Journal of Volcanology and Geothermal Research 304 (2015) 118–125

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

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

Short communication

Unexpected hazards from tephra fallouts at Mt Etna: The 23 November 2013 lava fountain

Daniele Andronico *, Simona Scollo, Antonio Cristaldi

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Piazza Roma 2, 95125 Catania, Italy

A R T I C L E   I N F O

Article history:
Received 15 May 2015
Accepted 10 August 2015
Available online 18 August 2015

Keywords:
Mt. Etna
Lava fountain
Bomb fallout
Volcanic hazard
Highly explosive event

A B S T R A C T

Hundreds of paroxysmal episodes and a few long-lasting ash-emissions eruptions make Mt. Etna, in Italy, one of the most productive basaltic volcanoes in the world over recent years. This frequent explosive activity certainly gives volcanologists plenty of stimulating scientific material for study. Volcanic hazard from tephra fallout associated with lava fountains is still an issue that has not been fully assessed, albeit having to face this scenario several times in 2013.

The 23 November 2013 lava fountain was exceptionally intense despite the short duration of the paroxysmal phase (<1 h). Abundant decimetric-sized bombs fell within the first 5–6 km from the vent, and a macroscopically thicker and coarser tephra deposit than usual formed between 5 and 25 km; in addition, ash was reported to fall up to distances of 400 km. The analysis of fallout deposit provided a total erupted mass of $1.3 \pm 1.1 \times 10^9$ kg (for a mass eruption rate of $4.5 \pm 3.6 \times 10^5$ kg/s), in agreement with the value of 2.4×10^9 kg estimated by modeling. Grain-size distribution of samples shows poor sorting at least up to 25 km from the vent. By comparing dispersal, sedimentological features and physical parameters of the fallout deposit with other lava fountains of Etna, the 23 November 2013 episode may well be one of the largest events of the 21st Century in terms of eruption column height, total erupted mass and mass eruption rate. Furthermore, the impact of tephra on the territory was so high as to make it opportune to introduce a distinction, within the class of lava fountains, between small- and large-scale episodes. This classification can be a starting point for hazard assessment and help prevent the hazards from large-scale lava fountains at Etna in the future.

1. Introduction

Tephra dispersal, both in the atmosphere and on the ground, is one of the greatest hazards raised by volcanoes. Severe inconveniences can be caused by short-lived and high intensity (in terms of mass eruption rate) as well as long-lived but low intensity explosive eruptions (Houghton et al., 2006). Mt. Etna, in Italy, may in this regard be considered a particularly hazardous volcano due to the high frequency and variability of its explosive eruptions. In the last 20 years, two prolonged explosive events produced long-lasting tephra emission from lateral vents opened on the flanks of Etna (21 days in 2001 and 55 days in 2002–03; e.g. Scollo et al., 2007; Andronico et al., 2008a). Furthermore, more than 200 paroxysmal events took place from one of its summit craters, each lasting from hours to days (Andronico et al., 2014a); most of them occurred during long sequences over periods ranging from 1.5 to 16 months, which Andronico and Corsaro (2011) defined episodic eruptions. The most renowned sequences were in 2000 (64 events in ~5 months; Alparone et al., 2003; Andronico and Corsaro, 2011), 2011–12 (25 events in ~16 months; Andronico et al. 2014a; Behncke et al., 2014) and 2013 (two distinct sequences of 13 and 8 episodes in about 3 and 2 months, respectively; Andronico et al. 2014a). Most of these paroxysmal events occurred from the South-East Crater (hereafter SEC) and, since 2011, from a lateral vent where a new cone named New-South East Crater (hereafter NSEC) formed (e.g. Behncke et al., 2014). Single episodes share a common eruptive pattern characterized by the beginning of Strombolian activity (*resumption phase*), followed by lava fountains and typically the formation of an eruption column above the volcano (*paroxysmal phase*), and finally the exhaustion of the eruptive phenomena (*conclusive phase*) (Alparone et al., 2003). Hazard from tephra fallout mainly impacts aviation operations and road traffic, while minor damage affects crops and roofing (Barnard, 2004; Scollo et al., 2013). Fortunately, serious injuries are not common.

In the past, field survey and video-camera recordings have provided useful information on tephra fallout and related physical parameters, such as total erupted mass (TEM), mass eruption rate (MER) and total grain-size (TGS) (e.g. Andronico et al., 2014a, b). One of the most important aspects to take into account is that the TEM, MER and TGS may significantly change from episode to episode depending on the main features of the *paroxysmal phase*, whose duration commonly lasts from a few tens of minutes up to several hours, and with the eruption

* Corresponding author. Tel.: +39 0957165806; fax: +39 095435801.
E-mail address: daniele.andronico@ingv.it (D. Andronico).

http://dx.doi.org/10.1016/j.jvolgeores.2015.08.007
0377-0273/

style (e.g. Strombolian to lava fountaining activity; Andronico et al., 2014a, b). Such a wide value range in physical parameters is reflected on the different levels of hazards associated with tephra fallout, and demands an accurate assessment of eruptive scenarios with dissimilar duration and intensity.

The 23 November 2013 lava fountain from the NSEC generated abundant tephra fallout and has all the right features for a useful case study for the research described above. It was a dramatic event and for the first time after several years, it caused direct injury to people and damage to vehicles up to a few km from the vent. Moreover, this episode occurred during the morning with excellent visibility and the high intensity of the lava fountaining produced a very unusual tephra fallout deposit in terms of continuity, thickness and grain-size. This considerably reduced the systematic errors during field data collection when only tens to a few hundred grams per square meter of volcanic tephra are available on the ground. The eruption was first observed by a real time survey and field data (sample collection and mapping) were then undertaken within 24 h from the end of the episode (Andronico et al., 2013). Video-recordings were made by the cameras of the monitoring system of Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo (INGV-OE).

In this paper, we describe the fallout deposit and its effects on the territory, and give an estimation of TEM and MER by field and modeling studies. Results are then compared with selected paroxysmal events from Etna to properly evaluate the size and eruptive scenario of the 23 November 2011 lava fountain. The considerable volcanic hazard was related to the coarse-grained fallout with bomb-sized clasts in touristic areas, i.e. at distances of 5–6 km from the vent. The event makes a thorough investigation into the causes of high energy paroxysmal events a matter of urgency, especially to mitigate hazard from tephra fallout with its different kinds of impact (e.g. bomb fallout, building collapse, tephra road cover).

2. Chronology

The lava fountain episode was heralded by the resumption of weak Strombolian activity on the afternoon of 22 November, and started to intensify a few minutes after 07:00 GMT (local time = GMT + 1) of 23 November. The Strombolian explosions then grew in frequency and power rapidly enough to evolve after 09:30 GMT to typical lava fountains over a wide area on the top of the NSEC. Continuous, sustained gas jets lifted an extraordinary amount of molten lava clots within a darker envelope of finer pyroclasts (e.g. Allard et al. 2005) and accompanied by the formation of a thick and broad eruption column (Fig. 1). A detail chronology of the episode is reported in Bonaccorso et al. (2014) together with an estimation of magma jet and eruption column heights, i.e. 2500 m and 5–6 km above the vent (the NSEC top being 3300 m high), respectively. Nevertheless, our analysis gives dissimilar values for the magma jets, reaching up to ~1000 m of height on comparing direct observations and video-camera recordings. In our opinion, their significantly higher value is due to the fact that they included the beginning of the convective region of the eruption column in the estimation of the fountain jet. We agree though for the eruption column, estimated by photos taken on websites, higher than 9 ± 1.8 km above the sea level (a.s.l.) during the paroxysmal phase. The volcanic plume propagated between NE and ENE producing an uncommon heavy, coarse-grained fallout as far as the Ionian Sea. The paroxysmal phase lasted ~50 min (up to 10:20 GMT), then the lava fountaining ceased and we observed diminishing Strombolian activity for another 20 min before its total cessation after 11:15 GMT. During the eruption, volcanic lightning, phenomena not commonly observed at Etna and documented only for the 1819, 3–4 August 1979 and 16–17 April 1980 paroxysmal activity (Mather and Harrison, 2006), was also clearly visible even in daytime.

2.1. Main effects on the territory

The area around the shelter “Rifugio Citelli”, at ~5 km from the NSEC, was hit by a heavy bomb fallout. Here, the solar panel system was heavily impacted and scratched (Fig. 2a), while hikers who were heading down the path over the NE slope of the volcano were forced to take flight from the heavy pyroclastic rain. Some of them were injured but fortunately not seriously. A few vehicles parked or moving around the Rifugio Citelli area and along the Mareneve Road were struck and seriously damaged by the largest falling bombs (Fig. 2b, c, d), bikers climbing the Mareneve Road were also forced to make a quick escape both for the bomb fallout and the tephra thickness as well as the extremely slippery road surface (Fig. 2e).

The intense fallout caused extensive damage also to the vehicular traffic, mainly due to the temporary closure of the Messina–Catania

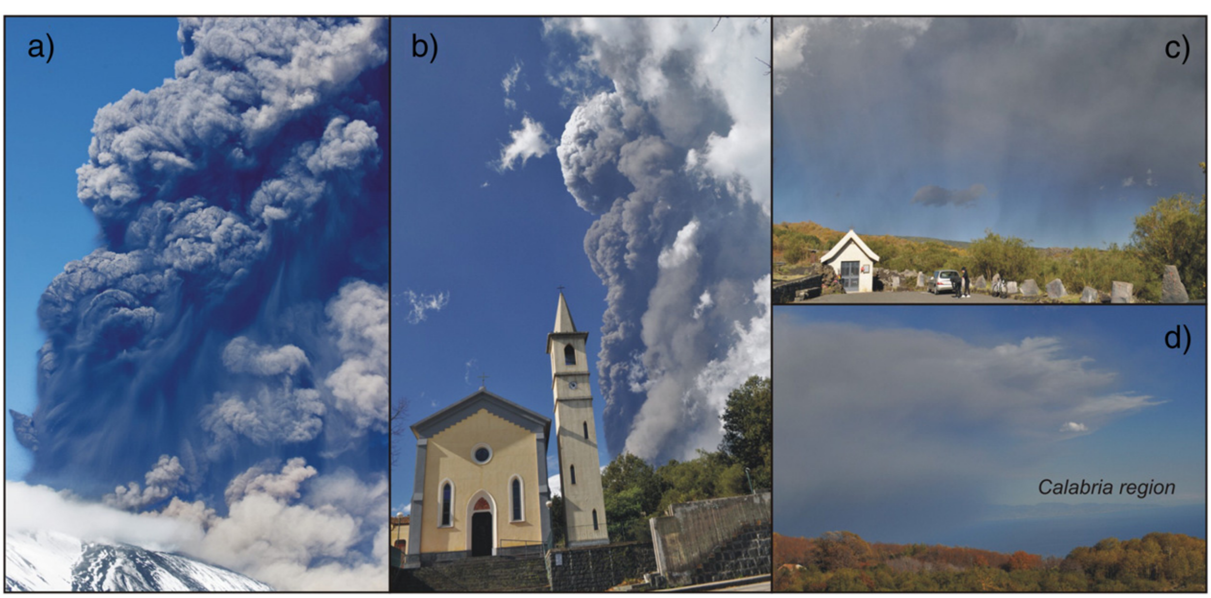

Fig. 1. Images of the eruption column above the volcano: a) the lower, turbulent portion view from the SE side of the volcano); b) view from the church of Fornazzo (E); c) view from the Mareneve road a few km above Fornazzo. Note the tephra fingers forming at the base of the plume and the bikers stopped on the roadside; d) the volcanic cloud moving to the NE toward the coast of Sicily and Calabria region. Photos: a, F. Mangiaglia; b–d, D. Andronico.