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Short communication

Merging field mapping and numerical simulation to interpret the lithofacies variations from unsteady pyroclastic density currents on uneven terrain: The case of La Fossa di Vulcano (Aeolian Islands, Italy)

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ABSTRACT

In order to obtain results from computer simulations of explosive volcanic eruptions, one either needs a statistical approach to test a wide range of initial and boundary conditions, or needs using a well-constrained field case study via stratigraphy. Here we followed the second approach, using data obtained from field mapping of the Grotta dei Palizzi 2 pyroclastic deposits (Vulcano Island, Italy) as input for numerical modeling. This case study deals with impulsive phreatomagmatic explosions of La Fossa Cone that generated ash-rich pyroclastic density currents, interacting with the topographic high of the La Fossa Caldera rim. One of the simplifications in dealing with well-sorted ash (one particle size in the model) is to highlight the topographic effects on the same pyroclastic material in an unsteady current. We demonstrate that by merging field data with 3D numerical simulation results it is possible to see key details of the dynamical current-terrain interaction, and to interpret the lithofacies variations of the associated deposits as a function of topography-induced sedimentation (settling) rate. Results suggest that a value of the sedimentation rate lower than 5 kg/m^2 s at the bed load can still be sheared by the overlying current, producing tractional structures (laminae) in the deposits. Instead, a sedimentation rate higher than that threshold can preclude the formation of tractional structures, producing thicker massive deposits. We think that the approach used in this study could be applied to other case studies (both for active and ancient volcanoes) to confirm or refine such threshold value of the sedimentation rate, which is to be considered as an upper value as for the limitations of the numerical model.

1. Introduction

Pyroclastic density currents (PDCs) represent the most devastating phenomena of explosive eruptions, and for this are extensively studied on active volcanoes to addressing the associated hazard (e.g. Wright et al., 2016). Unfortunately, they are very difficult to measure during actual eruptions, and most of our knowledge is based on the geological characteristics of their deposits, on laboratory experiments, and on computer simulations (e.g. Giordano and Dobran, 1994; Neri et al., 2007; Dellino et al., 2011; Doronzo, 2012; Esposti Ongaro et al., 2012; Sulpizio et al., 2014; Lube et al., 2015). On the other hand, results of the computer simulations are rarely merged with the geological evidence of pyroclastic deposits. It is quite challenging to reconcile results of a fluid dynamic model with the actual characteristics of field deposits, especially in the case of unsteady impulsive eruptions not related to sustained fountaining in a long-lived eruption (Cas and Wright, 1987; Branney and Kokelaar, 2002; Scarpati et al., 2014). Generally, unsteady eruptions are the result of discrete, short-lived multiple explosions. In many cases, explosive eruptions leave on the ground a succession of layers and beds related to multiple currents (or pulses), so the final lithofacies architecture may be the result either of a change in the fluid dynamic regime of a single current, or of the transition from one current to the other, or both. To add complexity, sedimentation processes within PDCs can strongly be affected by the morphological changes of the terrain encountered during runout (channels, positive and negative slopes). The current-terrain interaction leads to variations of flow velocity as for the topographic change, and this can strongly influence the sedimentation rate, with consequent variations of the lithological features in the deposits (Giordano and Dobran, 1994; Branney and Kokelaar, 2002; Sulpizio and Dellino, 2008; Sulpizio et al., 2008).

The formation of pyroclastic deposits, and more generally of all sedimentary deposits, is dictated by the rules of sedimentology, on the

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other hand the principles of classic stratigraphy may not always apply when interpreting PDCs and their deposits, especially in the case of changes in the lithofacies with runout distance. Therefore, we must left open the possibility that a PDC can experience different depositional styles, as a function of the dynamical evolution of the time-dependent depositional processes and of the space-dependent topographic changes involved. As an application of these concepts, we propose and develop here by means of a multidisciplinary approach the case study of the PDCs related to the Grotta dei Palizzi 2 pyroclastic succession at La Fossa di Vulcano, Aeolian Islands (Italy) (Dellino et al., 2011; De Astis et al., 2013a, 2013b). We stress that we do not explore in detail the physics of PDCs nor review the sedimentological details of their

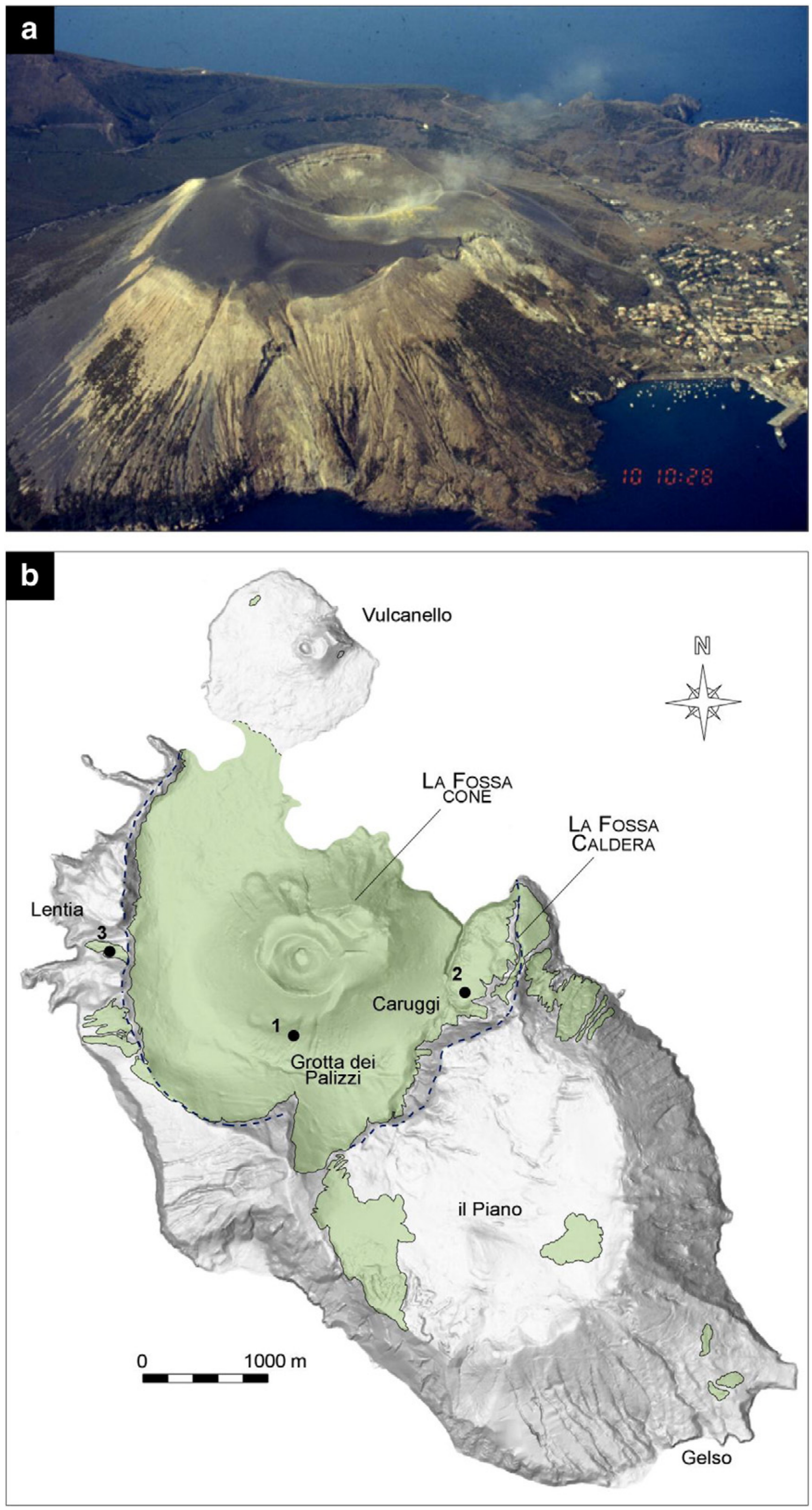

Fig. 1. a, Aerial photograph showing the La Fossa Cone at Vulcano Island, with the La Fossa Caldera walls in the background; b, Digital elevation model of the island of Vulcano showing the areal distribution of the Grotta dei Palizzi 2 deposits (from De Astis et al., 2013b). The main morphostructural features and localities taken as reference in this paper are shown.