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Remote and in situ plume measurements of acid gas release from La Soufrière volcano, Guadeloupe

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Abstract

This paper presents the first remote measurements of La Soufrière gas emissions since the fumarolic and seismic reactivation in 1992. The chemical composition of the plumes has been measured from May 2003 to September 2004 using an Open Path Fourier Transform InfraRed (OP-FTIR) spectrometer, up to 15 m downwind the South Crater. HCl is clearly detected (concentration between 2.4 and 12 ppmv) whereas SO_2 and H_2S generally remain below the detection limit of the OP-FTIR. Direct measurements of SO_2 and H_2S near the South Crater with a Lancom III analyzer show a fast decrease of their concentrations with the distance. Calculated Cl/S mass ratios are high: from 9.4 ± 1.7 at 15 m from the vent to 2.8 ± 0.6 at 140 m. The enrichment in HCl of the gas emitted at La Soufrière, observed since 1998, corresponds to the degassing of a magma enriched in Cl and depleted in S. This result agrees with isotopic measurements which suggest a magmatic origin of the gases. Readjustments inside the volcanic system may have taken place during the seismic activity beginning in 1992 and enhance the transfer of magmatic gases to the summit.

Keywords: volcanic gas; OP-FTIR; remote sensing; HCl/SO_2; La Soufrière of Guadeloupe

1. Introduction

Since the last magmatic eruption of 1440 AD, La Soufrière of Guadeloupe, an andesitic stratovolcano located in the subduction arc of the Lesser Antilles, has undergone at least four phreatic eruptions (Boudon et al., 1988, 1989; Komorowski et al., in press), the last of which was in 1976–1977. A stream-and-ash column rose above the summit in July 1976. The eruption lasted eight months and consisted of 26 phreatic explosions. After May 1977, the fumarolic activity decreased gradually and was further reduced between 1984 and 1992. Only small peripheral fumaroles were observed.

In 1992, the fumarolic activity resumed (Zlotnicki et al., 1994; Komorowski et al., 2001): and three volcanic plumes rose above the summit. The strongest one is emitted from the South Crater (CS). A substantial increase in shallow seismic activity accompanied this reactivation. Since 1992, the alert level is "yellow" (vigilance). The fumarolic activity has progressively extended toward the North–North-West, with a reacti-

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vation of the Tarissan (TAS) vent in 2000 and the Napoléon (NAP) vent in 2002.

Since 1976, gas chromatography (GC) analyses have been regularly performed. In 1997, GC analyses on samples from the CS vent showed that: (1) the most abundant gas released was water vapor (97–98% of the total volume); (2) the other main components were CO_2 (~85% mol), H_2S (~9% mol) and three diatomic gases: H_2, N_2, and O_2 (respectively, ~2.5%, 2.7%, 0.8% mol); (3) SO_2, HCl as well as CO were below the detection limits of the gas chromatograph.

In 1998, gas emanating from the main summit plume CS suddenly became very acid. The pH reached values close to 1, as opposed to 4 to 5 before. Tiny acid droplets and important solid sulfur deposits have been observed at the summit, near the CS.

The strong reactivation of the fumarolic activity at the summit and the remarkable change in chemical parameters are not associated with significant variations of the other important monitoring parameters such as seismic activity at depth, large scale ground deformation, and higher gas temperatures. Average gas temperatures remained around 105 °C. However, many catastrophic volcanic events are related to explosive activity on apparently dormant volcanoes (e.g., Montagne Pelée 1902, Mount St. Helen 1980, Pinatubo 1991, Soufrière Hills 1995). As a consequence, any attempt to understand an increase in volcanic activity in quiescent systems deserves attention.

The persistent degassing, the origin of the high acidity of gas emissions at La Soufrière of Guadeloupe and the source mechanisms of this reactivation are poorly understood. HCl concentration seem to be a key parameter. Unfortunately, the acidity made direct sampling and pH measurements unsafe since 1998, and gas chromatography is not suitable to study HCl behavior. Thus, a necessity for new tools has emerged. Correlation spectrometer (COSPEC) is widely used to monitor SO_2 during volcanic eruptions (Hoff and Millan, 1981; Stoiber et al., 1983). However, SO_2 measurements are not sufficient for the full understanding of the degassing mechanisms. Consequently, in the last ten years the remote sensing technique of Open Path Fourier Transform Infra Red spectrometry (OP-FTIR) has been widely used to monitor chemical composition of gases on different volcanoes: Unzen and Aso, Japan (Mori et al., 1993; Mori and Notsu, 1997), Galeras, Colombia (Stix et al., 1993), Masaya, Nicaragua (Horrocks et al., 1999; Burton et al., 2000; Duffell et al., 2003), Vulcano, Italy (Francis et al., 1995; Mori et al., 1995), Popocatépetl, Mexico (Goff et al., 2001), Stromboli, Italy (Burton et al., 2001); Oldoinyo Lengai, Tanzania (Oppenheimer et al., 2002), Soufrière Hills, Montserrat (Oppenheimer et al., 1998a,b,c,d; Edmonds et al., 2002), Etna, Italy (Francis et al., 1995; Burton et al., 2003; Allard et al., 2005). Thus, experience increases and the use of OP-FTIR becomes easier.

In order to better understand the volcano dynamics and provide critical information for evaluating hazards at La Soufrière, Guadeloupe, we undertook OP-FTIR measurements of volcanic plumes. In this paper we present OP-FTIR data and LANCOM III gas analysis collected between May 2003 and September 2004 at the summit of La Soufrière. In the discussion we focus on HCl/SO_2 ratios in order to give some new insights on the origin of the ongoing degassing at La Soufrière.

2. Two new tools to monitor La Soufrière gases: the OP-FTIR and the Lancom III gas analyzer (LIII)

2.1. OP-FTIR

We used a MIDAC Corporation OP-FTIR spectrometer which incorporates a Michelson interferometer attached to a 25 cm Newtonian telescope (Fig. 1) with a mercury–cadmium–telluride (MCT) detector or an ad-

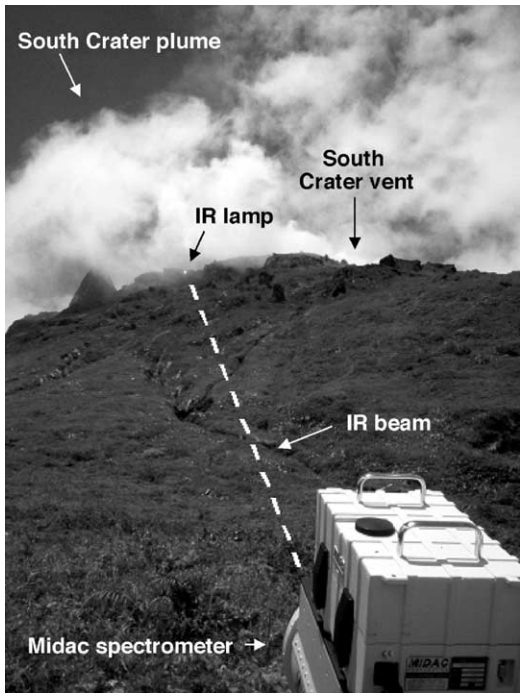

Fig. 1. Example of OP-FTIR measurement on April 15, 2004 at La Soufrière of Guadeloupe. The spectrometer was located at the 'Savane à mulets' parking and the infrared lamp on the crater rim (light spot).