The role of bubble ascent in magma mixing

Sebastian Wiesmaier[1], Daniele Morgavi[1], Diego Perugini[2], Cristina De Campos[1], Kai Uwe Hess[1], Yan Lavallee[3], Donald B Dingwell[1]

[1]Ludwig-Maximilians-University Munich, Earth and Environmental Sciences, Germany, [2]University of Perugia, Department of Earth Sciences, Italy, [3]University of Liverpool, School of Environmental Sciences, United Kingdom

E-mail: sebastian.wiesmaier@min.uni-muenchen.de

Understanding the processes that affect the rate of liquid state homogenization provides fundamental clues on the otherwise inaccessible subsurface dynamics of magmatic plumbing systems. Compositional heterogeneities detected in the matrix of magmatic rocks represent the arrested state of a chemical equilibration. Magmatic homogenization is divided into a) the mechanical interaction of magma batches (mingling) and b) the diffusive equilibration of compositional gradients, where diffusive equilibration is exponentially enhanced by progressive mechanical interaction (1). The mechanical interaction between two distinct batches of magma has commonly been attributed to shear and folding movements between two distinct liquids. A mode of mechanical interaction scarcely invoked is the advection of mafic material into a felsic one through bubble motion. Yet, experiments with analogue materials demonstrated that bubble ascent has the potential to enhance the fluid mechanical component of magma mixing (2).

Here, we present preliminary results from bubble-advection experiments. For the first time, experiments of this kind were performed using natural materials at magmatic temperatures. Cylinders of Snake River Plain (SRP) material were prepared for a static layered set-up, with basalt glass placed underneath rhyolite glass. Upon heating, air trapped in the interstices between glass cylinders and the crucible expanded, forming bubbles in the now molten basalt. The bubbles rose, thus entraining a portion of basaltic material into the rhyolite.

The plume-like structure that the advected basalt formed within the rhyolite was characterized by microCT and subsequent high-resolution EMP analyses. The diffusional gradient around the plume tail showed a progressive diffusional equilibration from top to bottom, consistent with increasing time of interaction towards the bottom end of the plume tail. Furthermore, single protruding filaments at the bottom end of the plume tail indicate that the plumous structure is a composite of many smaller plume tails. Possibly, the first bubble rising created a preferential pathway for bubble ascent thereafter. The normalised variance, which serves as a proxy of cation diffusion rate at the interface of rhyolite and basalt, is unsystematic. This is most likely a result of the many small plume tails combined in the hybridised region. In turn, stretching and folding experiments produce very systematic normalised variances. The normalised variance measured in natural magma mixing structures may thus provide characteristic evidence to distinguish between mixing induced by bubble action or scenarios of stretching and folding.

(1) De Campos et al. (2011) Enhancement of magma mixing efficiency by chaotic dynamics: an experimental study, Contrib. Mineral. Petrol., 161(6), 863-881.

(2) Thomas et al. (1993) Mixing of stratified liquids by the motion of gas bubbles: application to magma mixing, Earth Planet. Sci. Lett., 115(1-4), 161-175.