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Chlorine as a geobarometer tool: Application to the explosive eruptions of the Volcanic Campanian District (Mount Somma-Vesuvius, Phlegrean Fields, Ischia)

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One of the current stakes in modern volcanology is the definition of magma storage conditions which has direct implications on the eruptive style and thus on the associated risks and the management of likely related crisis. In alkaline differentiated magmas, chlorine (Cl), contrary to H_2O, occurs as a minor volatile species but may be used as a geobarometer.

Numerous experimental studies on Cl solubility have highlighted its saturation conditions in silicate melts. The NaCl-H_2O system is characterized by immiscibility under wide ranges of pressure, temperature and NaCl content (< 200 MPa, < 1000°C). The addition of the silicate melt to the system does not rule out this property. These P-T conditions are very common for alkaline magmas evolving in shallow reservoirs, and they strongly affect the evolution of sin-eruptive magmatic melts and fluids. In alkali magmas, the Cl concentration in the exsolved fluid phase may increase with that of Cl in the silicate melt. Yet this system becomes strongly non-Henryan at high Cl concentration, depending on P-T conditions: the exsolved fluid phase unmixes to form a low-density, Cl-poor and H_2O-rich vapour phase, and a dense hypersaline brine. In such a subcritical domain, as the composition of both vapour phase and brine is fixed, also the Cl concentration in the silicate melt is invariant, as expected from the Gibb's phase rule. The Cl buffer value will depend on the silicate melt composition, being higher in alkali-rich melts. In addition, we also underline the importance of considering the general HCOSClF system to well decipher pressure information from Cl buffering effect. As the equilibrium between the silicate melt and the fluid phase is generally inherited from conditions established in the reservoir rather than during magma ascent, Cl buffering effect can be evidenced through the analysis of the residual glass.

Here we applied systematically this methodology to the explosive eruptions of the three threatening volcanoes of the Neapolitan area: Mount Somma-Vesuvius, Phlegrean Fields and Ischia. We have analysed the products of the representative explosive eruptions of each volcano, including Plinian, sub-Plinian and strombolian events. We have focussed our research on the earliest emitted, most evolved products of each eruption, likely representing the shallower, fluid-saturated portion of the reservoir. As the studied eruptions cover the entire eruptive history of each volcanic system, the results allow better constraining the evolution through time of the shallow plumbing system. We highlighted for Mount Somma – Vesuvius two magma ponding zones, at ∼170-200 MPa and ∼105-115 MPa, alternatively active in time. For Phlegrean Fields, we evidence a progressive deepening of the shallow reservoirs, from the Campanian Ignimbrite (30-50 MPa) to the Monte Nuovo eruption (115 MPa). Only one eruption was studied for Ischia, the Cretaio eruption, that shows a reservoir at 140 MPa. The results on pressure are in large agreement with literature. The Cl geobarometer may help scientists to define the reservoir dynamics through time and provide strong constraints on pre-eruptive conditions, of utmost importance for the interpretation of the monitoring data and the identification of precursory signals.