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Steam and gas emission rate from La Soufriere volcano, Guadeloupe (Lesser Antilles): Implications for the magmatic supply during degassing unrest

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ABSTRACT

Since its last magmatic eruption in 1530 AD, La Soufrière andesitic volcano in Guadeloupe has displayed intense hydrothermal activity and six phreatic eruptive crises. Here we report on the first direct quantification of gas plume emissions from its summit vents, which gradually intensified during the past 20 years. Gas fluxes were determined in March 2006 and March 2012 by measuring the horizontal and vertical distributions of volcanic gas concentrations in the air-diluted plume and scaling to the speed of plume transport. Fluxes in 2006 combine real-time measurements of volcanic H_2S concentrations and plume parameters with the composition of the hot (108.5 °C) fumarolic fluid at exit. Fluxes in 2012 result from MultiGAS analysis of H_2S, H_2O, CO_2, SO_2 and H_2 concentrations, combined with thermal imaging of the plume geometry and dynamics. Measurements were not only focused on the most active South crater (SC) vent, but also targeted Tarissan crater and other reactivating vents. We first demonstrate that all vents are fed by a common H_2O-rich (97–98 mol%) fluid end-member, emitted almost unmodified at SC but affected by secondary shallow alterations at other vents. Daily fluxes in 2012 averaged 200 tons of H_2O, 15 tons of CO_2, ~4 tons of H_2S and 1 ton of HCl, increased by a factor ~3 compared to 2006. Even though modest, such fluxes make La Soufrière the second most important volcanic gas emitter in the Lesser Antilles arc, after Soufriere Hills of Montserrat. Taking account of other hydrothermal manifestations (hot springs and diffuse soil degassing), the summit fumarolic activity is shown to contribute most of the bulk volatile and heat budget of the volcano. The hydrothermal heat output (8 MW) exceeds by orders of magnitude the contemporaneous seismic energy release. Isotopic evidences support that La Soufrière hydrothermal emissions are sustained by a variable but continuous heat and gas supply from a magma reservoir confined at 6–7 km depth. By using petro-geochemical data for La Soufrière magma(s) and their dissolved volatile content, and assuming a magmatic derivation of sulfur, we estimate that the volcanic gas fluxes measured in 2012 could result from the underground release of magmatic gas exsolved from ~1400 $m^3\ d^{-1}$ of basaltic melt feeding the system at depth. We recommend that fumarolic gas flux at La Soufrière becomes regularly measured in the future in order to carefully monitor the temporal evolution of that magmatic supply.

1. Introduction

Increasing gas emission and compositional changes in fumarolic exhalations are common signals of unrest or even precursors of forthcoming eruption at dormant volcanoes in hydrothermal stage of activity (e.g. Giggenbach and Sheppard, 1989; Symonds et al., 1994, 1996). Deciphering the actual significance of these signals is thus important to discriminate between pure physical changes in the hydrothermal system regime (e.g. sealing, overpressuring) and evolution due to degassing of upraising magma prone to erupt. Both mechanisms can trigger phreatic eruptions of similar style but with highly contrasted implications. While monitoring fumarolic gas compositions is routinely operated on a number of dormant volcanoes worldwide, quantifying the total gas discharge sustained by fumarolic activity – one key information upon the evolution of volatile and heat budgets – is not trivial. On volcanoes with sustained open-vent magma degassing or/and hosting high-temperature (>400 °C) fumarolic systems, gas discharges are accurately quantified using remote UV spectroscopy of plume

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emissions of sulfur dioxide (e.g., Oppenheimer, 2010). The fluxes of other gas compounds are then calculated from knowledge of fumarole or plume compositions (e.g., Allard et al., 1994). Instead, this approach is prevented at less active (<200–300 °C) degassing systems that emit little SO_2 and predominantly H_2S, this latter being far more difficult to detect optically in volcanic plumes (O'Dwyer et al., 2003). Other techniques for the remote flux sensing of H_2O and CO_2, the two main volcanic gas species, are still in the developing stage (e.g. Fiorani et al., 2011; Schwandner et al., 2012). Alternative possibilities are in situ flux measurement using airborne gas plume profiling (Gerlach et al., 1999) or ground-based eddy gas profiling (Todesco et al., 2003), but these are often hampered by the weakness of air-diluted fumarolic

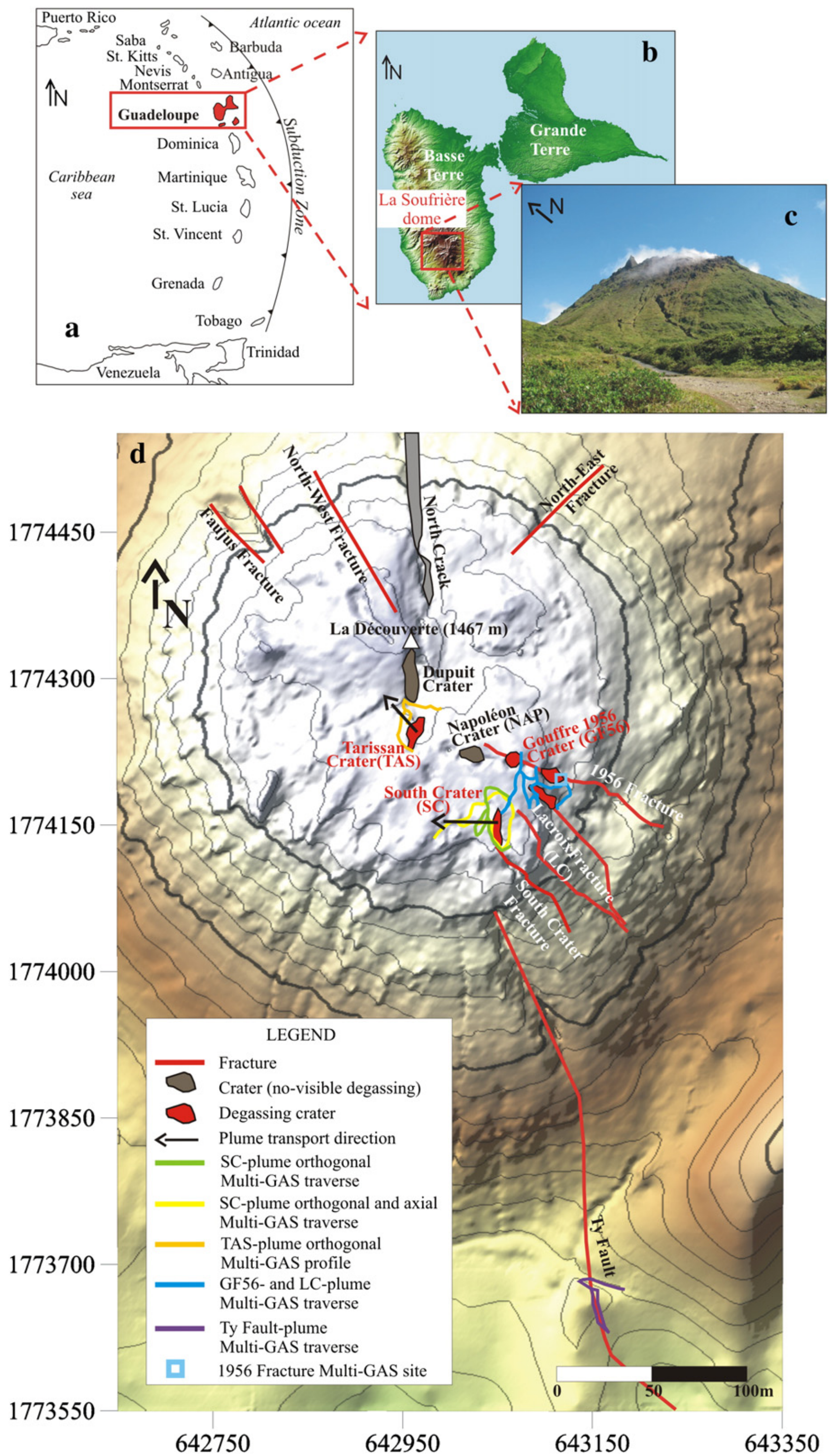

Fig. 1. Locations of (a) Guadeloupe island in the Lesser Antilles arc and (b) La Soufrière volcano in the southern part of Basse Terre island. (c) Picture of La Soufrière summit lava dome, extruded during the last eruption in 1530 AD, with its visible summit gas plume in March 2012. (d) Digital topographic map of the lava dome showing its main fractures and the active summit fumarolic vents investigated in this study (South Crater: SC; Tarissan crater: TAS; Gouffre 1956: GF56; Lacroix fracture: LC).