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# Vesiculation, fragmentation and aggregation processes during the 2014-2015 eruption of Hunga Tonga-Hunga Ha'apai volcano

Mathieu Colombier (1), Manuela Tost (2), Shane Cronin (2), Bettina Scheu (1), Katharine J. Dobson (3), Kai U. Hess (1), Bernhard Ruthensteiner (4), Tim Yilmaz (1), and Donald B. Dingwell ()

(1) LMU Munich, Department for Earth and Environmental Sciences, München, Germany (mathieu.colombier@min.uni-muenchen.de), (2) School of Environment, University of Auckland, (3) Department of Earth Sciences, Durham University, UK, (4) Bavarian State Collection of Zoology

Surtseyan eruptions are shallow emergent subaqueous explosive volcanic eruptions. Conditions of water-magma interaction along with magma ejection rates and its gas/expansion conditions control eruption styles during progressive emergence of the volcano. In order to better assess the effect of water on processes such as vesiculation, fragmentation, cooling or aggregation, we studied the textural and morphological properties of ash, lapilli and bombs from the deposits of the 2014-2015 surtseyan eruption of Hunga Tonga-Hunga Ha'apai volcano, Tonga.
We measured the vesicularity, vesicle connectivity, permeability and vesicle size distributions of juvenile lapilli and bombs from the deposits by Helium pycnometry, X-ray micro-computed tomography using Avizo 9.2 software and SEM using FOAMS software to infer the vesiculation processes. We also qualitatively assessed the fragmentation and aggregation mechanisms by analysing aggregates by X-ray micro-computed tomography and 2D textural analysis using BSE images at SEM. Finally, we measured the shape parameters of ash particles of different grain sizes to obtain further insights into the fragmentation processes.
The bombs show gradual textural variations with increase of vesicle size and degree of coalescence from rim to core. These textural variations are also observed in the lapilli. The vesicle connectivity in the lapilli and bombs covers a wide range from fully isolated to completely connected. Vesicle connectivity and permeability increase strongly with vesicularity. The percolation threshold, that is the critical vesicularity corresponding to the onset of connectivity and permeability due to system-spanning coalescence is estimated at around 0.2-0.4 and is lower than for scoria from fire fountaining and strombolian eruptions. These variations of connectivity and permeability with vesicularity are likely to reflect post-fragmentation vesiculation interupted at different stages by quenching in water. 2D and 3D images reveal that the rims of the lapilli are heavily cracked indicative of thermal granulation due to rapid cooling at the melt-water interface, confirming that the water played an important role in the vesiculation, cooling and fragmentation processes during this eruption. The link between vesiculation and cooling will be further constrained using heat transfer equations and geospeedometry.
Aggregates are ubiquitous in the deposits and most of these are armoured lapilli consisting of a juvenile lapillus coated by fine ash. The coated ash and the host lapilli have similar textures. Furthermore, there are textural evidences that some of the coated particles resulted directly from the fracturing of the edge by thermal granulation. These observations suggest that the thermal granulation partly contributed to the ash coating. Thermal granulation occured in dense and vesicular magma, leading to high variability of ash particle shapes.
This study exemplifies the diverse influence water-magma interaction can pose on the vesiculation, fragmentation and aggregation processes for instance in the role of thermal granulation during this surtseyan eruption.