Understanding the relation between pre-eruptive bubble size distribution and observed ash particle sizes: Prospects for prediction of volcanic ash hazards

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Recent advances in measuring pre-eruptive bubble size distributions (BSDs) from ash particle surface morphology now make it possible to calibrate ash fragmentation models for prediction of pyroclastic characteristics of concern to human health and infrastructure. The same magma bodies can generate various eruption products ranging from course bombs to fine ash, with a wide range of fractionation between these end members that in turn depends on the pre-eruptive bubble size distributions.

We have examined (a) distal ash fall deposits from the 1980 Mount St. Helens (MSH) lateral blast, and (b) the basaltic sub-plinian 1974 eruption of Fuego (Guatemala) using stereo-scanning electron microscopy (SSEM) to obtain pre-eruptive bubble size distributions (BSDs). The analysis routine involved (i) building of digital elevation models of single ash grains from SSEM stereo-pair images (using MeX software), and (ii) calculation of individual vesicle volumes using the BubbleMaker software package developed by the authors. We found two separate and independent ash particle populations within the examined samples: (1) Simple ash particles that contain no bubbles within their interiors, but are parts of the walls of individual bubbles; and (2) larger, compound ash particles that contain multiple bubble imprints on their surfaces as well as additional complete bubbles within their interiors. In the case of MSH eruption BSDs of the two ash types do not vary with distance from the vent, but compound ash particles did not travel beyond a distance of ~300 km from the source where primarily simple ash fragments are observed. These simple fragments are about four orders of magnitude smaller (by volume) than the bubble sizes observed on their surfaces, suggesting that bubble fragmentation leads to the generation of multiple simple ash fragments per nucleated bubble. Although the volume represented by simple ash particles is a minor fraction of the total erupted mass, their number density is quite high and exceeds those for compound ashes.

In order to assess fragmentation efficiency we have devised a method to produce spatial models of bubble textures that match inferred BSDs of pre-fragmentation magma in the eruption column based on conditions of 1-stage bubble nucleation and random nuclear spacing, with either of two bubble growth schemes- (1) unconfined growth in the absence of neighboring bubbles, and (2) limited growth in a melt volume shared with neighboring bubbles. These scenarios lead to different BSDs, thus controlling fragmentation thresholds and patterns. BSD leads to the thickness distribution of bubble walls and plateau borders, so we can predict the size distribution of ash particles formed by rupture of thinnest inter-bubble films, as well as the fraction of compound fragments or clasts derived from parcels of magmatic foam containing thicker walls. As such it is possible to determine the magmatic conditions that lead to eruptions with a high fraction of fine ash of concern to volcanic hazards and respiratory heath.