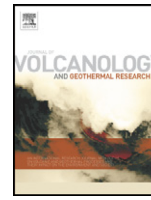
Journal of Volcanology and Geothermal Research 270 (2014) 10–21

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

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



The 2011–2012 summit activity of Mount Etna: Birth, growth and products of the new SE crater

Boris Behncke, Stefano Branca *, Rosa Anna Corsaro, Emanuela De Beni, Lucia Miraglia, Cristina Proietti

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

A R T I C L E I N F O

Article history:
Received 17 July 2013
Accepted 13 November 2013
Available online 28 November 2013

Keywords:
Etna
Summit eruptions
Scoria cone growth
Lava and tephra volume
Collapsing foam model

A B S T R A C T

Between January 2011 and April 2012, the Southeast Crater (SEC) on Mount Etna was the site of 25 episodes of lava fountaining, which led to the construction of a new pyroclastic cone on the eastern flank of the SEC. During these episodes lava overflows reached 4.3 km in length with an area of 3.19 km^2 and a volume of 28×10^6 m^3. The new cone, informally called New Southeast Crater (NSEC), grew over a pre-existing subsidence depression (pit crater), which had been formed in 2007–2009. The evolution of the NSEC cone was documented from its start by repeated GPS surveys carried out both from a distance and on the cone itself, and by the acquisition of comparison photographs. These surveys reveal that after the cessation of the lava fountains in April 2012, the highest point of the NSEC stood 190 m above the pre-cone surface, while the cone volume was about 19×10^6 m^3, representing 38% of the total (bulk) volume of the volcanic products including pyroclastic fallout erupted in 2011–2012, which is 50×10^6 m^3 (about 33×10^6 m^3 dense-rock equivalent). Growth of the new cone took place exclusively during the paroxysmal phases of the lava fountaining episodes, which were nearly always rather brief (on the average 2 h). Overall, the paroxysmal phases of all 25 episodes represent 51 h of lava fountaining activity — the time needed to build the cone. This is the fastest documented growth of a newborn volcanic cone both in terms of volume and height. Mean effusion rates during the lava fountaining episodes on 20 August 2011 (E11), as well as 12 and 24 April 2012 (E24 and E25) exceeded 500 m^3/s (with maximum rates of 980 m^3/s during E11) and thus they are among the highest effusion rates ever recorded at Etna. The composition of the erupted products varies in time, reflecting different rates of magma supply into the shallow feeding system, but without notable effects on the eruptive phenomenology. This implies that the dynamics leading to the episodic lava fountaining was largely, though not entirely, controlled by the repeated formation and collapse of a foam layer in the uppermost portion of the magmatic reservoir of the NSEC.

1. Introduction

The formation of pyroclastic cones can occur in different volcanic settings, such as in volcanic fields or at the summit or on the flanks of stratovolcanoes. Many of those newly constructed volcanic cones are typically related to mild to moderately strong explosive activity, ranging in magnitude from Strombolian to violent Strombolian and lava fountaining. The most common type of landform resulting from this type of activity is monogenetic scoria (or cinder) cones (Macdonald, 1972). Parícutin (Mexico), a large monogenetic scoria cone, is the most famous example of this type (Foshag and Gonzalez, 1956; Luhr and Simkin, 1993); another well documented case is the growth of the "Laghetto" cone on the south flank of Mount Etna (Italy) in 2001 (Calvari and Pinkerton, 2004; Fornaciai et al., 2010) and two large coalescent scoria cones formed during the 2002–03 Etna eruption (Andronico et al., 2005; Fornaciai et al., 2010). Conversely, long periods of repeated explosive activity form large polygenetic cones. The growth of this type of polygenetic volcanic landform has been observed right from its birth in some recent cases such as Cerro Negro in Nicaragua (McKnight and Williams, 1997). The growth of the Pu'u 'Ō'ō cone at Kīlauea volcano (Hawai'i) is particularly well documented (Heliker and Mattox, 2003; Heliker et al., 2003). On Etna volcano the explosive activity at its summit vents has led to the growth of large scoria cones during the XX century (Fig. 1). In particular, in May 1911 a 100 m wide pit crater was formed by collapse at the northeast base of the summit cone at 3100 m a.s.l. (Ponte, 1920). In the following years this new chasm, named Northeast Crater (NEC), soon became the site of intense explosive activity, which, especially between 1955 and 1981, led to the growth of a polygenetic scoria cone. Between 1977 and 1981, the NEC cone grew to become the highest point of Etna, at 3350 m a.s.l. (Tanguy and Patanè, 1984; Chester et al., 1985), though later collapse of its crater rims reduced its height to 3329 m (Neri et al., 2008). In the same way, the youngest and presently most active of Etna's summit craters, named the Southeast Crater (SEC), was formed in May 1971 at the southeast base of the summit cone (Calvari et al., 1994; Alparone et al., 2003; Behncke et al., 2006, 2008). Although the eruptive activity of the SEC has involved numerous and relatively closely-spaced vents,

* Corresponding author. Tel.: +39 095 7165800.
E-mail address: stefano.branca@ct.ingv.it (S. Branca).

0377-0273/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jvolgeores.2013.11.012

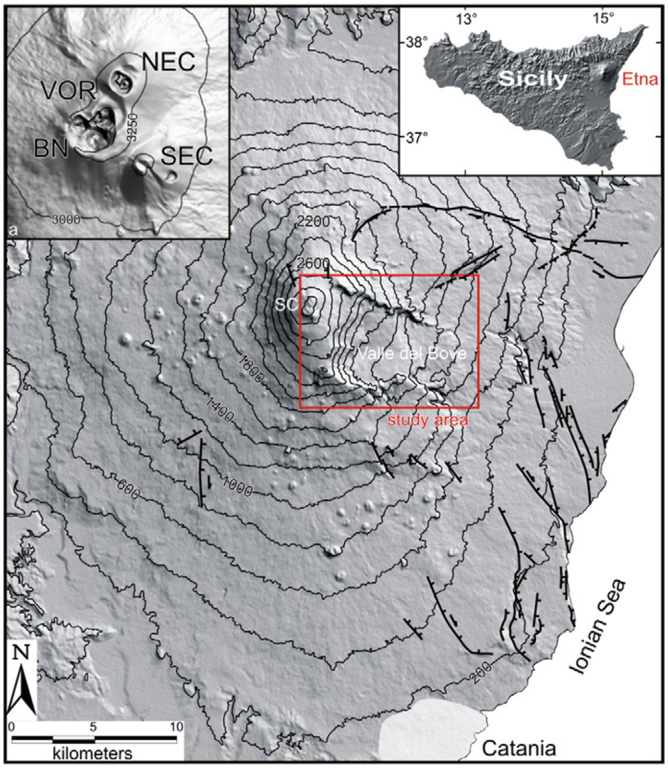


Fig. 1. Shaded relief of Mount Etna volcano. The red rectangle is the investigated area. a) 2007 shaded relief of the summit craters of Etna. NEC = Northeast Crater; VOR = Voragine; BN = Bocca Nuova; SEC = Southeast Crater.

a larger central or main vent has nearly always been present, presumably corresponding to the permanent main conduit of the crater.

In this paper we first provide a brief chronology of the 2011–2012 eruptive activity and then proceed to the reconstruction of the morphological evolution of the new cone formed on the eastern SEC slope, and finally quantify the main volcanological parameters and the geometry of the lava flow fields emplaced during all eruptive episodes. Furthermore, we benefit from lava and pyroclasts sampled during the monitoring activity and analyze them for the glass and bulk rock compositions. Our results are based on the integration of data collected through a multidisciplinary monitoring approach based on a combination of direct observation, field topographic surveys and petrological analysis of the products. In particular, the method applied for mapping and quantifying the lava flow field proved to be straightforward, allowing us to rapidly obtain the necessary quantitative information (front positions, flow lengths, number of branches). Moreover, it provides reliable measurements (lava flow volume, area, length, etc.) useful for monitoring activity of an on-going phenomenon. Petrologic data, collected as regularly as possible, proved to be an efficient tool to evidence the compositional changes of the erupted magma with time, in order to detect possible variations of pre-eruptive magma dynamics which, somehow could affect the evolution of eruptive style. The effort of combining different monitoring data into an integrated approach developed within a GIS (geographic information system) platform represents a key aspect for promptly providing information to Civil Protection and supporting the management of an eruptive crisis, especially when dealing with a densely populated and potentially hazardous volcano like Mount Etna in Sicily.

2. Volcanic activity at the New Southeast Crater

2.1. Prelude: collapse pits

Like all four present summit craters of Etna, the SEC was initially a pit formed mainly by internal collapses between 1971 and 1983. Small pyroclastic cones began to build up within this pit in the mid-1980s and, starting in 1989, a much larger cone began to grow around the main vent of the SEC. The period of the most rapid growth – by nearly 100 m – coincides with sequences of dozens of brief but intense episodes of violent Strombolian activity and/or lava fountaining, between fall 1998 and summer 2001, after which the summit of the cone reached approximately 3290 m a.s.l., 240 m above the pre-1971 surface (Behncke et al., 2006).

Between November 2004 and November 2009, a series of collapse pits formed in various locations on the eastern flank of the SEC cone (Fig. 2). The first of these, P1, was located high on the flank and was filled during renewed eruptive activity at the summit of the SEC in the fall of 2006, but while the 2006 eruption was still ongoing, a new pit (P2) formed about midway up the same flank. Differently from P1, which showed only minor eruptive activity (emission of lithic ash) throughout its existence, P2 did produce Strombolian activity and ash emissions during the late phase of the 2006 eruption (Behncke et al., 2008). P2 was obliterated during a series of four paroxysmal eruptive episodes in March–May 2007, but a new collapse pit, P3, was formed in late-May 2007 on the lower E flank of the SEC cone. This latest vent was the site of three powerful paroxysmal episodes between September 2007 and May 2008 (Andronico et al., 2008; Bonaccorso et al., 2011) which enlarged the pit. Although significant amounts of pyroclastics were deposited around P3 during these events, they failed to build a true pyroclastic cone.

On 6 November 2009, a small elliptical pit (P3a) opened on the lower eastern lip of P3; two years later, the site of this new pit was occupied by a large pyroclastic cone informally named "New Southeast Crater cone" (NSEC cone). This cone grew during a series of lava fountaining episodes in 2011–2012, which are described in more detail in the next section while the cone growth is quantified in Section 4.

2.2. Volcanic activity in 2011–2012

Between January 2011 and April 2012, all eruptive activity at the NSEC was concentrated in brief episodes of vigorous lava fountaining, pyroclastic emission, and generation of lava flows; such episodes are also known as "paroxysms". In total, 25 episodes (E01–E25; Table 1) took place and produced significant morphological changes in the summit area of the volcano, most notably the growth of the NSEC cone around the former pit crater (P3a).

The year 2011 marked the return of magmatic activity at Etna (Ganci et al., 2012; Bonaccorso et al., 2013; Patanè et al., 2013), one-and-a-half year after the end of its latest flank eruption (13 May 2008–6 July 2009). Following a few days of small emissions of hot material (gas with a minor proportion of pyroclasts), an episode of vigorous Strombolian activity occurred from P3a during the night of 2–3 January. Ten days later, the same crater produced the first (E01) in a series of paroxysmal eruptive episodes (Vicari et al., 2011). The whole sequence of events is detailed in Table 1, whereas more general aspects are discussed in the following paragraphs.

The paroxysmal episodes were all confined to the NSEC and vents on its southeastern, southern, and northern flanks. In the early events, at least two or three vents were active within the crater, one of which was located near its eastern rim, next to the place where lava spilled out of the crater. The first vent to open outside the crater itself was active at a late stage of the 10 April episode (E03; see Table 1), but during the next five episodes all activity occurred from vents within the crater.

Signs of structural weakening of the southeastern flank of the growing new cone were evident first during the 12 August episode (E10) when, shortly after the end of the main paroxysmal phase, a small vent opened on the flank, and emitted a very small volume. The same vent produced a more sizeable lava flow during the next episode on 20 August (E11). Finally, on 29 August episode (E12), the entire southeastern flank of the cone fractured, giving a curtain of fire from a short fissure which extended down nearly to the base