Geophysical Research Abstracts, Vol. 8, 07090, 2006
SRef-ID: 1607-7962/gra/EGU06-A-07090

Comparing in-situ and numerical measurements of permeability in silicic pumices

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Whether a volcanic eruption of viscous, water-rich magma occurs as a (relative slow) effusion of lava or as a highly hazardous explosive burst of hot gases and volcanic particles depends primarily on how the magma behaves in the conduit prior to reaching the earth's surface. The magma degasses as bubbles, the coalescence of which may cause a rapid transfer of gas out of the magmatic column. Such a development of permeability during magma ascent leads to an effusive eruption whereas a low magmatic permeability causes bubbles to accumulate and degas in a catastrophic way, yielding to an explosive eruption. Understanding magmatic permeability is thus essential to understand the transition between effusive and explosive regimes.

Juvenile clasts of explosive silicic eruptions are the only available natural sample that preserves information on the state of magma at fragmentation. We characterized the pyroclastic products from the largest explosive eruption of the South Aegean volcanic island arc (the Kos Plateau Tuff; KPT) because they permit a detailed comparison of pyroclasts from different eruptive styles, including a central-vent, pre-caldera phase, and the climactic, caldera-forming phase. KPT pumices are of particular interest because they can be grouped into four different types: frothy, tube, banded, and microvesicular. The permeability of juvenile clasts was obtained by two different methods: 1) in-situ by gas permeametry on pumice plugs, and 2) a 3D reconstruction of the pore space by X-ray Computed microTomography (CT) to acquire a statistical analysis of the network of connected bubbles and its permeability.

In-situ permeability measurements on KPT pumices were determined by an automated Gas permeameter at the University of Geneva (PMI GP-262). We used air as the gas phase and sample plugs drilled in pumices of 2.5 cm in diameter and 2.5-3 cm in

length. Preliminary results on the banded and microvesicular types suggest permeabilities on the order of 1e-12 to 1e-13 m2, in agreement with data obtained on other silicic pumices (e.g., Eichelberger et al., 1986).

To obtain the permeability by CT, we use the 3D volume reconstructed by microtomography as boundary conditions for a numerical model. The model computes the flow of a fluid within the bubble network by solving the Navier-Stokes equations as a pressure difference is applied across the CT volume. The porous network of bubbles resists to the flow, slowing it down. The magnitude of the resistance can be converted in a measure of permeability. CT volumes are on the order of 10 mm3 and calculations can be carried out only if the resolution is sufficient to resolve connected bubbles. When the medium is anisotropic, like in the case of the tube pumices, varying the direction of pressure difference allows us to get directional permeabilities of the sample.

Permeabilities calculated by the coupling of CT and numerical model are not affected by the same limitations as those measured by gas permeametry. We will compare the two methods and the way they complete each other in order to extend the analyzable range of pumice types.

Reference: Eichelberger, J.C., Carrigan, C.R., Westrich, H.R. and Price, R.H., 1986. Non-explosive silicic volcanism. Nature, 323: 598-602.