Monthly bulletin of the Piton de la Fournaise Volcanological Observatory

ISSN 2610-5101

A - Piton de la Fournaise activity

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

Piton de la Fournaise is a hot spot basaltic volcano located in the southeast of La Réunion Island (Indian Ocean).
Piton de la Fournaise first erupted about 500,000 years ago. Its volcanic activity is characterized by frequent effusive eruptions (with emissions of lava fountains and lava flows) with a mean of two eruptions per year since 1998. More rarely, explosive eruptions have occurred in the past (with blocks covering the summit area and ash emissions that can disperse over long distances) with a centennial recurrence rate.
Most of the current eruptive activity (97% during the last 300 years) occurred inside the Enclos Fouqué caldera, with the exception of a few eruptions that opened outside (1977, 1986, 1998 for the most recent ones).

Since end-1979, the Piton de la Fournaise activity is monitored by the Piton de la Fournaise Volcanological Observatory (Observatoire Volcanologique du Piton de la Fournaise - OVPF), from Institut de Physique du Globe de Paris (IPGP).

Volcano Alert level: SAUVEGARDE
(see table in appendix)

Seismicity

In July 2018, the OVPF recorded at Piton de La Fournaise:

- 1411 shallow volcano-tectonic earthquakes (0 to 2 km depth) below the summit craters and the north flank;
- 10 deep earthquakes (>2 km depth) ;
- 286 rockfalls (inside the Cratère Dolomieu or along the cliff of the Enclos Fouqué caldera).

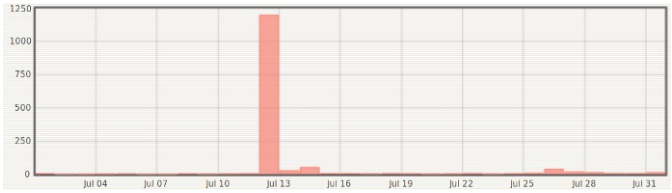

***Figure 1**: Daily number of shallow volcano-tectonic earthquakes recorded in July 2018 (© OVPF-IPGP).*

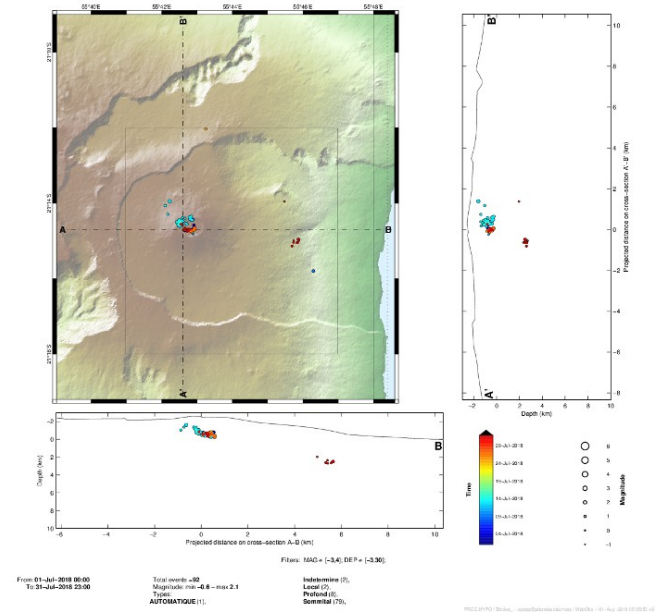

***Figure 2**: Location map (epicentres) as well as North-South and East-West cross-sections (hypocentres) of earthquakes that have been recorded by OVPF-IPGP in July 2018 below Piton de la Fournaise. Only localizable earthquakes are shown on the*

map. Low magnitude seismic events have occurred but are not shown on this map because they cannot be localized (© OVPF-IPGP).

In July 2018, the volcano-tectonic activity below the summit of Piton de la Fournaise has been mainly characterized by the July 12 seismic crisis preceding the July 13, 2018 eruption (with 1204 earthquakes in 5 hours; Figures 1 and 2).
Seismic activity below the volcano's summit craters can furthermore be summarized as follows.
From July 1 to 11, the seismicity remained relatively low with only 16 shallow volcano-tectonic earthquakes.
Following the July 13 eruption, 50 shallow volcano-tectonic earthquakes were recorded on July 14 followed by only 3 and 4 events on July 15 and 16, respectively. Between July 17 and 25, a mean of 3 earthquakes per day was recorded, before a significant increase on July 26 with 36 recorded earthquakes and a general decrease thereafter. On July 31, 9 deep earthquakes (about 2.5 km below sea level) were recorded below the eastern flank of the volcano (Figure 2).

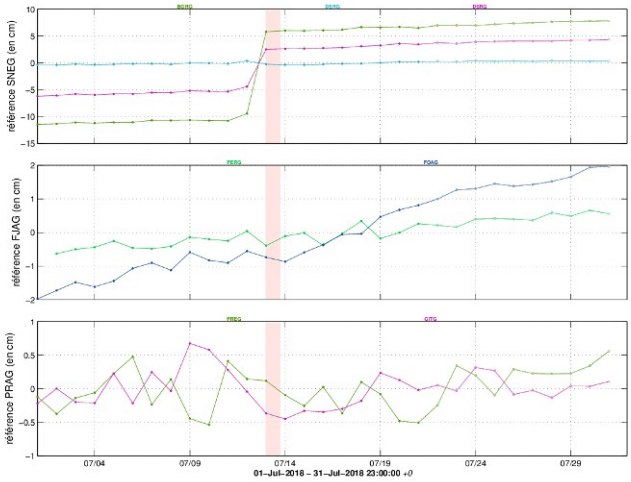

***Figure 3**: Illustration of the deformation in July 2018 (red shaded areas represent the eruptive periods). The time series plots show the distance changes between pairs of GPS stations crossing the Dolomieu crater, the terminal cone and the Enclos Fouqué caldera, from the north to the south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) show an edifice deflation (© OVPF-IPGP*

Deformation

In July 2018, the OVPF deformation networks recorded a continuous inter-eruptive inflation (Figures 3 and 4). Thus, between July 1 and 12 the GPS stations located at the summit of the volcano indicated a baseline elongation of about 2 cm max., while a basal elongation of about 3 cm max. was observed (Figure 3).
Summit inflation restarted just upon the end of the July 13 eruption, at pre-eruptive rates. These inter-eruptive inflation phases are thought to be linked to the pressurisation of the shallow (1.5-2 km depth) magma reservoir.
Therefore, the continuous and slow inflation phase that has been observed throughout the month of July was only interrupted by the strong ground deformation linked to magma propagation during the intrusive crisis preceding the July 13, 2018 eruption (Figure 3, Appendix B).

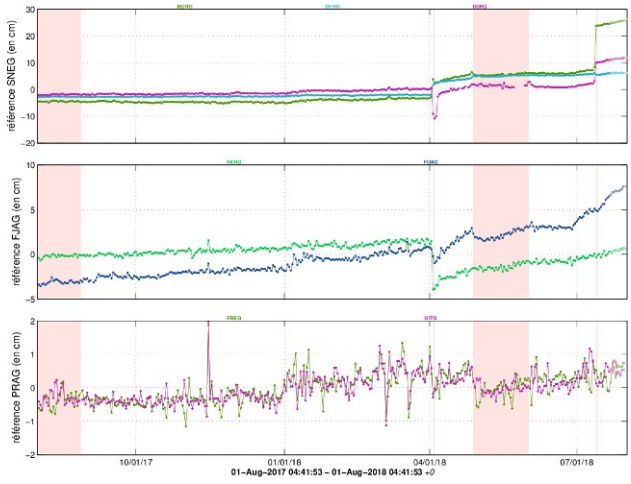

***Figure 4**: Illustration of the deformation over the last twelve months (red shaded areas represent the eruptive periods). The time series plots show the distance changes between pairs of GPS stations crossing the Dolomieu crater, the terminal cone and the Enclos Fouqué caldera, from the north to the south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) show 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.*

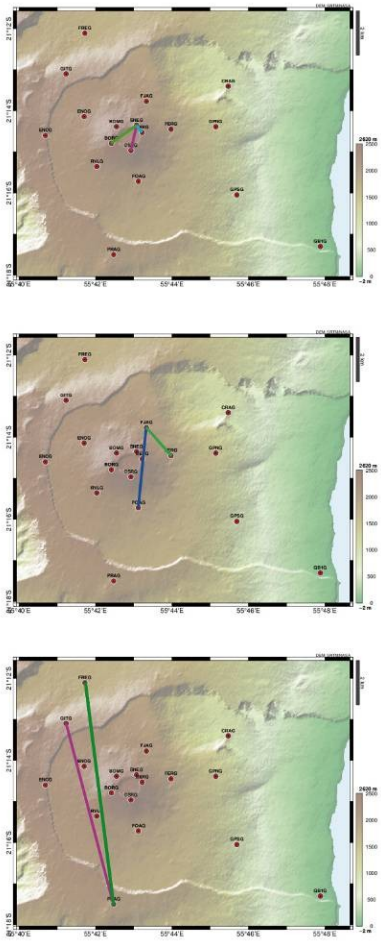

Figure 5*: Location of GPS stations and baselines as discussed in the text and shown in Figures 3 and 4 (© OVPF-IPGP).*

Gas geochemistry

CO_2 concentration in the soil

- In the far field (i.e. at the Plaine des Cafres and Plaine des Palmistes sectors): CO_2 concentrations in the soil were stable in July at high values (Figure 6);
- In the near field (i.e. at the « Gîte du volcan » sector): the CO_2 concentrations in the soil were stable at low values.

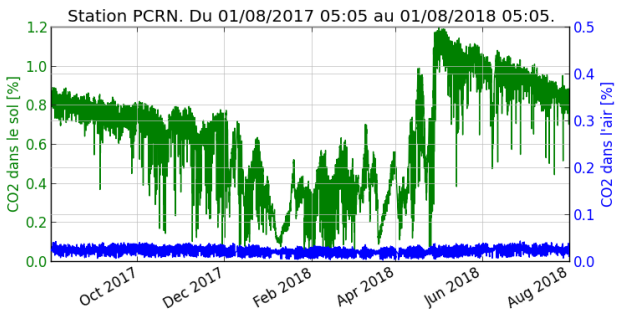

Figure 6: *Concentration of CO_2 in the soil recorded on the Plaine des Cafres station, located at the observatory, over the last twelve months (© OVPF-IPGP).*

** Glossary: CO_2 is the first gas to be released from deep magma (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 MultiGas method

Except during the July 13 eruption:
- *SO_2 content*: below the detection threshold;
- *H_2S content*: low concentrations;

** 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 C / S ratio (carbon / sulfur).*

SO_2 flux in the air by DOAS method

Except during the July 13 eruption, the SO_2 flux was below the detection threshold.

** Glossary: During rest periods, SO_2 flux at Piton de la Fournaise is below the detection threshold; 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 2018 was marked by a short-lived eruption that lasted about 18 hours and 30 minutes. The erupted lava flow volume was comparably low with ~ 0.3 millions m^3. The eruption occurred on the north north-west flank of the terminal cone on July 13 (see Appendix B for more details).

Summary

The continuous edifice inflation recorded throughout July 2018 was the sign of a deep magma refilling and a pressurization of the shallow magma reservoir. This pressurization led to the July 13 eruption, which only partially drained the reservoir. Thus, at the end of the eruption, the volcano inflation resumed. An increase in seismicity was also observed on July 26, which we interpret as a sign of accelerated reservoir pressurization and weakening.

B – The July 13, 2018 eruption

Eruptive precursors

In the long-term:
The July 13, 2018 eruption was preceded by about 15 days of edifice inflation, i.e. a sign of the shallow reservoir pressurization (at 1.5-2 km depth) (Figures 3 and 7). During this period, the seismicity remained low and began to increase on July 12, only one day before the eruption.

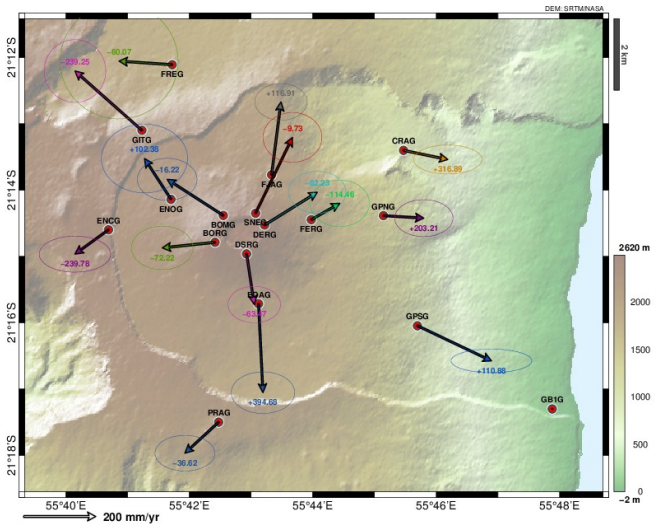

***Figure 7**: Map of horizontal surface displacements recorded between July 1 and 12. (© OVPF-IPGP).*

In general, eruptions of Piton de la Fournaise often occur after long periods of deep recharge of the magmatic feeding system. The July 13, 2018 eruption is part of a phase of deep magmatic refilling that intermittently continues since the resumption of activity in June 2014. The regular monitoring of CO_2 concentrations in the soil suggests that these phases of deep magmatic refilling are accompanied by a gradual increase in CO_2 concentrations in the soil along the volcano's flank. A significant increase in CO_2 flux was recorded in February-March 2018 on the geochemical network (R4 in Figure 8).
The magmatic transfer to shallower depths pressurizes the shallow magmatic system (leading to edifice inflation phases), and is accompanied by a decrease in CO_2 concentrations in the soil. The current eruptive sequence (that includes the eruptions of April and July 2018) began following a decrease in CO_2 flux in the soil since March 2018. It should be noted, however, that after the first eruption of this sequence (April 3, 2018), a further increase in CO_2 fluxes was recorded on the stations located in the "Plaines" sector (Figure 9). This new increase suggests that the deep magmatic refilling partially continued in May-June 2018.

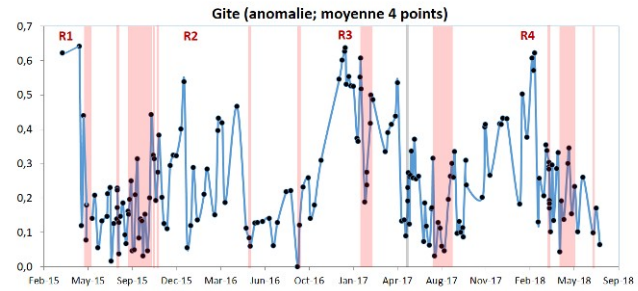

***Figure 8:** Concentration of CO_2 in the soil recorded on the "Gîte" sector (red shaded areas represent the eruptive periods while the grey portion marks the intrusion of May 2017). The letters "R" indicate the main phases of deep magmatic recharges identified by geochemistry (© OVPF-IPGP).*

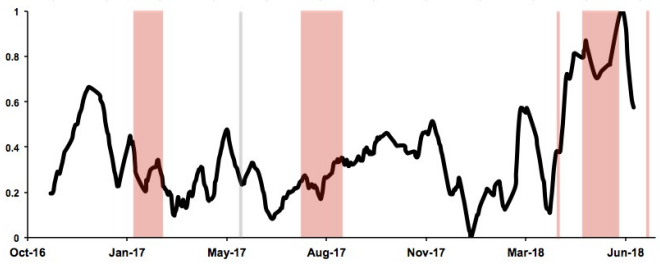

***Figure 9**: Concentration of CO_2 in the soil recorded on the "Plaines" sector (mean values for all the network) since end of 2016 (red shaded areas represent the eruptive periods while the grey portion marks the intrusion of May 2017). (© OVPF-IPGP).*

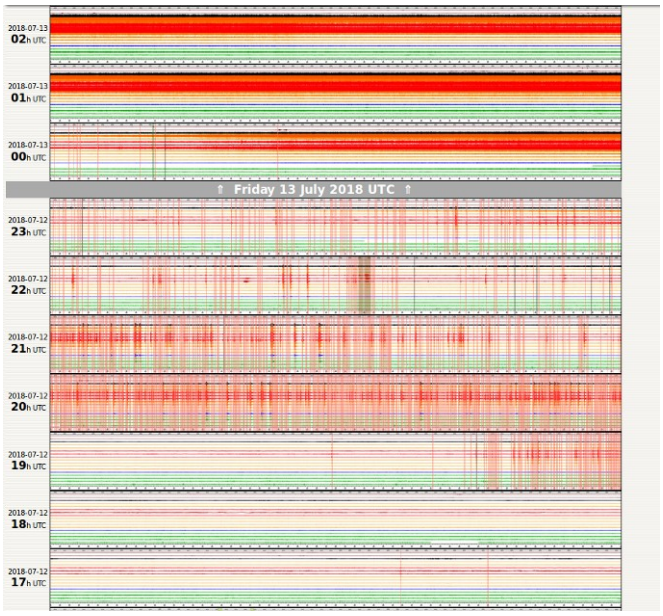

***Figure 10**: Seismic signals recorded between 17h00 UTC (21h00 local time) on July 12 and 02h00 UTC (06h00 local time) on July 13, 2018. For each hour (as indicated by the time step on the y-axis), the time is increasing to the right. Each red vertical bar represents an earthquake. Note the appearance of the tremor starting at 23h30 UTC (03h30 local time).*

In the short-term:
On July 12, 2018, 23h45 local time (19h45 UTC, Figure 10), a seismic crisis began. This was a sign that the roof of the shallow magma reservoir failed, triggering magma propagation towards the surface.
A total of 1204 shallow volcano-tectonic earthquakes (< 2 km depth) were recorded in 5 hours. This crisis was accompanied by rapid ground deformation (max: 27 cm; Figure 11).

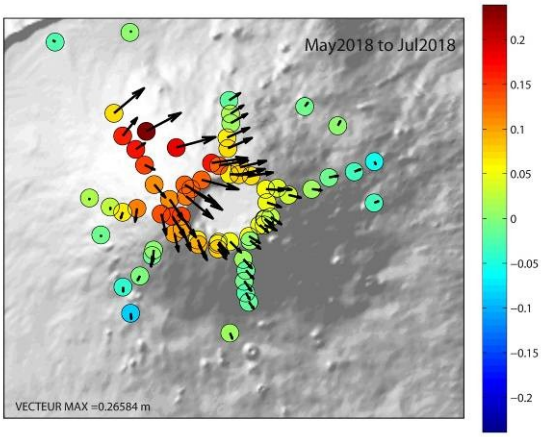

Figure 11*: Map of the ground displacements associated with the magma injection towards the surface leading to the July 13, 2018 eruption. The vectors represent the horizontal displacements (max=0.27 m) and the filled circles represent the vertical displacements (see the colour bar for the scale, max=0.22 m).*

The eruption

The eruption began between 03:30 (beginning of the tremor recorded on the OVPF seismic stations) and 04:30 local time (first lights visible on the OVPF's webcams) with the opening of 4 en-echelon fissures over a length of 500 m on the north-northwest flank of the terminal cone (Figure 12), in the Chapelle de Rosemont sector, at an elevation comprised between 2,320 and 2,245 m a.s.l.

During the first hours of the eruption, the discharge rate, estimated from satellite data via the MIROVA platform (University of Turin) was comprised between 2.88 and 5.34 m^3/s.

The four eruptive fissures remained active simultaneously during the first hours of the eruption with lava fountains less than 20 m high.

Figure 12*: Photographs of the eruptive vents on July 13, 08h00 local time (© OVPF/IPGP).*

Aerial and ground-based photographs were used to accurately map the evolution of the lava flows during the first hours of the eruption (Figure 13). The lava flow propagation rate was estimated at about 6 m/min during the first hour of eruption. Thereafter, this rate continued to decrease to less than 1 m/min at the end of the eruption.

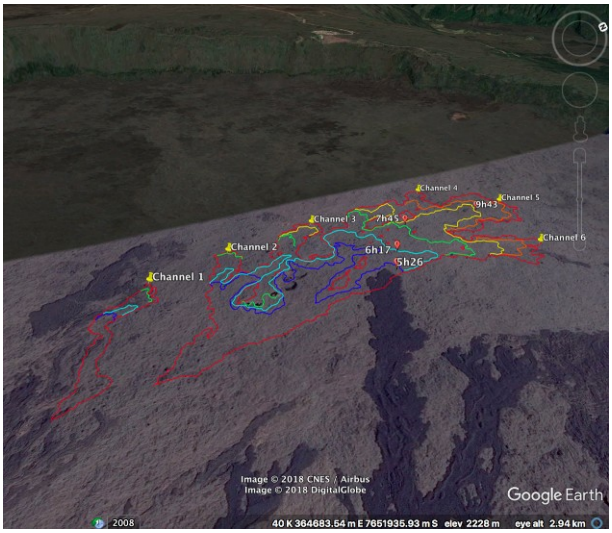

Figure 13*: Evolution of the lava flow coverage between 05h26 and 09h45 local time on July 13, 2018. The red outline represents the final lava flow front at the end of the eruption. This map was produced based on aerial and ground-based photographs processed by means of stereophotogrammetry.*

At 12h30 (local time), the most upstream fissure and the top of the next one were no longer active (Figure 14).

Figure 14*: Photograph of the eruptive vents on July 13, 14h00 local time (© OVPF/IPGP).*

After a progressive decrease of the tremor, and upon about 3 hours of gas pistons (i.e. "gas flushes" that are typically observed at the end of Piton de la Fournaise eruptions) the eruption stopped on July 13 at 22:00 local time (18:00 UTC).

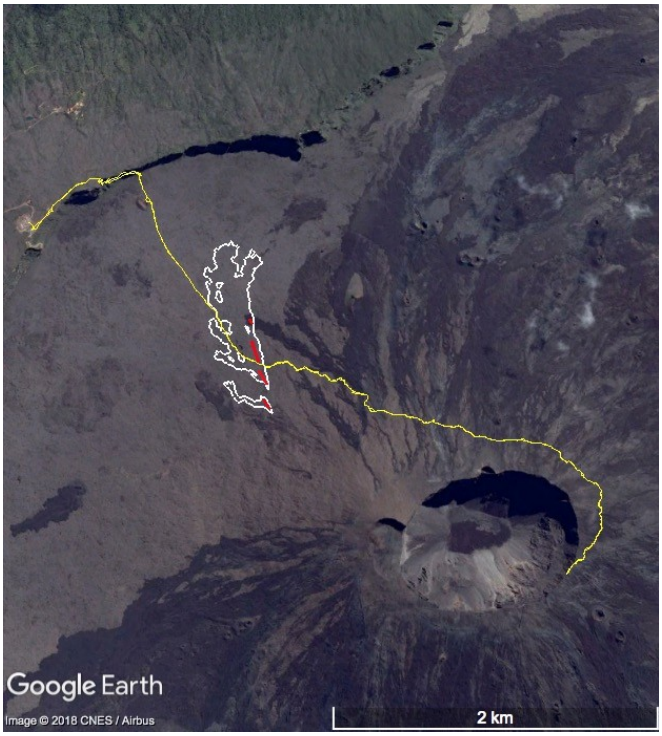

Figure 15*: Final map of the lava flows emitted during the July 13, 2018 eruption. This map was produced based on aerial and ground-based photographs processed by means of stereophotogrammetry. Lava flow outlines are shown in white, eruptive fissures in red and the hiking trail to the summit in yellow.*

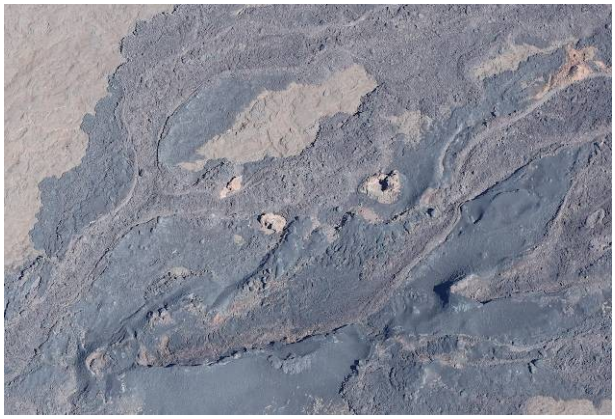

Figure 16*: Aerial Photograph of the Chapelle de Rosemont sector taken on July 14, 2018 (after the eruption had ended) (© OVPF/IPGP).*

Summary

The July 13, 2018 eruption lasted less than 18 hours and 30 minutes and emitted about 0.3 millions m^3 of lava. Lava flows covered more than 400 m of the hiking trail leading to the summit (Figure 15) and almost completely filled the Chapelle de Rosemont (Figure 16), i.e. an old vent and a characteristic feature within the Enclos Fouqué landscape. The Chapelle de Rosemont was already described in the reports of the first volcano expeditions at the end of the 18^{th} century.

The pathways used by the magmatic intrusion during this eruption (north-northwest flank) had not experienced dyke injections for at least the past 400 years.

Despite the low volume of lava flows emitted during this eruption and its short duration, this eruption has considerably changed the geomorphology of this sector, which was quite well known and popular amongst visitors.

C –Seismic activity on La Réunion and in the Indian Ocean basin

Seismicity

In July 2018, the OVPF recorded:

- 27 local earthquakes (below the island, on the Piton des Neiges area, Figure 17);
- 62 regional earthquakes (in the Indian Ocean basin).

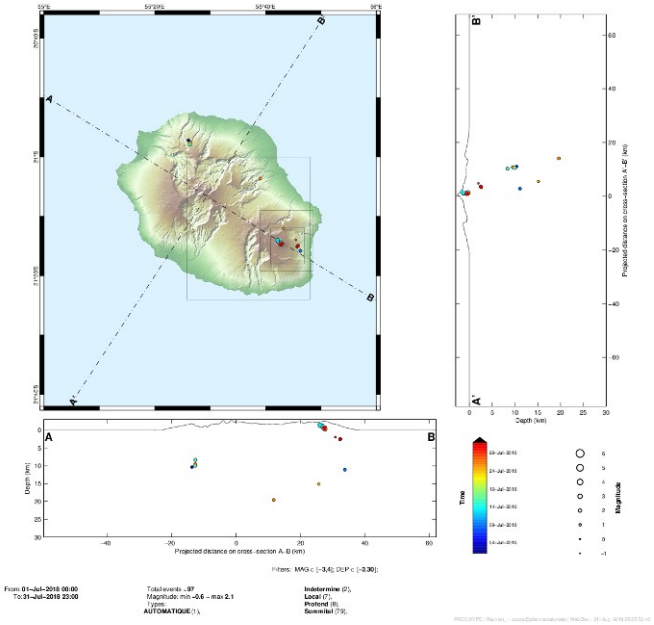

***Figure 17**: Location map (epicentre) and North-South and East-West cross-sections (hypocentre) of earthquakes recorded by OVPF-IPGP in July 2018 below La Réunion Island. Only localizable earthquakes have been shown on the map. The observatory records seismic events not shown on this map because they are not localizable due to their low magnitude (© OVPF-IPGP).*

On July 16, 2018, 06h02 local time (02h02 UTC), an earthquake was felt by inhabitants of the island, mainly in the North (Figure 18).

This earthquake was recorded by the seismometers of the Piton de la Fournaise Volcanological Observatory (OVPF). The earthquake could be located at 10 km below sea level in the sector of La Roche Ecrite, 7 km southwest of Sainte-Clotilde. Its magnitude was measured at 2.1 on the Richter scale. Events that are felt by the population are recorded several times a year. This event was isolated and of tectonic origin.

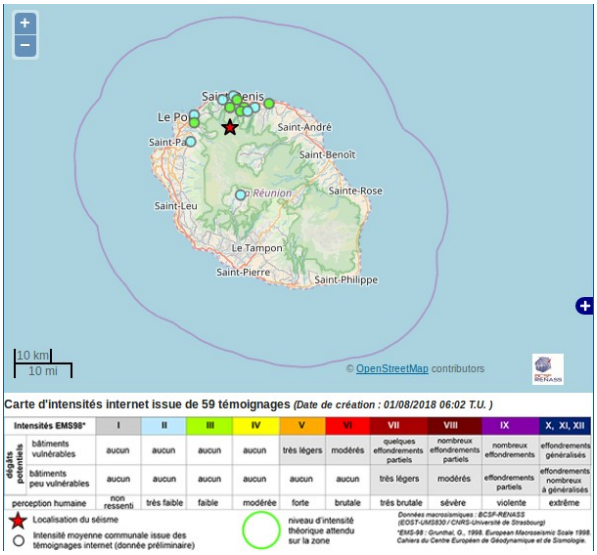

***Figure 18**: Intensity map deduced from 59 depositions (© franceseisme), http://www.franceseisme.fr/nseisme.php?IdSei=770.*

Seismic crisis in Mayotte

Seismic activity is recorded off shore the island of Mayotte since the beginning of May 2018. These earthquakes form a swarm located 50 to 60 km east of the coast of Mayotte. The majority of these earthquakes are of low magnitude, but several events of moderate magnitude (maximum 5.9) were felt by the population and damaged a few buildings. In July, the seismic activity continues at weaker intensities with a few events felt by the population.

More information:

- Dedicated webpage on the IPGP website : *http://www.ipgp.fr/fr/essaim-simique-a-lest-de-mayotte-mai-juin-2018*

- BRGM website : *www.ipgp.fr/fr/essaim-simique-a-lest-de-mayotte-mai-juin-2018*

http://www.brgm.fr/content/essaim-seismes-mayotte-faq-scientifique?pk_campaign=twitter&pk_kwd=2018-06_seismes-mayotte-faq

- BCSF website : *http://www.franceseisme.fr/*

- *"Préfecture de Mayotte" website : http://www.mayotte.pref.gouv.fr/*

August, 1 2018
OVPF-IPGP Director

C - 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 website (http://www.ipgp.fr/fr/ovpf/actualites-ovpf) and twitter (https://twitter.com/obsfournaise?lang=fr).