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The space-time architecture variation of the shallow magmatic plumbing systems feeding the Campi Flegrei and Ischia volcanoes (Southern Italy) from halogen constraints

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Abstract

For active volcanoes, knowledge of the architecture of the plumbing system and the conditions of magma storage prior to an eruption are highly important, given their influence on the eruptive style and, thus, the management of future volcanic crises. Here, chlorine is used as a geobarometer for potassic alkaline magmas at the Campi Flegrei volcanic complex, revealing the shallowest depth of fluid-melt equilibration with respect to Cl. The results for representative fallout deposits of selected explosive eruptions show the existence of a multi-depth equilibration zone through time, including shallow magma storage. We describe evidence for the shallowest zone located at a depth equivalent to 65 MPa for the Agnano Monte Spina eruption (4482–4625 cal. yrs BP), at ~100 MPa for the Pomici Principali (11 915–12 158 cal. yrs BP), and the Astroni 6 (4098–4297 cal. yrs BP) eruptions, and close to 115 MPa for the last explosive eruption of Monte Nuovo (AD 1538). For comparison, the pressure estimated for a possible reservoir feeding the Cretaio eruption of Ischia island (AD 430), the only studied eruption on Ischia, is ~140 MPa. The pressure estimates for the two largest magnitude eruptions, the Campanian Ignimbrite (40 ka) and the Neapolitan Yellow Tuff (14.9 ka), are also discussed with respect to available magma withdrawal models. The pressures estimated using the Cl geobarometer for the magma leading to the fallout phases of these two eruptions provide evidence for a low-volume, shallow domain (~40 MPa) for the Plinian phase of the Campanian Ignimbrite eruption and a main, deeper reservoir (~130–165 MPa) for the Neapolitan Yellow Tuff eruption. The inferred shallowest equilibration pressures are interpreted here as corresponding to transitory, short-lived magma apophyses, whose eruption may have been facilitated by optimum tectonic stresses, rheological behavior of the crust, and efficiency of volatile exsolution. Alternatively, these magma apophyses may represent an evolved, crystal-rich ponded magma into which a volatile-rich magma ascending from depth was injected. The transient nature of such very shallow reservoirs is suggested by the short timescales inferred from diffusion modeling on crystals available in the literature for the studied Campi Flegrei eruptions.

The influence of sulfur (S) on Cl solubility is assessed through Cl solubility modeling and applied to different eruptions. In addition, the pressure at which magmatic fluids and melts equilibrated with respect to Cl is shallower for the Campi Flegrei volcanic complex than the Somma-Vesuvio volcanic complex, erupting more homogeneous differentiated magma, of trachytic or phonolitic composition. This approach of using Cl to investigate the architecture of the plumbing system can be extended to all alkali-rich magma systems.

Keywords: Campi Flegrei, Ischia, chlorine, geobarometer, alkaline magmas, pre-eruptive conditions; Experimental Halogens in Honor of James Webster