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A study of degassing at mid-oceanic ridges by bubble-by-bubble analyses

Aurélia Colin, Peter Burnard, and Bernard Marty
CRPG-CNRS, Nancy Université, Vandoeuvres-lès-Nancy, FRANCE (acolin@crpg.cnrs-nancy.fr)

Under mid-oceanic ridges, decompression during magma ascent leads to CO2 solubility decrease and bubbles to nucleate. Vesicle size distributions measured in basaltic glasses sampled at the seabed suggests bubbles have nucleated at different times in the magma, the largest bubbles having probably nucleated earlier than smaller ones, as they have had time to grow. When bubbles form, volatiles like helium or argon partition between the magma and the gaseous phase. He-Ar-CO2 relative abundance in the vesicles is an indicator of the degree of degassing of the magma in which they have been formed. Indeed, as argon is less soluble than helium and CO2, the first bubbles to nucleate concentrate the argon, while the later bubbles are depleted in argon. This trend can be disturbed by kinetic effects if there is insufficient time to reach equilibrium (diffusivities are DHe>DAr»DCO2).
Previous works ([1], [2]) report differences in composition between the vesicles in some of their basaltic glass samples. This implies that at the millimetre scale the vesicles are not always totally equilibrated with surrounding magma. Study of the volatile composition of individual vesicles at the scale of a single sample of 1 cm3 can permit degassing mechanisms to be investigated, and provide estimates of the timescales implied to preserve (or not) compositional differences between the vesicles.
We present here analyses of individual vesicles in MORB glasses. For this study, we use the method of [1], which consist of opening the vesicles by laser ablation and analysing them with a mass spectrometer. Some improvements have been made, especially in tomographically imaging the opaque glass samples to localise and characterize the vesicles, which permit large vesicles (80μm to 1mm of diameter) to be studied as we are no longer limited to sample thin sections. Tomography was performed at the Mateis laboratory, Lyon and at the SLS synchrotron facility (Switzerland) with 5 and 3.7μm resolution respectively. For opening bubbles, we used a 193nm laser such as proposed by [2] to avoid noble gases diffusion by local heating. CO2 contents were estimated by pressure measurement in the laser cell using a sensitive manometer. We analysed 4He, and Ar isotopes (36, 38, 40) in order to calculate 40Ar* (40Ar corrected from atmospheric contamination) on a VG 5400@ mass-spectrometer.
Some MORB glass samples from different ridge systems have been investigated in order to link degassing processes to geodynamic context. We observe, depending on the samples, either a single composition for all bubbles, or variations in composition between bubbles consistent with a trend of equilibrium degassing in an open system. Models of magma degassing taking into account tomographic observations (vesicle volume and vesicle size distribution) and diffusivity and solubility of the volatiles during magma ascent will be presented. The observed heterogeneity or homogeneity in composition will be interpreted in term of magma ascent velocity and relative bubble velocity.

[1] P. Burnard, EPSL 174 (1999) 199-211. [2] A. Raquin, PhD thesis, 2008.