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Impact vesiculation – a new method of bubble nucleation and degassing in volcanic spatter

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We have observed two populations of vesicles in cowpat bombs from the 1930 eruption of Stromboli. Population I consists of non-spherical vesicles 1-4 mm in diameter. These occur throughout, but are most obvious in the 1 cm-thick chilled rind of bombs, because of the absence of the second population. Population II is absent from rinds, but occurs throughout bomb interiors, and consists of spherical bubbles 0.2-0.4 mm in diameter. We explain the two populations as follows. Population I consists of bubbles that grew either within the magma conduit or during the explosive ejection of the spatter. We interpret the shapes of these bubbles as reflecting distortion by deformation of the bomb during flight and upon landing. In contrast, Population II bubbles did not grow until the bomb landed, and are near-spherical because there was little or no bomb deformation after they had grown. These bubbles could not form in the rind, because the rind was already solid (plastic) at the time of their origin. We suggest that the trigger for Population II bubbles to nucleate was provided by the impact of the bomb onto the ground, and we term this 'impact vesiculation'. The likely impact speed of the bombs we studied is about 70-90 m/s. There are two possible mechanisms for impact vesiculation. One is simply that impact-induced rupture of the chilled rind leads to pressure release in the bomb interior, and that this stimulated a new episode of bubble nucleation. The other is that it is the shock of the impact that acts as the stimulus. We believe this to be the more likely alternative, because the triggering forces are much stronger. We speculate that the rarefaction pulse that must follow the impact-induced compression pulse leads to formation of microcracks or shock-induced nucleation, stimulating bubble growth throughout the remaining fluid volume of the bomb.

We have been able to simulate impact vesiculation of this sort in the laboratory by

impacting an airgun pellet into a sample of viscoplastic rhyolitic obsidian (Rocche Rosse flow, Lipari). The sample was heated in a furnace to 1006 ^{o}C over a period of 2 hours to ensure it crossed the glass transition temperature. The supercooled liquid sample was then shot at with a diabolo airgun pellet from a distance of 1m. The speed of the pellet was c250 m/s Footage taken with a high speed camera shows the sample beginning to inflate because of vesiculation that began upon impact.

If impact vesiculation is a widespread phenomenon this has implications for studies of volcanic degassing and its climatic influence. For example, impact vesiculation releases gas at ground-level only. Thus any study comparing the sulfur content of degassed lava that had undergone impact vesiculation (e.g. a clastogenic lava flow) with the sulfur content of melt inclusions would tend to overestimate the amount of sulfur that could have been injected high into the atmosphere.