Concentration variance decay during magma mixing: a volcanic chronometer

DIEGO PERUGINI[1], CRISTINA P. DE CAMPOS[2], MAURIZIO PETRELLI[1] & DONALD B. DINGWELL[3]

[1] Department of Physics and Geology, University of Perugia, Piazza Università, 06100, Perugia, Italy
[2] Department of Mineralogy and Geotectonics, University of São Paulo, Rua do Lago, USP, 05508-080, São Paulo, Brazil
[3] Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität, München, 80333, Munich, Germany

The mixing of magmas is a common phenomenon in explosive eruptions. Concentration variance is a useful metric of this process and its decay (CVD) with time is an inevitable consequence during the progress of magma mixing. In order to calibrate this petrological/volcanological clock we have performed a time-series of high temperature experiments of magma mixing. Experiments were performed on mixing volcanic melts using a high-temperature (1,200 °C) centrifuge furnace. The initial compositions of end-members were an alkali basalt and a phonolite from the Campi Flegrei volcanic system (Italy). The centrifugal force exerted by rotation has accelerated the injection of the basalt into the phonolite triggering widespread mixing at the interface between the two melts generating mixing patterns that are topologically similar to those observed in natural rock samples. The chemical variability triggered by the mixing process was quantified monitoring the variation of major and trace elements. Results demonstrate that compositional variance decays exponentially with time. With this calibration the CVD rate (CVD-R) becomes a new geochronometer for the time lapse from initiation of mixing to eruption. The resultant novel technique is fully independent of the typically unknown advective history of mixing – a notorious uncertainty which plagues the application of many diffusional analyses of magmatic history. Using the calibrated CVD-R technique we have obtained mingling-to-eruption times for three explosive volcanic eruptions from Campi Flegrei (Italy) in the range of tens of minutes. These in turn imply ascent velocities of 5-8 meters per second. We anticipate the routine application of the CVD-R geochronometer to the eruptive products of active volcanoes in future in order to constrain typical “mixing to eruption” time lapses such that monitoring activities can be targeted at relevant timescales and signals during volcanic unrest.