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Rheological control on the AD 472 Pollena eruption dynamics (Somma-Vesuvius)

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The 472 AD Pollena sub-Plinian eruption of Vesuvius was characterized by three main eruptive phases. Pulsatory eruptive dynamics were driven by magmatic fragmentation of a phonolitic (L1) to tephri-phonolitic magma (L8) during Phases I and II, whereas phreatomagmatic fragmentation dominated Phase III. In order to investigate magma dynamics, we integrated field data on the physical properties (column height, mass discharge rate) with a detailed chemico-textural analysis of the fall-out products (L1-L8), and with laboratory measurements of the phonolite (L1) and tephriphonolite (L8) multiphase rheology.

The fall deposits mainly consist of crystal-bearing pumice (L1) or scoria (L2 to L8) lapilli. Gaussian Vesicle Volume Distributions (VVDs) indicate a single and rapid event of bubble nucleation and growth (Vesicle Number Density, VND = 10^7-10^9 cm^{-3}). Cristallinity is constituted by dominant leucite and clinopyroxene and increases with stratigraphic height. The amount of H_2O initially dissolved in the magma (1.7-3.6 wt% by Raman spectroscopy on Cpx-hosted melt inclusions) decreases from L1 to L8 layer.

Anhydrous melt viscosity of the two end-member compositions was measured at high T (1000˚C $<$ T $<$ 1500 ˚C) and low T (680 ˚C $<$ T $<$ 760 ˚C) by concentric cylinder and micropenetration viscometry. Despite their chemical difference the non-Arrhenian behaviour of the viscosity-temperature curves yields very similar values at the inferred eruptive temperature (T =850˚C). Liquid+crystals rheology of tephriphonolites (L8) was determined by isothermal (T= 1150 - 1190 ˚C) crystallization experiments in a concentric cylinder set-up. The measured effect of crystals is in good agreement with literature models and the results can be extended to estimate natural magma rheology.

During the first part of the eruption (L1 - L3), despite a decrease in H_2O, the column height increases from 12 to 17 km, possibly related to a change of conduit/vent geometry. The following phases are characterized by relatively steady conditions, while the highest eruptive energy is reached at level L8 (20 km column height) despite its lowest silica content. Textural analyses indicate that the crystal content reaches almost maximum packing (ϕ = 0.48) in L8 and accordingly bulk viscosity increases by 2 orders of magnitude.

We suggest that the overall dynamics of the Pollena eruption is primarily controlled by the magma multiphase rheology, non-linearly evolving as a function of eruptive temperature, crystal and volatile contents.