

The review of the 1975-1977 eruption of La Soufrière de Guadeloupe (FWI)

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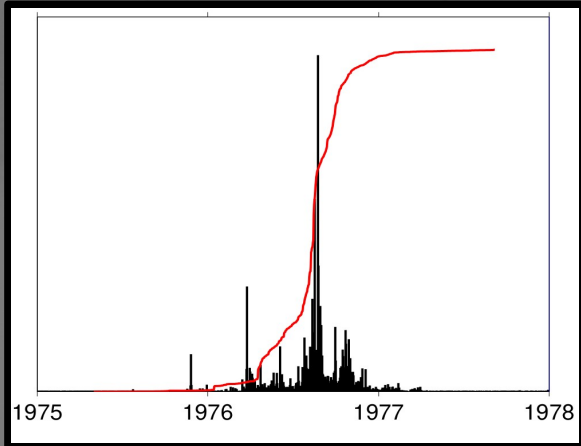
Seismology / former Director of Guadeloupe Obs. 2001-2007

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Geology of Volcanic Systems



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Plan

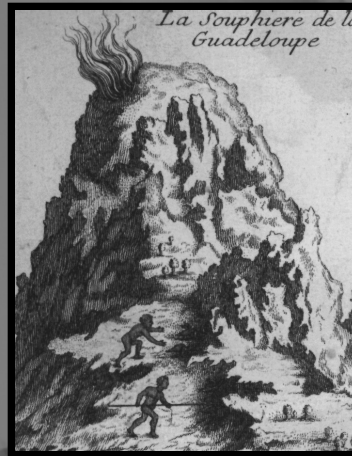
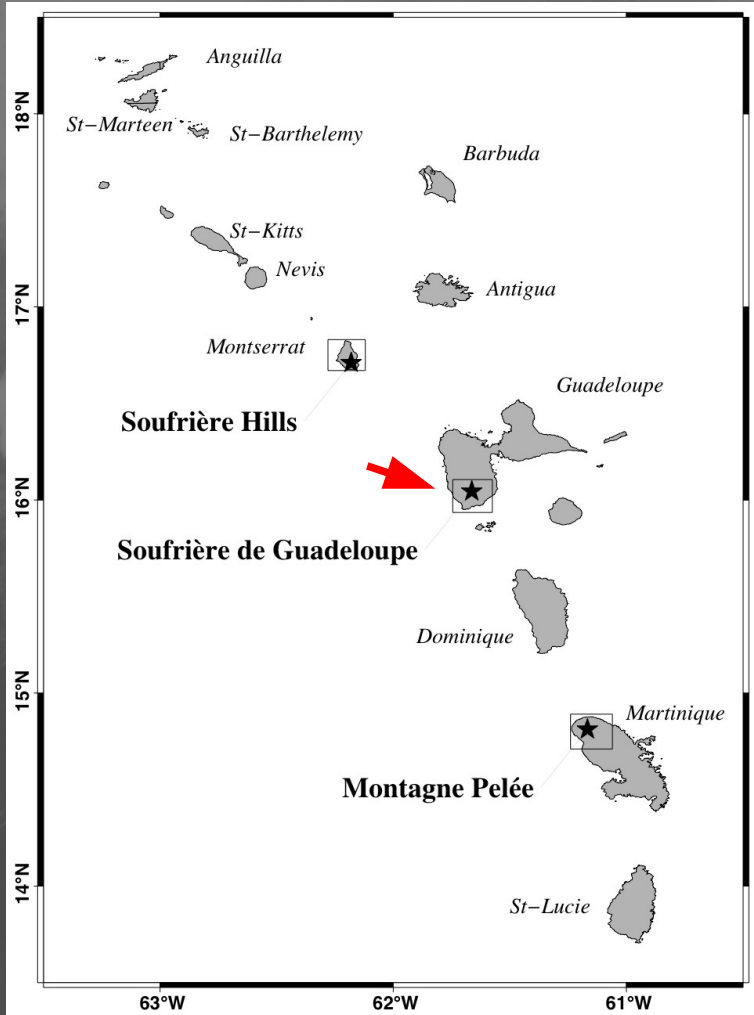
I. Phenomenological chronology

II. Crisis management

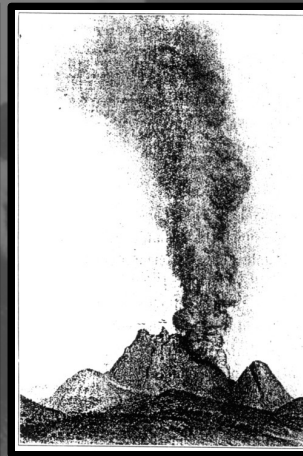
III. Consequences for present activity interpretation

Introduction

- ✓ Active subduction zone context
- ✓ Volcanic complex ~200 ky
- ✓ 1535 AD: last magmatic eruption (dome, pyroclastic flows, flank collapse, small subplinian VEI=3 ...) [Komorowski et al., 2008]
- ✓ 4 known phreatic eruptions: 1690, 1797-1798, 1836-1837, and 1956



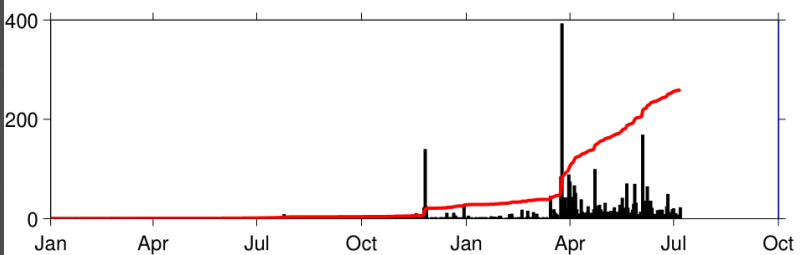
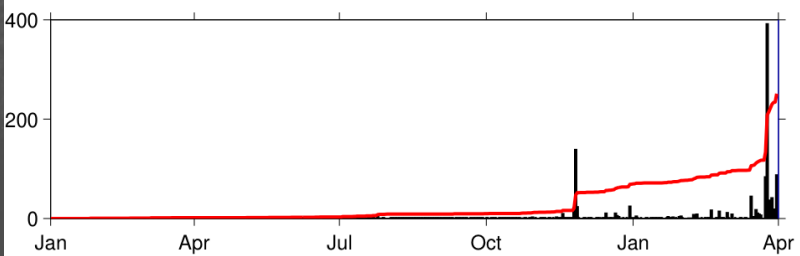
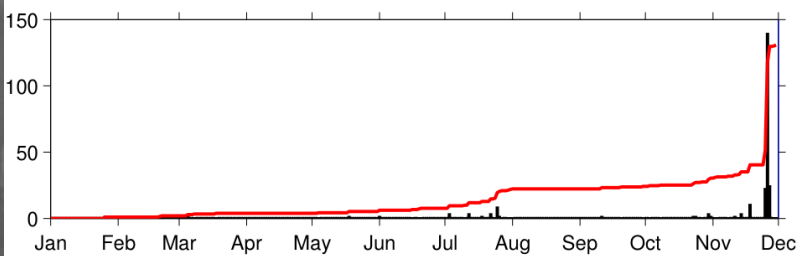
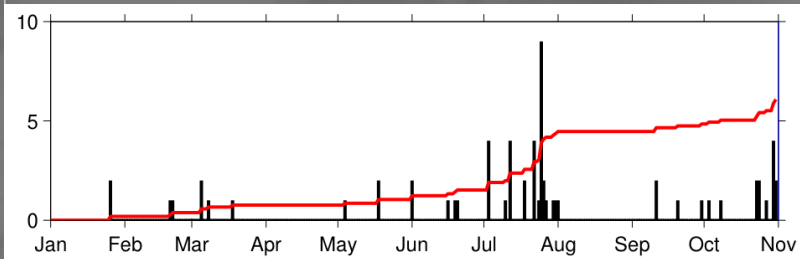
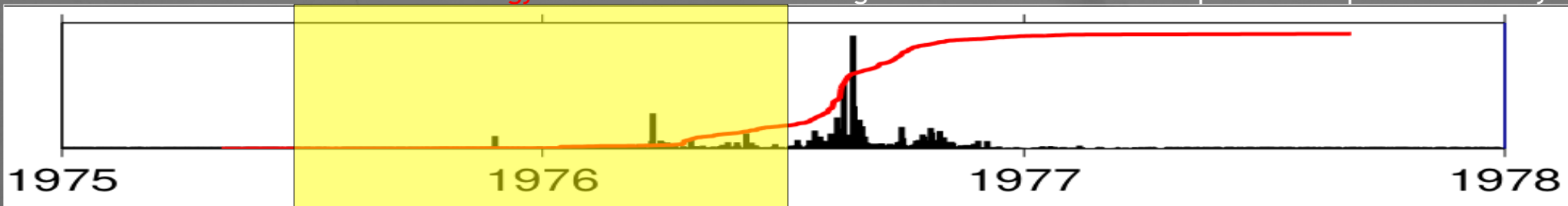
XVIIth - XVIIIth



1836-1837

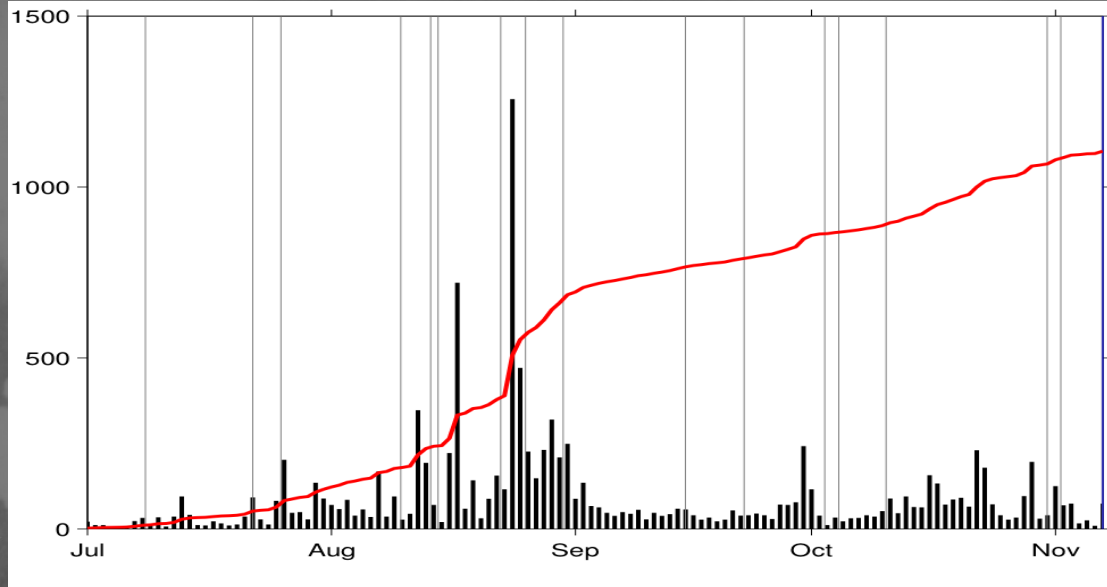
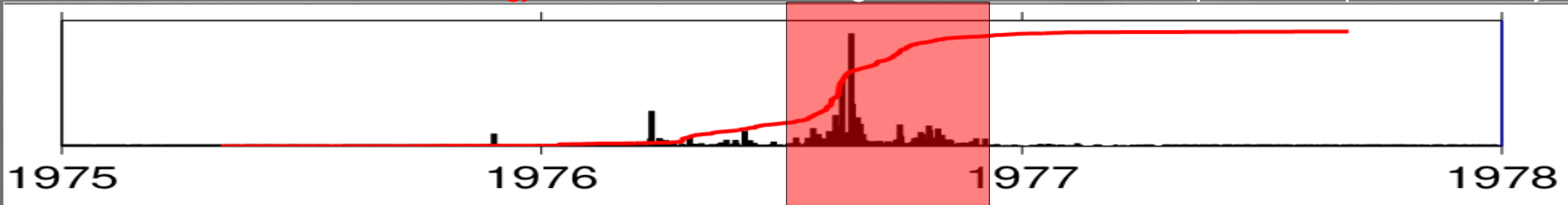


1956



a. The precursor phase

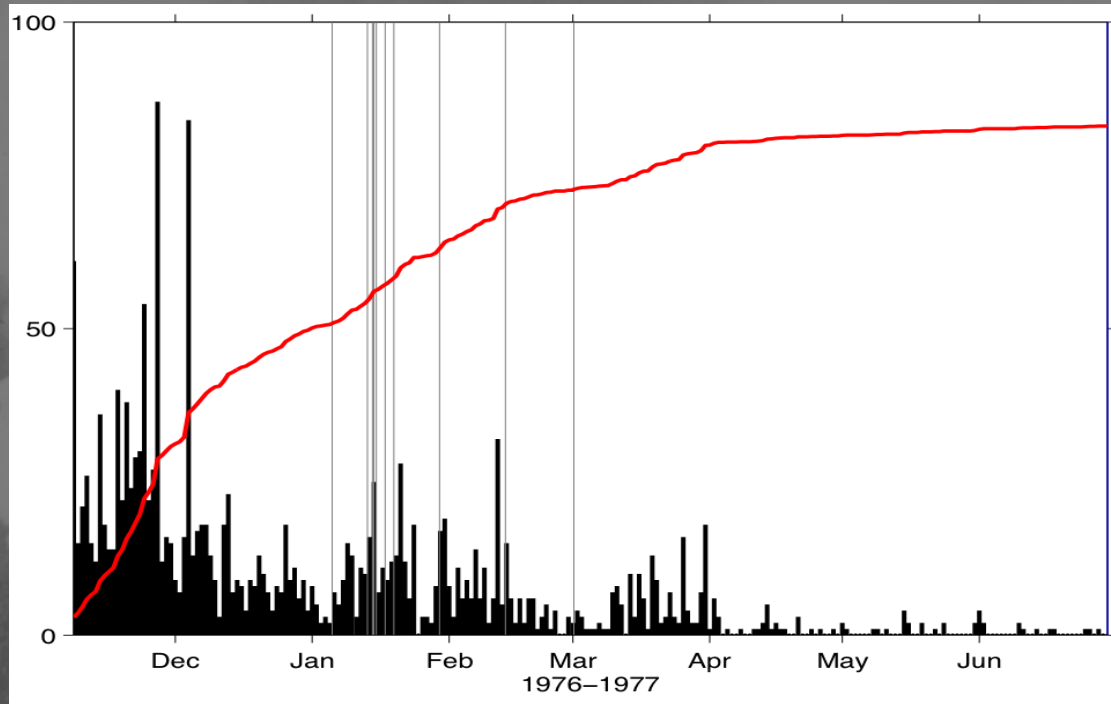
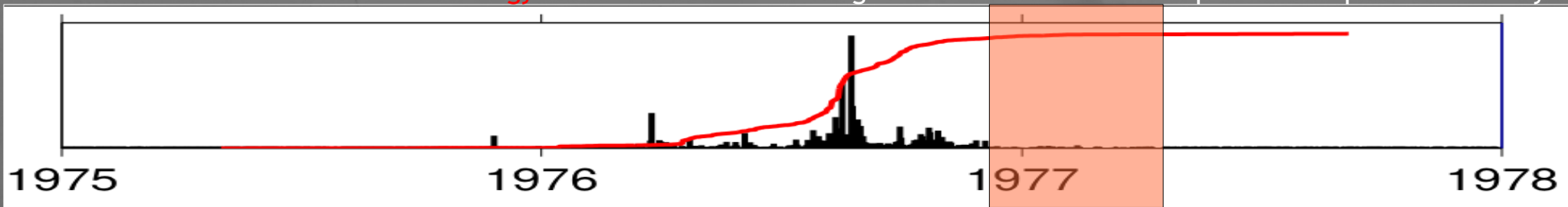
- ✓ Jul. 1975: seismic anomaly (above noise background since 1956)
- ✓ Nov. 1975: significant seismicity increase (>100 #/day)
- ✓ Mar. 1976: first seismic swarm with felt events (~400 #/day)
- ✓ Apr.-Jun. 1976: constant high level of seismicity (~100 #/day)



b. Surface phenomena

- ✓ Jul. 8, 1976: First phreatic explosion (600,000 m³) with new 300-m long crack and lahar
- ✓ Jul. to Aug. 1976: 8 other phreatics preceded by tremors
- ✓ Aug. 16, 1976: mag. 4.2, VI
- ✓ Aug. 24, 1976: maximum seismicity (1300 #/day)
- ✓ Aug. 30, 1976: creation of new crack “Aug. 30th Fault”
- ✓ Sep. to early Nov., 1976: still high level of seismicity





c. Decrease of seismic activity - renewed explosivity

- ✓ Nov. 1976 to mid-Jan. 1977: seismicity starts to decrease, lull in explosions
- ✓ Jan. to Mar. 1977: 10 new phreatics, including one of the strongest on Jan. 29th
- ✓ March 1st, 1977: last phreatic explosion
- ✓ July 1977: return to pre-eruptive seismic background level



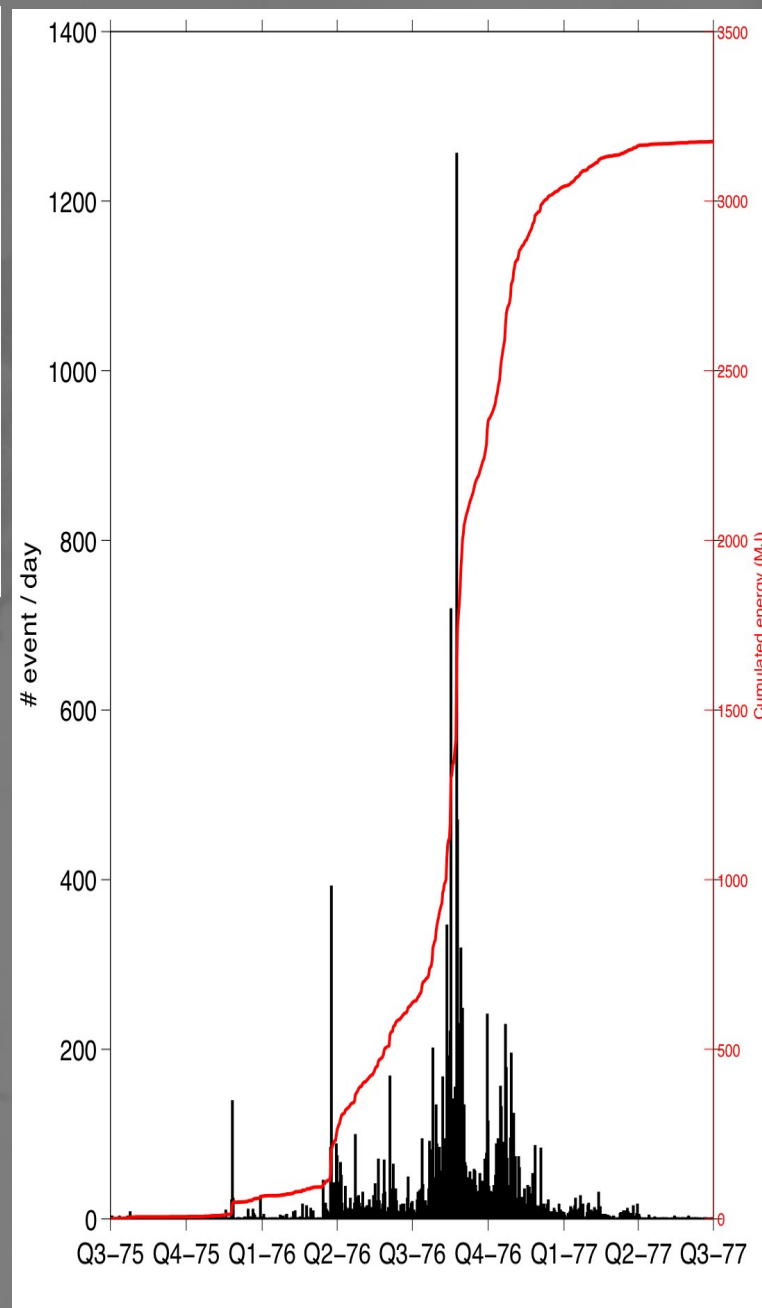
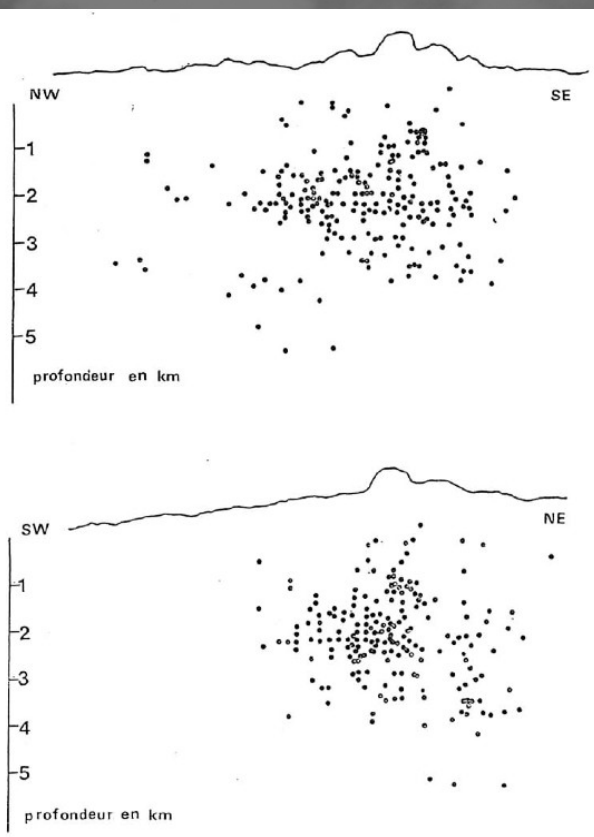
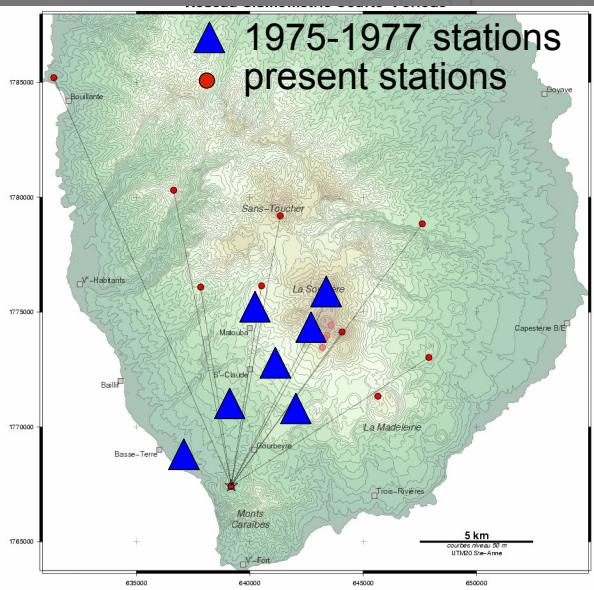


(c) F. Beauducel / IPGP, 2000



(c) F. Le Guern, 1976



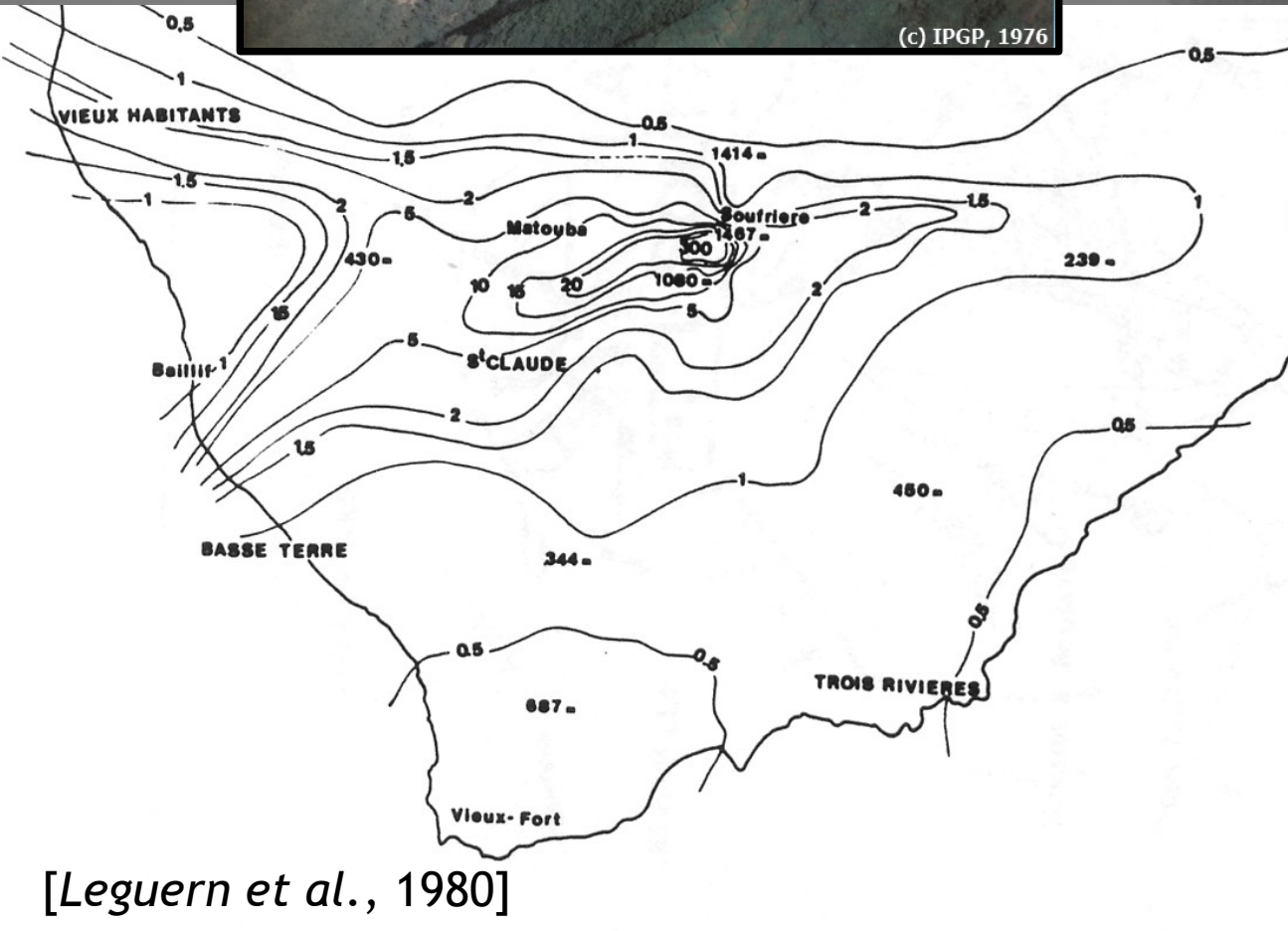


Seismicity

- ✓ 7 seismic stations (poor network configuration)
- ✓ 1 to 4-km depth
- ✓ 1-D velocity model
- ✓ Error on focii depth = ?
- ✓ Total of 16,467 events
- ✓ 153 felt
- ✓ Maximum mag. = 4.2
- ✓ Total energy = 3 GJ

[Dorel and Feuillard, 1980]

Ash deposits



- ✓ 26 main explosions
- ✓ Thickness: from 0.5mm to several meters at summit
- ✓ Composition: unaltered glassy fragments first interpreted as juvenil component, then abandoned
- ✓ Total volume of erupted material = 800,000 m³ (VEI = 2)

Other methods

- ✓ **Gaz analysis:**
 - 184°C max,
 - pH ~1.5,
 - 95% H₂O, low SO₂, H₂S, CO
- ✓ **Ground deformation:** not significant due to inappropriate installation
- ✓ **Magnetic field:** 15-nT anomalies interpreted as hydrostatic pressure variations in the magma chamber

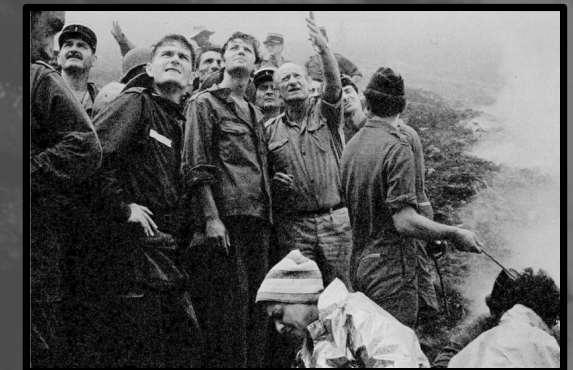
II. Crisis Management

a. Context

- ✓ ~75,000 inhabitants around the volcano
- ✓ No historical magmatic eruption in Guadeloupe but Mt Pelée 1902 eruption still in mind
- ✓ Rudimentary observatory (since 1951)
- ✓ No regular information to population
- ✓ Inexistent prevention of volcanic risk

b. Chronology

- ✓ **Jul. 1975:** observatory internal “alert” (based on seismic anomaly)
- ✓ **Nov. 1975:** first official information to authorities, preparation of emergency plan
- ✓ **Mar. 1976:** first information to population (due to felt earthquakes)
- ✓ **Apr. 1976:** H. Tazieff public intervention, french President demands: “zero fatality”
- ✓ **Jul. 8, 1976:** 25,000 people spontaneously leaving during few days (due to first phreatic explosion)
- ✓ **Mid-July 1976:** H. Tazieff announces a total absence of risk for population, then quits Guadeloupe



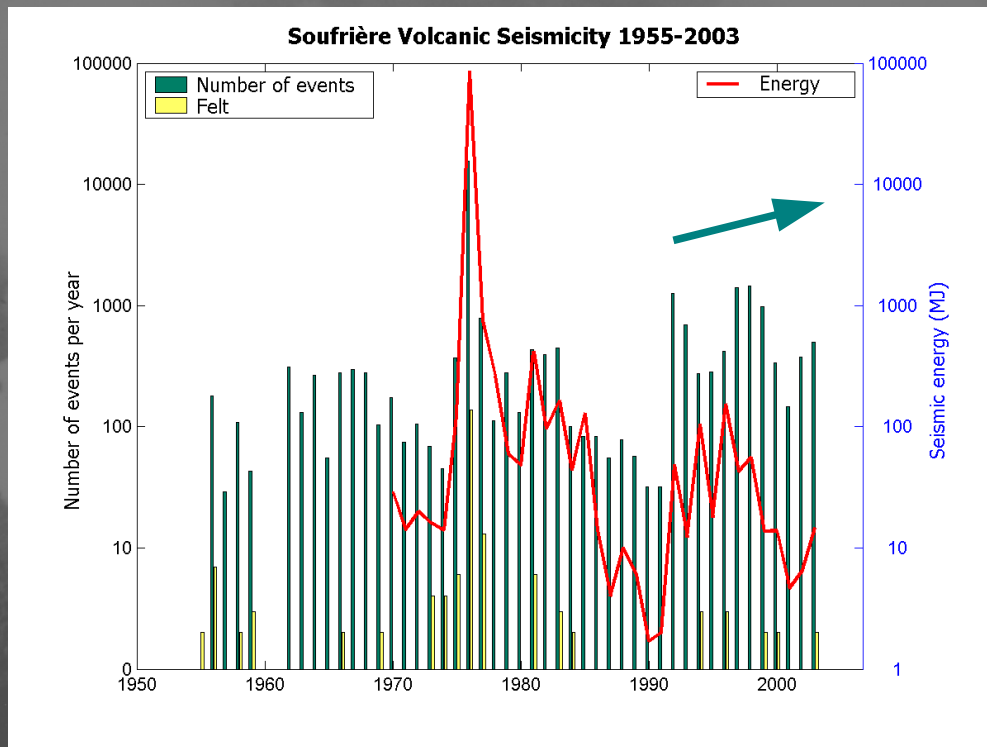
- ✓ Aug. 12-15 1976: official evacuation of 73,000 people on scientists advice (R. Brousse and J. Tomblin)
- ✓ Sep. to Oct. 1976: conflict between scientists (H. Tazieff and C.J. Allègre)
 - 2 hypothesis: A. purely phreatic with low immediate risk, or B. magmatic intrusion with possible worsening
 - 1 question: since 3 days are needed for complete evacuation, how many time between “significant” precursors and dangerous volcanic event ?
- > consequences: discontent of the population + scientist discredit
=> authorities ask for international committee



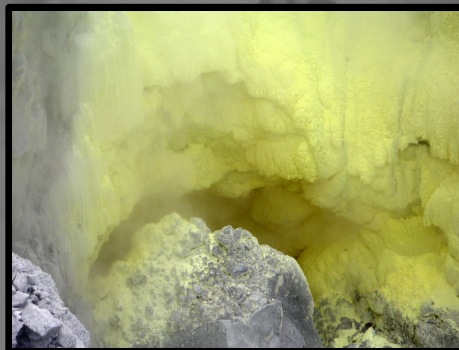
- ✓ **Nov. 15-18 1976: international committee** (F. Press, R. Aramaki, F. Barberi, J. Coulomb, R.S. Fiske, P. Gasparini, C. Guillemin, G. Sigvaldason)
 - maintains the 2 possible eruptive scenarios,
 - suggests population return and monitoring reinforcement,
 - suggests better scientist/population communication.
- ✓ **Dec. 1st 1976: official return of the population**
- ✓ **Dec. 1976 to Mar. 1977: paradoxical situation**
 - societal activity renewal (back to “normal”)
 - ash falls, water and cultivation contamination
 - 10 phreatic explosions until Mar. 1st, 1977 (including one of the major on Jan. 29, 1977)

- ✓ **Until today:**
 - population feels that evacuation was unnecessary
 - one of the observatory priority is to get back population's confidence

III. Consequences for present activity interpretation



- ✓ 1977-1991: activity decrease
- ✓ 1992: start of new seismic unrest and fumarole activity
- ✓ 1997: apparition of chlorine in fumaroles ($\text{pH} < 0$)
- ✓ 2000 to present: constant increase in gas flux, sulfure content and temperatures
- ✓ 2004: shallow Mw 6.3 tectonic earthquake lead to small avalanches on the volcano flanks



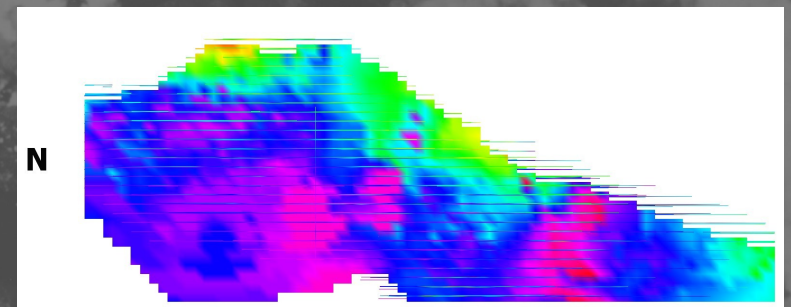
Recent studies:

- ✓ Amongst world's most unstable volcanoes, 10 collapses / 15 ky (hydrothermal alteration, structure)
- ✓ 5-7 collapses + magmatic blast/surges - Last collapse 564 years ago with last magmatic
- ✓ 7 dome eruptions / 15 ky
- ✓ Electrical tomography shows altered rocks inside and below the lava dome



[Komorowski et al., 2005]

But...
what is the present stage ?



[Nicollin et al., 2006]

Arguments supporting purely phreatic eruption		Arguments supporting still-born magmatic eruption	
Nothing happened...	✓	-	
Surface observations (gas content, temperatures, ash) only phreatic	✓	-	
Lack of any violent historical eruption at La Soufrière, small proportion of pyroclastic flows deposits... [Tazieff, 1976]	✗	Recent geological evidences [Boudon et al., 1987; 2008, Komorowski et al., 2005; 2008]	✓
Frequent seismic crisis in the Caribbean without any eventual eruption (e.g. Montserrat)... [Tazieff, 1976]	✗	Posterior facts: St-Vincent 1979; Soufrière Hills 1995-present	✓
No migration of seismic events during crisis [Tazieff, 1976]	✗	Evidence for migration of seismic events [Hirn and Michel, 1979]	✓
-		Seismicity energy and magnetic anomaly [Feuillard et al., 1983]	✓
-		Hot springs chemical modeling (degassing pulses of Cl) [Villemant et al., 2005]	✓
Phreatic surface phenomena usually not followed by magmatic stage	✗	Posterior facts: St-Helens, Pinatubo, Unzen, Soufrière Hills	✓

Comparison with other explosive volcanoes

	Soufrière Guadeloupe 1976	St-Helens 1980	Pinatubo 1991	Unzen 1991	Soufrière Hills 1995- present
<i>Duration since last magmatic</i>	341 years	123 years	500 years	198 years	363 years
<i>First seismic anomaly</i>	Nov 1975	March 1980	Mid-March 1991	Nov 1989	1989, 1992, 1994
<i>Delay 1</i>	236 days	11 days	20 days	360 days	?
<i>First phreatic</i>	July 8, 1976	March 27, 1980	April 2, 1991	Nov 17, 1990	July 18, 1995
<i>Delay 2</i>	-	53 days	67 days	186 days	121 days
<i>First magmatic</i>	None	May 18, 1980	June 8, 1991	May 20, 1991	Nov 15, 1995

?

Conclusions

If there was a magmatic intrusion during 1976 crisis:

- ✓ magma already reached ~ 2-km depth,
- ✓ no need for strong precursors / long delay before a future magmatic eruption,
- ✓ medium local earthquake may easily trigger an eruption,
- ✓ present activity is more worrying...

Work in progress:

- ✓ Digitize of old seismic recordings (for relocation using recent velocity models, and waveforms analysis)
- ✓ Tomography of the dome (seismic, muonic, electric)