Synchrotron Light Brightening Research in Volcanology

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Volcanology research combines physical, chemical and geological research methods into understanding the processes by which magmas are formed deep in the Earth and how they are erupted at the surface. One research topic of great relevance for hazard assessment is the search for factors modulating the degree of explosivity of volcanic eruptions. This quest takes us deep into the root zones of volcanoes to examine the conditions of magma formation and evolution of volatile solubility . It is the content and behavior of these volatiles (H_2O, CO_2, S, halogens and light metals) that influences transitions magmas undergo in volume and rheology during the final stage of rise through a conduit to the surface. Analyses of increasingly higher spatial resolution are required to pinpoint the fundamental phase and chemical transformations occuring. For these studies, the application of synchrotron techniques offers great potential, but is yet in its infancy.

X-ray Fluorescence Microscopy (XFM) is a powerful tool for investigating the fine-sale distribution of chemical elements within portions of a rock or single mineral/interface. The unparalleled speed of data acquisition associated with the Maia detector at the Australian Synchrotron enables a hither-to impossible ability to map and generate chemical profiles throughout multiple interfaces within a rock sample. This technique was applied to understand rocks at Ulleung volcano, Republic of Korea, where the inter-diffusion of trace elements (e.g. Zr, Rb, Rare Earth Elements) between volcanic glass and crystals, and zonation patterns within crystals is being used to determine magma affinity, residence time and ascent rates.

The degree of magma explosivity during volcanic eruptions is controlled to a large degree by the pre-eruptive dissolved volatile (mainly water) content. The growth of water bubbles in magma initiates catastrophic volcanic eruptions by building up pressure, followed by collapse of the residual foam of bubbles and magma which leaves a degassed magmatic plug behind. Our recent studies at the Australian Synchrotron have shown that water can be both enriched as well as depleted in a very thin margin around the bubbles. The fast processes during volcanic eruptions and the high viscosities of magma limit diffusion of volatiles. Therefore, the high spatial resolution and signal-to-noise ratios of synchrotron sourced Fourier transform infrared spectroscopy (FTIR) are needed to measure the distribution of volatiles and to model the diffusion that drives the growth and collapse of bubbles in magma.

If the process of bubble growth in magma is rapid, a sudden volume expansion drives explosive eruptions. Vesicles remaining in cooled eruption products therefore provide insights into the last stages of eruptions. Synchrotron sourced X-ray micro computed tomography (micro CT) enables non-destructive 3D visualization of these. The heterogeneity in vesicle and crystal content within pumice from Mount Ruapehu, New Zealand could be quantified by synchrotron sourced microCT to infer complex flow and degassing processes within the volcanic conduit that related to both stable and collapsing eruption columns. A greatly improved quantification of magma decompression rates from such studies helps define the types of volcanic hazards expected at volcanoes around the world.