Monthly Bulletin

Institut de physique du globe de Paris
Observatoire volcanologique du Piton de la Fournaise

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April, 2023

PITON DE LA FOURNAISE *(VNUM #233020)*
Latitude: *21.244°S*
Longitude: *55.708°E*
Summit elevation: *2632 m*

Piton de la Fournaise is a basaltic hot spot volcano located in the southeastern part of La Réunion Island (Indian Ocean).
The volcano first erupted about 500,000 years ago. Its volcanic activity is characterized by frequent effusive eruptions (with emissions of lava fountains and lava flows) that occur on average twice a year since 1998. More rarely, larger explosive eruptions (with blocks covering the summit area and ash emissions that can disperse over long distances) have happened in the past with a centennial recurrence rate.
Most of the current eruptive activity (97% during the last 300 years) occurs from vents inside the Enclos Fouqué caldera. A few eruptions, however, have occurred from vents outside the caldera (most recently in 1977, 1986, and 1998). Such eruptions can potentially threaten communities that live in the surrounding areas.
Since late 1979, the activity of Piton de la Fournaise is monitored by the Piton de la Fournaise Volcanological Observatory (Observatoire Volcanologique du Piton de la Fournaise - OVPF), which belongs to the Institut de Physique du Globe de Paris (IPGP).

Alert level: Vigilance
(since April 24, 2023)

October 14, 2022 (08h00) to April 21, 2023 (15h45): Vigilance
April 21, 2023 (15h45) to April 24, 2023 (14h00): Alert 1

(cf. table in the appendix)

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A. Piton de la Fournaise activity

Seismicity

In April 2023, the OVPF-IPGP recorded at Piton de La Fournaise:

- 808 shallow volcano-tectonic earthquakes (0 to 2.5 km above sea level) below the summit craters;
- 7 deep earthquakes (below sea level);
- 39 long-period earthquakes;
- 387 rockfalls.

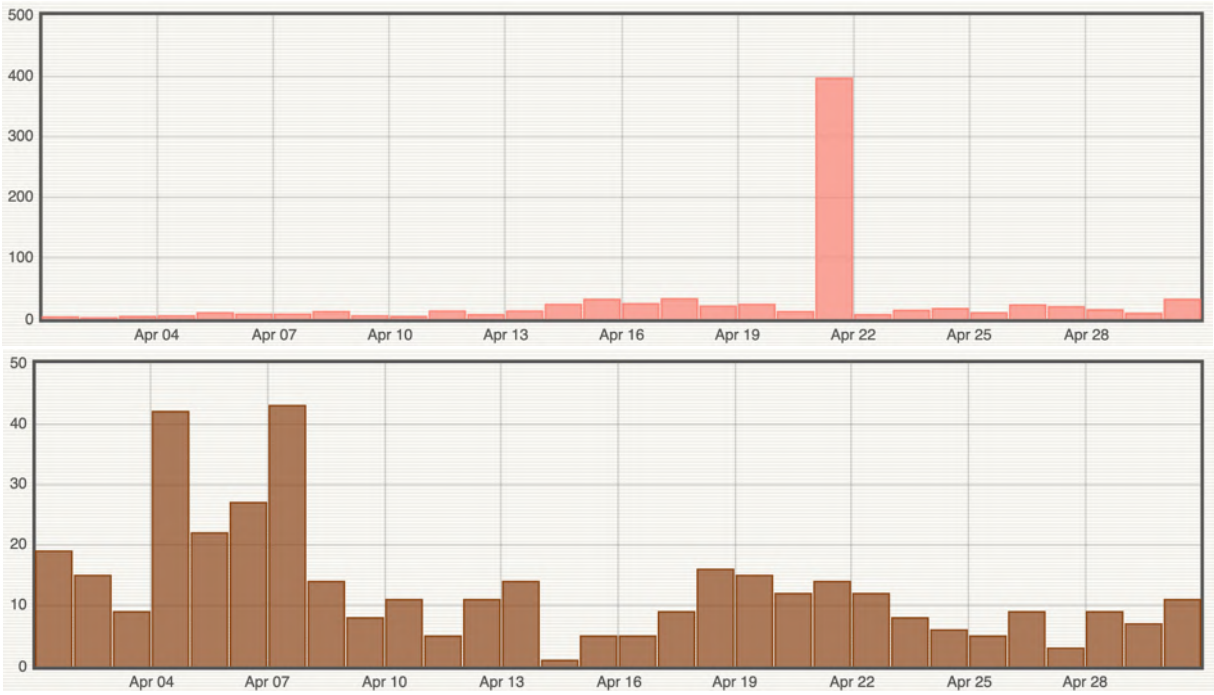

Figure 1: Number of (top) shallow volcano-tectonic earthquakes and (bottom) rockfalls per day recorded in April 2023 (© OVPF-IPGP).

The seismic activity at Piton de la Fournaise in April was marked by an increase in seismicity, from about ten shallow volcano-tectonic earthquakes per day between April 1 and 12 to about twenty between April 13 and 20 (Figure 1).

This seismic activity culminated on April 21 with a seismic crisis during which 370 volcano-tectonic earthquakes were recorded between 15h11 and 16h20 local time. These earthquakes were located below the south-western edge of the Dolomieu crater (Figure 2). This seismic crisis corresponds to an injection of magma from the reservoir towards the surface but not reaching the surface.
Following the seismic crisis of April 21, the seismicity was maintained and increased from 7 shallow volcano-tectonic earthquakes on April 22 to 32 on April 30 (Figure 1).

Deep seismicity was also recorded throughout April, particularly below the eastern flank and on the southern edge of the *Enclos Fouqué* caldera (Figure 2).

Numerous rockfalls also occurred inside the *Cratère Dolomieu*, along the cliffs of the *Rivière de l'Est* and on the September-October lava flows.

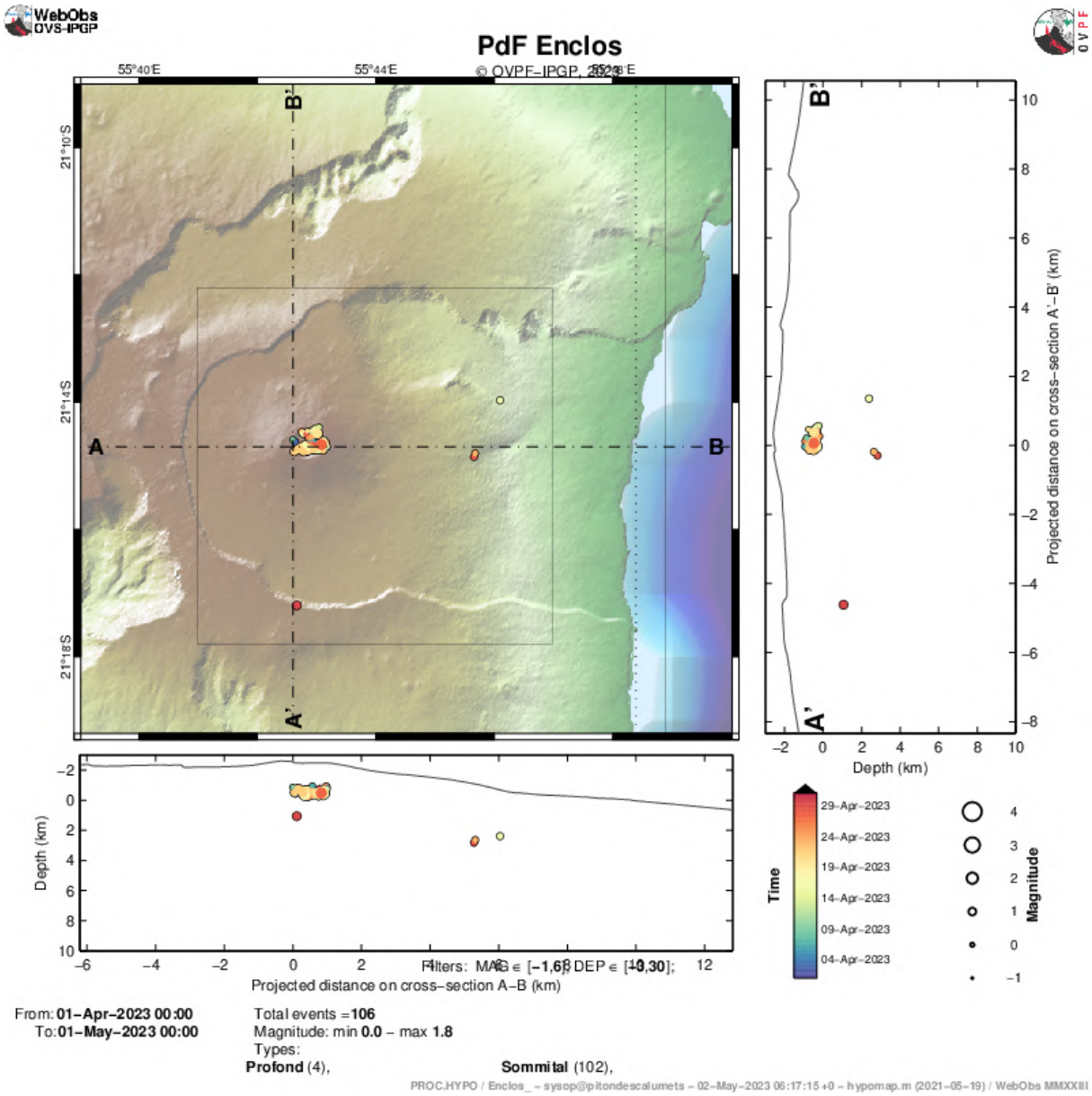

Figure 2: Seismicity below Piton de la Fournaise in April 2023. Location map (epicenters) and north-south and east-west cross-sections (hypocenters) of earthquakes as recorded by OVPF-IPGP. Only manually located earthquakes are shown on the map (© OVPF-IPGP).

Deformation

In March 2023, a resumption of summit inflation was recorded (Figure 4). This inflation continued in April (with a maximum elongation of the terminal cone of the order of 2-3 cm in two months; Figure 4) and is linked to the pressurization of the shallow magmatic reservoir located 1.5-2 km below the craters (Figure 5).

The April 21 intrusion generated only very small deformation not visible by GPS and recorded only at one tiltmeter station located on the southern rim of the crater (slope variation of about 5 micro radians).

Following the intrusion, the inflation of the edifice continued (Figures 3 and 4).

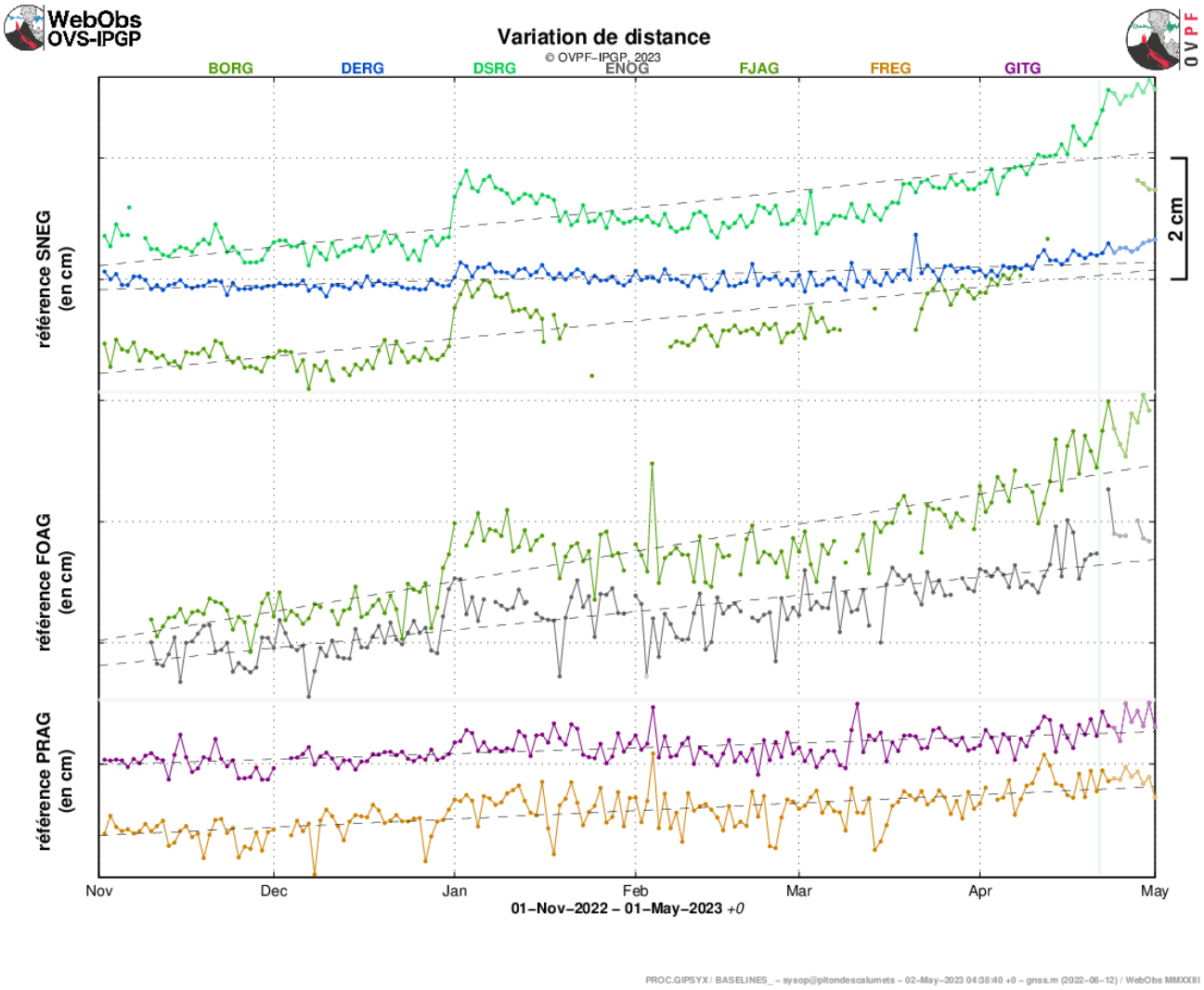

Figure 3: Ground deformation records over the past six months (wherein red and green bars represent eruptions and intrusions, respectively). The time series plots show the changes in distance between pairs of GPS stations located around the Dolomieu summit crater (reference: BOMG; top graph), the terminal cone (reference: FOAG; middle graph) and the Enclos Fouqué caldera (reference: PRAG; bottom graph), from north to south (see location in Figure 6). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect edifice deflation (© OVPF-IPGP).

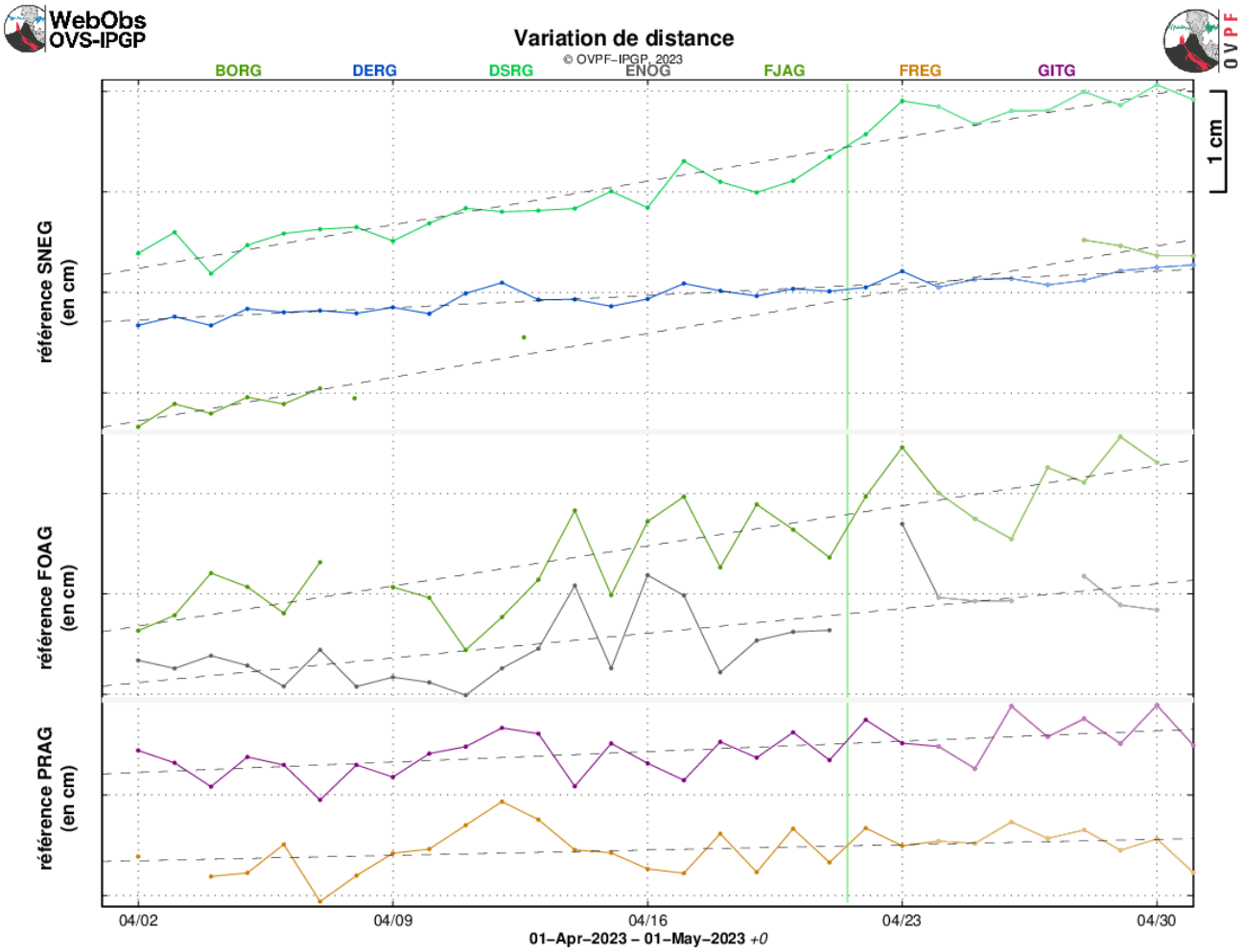

Figure 4: Ground deformation records over the course of April 2023. The time series plots show the changes in distance between pairs of GPS stations located around the Dolomieu summit crater (reference: BOMG; top graph), the terminal cone (reference: FOAG; middle graph) and the Enclos Fouqué caldera (reference: PRAG; bottom graph), from north to south (see location in Figure 6). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect edifice deflation (© OVPF-IPGP).

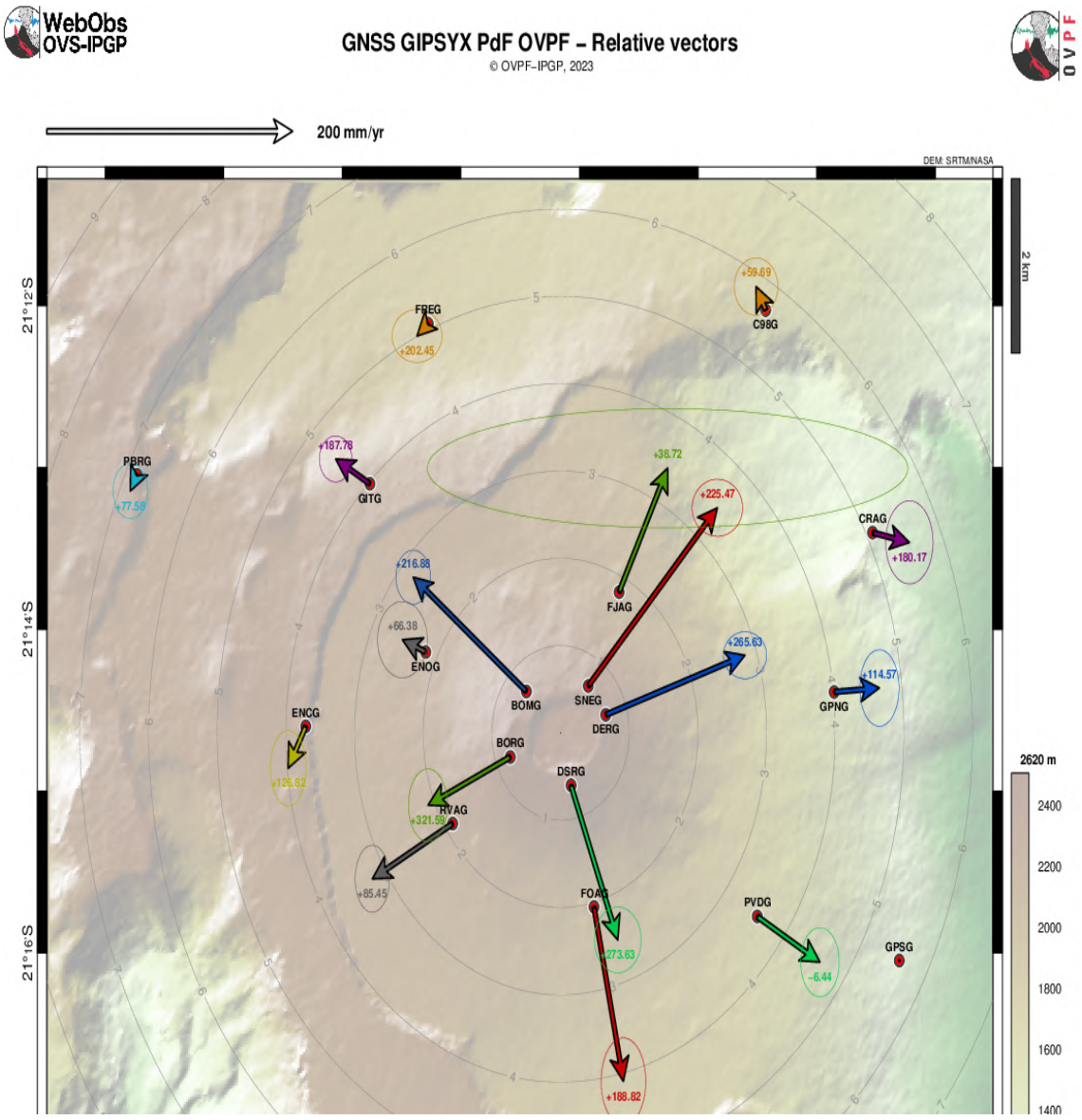

Figure 5: Map of ground displacements (expressed in velocity) recorded in April 2023 by the OVPF-IPGP permanent GPS network. Horizontal displacements are represented in vector form and vertical displacements are indicated by numerical values in color (© OVPF-IPGP).

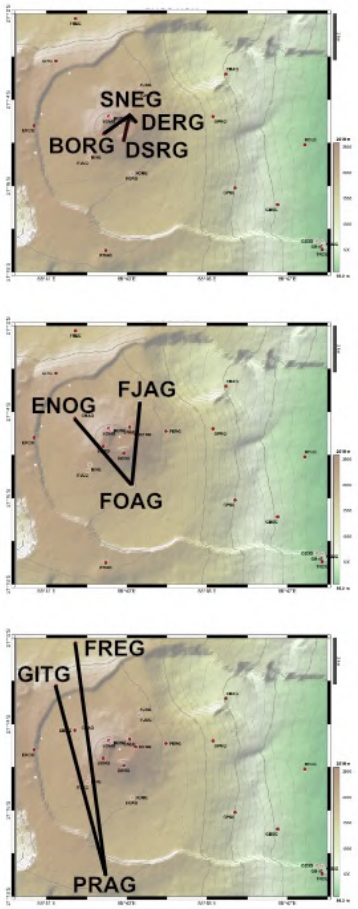

Figure 6: Location map of GPS stations and baselines as discussed in the text and shown in Figures 3 and 4 (© OVPF-IPGP).

** Glossary: The summit GPS signals indicate the influence of a shallow pressure source below the volcano, while distant GPS signals indicate the influence of a deep pressure source below the volcano. Inflation usually means pressurization; and conversely deflation usually means depressurization.*

Gas geochemistry

CO_2 concentration in the soil

In the proximal Gite site, a sudden drop to very low CO_2 fluxes was detected after January 3, 2022. Since the end of the December 22 - January 17 eruption a new phase of increase was recorded, but with a lower rate.
The significant fluctuations observed during February 2022 are likely related to the environmental influence of two cyclonic events (Figure 7).

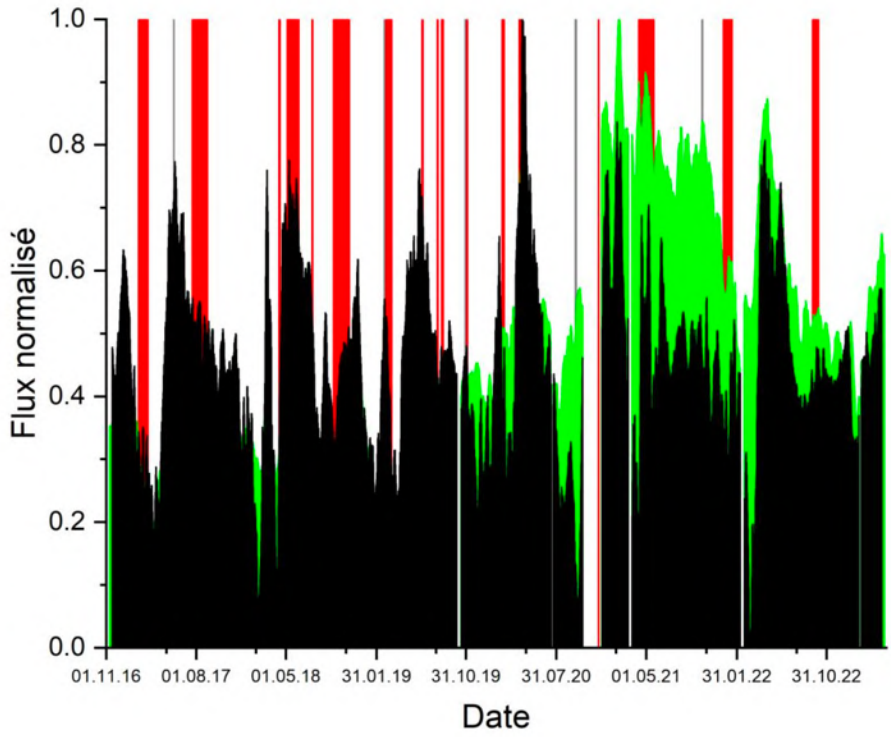

Figure 7: Comparison between the normalized average of uncorrected (OVPF-model; 15 days moving average; in green) and corrected for long-term influence of environmental parameters (INGV MALFIT model; in black) soil CO_2 flux from distal stations since October 2016 (last station set). Red bars: eruptions; Gray bars: intrusions (© OVPF-IPGP).

A new increase in soil CO_2 emissions was recorded in both distal and proximal stations at the end of February 2022 (Figure 7), with a strong acceleration from March 15. The new phase of increase in CO_2 soil emissions has lasted till May 05 in the distal area and till May 19, 2022 in the proximal area.

Since mid-May, a trend of decrease in CO_2 gas fluxes is recorded in both proximal and distal sites. The September 19, 2022 eruption occurred after a significant decrease in CO_2 fluxes, likely recording the progressive transfer of magma to shallow crustal levels. Since the end of the September 19 – October 5 eruption CO_2 fluxes have remained on a stable level.

Interestingly, isotopic analysis of gas sampled at both distal (PNRN, BLEN, PCNR) and proximal (P0; GITN) sites shows a marked increase in the magmatic contribution in the March-April 2022 period (Figure 8). The magmatic contribution has then decreased in the second half of 2022.

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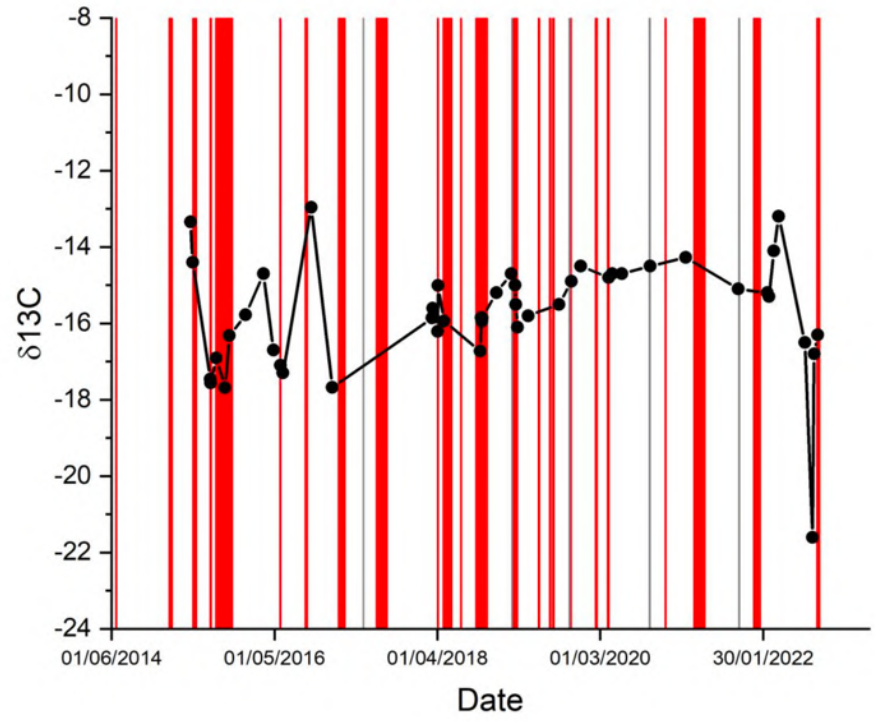

Figure 8: Carbon isotope (δ13C) variations in CO_2 from soil gas emitted from the control point with the highest flux in the proximal area (control point: GIT0).

A new trend of fluctuating increase in soil CO_2 emissions has started since the beginning of December 2022 in both distal and proximal sites.

** Glossary: CO_2 is the first gas to be released from deep magma (rising from the mantle), so its detection in the far field often means a deep rise of magma. Its near-field evolution may be related to magmatic transfer in the shallowest part of the feeding system (< 2-4 km below the surface).*

Summit fumaroles composition obtained by the MultiGas method

- SO_2: close or below the detection threshold.

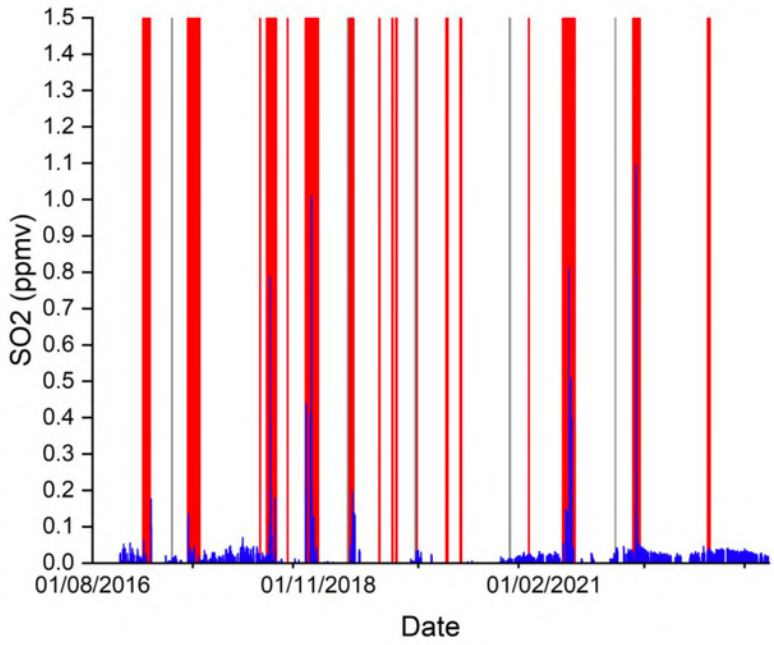

Figure 9: Raw (in blue) concentrations of SO_2 in the atmosphere at the summit of Piton de la Fournaise (MultiGaS station). Red bars: eruptions; Gray bars: intrusions (© OVPF-IPGP).

** Glossary: The MultiGaS method allows measuring the concentrations of H_2O, H_2S, SO_2 and CO_2 in the atmosphere at the summit of the Piton de la Fournaise volcano. Magmatic transfer in the Piton de la Fournaise feeding system can result in an increase in SO_2 concentrations and in the C/S ratio (carbon/sulfur).*

SO_2 flux in the air obtained by DOAS method

The SO_2 fluxes in the air are low; close or below the detection threshold.

** Glossary: During rest periods, SO_2 flux at Piton de la Fournaise is below the detection threshold. The SO_2 flux may increase during magma transfer in the shallowest part of the feeding system. During eruptions, it is directly proportional to the amount of lava emitted at the surface.*

Phenomenology

The month of April 2023 was marked by one magma intrusion on April 21 that did not reach the surface.

Summary

In April 2023, the pressurization of the magma reservoir continued with an inflation of the whole edifice and an increase in seismic activity. This pressurization is at the origin of the seismic crisis of April 21, which is linked to an injection of magma from the reservoir towards the surface but that did not reach the surface.

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B. Seismic activity on La Réunion and in the Indian Ocean basin

Local and regional seismicity

In April 2023, the OVPF-IPGP recorded:

- 61 local earthquakes (below the island, within a radius of 200 km around the island, Figures 10 and 11);
- 7 regional earthquakes (in the Indian Ocean basin).

In April, the OVPF-IPGP recorded 61 local earthquakes below the La Réunion island, mainly near *La Roche Écrite* and *Cirque de Salazie* (Figure 11).

These earthquakes were located between 10 km and 20 km depth in oceanic lithosphere on which was built the volcanic edifice at the origin of Reunion.

One earthquake of low magnitude (1.6) located below the northern rim of *Cirque de Salazie,* has been felt by a few inhabitants on April 13 (16h18 UTC).

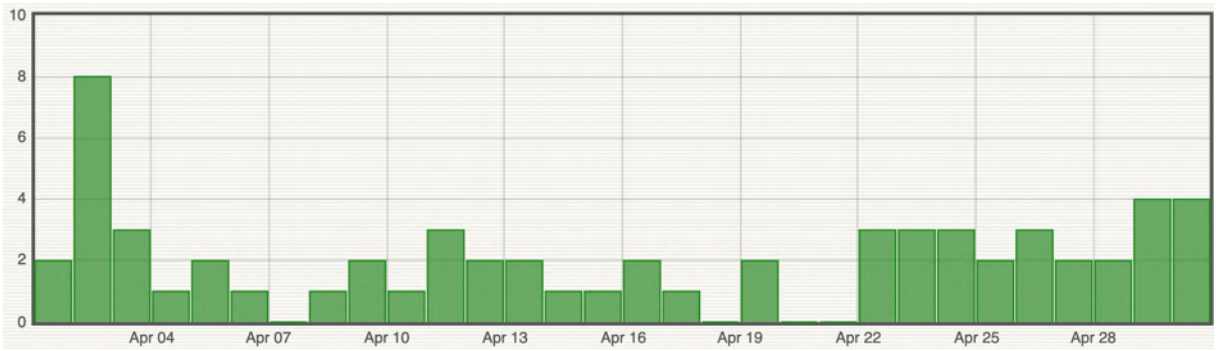

Figure 10: Number of local earthquakes (La Réunion island) per day recorded in April 2023 (© OVPF-IPGP).

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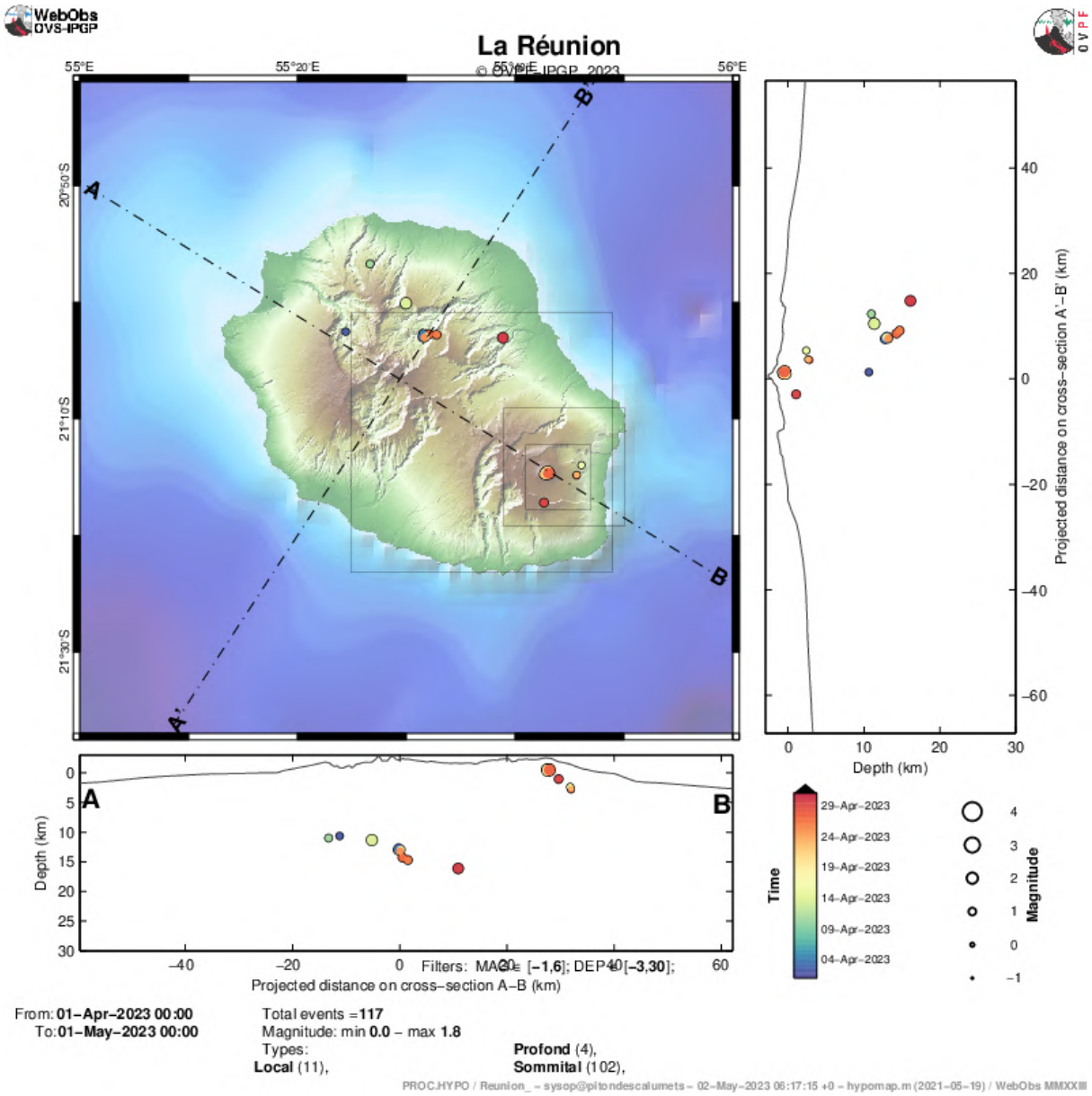

Figure 11: Seismicity below La Réunion in April 2023. Location map (epicenters) and north-west – south-east and south-west – north-east cross-sections (hypocenters) of earthquakes as recorded by OVPF-IPGP. Only localizable earthquakes are shown on the map (© OVPF-IPGP).

Seismic-volcano activity in Mayotte

The « REseau de surveillance VOlcanologique et SIsmologique de MAyotte (REVOSIMA) » is the structure in charge of the volcano and seismic monitoring of Mayotte. IPGP operates this network through the Piton de la Fournaise Volcanological Observatory in La Réunion with the support of the BRGM regional office in Mayotte. REVOSIMA is supported by a scientific and technical partnership. The REVOSIMA consortium: IPGP and Université Paris Cité, BRGM, IFREMER, CNRS, BCSF-RéNaSS, ITES and Université de Strasbourg, IGN, ENS, SHOM, TAAF, Météo France, CNES, Université Grenoble Alpes and ISTerre, Université Clermont Auvergne, LMV and OPGC, Université de La Réunion, Université Paul Sabatier, Toulouse and GET-OMP, Université de la Rochelle, Université de Bretagne Occidentale, IRD and collaborators.

All information on the REVOSIMA and the activity in Mayotte can be found on the dedicated webpages:
•http://www.ipgp.fr/fr/reseau-de-surveillance-volcanologique-sismologique-de-mayotte
•http://www.ipgp.fr/fr/actualites-reseau
•https://www.facebook.com/ReseauVolcanoSismoMayotte/

May, 2 2023
OVPF-IPGP Director

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C. Appendix

Definition of Volcanic Alert Levels for Piton de la Fournaise

from *disposition spécifique « Volcan Piton de la Fournaise » - arrêté n°2242-* Emergency plan set up by the department responsible for the protection of the population in the event of unrest or activity of the Piton de la Fournaise

•**"Vigilance"**: possible eruption in medium term (a few days or weeks) **or** presence of risks on the sector (rockfalls, increase of gas emissions, still hot lava flows…).

Access to the Enclos Fouqué caldera and to the summit volcano are allowed with restrictions.

• **"Alert 1"**: probable or imminent.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited.

• **"Alert 2"**: ongoing eruption.
Alert 2-1: ongoing eruption inside the Enclos Fouqué caldera without threat to the safety of people, property or the environment

Alert 2-2: ongoing eruption inside the Enclos Fouqué caldera with direct or indirectthreat to the safety of people, property or the environment.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited. For Alert 2-2, evacuation of the people and vehicles depending on the issues.

• **"Alert 2-3"**: ongoing eruption outside the Enclos Fouqué caldera with threat to the safety of people, property or the environment.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited. Evacuation of the people and vehicles depending on the issues.

• **"Sauvegarde"**: end of eruption.

Evaluation of a partial reopening of the Enclos Fouqué caldera access.

Synthetic report on the last emitted products

To characterize the eruption of 19 September - 5 October 2022, 8 samples were collected among which two are pyroclast fall out deposits (lapilli, scoria) and the other 6 are lava fragments that were either collected in a molten state and quenched on site (syn-eruptive), or collected once solidified (post-emplacement).

Figure 12: Fragments of samples collected by the OVPF during the 19 September - 5 October 2022 eruption of Piton de la Fournaise

The pyroclastic fragments show a vesicularity of 37vol% to 76vol%, with up to 33vol% of isolated vesicles. The golden pumice scoria deposits are the most vesicular fragments (68-80 vol%) with significant values of isolated vesicles (up to 26vol%). The lava samples have a lower vesicularity (28-60vol%) than the pyroclasts. As previously observed, the quenched lavas have a lower vesicularity than the one collected post-emplacement and have some isolated vesicles (17vol%). **The data from this eruption confirm the increase in density of the eruptive products measured since 2019 and the overall trend of increasing density since the start of the eruptive cycle in 2014.**

All samples are nearly aphyric in terms of phenocrysts (<5vol% phenocrysts), with microphenocryst content ranging from 13vol% in pyroclasts to 21- 29vol.% in lavas.

The composition of the interstitial glassy matrix and microlites are similar to those of the lavas emitted during previous eruptions since 2020 and indicate a pre-eruptive temperature that varies between 1140°C at the beginning of the eruption to 1153°C towards the end of the eruption. **These relatively low temperatures are consistent with a shallow magmatic system.**

On long-term geochemical monitoring, the lavas emitted until the eruption of 22 December 2021 - 17 January 2022 have an intermediate CaO/Al_2O_3 signature - an indication of the degree of magma evolution - which decreases with the eruption of 19 September - 5 October 2022. **This trend could mark a progressive cooling of the shallow part of the magma system.**

As often observed during long-lasting eruptions, the lavas emitted at the end of the eruption (samples from 5 oct. 2022) are slightly more mafic (higher MgO, higher CaO/Al_2O_3 ratio and higher Ni and Cr content) and have slightly higher ratios of incompatible elements than those emitted at the beginning of the eruption. This temporal evolution is indicative of heterogeneities in the magma plumbing system. **These variations are correlated with a slight increase in the MgO concentration of the glasses, indicating a slightly hotter magma emitted towards the end of the eruption.**

The products of the September-October 2022 eruption have a 'depleted' signature (low La/Yb ratio), which has been attributed to the melting of a more refractory mantle source. **The decrease in the trace element signature of the eruption was attributed to the melting of a more refractory mantle source.**

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Acknowledgments
Thank you to organizations, communities and associations for publicly posting this report for the widest dissemination

Information
All information on the Piton de la Fournaise activity can be found on the OVPF-IPGP media:
- Internet website : ipgp.fr/fr/ovpf/actualites-ovpf
- Twitter : twitter.com/obsfournaise
- Facebook : facebook.com/ObsVolcanoPitonFournaise

A preliminary automatic daily bulletin of the OVPF-IPGP, relating to the activities of the day before, validated by an analyst, is published daily. It can be accessed directly at this link:
http://volcano.ipgp.fr/reunion/Bulletin_quotidien/bulletin.html

The seismicity validated in continuous by OVPF-IPGP can also be followed on the RENASS portal: https://renass.unistra.fr/fr/zones/la-reunion