Volcano-seismic signals and monitoring network on La Soufrière of Guadeloupe

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1. Abstract

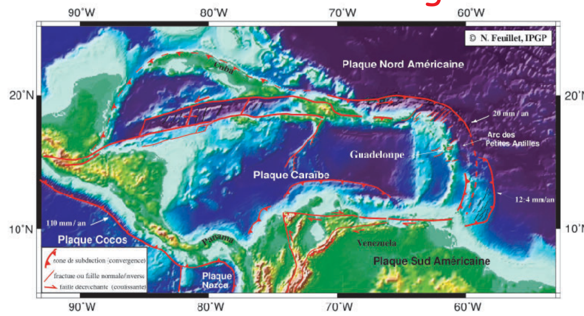
The last phreatic eruption lasted 8 months in **1976-77** and presented very high seismic activity (**16,000 events**, 150 felt). After a short decrease, a phase of elevated activity associated with increased fumarolic activity started in 1992, and frequent volcanic seismic swarms are still being recorded (15 felt events since 1981). Events remain within 6 km below the dome and show no signs of rising magma. Presently, most of the seismic energy is released during swarms lasting several days up to two weeks and occurring few times a year since 1997.

Although volcanic seismicity shows common features (shallow depth, low energy), several types of events with different characteristics occur at Soufrière volcano: **few isolated volcanic-tectonic** high-frequency events with impulsive P (VT-A), **numerous imbricated** emergent high-frequency events, no hybrid events, no tremor, **sporadic long-period events** with spindle shaped signal (resonant frequency near 4 Hz).

The **LP events** could be generated by a resonant source or propagating-path effects. Preliminary processing (a dozen events recorded in the last 2.5 years) highlights a zone that could be interpreted as a **plane of hydrothermally altered material** within the dome. Overall, the shallow-depth low-energy seismic activity seems associated with the superficial hydrothermal system. The occurrence of seismic swarms does not show a simple correlation with rainfall. This points towards a temporal modification of superficial aquifers and their permeability by a process of local self-sealing.

The Institut de Physique du Globe de Paris has been in charge of the monitoring of the Soufrière volcano since 1951. During the late 70s and moreover during the 90s, the seismic monitoring network was significantly upgraded. Presently, 12 telemetered short-period seismic stations (including three 3-components seismometers) are located within a 20-km radius of the summit. In 2003, four broadband seismometers (Guralp CMG-40T, 60 sec period) were installed near the dome.

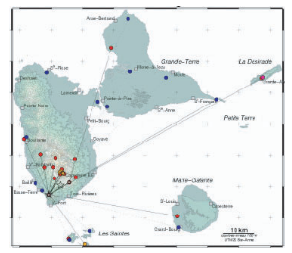
2. General setting



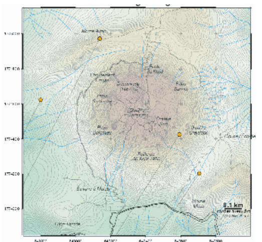
Location of Guadeloupe in the Caribbean arc

View of Soufrière volcano from the sea (the two active hydrothermal plumes are visible).

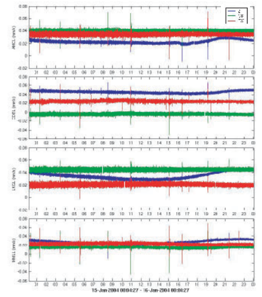
3. OVSG seismic monitoring network



The IPGP seismic monitoring started in 1953 with one station in St-Claude. Actual seismic network : 12 short-period (red) and 4 broad-band stations (orange circles) monitor the Soufrière volcano.



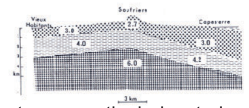
A broad-band seismic network was installed near the dome in 2003. It is real-time telemetered to the observatory (black lines).



24h real-time visualization of the 4 braod-band station signals. This figure was made during the january '04 swarm : vertical bars indicate seismic events. The long-period fluctuation is probably due to diurnal thermal effect.

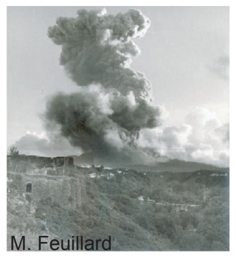
Radio reception and real-time acquisition of the seismic data.

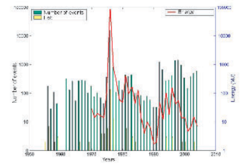
Installation of four broad-band stations. The sensors were buried in 2 meter-depth holes to avoid external noise. Azimuth corrections were computed using teleseismic Rayleigh and Love waves.



Events are routinely located using HYPO71 and a 1D velocity profile derived from a marine and land active seismic experiment (Dorel, 1978).

4. Past and present seismic activity



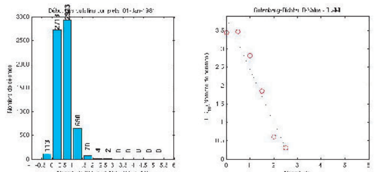


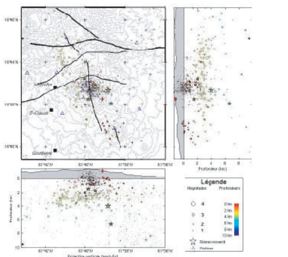
The 1976-77 phreatic eruption presented very high seismic activity. After a short decrease, a phase of elevated activity started in 1992 with increased fumarolic output.

List of recent felt Soufrière earthquakes:

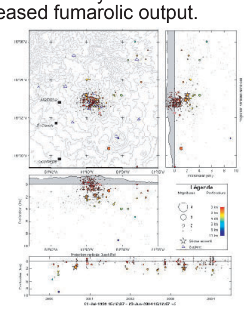
January, 7 1981 10:52TU	
January, 8 1981 06:50TU	August, 16 1994 08:18TU, Md=2.7, I=II-III
January, 8 1981 07:15TU	August, 16 1994 08:59TU, Md= 2.3, I=II
January, 8 1981 08:37TU	August, 27 1996 17:02TU, Md=2.5
January, 8 1981 08:47TU	August, 27 1996 17:14TU, Md=2.4
October, 17 1983 02:50TU	April, 15 1999 14:53TU, Md=1.9
October, 17 1983 08:53TU	August, 20 2000 03:08TU, Md=2.0
October, 15 1984 14:20TU	April, 29 2003 11:17TU, Md=2.1, I=II

3 strong events in 1998 could have been felt but were not reported.

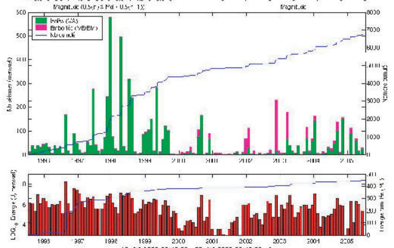




All the located hypocenters since 1953. Stars indicate felt events. The NW activity centered below older massifs (crête des Icaques) does not seem to be active anymore. Red diamonds correpond to a quarry activity.

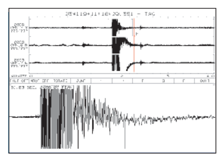


Hypocenters over the last 5 years. Events remain within 6km below the dome. It is difficult to compare seismicity over long period of time as the network has considerably evolved (detection threshold and position accuracy).

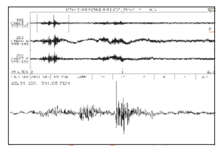


Temporal distribution of events and energy over the last 10 years. Frequent swarms are recorded. Many imbricated events (pink histograms) are counted for energy estimates but cannot be localized.

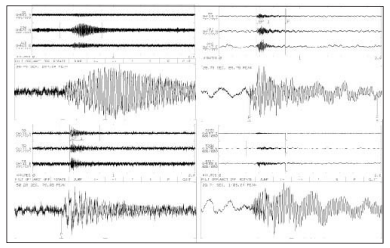
5. Types of seismic events



Example of the last felt **volcano-tectonic event (VT-A)**. VT events of magnitude over 2 are usually felt.

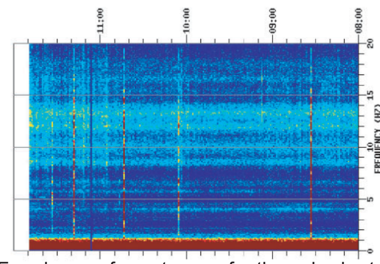


Example of very common **imbricated events** (same station as above). Maximum magnitudes are on the order of 1.4. Most of these events cannot be localized.

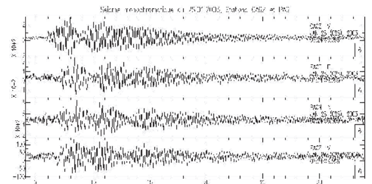


A **long-period event (LP)** observed during the january '04 swarm. The dominant frequency is 4Hz. We have recorded a dozain of these spindle-shape events (tornillos) since 2002.
The two left stations are short-period (1Hz for the top and 20s for the bottom panel). The two right stations are CMG40T (60 s).

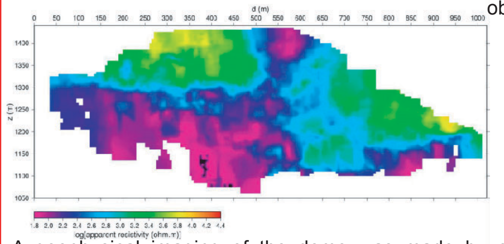
6. Interpretations



Four-hours of spectogram for the only short-period station located on the dome. This figure was made during the january '04 swarm : we can observe five high-frequency events. On top of the activity, we measure a narrow band of activity at 4 Hz (and its overtones).



One LP event located whithin the dome and recorded by two 1Hz sensors a few km away. The dominant frequency is 4Hz but we can also observe a frequency modulation.
All the LP events have the same dominant frequency but are not localized at the same place whithin the dome. Their positions seem to indicate a resonating body which could be a plane of hydrothermally altered material at the base of the dome. For several LP events, we can also observe a propagating-path effect. Further modeling is necessary to understand these observations. Feedbacks are welcome!



A geophysical imaging of the dome was made by electrical tomography (Nicollin et al., 2004). This pseudo-section of apparent resistivity enhances the present and fossil hydrothermal zones by low values (purple). Hydrothermally altered material is a good candidate for resonnant sources of the LP seismic events.

7. References

The work is dedicated to our regretted colleague Alberto Tarchni who was shot in 2003.

We thank for his help Philippe Lesage (LGIT) who first analyzed the LP events.

Bibilography:

-DOREL, J., Sismicité et structure de l'arc des Petites Antilles et du Bassin Atlantique, thesis, 1978.

-NICOLLIN F., GIBERT D., BEAUDUCEL F.. Structure of the Soufriere of Guadeloupe by electrical tomography : Preliminary results. In : RST, 20-25 septembre 2004, Strasbourg, France, RSTGV-A-00538, 2004.