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Discriminating the long distance dispersal of fine ash from sustained columns or near ground ash clouds: The example of the Pomici di Avellino eruption (Somma-Vesuvius, Italy)

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ABSTRACT

Ash samples from tephra layers correlated with the Pomici di Avellino (Avellino Pumice) eruption of Somma-Vesuvius were collected in distal archives and their composition and particle morphology investigated in order to infer their behaviour of transportation and deposition. Differences in composition and particle morphologies were recognised for ash particles belonging to the magmatic Plinian and final phreatomagmatic phases of the eruption. The ash particles were dispersed in opposite directions during the two different phases of the eruption, and these directions are also different from that of coarse-grained fallout deposits. In particular, ash generated during magmatic phase and injected in the atmosphere to form a sustained column shows a prevailing SE dispersion, while ash particles generated during the final phreatomagmatic phase and carried by pyroclastic density currents show a general NW dispersion. These opposite dispersions indicate an ash dispersal influenced by both high and low atmosphere dynamics. In particular, the magmatic ash dispersal was first driven by stratospheric wind towards NE and then the falling particles encountered a variable wind field during their settling, which produced the observed preferential SE dispersal. The wind field encountered by the rising ash clouds that accompanied the pyroclastic density currents of the final phreatomagmatic phase was different with respect to that encountered by the magmatic ash, and produced a NW dispersal. These data demonstrate how ash transportation and deposition are greatly influenced by both high and low atmosphere dynamics. In particular, fine-grained particles transported in ash clouds of small-scale pyroclastic density currents may be dispersed over distances and cover areas comparable with those injected into the stratosphere by Plinian, sustained columns. This is a point not completely addressed by present day mitigation plans in case of renewal of activity at Somma-Vesuvius, and can yield important information also for other volcanoes potentially characterised by explosive activity.

1. Introduction

Volcanic ash (diameter < 2 mm) is the result of intense magmatic or phreatomagmatic fragmentation during explosive eruptions. After injection into the atmosphere, the ash is dispersed as convective columns and umbrella clouds, which are subjected to the combined effects of gravity and wind speed, or are transported close to the ground as pyroclastic density currents (e.g. Cas and Wright, 1987). Irrespective of the eruptive mechanism or intensity, ash particles usually affect wide areas around volcanic centres, and have a greater mobility than the coarse-grained parental deposits. This is mainly due to the effect of atmospheric viscosity that influences their settling behaviour in much more efficient way than that of coarse-grained and heavier particles (Bonadonna et al., 1998; Dellino et al., 2005). Furthermore, the longer time of residence in the atmosphere with respect to the coarse particles allows also low-altitude, highly variable winds to have an important role in the dispersal behaviour of fine ash.

Research in genesis, dispersal and accumulation of ash during and after explosive eruptions is topic in the current research in volcanology (e.g. Zimanowski et al., 2001). Fine ash preserve important information about fragmentation mechanisms and energy budget of the eruption (Dellino and La Volpe, 1995; Buttner et al., 2006). Dispersal and deposition of ash has also serious implications when dealing with volcanic hazard evaluation. The accumulation of ash can induce roof collapses (e.g. Blong, 2003), interruption of lifelines (roads, railways, etc.), closure of airports and noise to communication or electric lines (e.g. Blong, 1984). The injection of ash into the

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atmosphere can cause damage to aircraft or can impact public health causing, for example, respiratory problems (e.g. Horwell et al., 2003; Horwell and Baxter, 2006). Ash deposition decreases soil permeability, increases surface runoff, and promotes floods (Zanchetta et al., 2004; Favalli et al., 2006). Ash leachates (Dahlgren et al., 1999; Armienta et al., 2002; Witham et al., 2005) can result in pollution of water resources (Stewart et al., 2006), damage to agriculture and forest, impact pasture and livestock health, impinge on aquatic ecosystems and alter the geochemical environment of the seafloor (e.g. Haekel et al., 2001). All these processes and impacts call for a care consideration in assessing volcanic hazard over large areas far beyond the volcano surroundings.

Despite some recent advances in understanding the impact of fine ash on environment and infrastructure (e.g. Blong, 1984; Haekel et al., 2001; Witham et al., 2005; Stewart et al., 2006), the dynamic of dispersal of fine ash remains poorly understood, and consideration of the associated hazards have not yet been fully addressed and included in the mitigation plans.

The Pomici di Avellino (PdA) eruption of Somma-Vesuvius (Lirer et al., 1973; Santacroce, 1987; Cioni et al., 2000) represents an unique opportunity to shed light on dispersal of fine ash during explosive eruptions. This is because the PdA eruption was characterised by two clearly distinct eruptive phases: an initial sustained column phase driven by magmatic fragmentation and dominated by fall deposits, and a final phreatomagmatic phase dominated by generation of pyroclastic density currents (Cioni et al., 2000). Furthermore, ash particles generated during the two phases have different, idiosyncratic morphologies and partially different chemical composition, which make their detection and discrimination of the respective eruptive phase straightforward even in distal archives.

This paper deals with the morphologic and compositional study of distal ash (tephra layers) of PdA eruption recognised in different archives from central and southern Italy (Fig. 1). Morphology and composition of these distal tephra layers demonstrate how small-volume PDCs can disperse fine ash at distances comparable with those commonly reached by particles dispersed by high-altitude sustained columns.

2. Outline of Pomici di Avellino eruption

2.1. Proximal stratigraphy

The PdA eruption of Somma-Vesuvius (Lirer et al., 1973; Santacroce, 1987; Cioni et al., 2000) occurred during the Ancient Bronze Age (Cioni et al., 2000), and has a best estimated maximum age of 3930±20 ^{14}C yr BP (4370±40 cal yr BP; Santacroce et al., 2008-this issue). Cioni et al. (2000) divided the stratigraphic succession in three main phases (opening, magmatic Plinian and phreatomagmatic; Fig. 2), and five Eruption Units (EU1 to 5; Fig. 2; *sensu* Fisher and Schmincke, 1984), which represent the most recent and complete description of the PdA eruption. Based on a more detailed stratigraphy of the final phreatomagmatic succession, four main depositional units can be identified within EU5 (from a to d; Fig. 2). In particular, the interbedding of fine ash at different heights within the EU5 succession helped in the identification of the different depositional units.

Fallout deposits dominate the opening and magmatic Plinian phases, while PDC deposits represent the most part of the last erupted deposits (phreatomagmatic phase). A pair of white pumice lapilli and brownish ash deposits occur at the very base of the stratigraphic succession, defining the opening phase of the eruption (EU1a and b; Fig. 2). Their dispersal is limited to few km in NE direction. The main fallout deposits,

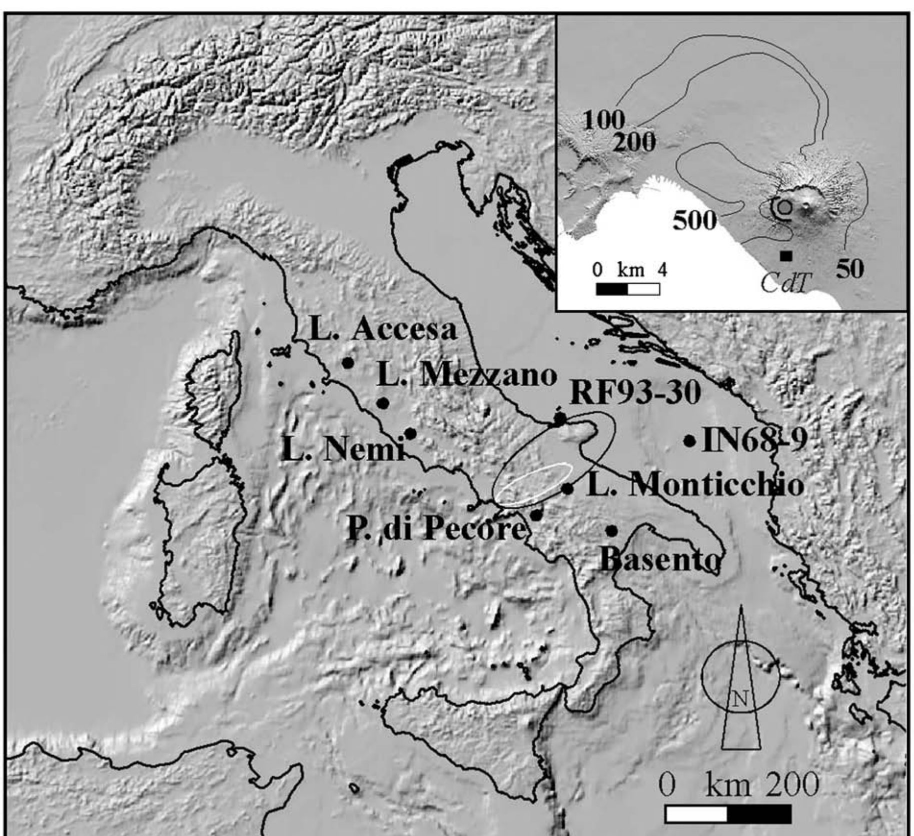

Fig. 1. Location map of the studied sites. The 1 cm isopachs of white and grey pumice fallout deposits are reported as white and black ellipses, respectively (from Cioni et al., 2000). In the framework in the upper right angle is reported a schematic dispersion of proximal pyroclastic density current deposits from the final phreatomagmatic phase (thickness in cm). The thick black line delimits the Piano delle Ginestre area. Grey circle indicates the inferred vent of PdA eruption. CdT = Camaldoli della Torre drilling point.