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A case history of paroxysmal explosion at Stromboli: Timing and dynamics of the April 5, 2003 event

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Abstract

On April 5, 2003, Stromboli volcano (Italy) produced the most violent explosion of the past 50 years. The event was exceptionally well documented thanks to the presence on the island of several scientists and a large number of instruments deployed over the preceding months to monitor the effusive eruption that began in December 2002. Integration of visual documentation, deposit features and geophysical data allowed an accurate reconstruction of the explosive event and its dynamics. The eruption consisted of a 8-min long explosive event which evolved through four phases whose timing was precisely recorded by an infrared thermometer located about 450 m from the summit crater. Phases 2 and 3 lasted 39 and 42 s, respectively. Both had an impulsive character, were responsible for ejecting almost the entire mass of the pyroclastic products. Phases 1 and 4 represented, respectively, a short-lived precursory event and a waning tale. During Phase 2, meter-sized ballistic blocks were launched with velocities of 170 m/s to altitudes of up to 1400 m above the craters. These fell on the volcano flanks and on the village of Ginostra, about 2 km distant from the vent. A vertical jet rose above the craters which developed to feed a convective plume that reached a height of up to 4 km. The calculated mass of the Phase 2 fallout deposit and mass discharge rate were $1.1–1.4\times10^8$ kg and $2.8–3.6\times10^6$ kg/s, respectively. During Phase 3 a scoria flow deposit, with an estimated volume of $0.9–1.1\times10^4$ m^3, was erupted from the same vent that fed the ongoing sustained lava flow. The average mass discharge rate for this phase was $2.5–3.1\times10^5$ kg/s.

Products emitted during Phases 2 and 3 consisted of lithic and fresh magmatic material in similar proportions. The juvenile fraction consisted of a deep-originated, almost aphyric, highly vesicular pumice mingled with a shallow-derived, crystal-rich, moderately vesicular scoria.

Similarities with the eruption dynamics of other historical paroxysms at Stromboli makes the April 5, 2003 explosion representative of these highly energetic events that constitute the most hazardous volcanic phenomena at Stromboli volcano.

Keywords: stromboli; Thermal monitoring; paroxysm; explosive dynamics; ballistic ejecta

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1. Introduction

Stromboli island, located in the Tyrrhenian Sea 60 km north of Sicily (Fig. 1), is a 924 m high volcanic cone, which rises from a depth of 1500–2000 m below sea level. The most prominent feature of the island is the Sciara del Fuoco, a horseshoe-shaped depression bounded by steep cliffs hundreds of meters high, which formed as a result of a series of slope failures [1]. The current activity of Stromboli has likely persisted since the IV–VII century AD. Activity has been dominated, at least over the last two centuries, by low-energy, Strombolian explosions that usually occur at intervals of 10–20 min from vents within an elliptical, SW–NE elongated, crater area located at an elevation of 700 m [2] (Fig. 1). The persistent activity is accompanied at intervals of years by lava flow emission onto the Sciara del Fuoco. Strombolian explosions and lava flows are fed by a crystal-rich HK basalt, probably residing in the shallow part of the magmatic system. This normal activity is occasionally broken by discrete, violent explosions called 'paroxysms' [3]. These consist of explosive events of several minutes in duration that launch blocks up to 2–3 km from the source, damaging the settled area, and feed a vertical column of gas and pumice extending to several kilometers in height [4,5]. These events occur suddenly, during persistent mild activity and appear not to be preceded by any anomalous activity or instrumental precursors. Because of their violent and unpredictable nature, paroxysms represent a major threat to people either visiting the volcano summit or living in the settled areas.

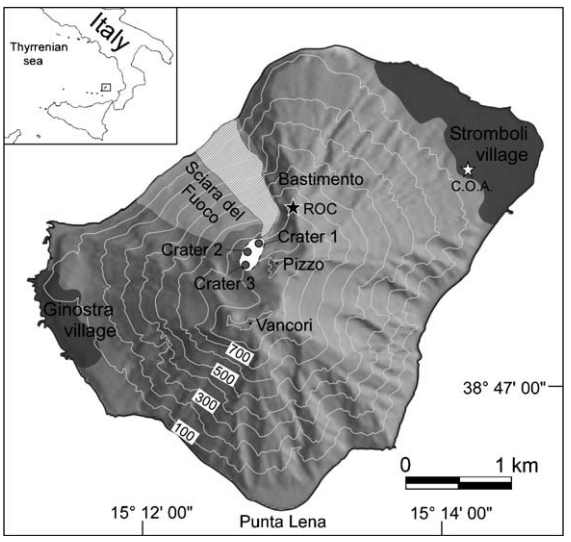

Fig. 1. Map of Stromboli Island. White zone: summit crater area; striped zone: 2002–2003 lava flow field; black star: location of IR thermal station (ROC); white star: location of Italian Civil Protection Center (COA).

On April 5, 2003, at 9:13 local time (7:13 GMT), a paroxysmal eruption occurred while an effusive eruption was in progress. At that time the Italian Civil Protection and scientific personnel were present on the island to handle and monitor the eruptive crisis. The paroxysm was observed, photographed and filmed by several researchers. In addition to visual observations, instruments deployed in the preceding months provided an unprecedented geophysical and geochemical record that could be applied to fully document and understand the paroxysmal event. In this paper we analyze the visual documentation of the event and assess the time correlations with thermal radiometer, seismic and acoustic records to precisely track the progression of the different eruptive phases. Accurate field analysis of pyroclastic deposits carried out shortly after the paroxysm are added to further constrain the event and to make inferences regarding the origins of the different eruptive phenomena and to assess the physical volcanology of the event. Integration of all data sets provides a compelling quantitative reconstruction that sheds new light on the intimate dynamics of these events.

2. The 2002–2003 eruptive crisis and the paroxysmal explosion of April 5, 2003

The 2002–2003 eruptive crisis of Stromboli began in the late afternoon of December 28, 2002, when lava flows were generated by vents opening in the NNE sector of the Sciara del Fuoco and from the crater area (crater 1, Fig. 1). The onset of the lava emission was accompanied by a substantial destabilization and seawards displacement of the Sciara del Fuoco and the generation of moderate scale avalanches of dry volcanic debris [6]. On December 30, 2002 the lava emission and concurrent slope movements culminated in a catastrophic slide that involved both subaqueous and subaerial parts of the Sciara del Fuoco [7]. The slide led to the formation of tsunami waves that caused extensive damage to the village of Stromboli along the northeastern coast of the island [8]. A drop in the magma level within the central conduit, produced by the opening of vents at 500 m a.s.l., also resulted in the collapse of the summit craters and the temporary cessation of the usual mild explosive activity [9].

On April 5, with lava emission still in progress from vents located at 600 m a.s.l. and the summit craters clogged with debris, a paroxysmal explosion occurred. The paroxysm was accompanied by a cannon-like detonation and the formation of a compressive wave