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Characterizing high energy explosive eruptions at Stromboli volcano using multidisciplinary data: An example from the 9 January 2005 explosion

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ABSTRACT

Stromboli is well known for its persistent, normal explosive activity, consisting of intermittent, mild to moderate, Strombolian explosions that typically occur every 10–20 min. All tephras erupted during this activity usually fall back into the crater terrace, and consist of volatile-poor scoriae fed by Highly Porphyritic (HP) magma. More occasionally, large explosions or "paroxysms" eject a greater quantity of tephra, mainly consisting of HP scoriae and pumice clasts of Low Porphyritic (LP) magma, but also including large lithic blocks. In addition to this activity, between 2004 and 2006 high energy explosions, displaying an intermediate eruptive style between that of normal and paroxysmal explosions in terms of column height, duration and tephra dispersal, were observed to occur at a frequency of one to eight events per year. While many volcanological, geochemical and geophysical studies have focused in the last few years on the two end-members of activity, i.e. normal or paroxysmal, a detailed investigation on these intermediate types of events has not been carried out yet. Here we report of a study on the 9 January 2005 explosion, one of the high energy explosions during which the main fountaining phase lasted nearly a minute causing ejection of coarse bombs up to a height of 120 m, and of ash and lapilli to >200 m. An accompanying ash plume rose up to 500 m at the end of the explosion. We present a multidisciplinary approach that integrates the results from analysis of live-camera images with compositional and textural characterization of the erupted products. Major element composition of glassy groundmass and 3D views of textures in the erupted scoriae support the hypothesis based on volcanological observations that this explosion falls between normal and paroxysmal activity, for which we use the term "intermediate". By comparing the video-camera images of the 9 January 2005 explosion with volcanological features of other high energy explosions that occurred at Stromboli between June 2004 and October 2006, we find that three additional events can be considered intermediate explosions, suggesting that this type of activity may be fairly common on this volcano. The results of this study, although preliminary given our limited dataset, clearly indicate that the methodology used here can be successfully applied to better define the range of eruptive styles typifying the normal explosive activity, potentially improving our capability of eruption forecasting and assessing volcanic hazard at Stromboli.

1. Introduction

Stromboli is a 924 m-high volcano in the Aeolian Islands (Italy) that is well known for the persistent explosive activity from its summit vents located in a crater terrace at about 750 m a.s.l. (Fig. 1). The normal activity of the volcano consists of passive degassing (Burton et al., 2007) and intermittent, mild to moderate, Strombolian explosions (Bertagnini et al., 1999; Rosi et al., 2000; Patrick et al., 2007). These explosions usually occur from a single vent every 10–20 min on average and last between a few to 20 s, ejecting coarse material up to a height of 100–150 m that falls back to the crater terrace (Bertagnini et al., 1999). Within the range of this type of activity, the strongest explosions produce jets of magma and gas higher than 150-200 m, with material that may occasionally fall outside the crater rims. All tephras erupted during normal explosive activity are volatile-poor scoriae fed by Highly Porphyritic (HP) magma (Francalanci et al., 1999, 2004; Corsaro et al., 2005).

The eruptive history of Stromboli is also characterised by the occurrence of more violent events that exhibit much greater explosivity with respect to the normal bursts. Barberi et al. (1993) defined two classes of powerful events based on their intensity: more frequent and less hazardous "major explosions", and rarer and powerful "paroxysms". Bertagnini et al. (1999) simplified this classification naming all these events paroxysms due to the difficulty of distinguishing, in terms of the intensity of the phenomena, between the two classes of explosive activity. Later, Métrich et al. (2005) introduced the term "small-scale" paroxysm to name events of significantly lower intensity than paroxysmal explosions. More recently, Landi et al. (2008) suggested distinguishing "small-" from "large-scale" paroxysms. The former represent explosive events constituting a serious risk for people at the

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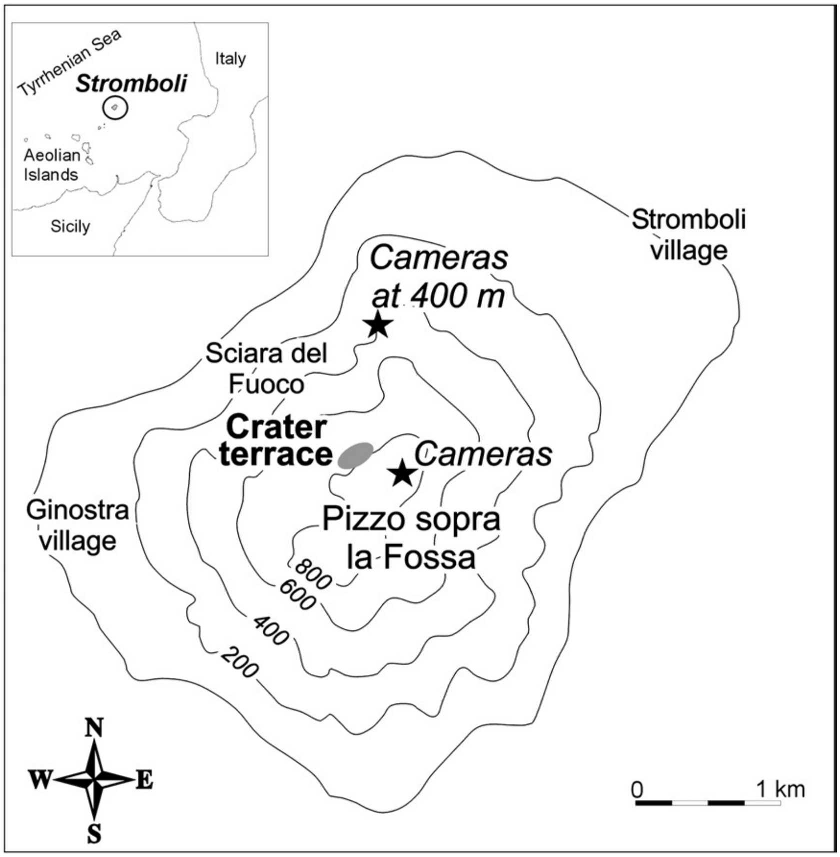

Fig. 1. Map of Stromboli volcano with locations of video-cameras.

summit of the volcano, like those occurring in September 1996, August 1998 and August 1999 (Métrich et al., 2005), while the latter may represent a potential hazard also for people living or staying at the foot of the volcano. Examples of this second kind of event are the 1919 and 1930 eruptions (Ponte, 1919; Imbò, 1928; Rittmann, 1931). In addition to HP scoria erupted during normal Strombolian explosions, large-scale paroxysms typically produce volatile-rich pumice clasts of Low Porphyritic (LP) magma (Métrich et al., 2001; Bertagnini et al., 2003; Métrich et al., 2005), as well as mingled products of the LP and HP type (Rosi et al., 2006). Frequently, but not always, small-scale paroxysms discharge also LP magma, like the August 1998 and 1999 major explosions of Bertagnini et al. (2003), re-named small-scale paroxysms by Landi et al. (2008).

In agreement with Bertagnini et al. (1999) and Landi et al. (2008), in this paper we use the term paroxysms (both small- and large-scale) to indicate explosive events characterised by higher magma jets, longer duration, more abundant ejection of incandescent material, and wider fallout dispersal in comparison to the normal explosive activity. In addition, we observe that more than one vent within the crater terrace is usually involved in the paroxysmal activity. Such a definition, therefore, includes a wide range of paroxysmal events that may greatly differ in eruptive intensity.

Between 1888 and 1986, the normal explosive activity at Stromboli was interrupted by an effusive eruption every 4 years (Barberi et al., 1993). The last two effusive events occurred in 2002–03 (Calvari et al., 2005) and between February and April 2007. These eruptions were accompanied by paroxysms on 5 April 2003 (Calvari et al., 2006; Rosi et al., 2006) and 15 March 2007 (Andronico et al., 2007). The eruptive magnitude of the 5 April 2003 paroxysm was enough to severely change the morphology of the crater terrace, leaving an almost flat area that does not allow us to recognize a clear morphology of the three summit craters as it was prior to the 2002–03 eruption. In the following, we conventionally refer to the three sectors within the crater terrace as Northern, Central and Southern sectors (Fig. 2), terminology commonly used before the 15 March 2007 paroxysm.

The 2002–03 effusive eruption, together with the 5 April 2003 paroxysmal episode, have marked a turning point in the study of the volcano, in terms of improvement of scientific results and number of research projects carried out. In the past, volcanological observations of Stromboli were performed in a discontinuous way and the range of the normal explosive activity poorly investigated. The first quantitative volcanological studies were those by Chouet et al. (1974) and Blackburn et al. (1976), followed by several other studies (e.g., Ripepe et al., 1993). Although these authors performed rigorous studies of eruption dynamics, they investigated restricted periods of the normal explosive activity, and no attempt was made to examine the eruptive variations in terms of explosion frequency and intensity. Since June 1996, the installing of a remote, live-camera pointing to the crater terrace allowed the researchers of the Istituto Internazionale di Vulcanologia (IIV) of Catania continuous, long-term monitoring of the explosive activity, thereby largely improving the quality and quantity of volcanological observations. This visible surveillance system was further enhanced after the 5 April 2003 paroxysmal episode, when the Istituto Nazionale di Geofisica e Vulcanologia, sezione di Catania (INGV-CT), formerly IIV, deployed a permanent video-camera network on the volcano consisting of four live cameras (Fig. 1).

Visual monitoring of the normal explosive activity is accompanied by periodical sampling of the products erupted from the vents. All the collected samples (ash, lapilli and bombs) are routinely analysed for componentry, morphological and petrochemical characterization at INGV-CT. Recently, synchrotron X-ray computed microtomography has been introduced to study the 3D textural features of scoria clasts (Polacci et al., 2006; 2007). Video-camera recordings help us to correlate sampled tephras to explosive events, a multidisciplinary