Piton de la Fournaise is a basaltic hot spot volcano located in the southeast 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. 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).

Volcano Alert level: Sauvegarde
(since July 30, 2019)

June 13 (13h) to July 6 (8h): Sauvegarde
July 6 (8) to July 29 (6h): Vigilance
July 29 (6h) to July 29 (13h): Alert 1
July 29 (13h) to July 30: Alert 2-2

(see table in appendix)
Seismicity

In July 2019, the OVPF recorded at Piton de La Fournaise:
- 1267 shallow volcano-tectonic earthquakes (0 to 2 km depth) below the summit craters;
- 5 deep earthquakes (>2 km depth);
- 199 rockfalls (inside the Cratère Dolomieu or along the cliff of the Enclos Fouqué caldera).

![Figure 1: Daily number of shallow volcano-tectonic earthquakes recorded in July 2019 (© OVPF-IPGP).](image)

In July 2019, the volcano-tectonic activity below the summit of Piton de la Fournaise has been mainly characterized by the seismic crisis preceding the July 29-30, 2019 eruption (with 1099 earthquakes recorded on July 29; cf. Figures 1 and 2).

In continuity of the increased seismic activity that had been recorded between June 21 and the beginning of July, about 6 volcano-tectonic earthquakes per day were recorded below the summit from July 1 to 28. During this seismic crisis, the earthquakes were located under the northern edge of the summit and at the location of the eruptive fissures that opened after about 6:45 of seismic crisis (Figure 2; cf. section B for more details).

![Figure 2: Location map (epicenters) and north-south and east-west cross-sections (hypocenters) of earthquakes at Piton de la Fournaise as recorded by OVPF-IPGP in July 2019. Only localizable earthquakes are shown on the map, while the observatory records more seismic events that are not localizable due to their small magnitude (© OVPF-IPGP).](image)
Deformation

The volcanic edifice continued to inflate right upon the end of the June 11-13 eruption (cf. Figures 3 and 4). Since mid-June and until the July 29, 2019 eruption, 4 cm of distance elongation between two GNSS stations that are spanning the base of the terminal cone was recorded (cf. Figures 3 and 4).

This phase of inflation preceded the July 29-30 eruption and is thought to be linked to the pressurization of the shallow magma reservoir that is located at ~1.5-2 km depth below the summit.

Rapid inflation of up to 12-13 cm was measured at a permanent GNSS station that is located west of the summit. This is a sign that is thought to be associated to the intrusion, i.e. the movement of magma towards the surface that finally led to the eruption (cf. section B for more details).

Figure 3: Illustration of the ground deformation in July 2019 (wherein red shaded area represents the eruption). The time series plots show the distance changes between pairs of GPS stations crossing the Dolomieu crater, the terminal cone and the Enclos Fouqué caldera, from north to south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect an edifice deflation (© 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.
Figure 4: Illustration of the ground deformation over the past six months (wherein red shaded areas represent eruptions). The time series plots show the distance changes between pairs of GPS stations crossing the Dolomieu crater, the terminal cone and the Enclos Fouqué caldera, from north to south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect an edifice deflation (© OVPF-IPGP).

Figure 5: Location map of GPS stations and baselines as discussed in the text and shown in Figures 3 and 4 (© OVPF-IPGP).
Gas geochemistry

**CO$_2$ concentration in the soil**

*In the far field (Plaine des Cafres and Plaine des Palmistes sectors):* A new increase of soil CO$_2$ flux is recorded since the beginning of April 2019, reaching intermediate values. Following the June 11-13, 2019 eruption, soil CO$_2$ flux decreased during the last month (Figure 6).

*Figure 6:* Comparison between the normalized average of raw (in blue) and corrected (in red) soil CO$_2$ flux from distal stations (a) since October 2016 (last station set) and (b) over the course of one year. (© OVPF-IPGP).

* 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 by the MultiGas method

The MultiGas station is currently out of service.

* Glossary: The MultiGaS method allows measuring the concentrations of H$_2$O, H$_2$S, 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 by DOAS method

The NOVAC stations detected the eruption plume produced by the July 29-30 eruption (Figure 7).

![Graph](attachment:SO2_flux.jpg)

*Figure 7a: SO$_2$ flux in the air detected by the DOAS method on the “Piton de Bert” station in July 2019 (© OVPF-IPGP).*
**Figure 7b**: SO$_2$ flux in the air detected by the DOAS method on the "Enclos 0" station in July 2019 (© OVPF-IPGP).

**Figure 7c**: SO$_2$ flux in the air detected by the DOAS method on the "Piton Partage" station in July 2019 (© OVPF-IPGP).

* 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 July 2019 was marked by a short-lived eruption, which occurred on the northern flank of the terminal cone about 600 m east of the prominent Formica Leo cone. This eruption lasted less than 24 hours (from July 29 to 30, cf. section B for more details).

Summary

Continuous edifice inflation, as recorded since the end of the June 11-13 eruption, and increased seismic activity were signs of deep magma refilling and reservoir pressurization that finally led to the July 29-30 eruption. Only a relative small volume of lava erupted during this short-lived event, indicating that the reservoir drained only partially.
Eruptive precursors

In the long term:
The July 29-30, 2019 eruption was preceded by about 45 days of edifice inflation, which is a sign of pressurization of the shallow magma reservoir (located at about 1.5-2 km depth below the summit cone) (cf. Figures 3 and 8). Since June 21, also the seismic activity started to increase.

In the short-term:
A seismic crisis started on July 29, 2019, at 05h13 local time (01h13 UTC, Figure 9). This was a sign that the roof of the shallow magma reservoir had failed under the pressure, triggering magma propagation towards the surface. A total of 1099 volcano-tectonic earthquakes were recorded at depths of less than 2 km below the summit on July 29. This seismic crisis was accompanied by rapid ground deformation of about 12-13 cm, recorded at a station that is located west of the Dolomieu crater (Figure 10).
Figure 9: Seismic signals recorded between 01h00 UTC (05h00 local time) and 10h59 UTC (14h59 local time) on July 29, 2019. For each hour (as indicated by the time step on the y-axis), the time is increasing towards the right. Each red vertical bar represents an earthquake. Note the appearance and progressive increase of the tremor starting at 08h00 UTC (12h00 local time) (© OVPF-IPGP).
Figure 10: Map of horizontal surface displacements recorded on the permanent GPS network. Measured displacements are associated to the subsurface movement of magma towards the eruption site of the July 29-30, 2019 event (© OVPF-IPGP).

The eruption

Volcanic tremor is a sign that magma is close to the surface. This signal appeared on the OVPF seismic monitoring network at around 08h00 UTC (12h00 local time; Figure 9) on July 29.

The eruptive activity was characterized by the opening of 3 fissures over a total distance of ~450 m on the northern flank of the terminal cone, about 600 m east of the prominent Formica Leo cone and in close proximity to the tourist trail leading visitors to the summit of the volcano (cf. Figures 11 et 12).
Thermal images and in-situ temperature measurements as well as lava sampling were carried out by the OVPF team on July 29 (Figures 12 and 13). Maximum temperatures of ~1100°C were recorded at the base of the lava fountains within the central part of the vent and at the lava flow front using the thermocouple.

The samples were sent promptly to the Institut de Physique du Globe de Paris and the LMV-Clermont-Ferrand for analysis. Their analysis will help to better understand the source and the path that magma took before erupting on the surface.
At the beginning of the eruption, discharge rates were estimated from satellite data acquired by the HOTVOLC platform (LMV, OPGC, Clermont Auvergne University) and MIROVA platform (University of Turin) at about 21 m$^3$/s and 4.5 m$^3$/s, respectively. Over the entire eruption duration, the HOTVOLC platform estimated an average discharge rate of 11.6 m$^3$/s.

The eruption stopped on July 30, 2019 at 04h30 local time (Figure 14) after less than 24h of activity. The erupted lava flow volume is to be quantified, but is presumably very small compared to the average Piton de la Fournaise eruptive volumes, given the maximum lava flow length of only ~730 m (Figure 15).
Figure 14: Evolution of the RSAM between 04h00 (00h00 UTC) on July 29 and 05h45 (01h45 UTC) on July 30 2019 on the BOR seismic station, located at the summit (© OVPF/IPGP). This signal is an indicator of the magnitude of the volcanic tremor and therefore the intensity of the eruption.

Figure 15: Map of lava flows (in white) emitted during the July 29-30, 2019 eruption as derived from aerial pictures (©OVPF/IPGP).
C - Seismic activity on La Réunion and in the Indian Ocean basin

Seismicity

In July 2019, the OVPF recorded:

- 51 local earthquakes (below the island, mainly below the Piton des Neigesedifice, Figure 16);
- 2 regional earthquakes (in the Indian Ocean basin).

![Location map](image)

**Figure 16**: Location map (epicenters) and north-south and east-west cross-sections (hypocenters) of earthquakes below La Réunion Island as recorded by OVPF-IPGP in July 2019. Only localizable earthquakes are shown on the map, while the observatory records more seismic events that are not localizable due to their small magnitude (© OVPF-IPGP).

Seismic crisis in Mayotte

The volcano-seismic crisis in Mayotte will now be the subject of a specific bi-monthly bulletin published and distributed by OVPF-IPGP and BRGM. The first bulletin will be published in August.

August, 1 2019
OVPF-IPGP Director
# D - Appendix

## Definition of Volcanic Alert Levels for Piton de la Fournaise

from: dispositif ORSEC974 – D.S « Volcan du Piton de la Fournaise »

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 in the Dolomieu crater.

Alert 2-2: ongoing eruption inside the Enclos Fouqué caldera.

Alert 2-3: ongoing eruption outside the Enclos Fouqué caldera.

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

**“Sauvegarde”**: end of eruption or eruption stabilized.

Evaluation of a partial reopening of the Enclos Fouqué caldera access.
Thank you to organizations, communities and associations for publicly posting this report for the widest dissemination.

All information on the Piton de la Fournaise activity can be found on the OVPF-IPGP media:
- website (http://www.ipgp.fr/fr/ovpf/actualites-ovpf)
- Twitter (https://twitter.com/obsfournaise?lang=fr)
- Facebook (https://www.facebook.com/ObsVolcanoPitonFournaise/)

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