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The 2007 eruption of Stromboli volcano: Insights from real-time measurement of the volcanic gas plume CO_2/SO_2 ratio

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ABSTRACT

The recent eruption of Stromboli in February–April 2007 offered a unique chance to test our current understanding of processes driving the transition from ordinary (persistent Strombolian) to effusive activity, and the ability of instrumental geophysical and geochemical networks to interpret and predict these events. Here, we report on the results of two years of in-situ sensing of the CO_2/SO_2 ratio in Stromboli's volcanic gas plume, in the attempt to put constraints on the trigger mechanisms and dynamics of the eruption. We show that large variations of the plume CO_2/SO_2 ratio (range, 0.9–26) preceded the onset of the eruption (since December 2007), interrupting a period of relatively-steady and low ratios (time-averaged ratio, 4.3) lasting from at least May to November 2006. By contrasting our observations with numerical simulations of volcanic degassing at Stromboli, derived by use of an equilibrium saturation model, we suggest that the pre-eruptive increase of the ratio reflected an enhanced supply of deeply-derived CO_2-rich gas bubbles to the shallow-plumbing system. This larger-than-normal ascent of gas bubbles was likely sourced by a 1–3 km deep gas–melt separation region (probably a magma storage zone), and caused faster convective overturning of magmas in the shallow conduit; an increase in the explosive rate and in seismic tremor, and finally the collapse of the la *Sciara del Fuoco* sector triggering the effusive phase. The high CO_2/SO_2 ratios (up to 21) observed during the effusive phase, and particularly in the days and hours before a paroxysmal explosion on March 15, 2007, indicate the persistence of the same gas source; and suggest that de-pressurization of the same 1–3 km deep magma storage zone could have been the trigger mechanism for the paroxysm itself.

1. Introduction

The persistent emission of a volcanic gas plume on Stromboli (Fig. 1), in the Aeolian Islands (Southern Italy), is the "continuous" counterpart of the "discrete and rhythmic" explosions characteristic of the volcano's world-well known mild Strombolian activity. This volcanic gas plume consists of an atmospheric dispersion of volcanogenic gaseous volatiles (H_2O, CO_2, SO_2 and HCl in roughly 1:0.2:0.02:0.02 proportions; Allard et al., 1994, in press; Burton et al., 2007a) and metal-rich volcanic aerosols (Allard et al., 2000).

Volcanic gases represent a source of otherwise inaccessible information on the volcano's dynamics, and it is no doubt they play a central role on the most various aspects of Stromboli's behaviour. It has recently been pointed out that Stromboli volcano emits through its summit plume more gas than potentially contributed by degassing of the erupted magma (Allard et al., 1994). This has been taken as an evidence of degassing-driven continuous magma convection into a relatively shallow (<1 km) magma reservoir, with degassed non-erupted magma sinking back into the conduit and being replaced by the ascent of gas-rich less-dense magma (Harris and Stevenson, 1997; Stevenson and Blake, 1998). Volcanic gases have also been demonstrated to account for a large volumetric fraction of individual Strombolian explosions (Chouet et al., 1974; Ripepe et al., 1993); and the ascent, accumulation and coalescence of gas bubbles in the conduit is thought to be the source mechanism for the formation of the gas slugs triggering the rhythmic Strombolian explosions and the related very-long period seismicity (Ripepe et al., 2002; Chouet et al., 2003). The magmatic gas phase is also heavily implicated in the generation of Stromboli's paroxysms: these gas-driven more energetic events (Barberi et al., 1993; Rosi et al., 2006) being likely triggered by the fast ascent of highly-vesicular magma (Bertagnini et al., 2003; Métrich et al., 2005) or gas slugs (Allard, 2007) into the shallow volcano reservoir. Notably, the post-hoc interpretation of volcanic gas

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Fig. 1. The persistent emission of a volcanic gas plume on Stromboli volcano.

composition data has offered the only precursory observation to a paroxysm, hitherto (Aiuppa and Federico, 2004).

Despite a better knowledge of volcanic gas plume compositions is thus essential to put constraints on degassing and eruptive phenomena, Stromboli's volcanic gas emissions have only occasionally been characterised in the past (Allard et al., 1994, 2000, in press; Aiuppa and Federico, 2004; Burton et al., 2007a). This paucity of volcanic gas measurements has been determined by many factors, including the

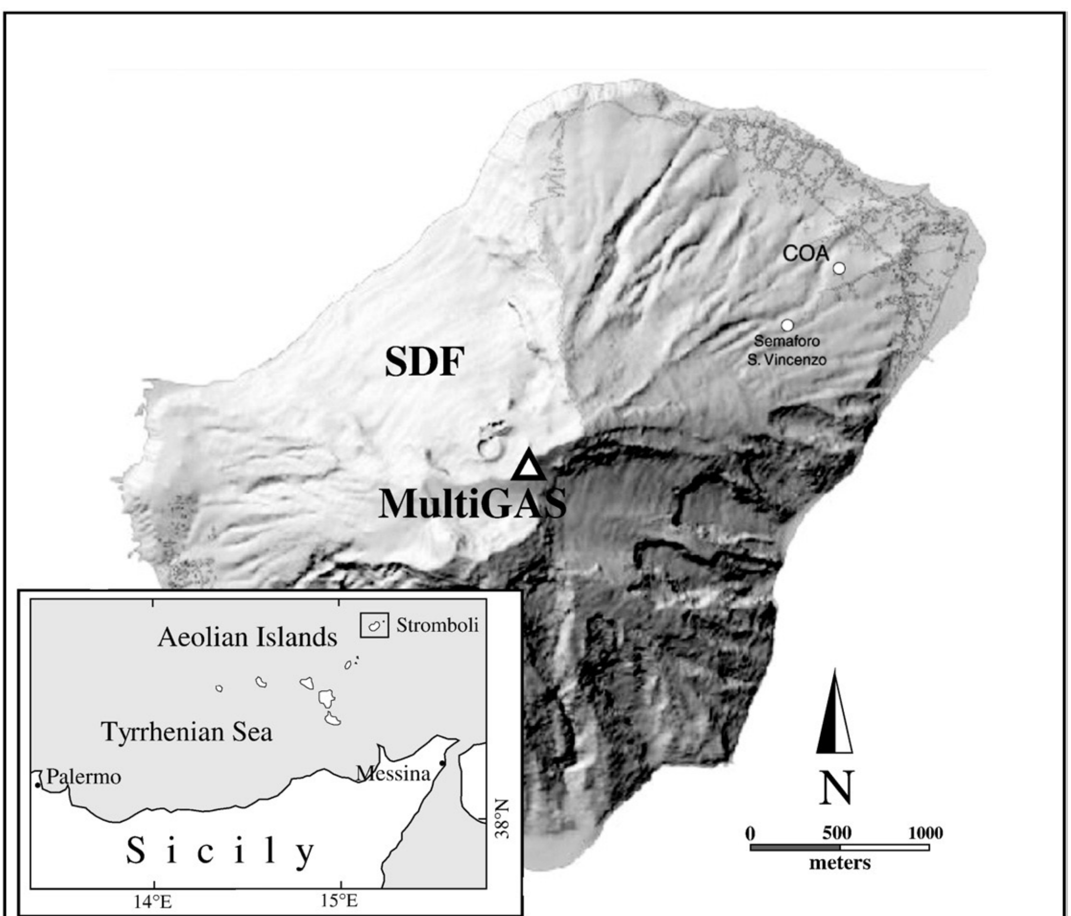

Fig. 2. Map of Stromboli volcano, showing the location of the automatic Multi-GAS on the summit crater's area at *Pizzo Sopra la Fossa* (triangle). SDF: Sciara del Fuoco.