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Investigating the explosivity of shallow sub-aqueous basaltic eruptions

R. Murtagh and J.D.L. White
University of Otago, Geology, New Zealand (murra257@student.otago.ac.nz)

Volcanic eruptions produce pyroclasts containing vesicles, clearly implying exsolution of volatiles from the magma has occurred. Our aim is to understand the textural characteristics of vesiculated clasts as a quantitative indicator of the eruptive behaviour of a volcano.
Assessing water's role in volatile degassing and outgassing has been and is being well documented for terrestrial eruptions; the same cannot be said, however, for their shallow subaqueous counterparts. The eruptive behaviour of Surtseyan volcanoes, which include both subaqueous and subaerial phases (for example, the type-location Surtsey, Iceland in 1963) is under investigation here and for good reason. Volcanic eruptions during which water and basaltic magma come into contact appear to ignite violent eruptions of many of the small "monogenetic" volcanoes so abundant on Earth. A key problem remains that detailed conditions of water-magma interactions are not yet fully understood.

Field samples obtained from exposed sequences deposited originally in a subaqueous environment allow for the necessary analysis of lapilli. With the aid of experimental data, mathematical modelling and terrestrial analogues the ambition is to unravel volatile degassing, ascent histories and fragmentation processes, allowing us ultimately to identify both the role water plays in the explosivity of shallow subaqueous eruptions, and the rise history of magma to the point of interaction.

The first site, Pahvant Butte is located in southwest Utah, U.S. It is a well preserved tuff cone overlying a subaqueously deposited mound of glassy ash composed of sideromelane and tachylite. It was erupted under ~85m of water into Lake Bonneville approximately 15,300 years ago. Our focus is on samples collected from a well-bedded, broadly scoured coarse ash and lapilli lithofacies on the eastern flank of the edifice. Vesicularity indices span from 52.6% - 60.8%, with very broad vesicularity ranges, 20.6% - 81.0% for one extreme sample. The diverse nature of the vesicularity is reflected also in SEM images. Dense clasts display textures with isolated, tiny, serrate-edged bubbles, while mean- and high-vesicularity clasts display more numerous, medium-sized, rounded bubbles. Based on these observations, fragmentation at various stages of a complex vesiculation history is suggested.

The second site, Black Point, is situated in eastern California, U.S. Another emergent volcano, it was erupted into Lake Russell ~13,000 years ago. Similar to Pahvant Butte, its unconsolidated mound consists of glassy ash and lapilli and is topped by indurated, palagonitized tuff ring/cone deposits. A well exposed quarry section on the southeast slopes of the edifice is considered here. Sub-horizontal beds display pinch and swell structures and some cross-stratification. Vesicularity indices extend from 58.7% - 66.6% while vesicularity ranges are broad, 27.8% - 79.7% for example. The higher overall vesicularity implies higher rates of ascent and eruption discharge, a conclusion supported by textural features of bubbles in this section such as a population of uniformly sized small vesicles.

Bubble nucleation and growth in an ascending parcel of magma is controlled both by decompression and diffusion of oversaturated volatiles as the magma rises. Bubble growth plays a major role in controlling eruption behaviour and we can obtain useful quantitative records of vesicle size data through thin section imaging and analysis.

Vesicle size data can be expressed as number per area (NA), number per volume (NV), cumulative number density (N(>L)), volume fraction, cumulative volume fraction and vesicle size distribution (VSD). Not only can the trends and patterns of bubble size reveal insights into eruptive styles, intensity; bubble nucleation, growth, coalescence and deformation, they can also be analysed with other information to infer volatile content and degassing record. High vesicle number densities have been interpreted as being the result of rapid bubble nucleation at high supersaturations. Homogenous bubble nucleation is symptomatic of large supersaturations and high decompression values, whereas heterogeneous bubble nucleation on pre-existing microlites may occur at much lower saturation and decompression values. The spatial density of bubble nuclei controls the rate of diffusion-limited bubble growth and growth of volatile depletion shells around bubbles.

Results thus far are restricted to the Pahvant Butte sample suite and indicate low bubble number densities, which could be reflecting a high connectivity of bubbles; polymodal volume fraction distributions, indicating bubble coalescence and multiple stages of bubble nucleation; VSD plots display curved trends further supporting the theory that bubble coalescence and other ripening processes have occurred. These vesicle-population characteristics are most similar to those reported from Stromboli. Despite this similarity, eruption style, energetics and dispersal are unique to subaqueous eruptions, and are inferred to be equivalent to those that formed the subaqueous base of Surtsey volcano.