Vesiculation and fragmentation in silicic subaerial and submarine magmas: insights from case studies in the Kermadec arc

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There is debate over the processes involved in the vesiculation and fragmentation of silicic magmas. One aspect is to what extent do the densities and vesicularity characteristics of pyroclasts accurately reflect the point of fragmentation, or whether they have undergone post-fragmentation modification. Here we present pyroclast densities and bubble size and number characteristics from a suite of representative clasts from six silicic eruptions of contrasting size and style from Raoul volcano in the Kermadec arc. Density/vesicularity distributions show a dearth in pyroclasts with 70-75% vesicularity. However, pyroclasts closest to 70-75% vesicularity have the highest bubble number density (BND) values for all eruptions regardless of intensity, style or degree of interaction with external water. Bubble size distributions and BNDs, corrected for clast vesicularity and crystal content, show variations consistent with this vesicularity range representing a critical transition at which vesiculating magma is most likely to undergo fragmentation. Clasts with vesicularity >70-75% have decreasing BNDs, interpreted to reflect bubble coalescence and growth after magmatic fragmentation, but prior to quenching. Clasts with vesicularities <70-75% also have decreasing BNDs but in our examples preserve textures indicative of pre-fragmentation processes such as stalling and volatile loss prior to vesiculation in a microlite-rich magma, or vesiculation during slow ascent of degassing magma. The results of this study, therefore, show that modal density clasts (the usual targets for vesicularity studies) have likely undergone some degree of post-fragmentation vesiculation and are therefore may not be accurately representative of the magma at the moment of fragmentation.

Textures from subaerial erupted Raoul pyroclasts were then compared to similar chemistry submarine erupted pyroclasts sampled via dredging. These results permit inferences to be drawn as to the influence of both eruption rate and water depth on the eruption dynamics, with the interplay between the two playing a vital role. Results of this work challenge the notion of simple end-member explosive or effusive regimes of submarine volcanism and define a new intermediate eruptive style (Tangaroan) that is unique to the subaqueous realm. In contrast, deep submarine higher eruption rate is causes fragmentation to occur within the conduit prior to any quenching influence of the overlying water column. The higher dynamic pressure of a significant overlying water column acting on the eruption jet inhibits rapid decompression and expansion of clasts, as it would if erupted into air, and therefore affects the vesiculation processes and resulting textures in the resulting pyroclasts. The distinctive textural differences seen in subaerial and submarine pyroclasts open up the possibility of being able to fingerprint pyroclasts in ancient volcaniclastic sequences.