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Viscosity of Campi Flregrei (Italy) magmas

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Viscosity is an important factor governing both intrusive and volcanic processes. The most important parameters governing silicate melts viscosity are bulk composition of melt and temperature. Pressure has only minor effect at crustal depths, whereas crystals and bubbles have significant influence. Among compositional parameters, the water content is critical above all in terms of rheological behaviour of melts and explosive style of an eruption. Consequently, without an appropriate knowledge of magma viscosity depending on the amount of dissolved volatiles, it is not possible to model the processes (i.e., magma ascent, fragmentation, and dispersion) required to predict realistic volcanic scenarios and thus forecast volcanic hazards.

The Campi Flegrei are a large volcanic complex ($\sim$150 km^2) located west of the city of Naples, Italy, that has been the site of volcanic activity for more than 60 ka and represents a potential volcanic hazard owing to the large local population.

In the frame of a INGV-DPC (Department of Civil Protection) project devoted to design a multidisciplinary system for short-term volcano hazard evaluation, we performed viscosity measurements, under dry and hydrous conditions, of primitive melt compositions representative of two Campi Flegrei eruptions (Minopoli-shoshonite and Fondo Riccio-latite).

Viscosity of the two melts have been investigated in the high temperature/low viscosity range at atmospheric pressure in dry samples and at 0.5 GPa in runs having water content from nominally anhydrous to about 3 wt%. Data in the low temperature/high viscosity range were obtained near the glass transition temperature at atmospheric pressure on samples whose water contents vary from 0.3 up to 2.43 wt%.

The combination of high- and low-viscosity data permits a general description of the viscosity as a function of temperature and water content using a modified Tamman-Vogel-Fulcher equation.

$$\log \eta = a + \frac{b}{(T-c)} + \frac{d}{(T-e)} \cdot \exp\left(g \cdot \frac{w}{T}\right) \tag{1}$$

where η is the viscosity in Pa·s, T the temperature in K, and w is the water content in wt%; *a, b, c, d, e, g* are the Vogel-Fulcher-Tamman parameters. Each of the two compositions shows its own VTF parameters. Following this equation we can now calculate viscosity values for the two compositions under the condition inferred for Campi Flegrei magma chambers, i.e., water content from 0.3 to 3 wt%, T=1393K (Mangiacapra et al., 2008). For melt with 0.3 wt% water content we obtain viscosity values (η in Pas) of $10^{2.68}$and $10^{2.24}$ for shoshonite and latite, respectively. At higher water contents of about 3 wt% the viscosity difference decreases to $10^{1.71}$ (shoshonite) and $10^{1.51}$ (latite). One important application of these data is the estimate of flow regime and magma rising velocity from deep to shallow reservoirs. Given the inferred magma water contents (0.3 and 3 wt%), temperature (1393K) and depth of deep and shallow reservoirs (9 and 4 km, respectively, Mangiacapra et al., 2008) and assuming a 2 m dyke wide, we have calculated (Lister and Kerry, 1991) a rising time from deep to shallow reservoir in the order of few minutes, 4.4 and 5.9 for a shoshonitic magma with 3 and 0.3 wt% water content, respectively. The same order of magnitude (4.1 and 5.2) has been obtained for latitic magma with similar amount of water.

Lister and Kerry (1991) Fluid mechanical models of cracks propagation and their application to magmatic transport and dyke. Journal of Geophysical Research 96, 10049-10077.

Mangiacapra A., Moretti, R., Rutherford L., Civetta L., Orsi G., Papale P. (2008) The deep magmatic system of the Campi Flegrei caldera (Italy). Geophysical Research Letters 35, L21304.