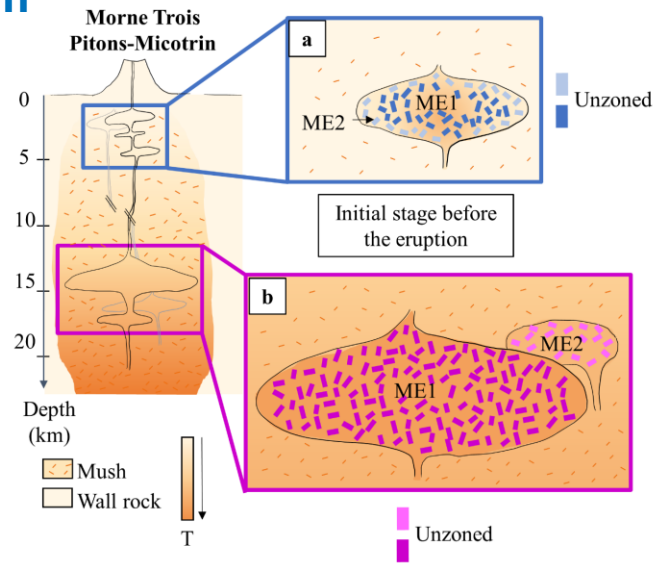


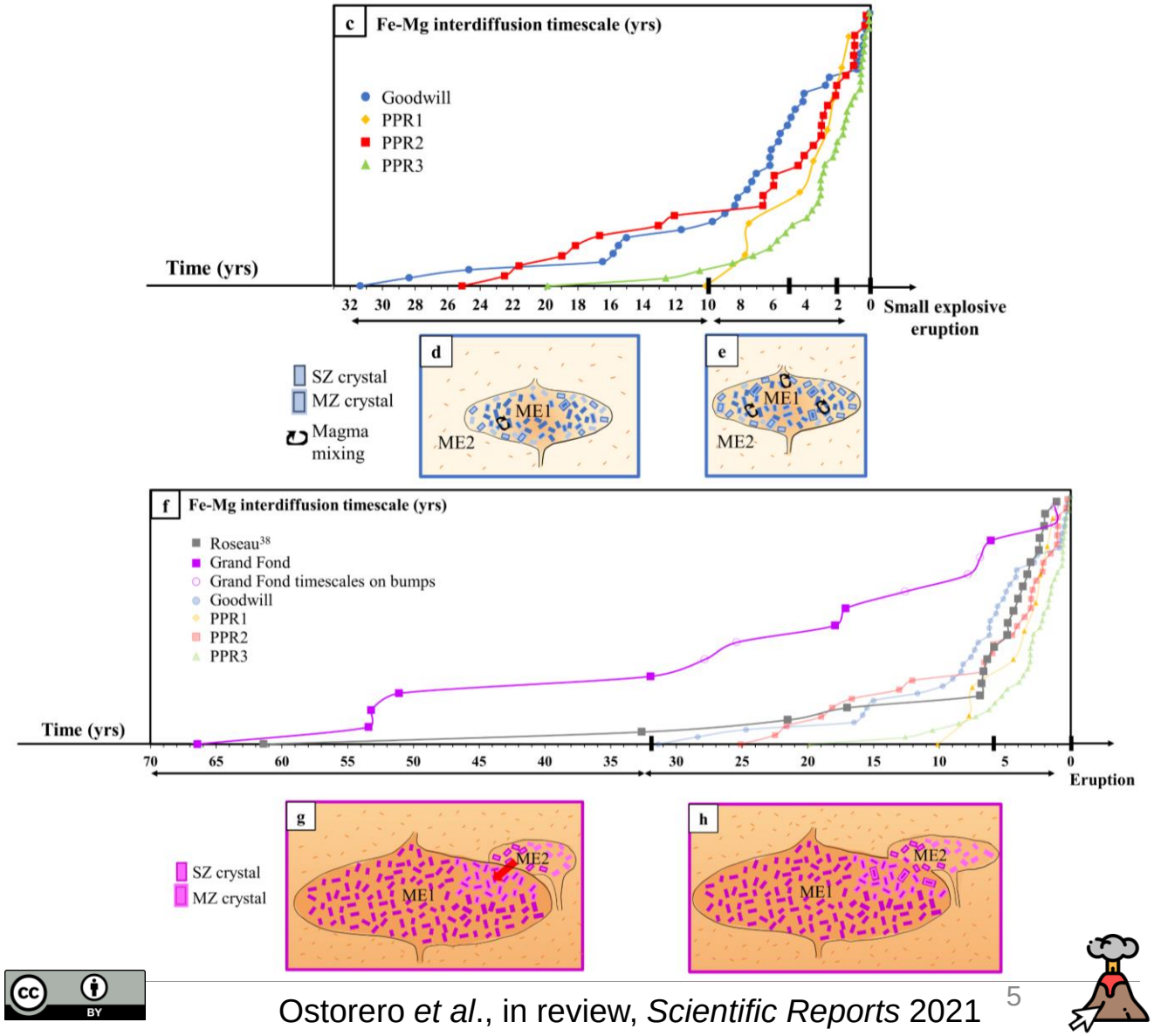

**Figure 6: Crystal System Analysis approach of the zonations recorded by the two populations of opx of PPR3 (e).**

Evidence of a magmatic process: temperature increase

## 2) Storage system




## 3) Spatiotemporal dynamics of the five eruptions





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## Take home messages:

- We propose a spatiotemporal evolution of the magma plumbing system within a transcrustal system, beneath **Morne Trois Pitons-Micotrin volcano in Dominica**, using opx as they are trackers of pre-eruptive processes.

- Two main storage areas are present:

- A deep one (at ~12-16 km; Solaro *et al*., 2019). 33 kyrs ago, **partial mixing** between two magma batches occurred one decade or more prior to the **voluminous pumiceous eruptions** of Roseau (Solaro et al., 2020) and then Grand Fond, 9 kyrs later.

- At shallower depth (~2-8 km; d'Augustin *et al*., 2020). Since 18 kyrs, **vigorous and relatively extensive mixing** occurred in a thermally-zoned reservoir, possibly following an injection of a hot magma from a deeper source. These magmatic zones are likely to have been disturbed ~**10 to 30 years prior to eruption and then more dynamically ~2-10 years prior eruption**, with activity ramping up prior to the resulting eruption.

- Such investigations have a potentially major role in terms of volcanic risk mitigation and management of future explosive volcanic crises.

# Thank you for your time!

## References


- Boudon, G., Balcone-Boissard, H., Solaro, C., & Martel, C. 2017. "Revised Chronostratigraphy of Recurrent Ignimbritic Eruptions in Dominica (Lesser Antilles Arc): Implications on the Behavior of the Magma Plumbing System." Journal of Volcanology and Geothermal Research 343 (September): 135–54. https://doi.org/10.1016/j.jvolgeores.2017.06.022.
- d'Augustin, T., Balcone-Boissard, H., Boudon, G., Martel, C., Deloule, E. & Bürckel, P. 2020. "Evidence for an Active, Transcrustal Magma System in the Last 60 Ka and Eruptive Degassing Budget (H 2 O, CO 2, S, F, Cl, Br): The Case of Dominica." Geochemistry, Geophysics, Geosystems 21 (9). https://doi.org/10.1029/2020GC009050.
- Kahl, M., Chakraborty, S., Costa, F. & Pompilio, M. 2011. "Dynamic Plumbing System beneath Volcanoes Revealed by Kinetic Modeling, and the Connection to Monitoring Data: An Example from Mt. Etna." Earth and Planetary Science Letters 308 (1–2): 11–22. https://doi.org/10.1016/j.epsl.2011.05.008.
- Kahl, M., Chakraborty, S., Costa, F., Pompilio, M., Liuzzo, M. & Viccaro, M. 2013. "Compositionally Zoned Crystals and Real-Time Degassing Data Reveal Changes in Magma Transfer Dynamics during the 2006 Summit Eruptive Episodes of Mt. Etna." Bulletin of Volcanology 75 (2): 692. https://doi.org/10.1007/s00445-013-0692-7.
- Kahl, M., Chakraborty, S., Pompilio, M. & Costa, F. 2015. "Constraints on the Nature and Evolution of the Magma Plumbing System of Mt. Etna Volcano (1991–2008) from a Combined Thermodynamic and Kinetic Modelling of the Compositional Record of Minerals." Journal of Petrology 56 (10): 2025–68. https://doi.org/10.1093/petrology/egv063.
- Kahl, M., Viccaro, M., Ubide, T., Morgan, D. J. & Dingwell, D. B. 2017. "A Branched Magma Feeder System during the 1669 Eruption of Mt Etna: Evidence from a Time-Integrated Study of Zoned Olivine Phenocryst Populations." Journal of Petrology 58 (3): 443–72. https://doi.org/10.1093/petrology/egx022.
- Solaro, C., Balcone-Boissard, H., Morgan, D.-J., Boudon, G., Martel, C. & Ostorero, L. 2020. "A System Dynamics Approach to Understanding the Deep Magma Plumbing System Beneath Dominica (Lesser Antilles)." Frontiers in Earth Science 8 (November). https://doi.org/10.3389/feart.2020.574032.
- Solaro, C., Martel, C., Champallier, R., Boudon, G., Balcone-Boissard, H. & Pichavant, M. 2019. "Petrological and Experimental Constraints on Magma Storage for Large Pumiceous Eruptions in Dominica Island (Lesser Antilles)." Bulletin of Volcanology 81 (9): 55. https://doi.org/10.1007/s00445-019-1313-x.



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**The Figures in this presentation are part of the In review paper from Ostorero, L., Boudon, G., Balcone-Boissard, H., Morgan, D. J., d'Augustin, T., Solaro, S. in review for *Scientific Reports*, 2021**
Check it out soon in *Scientific Reports*!