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The evolution of the Sciara del Fuoco subaerial slope during the 2007 Stromboli eruption: Relation between deformation processes and effusive activity

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ABSTRACT

Focusing on the Island of Stromboli, this research investigates whether airborne remote sensing systems, such as those based on digital photogrammetry and laser scanner sensors, can be adopted to monitor slope deformation and lava emplacement processes in active volcanic areas. Thanks to the capability of extracting accurate topographic data and working on flexible time schedules, these methods can be used to constrain the regular and more frequent measurements derived from satellite observations. This work is dedicated to the monitoring of Stromboli's volcanic edifice which is beneficial when obtaining quantitative data on the geometry of deformation features and the displaced (failures and landslides) and emplaced (lava flows) volumes. In particular, we focus on the capability of extracting average effusion rates from volume measurements that can be used to validate or integrate satellite-derived estimates.

Since 2001, a number of airborne remote sensing surveys, namely Digital Photogrammetry (DP) and Airborne Laser Scanning (ALS), have been carried out on Stromboli's volcano to obtain high resolution Digital Elevation Models (DEM) and orthophotos with sub-meter spatial resolution and a time schedule suitable for monitoring the morphological evolution of the surface during the quiescent phases. During the last two effusive eruptions (2002–2003 and 2007) the surface modifications, created on the Sciara del Fuoco slope and on the crater area as a consequence of effusive activity, were quantified and monitored using the same methodologies. This work, which is based on the results obtained from the multi-temporal quantitative analysis of the data collected from 2001 to 2007, mainly focuses on the 2007 eruption but also accounts for analogies and differences regarding the 2002–2003 event. The 2007 eruption on the Sciara del Fuoco slope from 27 February until 2 April, produced a compound lava field including a lava delta on the shoreline, discharging most of the lava into the sea. The comparison of the 2007 DEMs with a pre-eruption surface (2006 LIDAR survey) allowed for the evaluation of the total lava volume that accumulated on the subaerial slope while two syn-eruption DEMs were used to calculate the average effusion rates during the eruption. Since the evolution of a lava field produced during an eruption can be seen as a proxy for the magma intrusion mechanism, hypotheses are formulated on the connection between the lava discharge and the instabilities suffered by the slope.

1. Introduction

The recent history of Stromboli's volcano showed that major effusive eruptions can be accompanied by large deformations along the Sciara del Fuoco (SdF) slope. As a matter of fact, the slope can be affected by both wide landslides with tsunamogenic potential, such as those observed in 2002–2003 (Tommasi et al., 2003, 2005; Maramai et al., 2005), or that presumably connected to the 1930 eruption (Rittmann, 1931) and also by large deformations which were not followed by any destructive movement, such as those observed in 2007.

On- and off-shore investigations for analysing morphological features related to recent volcanic activity have been performed on Stromboli Island since 2001. Surveying activity intensified during the 2002–2003 eruption and was then regularly performed to assess and monitor potential instability phenomena (Puglisi et al., 2005; Baldi et al., 2005, 2008a,b). The surveys carried out between 2006 and 2007 were dedicated to the observation of the 2007 eruption.

The analysis presented here is focused on reconstructing the geometry of the instability phenomenon and its relationship to the effusive activity of the 2007 eruption. In order to conduct this investigation, Digital Elevation Models (DEMs), with an accuracy range of between 0.2 and 0.5 m, were extracted from the data collected by AP and ALS surveys (Table 1). AP surveys also provided images to generate digital orthophotos at a scale greater than 1:5000 (pixel size ranging from 0.5 to 1 m). Aerial data was integrated with orthorectified oblique aerial images (Table 1) taken during daily helicopter surveys by the Italian Department for Civil Protection (DCP). This approach, based on

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the use of a scientific software specific to the orthorectification of oblique aerial images, increased the quantity of the available georeferenced information (vent and fracture locations, lava field extension, etc.). A multi-temporal analysis of the DEMs allowed for the evaluation of the height variations that were connected to the 2007 eruptive phenomena, i.e. the large deformations that affected the upper portion of the SdF slope and the lava flows emplaced on the subaerial portion of the slope, including the large lava delta built up along the coastline.

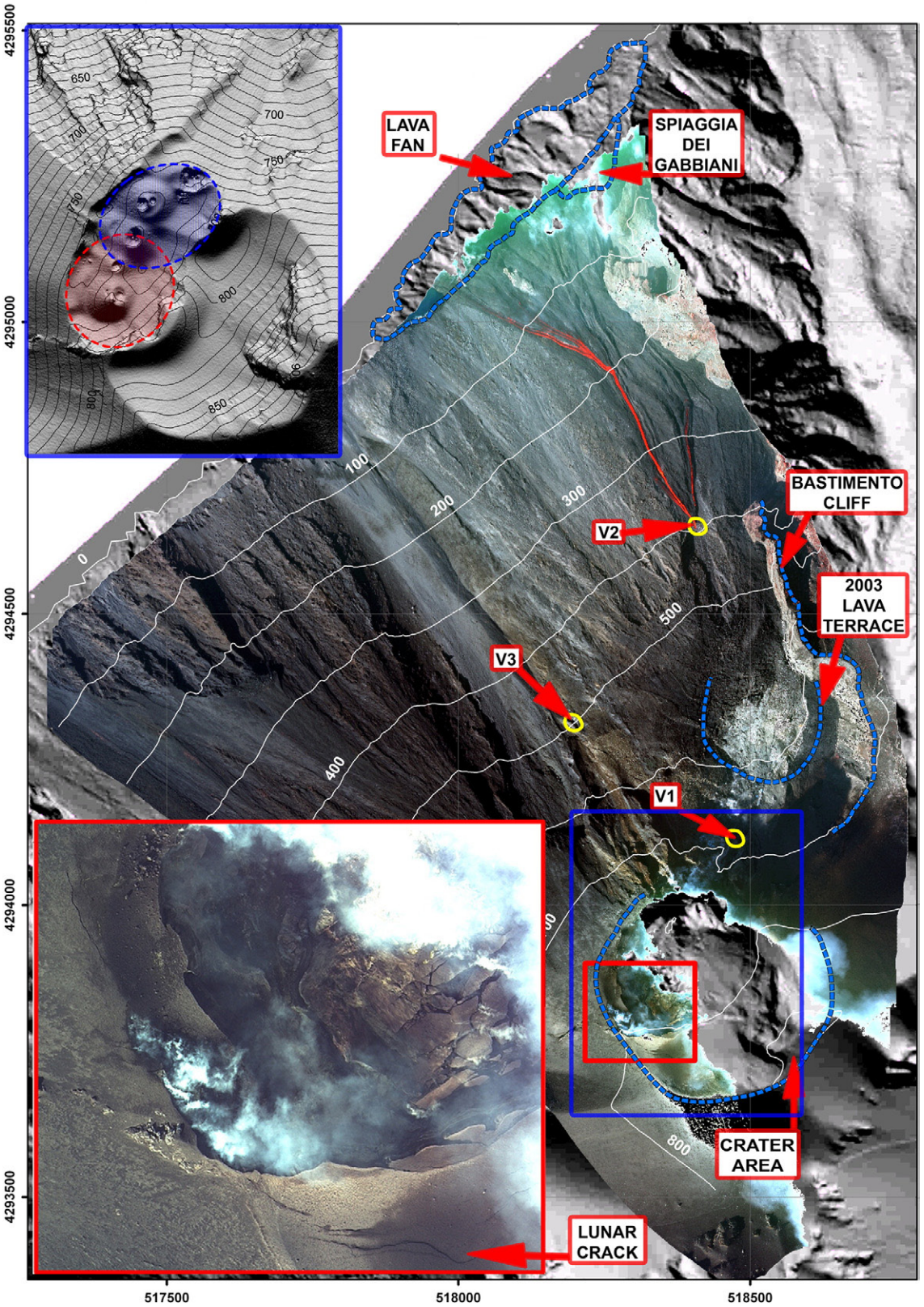

Fig. 1. Orthophoto of 15 March 2007 showing the Sciara del Fuoco slope during the eruption. The background image is a shaded relief view of the pre-eruption DEM. The inset in the top left corner indicates approximately, on the 2006 topography, the North (blue highest ellipse) and South (red lowest ellipse) craters and the vents roughly aligned along a SW–NE direction (azimuth of about 25°). The inset in the bottom left corner shows a magnification of the crater area. (For the colour version of this figure the reader is referred to the web version of this article.)