Journal of Volcanology and Geothermal Research 188 (2009) 395–400

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Quantification of the gas mass emitted during single explosions on Stromboli with the SO_2 imaging camera

Toshiya Mori [a], Mike Burton [b,*]

[a] Laboratory for Earthquake Chemistry, Graduate School of Sci., Univ. of Tokyo, Japan
[b] Instituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy

ARTICLE INFO

Article history:
Received 15 June 2009
Accepted 10 October 2009
Available online 21 October 2009

Keywords:
magmatic degassing
remote sensing
gas imaging
Stromboli
Strombolian explosions

ABSTRACT

We performed measurements using an SO_2 imaging camera of the SO_2 gas mass emitted during five discrete explosive events on Stromboli volcano on 3 October 2006. The SO_2 gas mass released during discrete explosions was 15–40 kg per explosion, producing 3–8% of the total daily SO_2 gas emission, demonstrating that in terms of gas flux Strombolian explosions are a second-order phenomenon compared with quiescent degassing. Using the typical gas composition measured with OP-FTIR allows us to determine the total gas mass released during an explosion as 360–960 kg with a volume of 1500–4100 m^3 at 1 bar. At the probable source pressure of gas slug formation of 75 MPa this gas amount would occupy a volume equivalent to a sphere with a radius of 0.8–1 m, comparable with estimates of Stromboli's conduit geometry.

1. Introduction

Stromboli, the most easterly volcanic island in the Aeolian island archipelago, lies ~60 km north of Sicily, Italy, (see Fig. 1) and is one of the most active volcanoes in the world. The activity of the volcano is characterized by persistent degassing and intermittent mild eruptions ejecting incandescent bombs and gas, so called Strombolian eruptions (Barberi et al., 1993). The dynamics of Strombolian eruptions has been studied extensively by seismicity, geochemistry, infrasound and petrology by various researchers (e.g. Ripepe et al., 2002; Bertagnini et al., 2003; Chouet et al., 2003; Burton et al., 2007a). Recent advances in hand-held forward looking infrared radiometer (FLIR) cameras has allowed detailed observation of eruptive plume dynamics of Stromboli (Patrick et al., 2007; Patrick, 2007; Harris and Ripepe, 2007).

Stromboli is an ideal target to understand the relationship between eruptive activity, chemical composition and flux of volcanic gas (Allard et al., 1994). Although its persistent explosive activity hinders direct sampling of high temperature volcanic gas directly from the crater vents, the challenge of monitoring chemical composition has been recently surmounted by using new techniques such as FTIR (Mori and Notsu, 1997; Allard et al., 2005; Burton et al., 2007a) and MULTIGAS (Shinohara, 2005; Aiuppa et al., 2009). Burton et al. (2007a) successfully showed that volcanic gas at Stromboli for quiescent degassing and explosions has different chemical compositions and that swiftly ascending gas slugs are responsible for the explosive activity, rising from the volcano-crust interface at about 3 km depth.

Volcanic gas flux carries important information on both the amount of magma degassing and the magma plumbing system. Although the major volcanic gas component is water vapour, SO_2 has been the target of gas flux measurements (Stoiber et al., 1983; Galle et al., 2002; McGonigle et al., 2002) because of easy detection by remote ultraviolet spectroscopy and low background concentration. On Stromboli, fluxes have been found to range between 100 t/day and 1400 t/day with mean of several hundred tons per day of SO_2 (Allard et al., 1994; Allard et al., 2008). Recent installation of scanning ultraviolet spectrometers on the island has enabled automatic measurement of SO_2 flux at high temporal resolution (Burton et al., 2009), and the detection of elevated fluxes prior to paroxystic explosions.

While Strombolian eruptions occur with a frequency of 8–17 events/h at Stromboli (Harris and Ripepe, 2007), there are relatively few measurements of the gas flux released during the explosions. Allard et al. (1994) used air-borne COSPEC to detect a 40–400% increase in SO_2 flux during explosions relative to the quiescent flux. Several geophysical approaches have attempted to constrain the volume of gas involved in explosive activity; photoballistic measurements of jets (600–1200 m^3 gas/explosion, Chouet et al., 1974), acoustic measurements (1–100 m^3 gas/explosion, Vergniolle and Brandeis, 1996) and explosion quake modelling (~200 m^3 gas/explosion at source pressure, Chouet et al., 2003). To date there have been no direct volcanic gas measurements constraining the SO_2 amount emitted by a single Strombolian eruption. This is an important parameter, as it constrains the relative amount of gas lost quiescently compared with explosions, and highlights quantitatively the relative

* Corresponding author.
E-mail address: burton@pi.ingv.it (M. Burton).

0377-0273/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.jvolgeores.2009.10.005

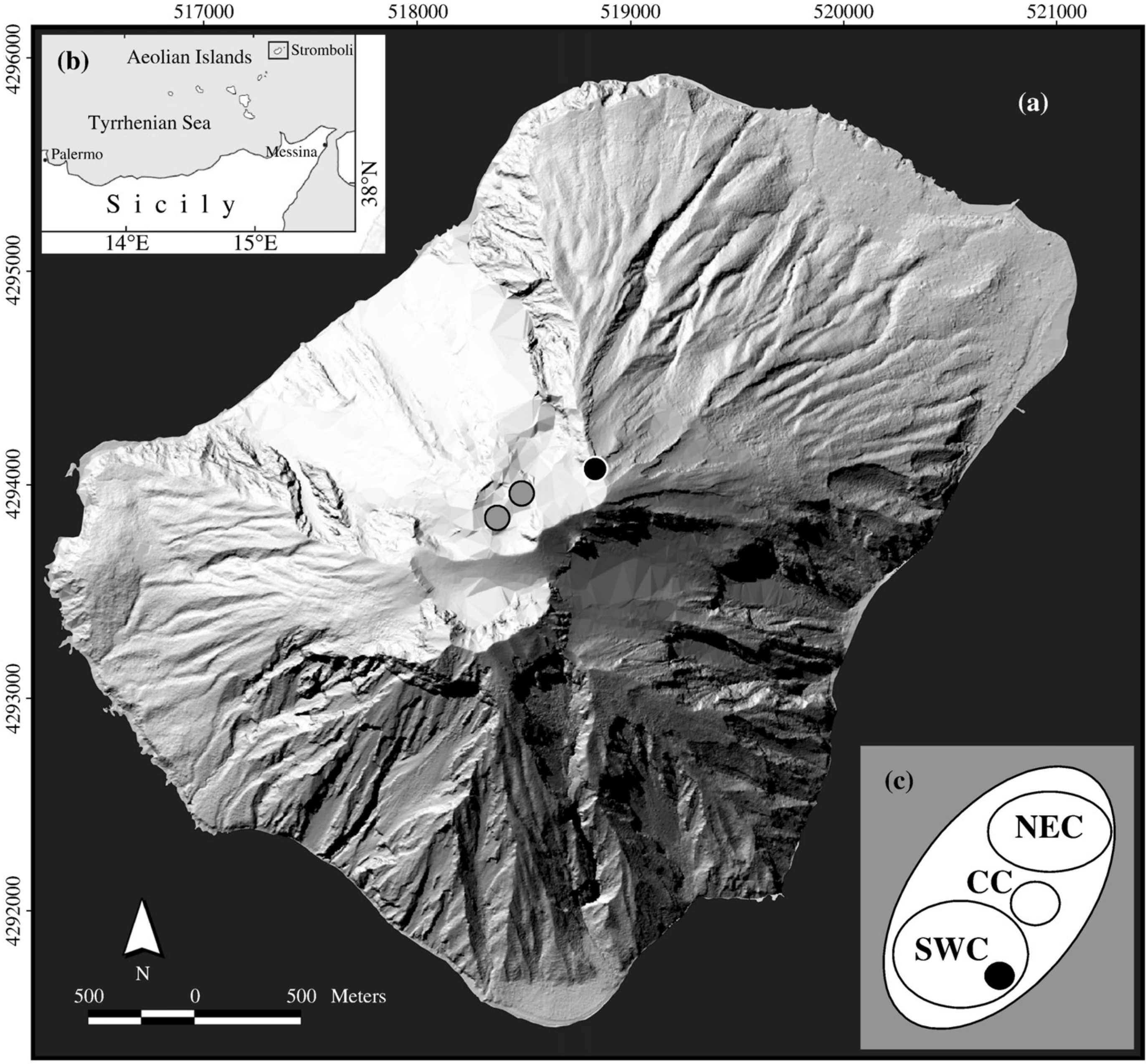

Fig. 1. (a) Map of Stromboli with the Roccetta observation site (black circle) and summit craters (grey circles) indicated. Approximate measurement distance is 650 m. (b) Inset indicating location of Stromboli with respect to Sicily. (c) Schematic map of the crater area, with Northeast crater (NEC), central crater (CC), Southwest crater (SWC) and hornito (black circle) indicated.

importance of each process in terms of magma supply and degassing. In this paper, we present the first measurements of SO_2 amounts emitted by single Strombolian events using the recently developed SO_2 imaging camera (Mori and Burton, 2006; Bluth et al., 2007).

2. SO_2 imaging camera measurements at the summit of Stromboli

The SO_2 imaging camera (Mori and Burton, 2006) consists of a UV-sensitive CCD camera (Apogee Alta U-260), C-mount quartz lens (Pentax B2528-UV) and UV bandpass filters (Asahi Bunko Co.). The camera sensor is a 512×512 pixel 16-bit CCD. In the original configuration of the SO_2 camera, two UV bandpass filters centred at 310 nm and 330 nm with FWHM of ~10 nm were used for image processing (Mori and Burton, 2006). The 310 nm filter is sensitive to both SO_2 absorption and aerosol attenuation, whereas the 330 nm filter is only sensitive to aerosol attenuation. Obtaining images alternately using the two filters allowed the aerosol attenuation to be removed, revealing the uncontaminated SO_2 signal.

On the afternoon of October 3, 2006, we took the SO_2 camera to the summit area of Stromboli and placed it at the Roccetta site (Fig. 1a), about 450 m from and at the same altitude as the crater terrace (~750 m), where the ascending plume emitted from the summit craters could be observed against the background sky. The NE crater was directly visible and Central and SW craters were hidden behind the NE crater. The eruption plumes of the Central and SW craters were only observed when they rose above the rim. On the South-eastern edge of the SW crater, there was a hornito several tens of meters high. The top of this hornito was directly visible from the Roccetta site above the crater terrace rim (Fig. 2).

At the time of observation, all the craters including the hornito were persistently degassing. The NE crater was the most vigorously degassing vent with puffing activity similar to the puffing conditions