

Heterogeneity of volatile species (H, C, F, S and Cl) in pillow basalts, determined by FTIR spectrochemical imaging and SIMS.

Richard Wysoczanski[1], Erik Hauri[2]

[1] IFREE, JAMSTEC, [2] Carnegie Institution

The analysis of volatile species in basaltic rocks (particularly pillow basalts from water depths sufficient to prevent degassing), has been performed by a number of techniques in recent years to directly determine volatile contents present during the generation and evolution of magmatic systems. These analyses, on sample sizes that range from micron-scale to bulk samples depending on the technique used (e.g. Fourier Transform Infrared Spectrometry (FTIR), Secondary Ion Mass Spectrometry (SIMS), or manometry), invariably involve analysing several samples to constrain the heterogeneity of the volatile species. The accuracy and precision of volatile measurements for these techniques is typically on the order of 5-10%. Furthermore, results of similar samples analysed by two or more of different techniques only agree to within 5% at best, making it difficult to determine if any heterogeneity reported is a reflection of variable volatile contents in the samples, or an artifact of the analytical techniques used. The heterogeneity of volatile contents in pillow basalt glasses therefore remains a largely unresolved issue.

Here, we investigate the heterogeneity of volatile elements in pillow basalts by two microanalytical techniques: imaging FTIR and SIMS. The two samples analysed come from differing tectonic settings; the Southwest Pacific Kermadec Arc-Havre Trough convergent margin, and a sample from a spreading Mid Oceanic Ridge. Of particular interest is the reproducibility of results between the two techniques, and the variation, if any, of volatile contents from the rim of the glass towards the interior, and around vesicles where degassing occurs.

Infrared spectrochemical images were obtained using a Digilab Stingray FTIR fitted with an UMA 600 Infrared Microscope, and a 64x64 pixel Focal Plane Array Detector at the Institute for Frontier Research on Earth Evolution, Japan Marine Science and Technology Center, Yokosuka, Japan. The data obtained consist of 4096 spectra over two spatial dimensions covering an area of 400 microns by 400 microns. Individual spectra consist of intensities over the frequency range 900 to 4000 cm^{-1} . Combining spectra at a given frequency (e.g. 3550 cm^{-1} for H_2O) over the analytical area allows us to construct a 3-D frequency slice image of the sample. Using this technique, images of water (molecular and OH-) and carbon (CO_3 -) can be obtained from doubly polished wafers of the pillow basalts, and concentrations obtained from areas as small as six microns in diameter. This allows a visual and quantitative assessment of the heterogeneity of these volatile species over a sub-millimeter scale.

In addition to water and carbon, F, S and Cl were also analysed by a Cameca 6f SIMS at the Department of Terrestrial Magnetism, Carnegie Institution of Washington. Several transects on each pillow basalt were made, comprising up to 50 analyses per transect, and ranging up to a centimeter from the glassy rim of the pillow basalt to the interior where small patches of glass form isolated islands in microcrystalline groundmass. Transects between vesicles were also made to investigate any remnants of degassing of volatile elements through vesicles. Individual analyses were 20 microns in diameter, and 2-3 microns in depth. Detection limits are estimated at less than 30 ppm H_2O , less than 3 ppm CO_2 , and less than 1 ppm F, S and Cl.

Spectrochemical 4-D images of the pillow basalts will be presented, and the heterogeneity of all five volatile species (H, C, F, S and Cl) discussed, including a direct comparison of water and carbon contents obtained by FTIR and SIMS from pillow rim to interior, and at vesicle boundaries.