Excitation of airwave by a bubble bursting in particle-bearing fluids : regime transitions and implications for basaltic volcanic eruptions

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Basaltic magma becomes more viscous, solid-like (i.e., elastic-like) and non-Newtonian (shear-thinning, possessing yield stress), as its crystal content increases. However their effects on bubble bursting and airwave excitation are poorly understood. Here we conduct laboratory experiments to investigate these effects by injecting a bubble with a volume V into a suspension consisting of non-Brownian particles (volumetric fraction phi) and a Newtonian liquid. We match the refractive indices of the particles and liquid, so that the subsurface bubble is visualized. We show that depending on phi and V, airwaves with diverse waveforms are excited, covering a broad frequency band of f of the order of 10-10^4 Hz. In a suspension of phi <= 0.3, the bubble bursts after forming a hemispherical cap at the surface and excites a high-frequency (HF) - wave (f = 1 - 2 x 10^4 Hz) having an irregular waveform. However in a suspension of phi = 0.4, when the bubble V is above critical, it bursts as soon as it protrudes above the surface and excites Helmholtz resonance with f of the order of 10^3 Hz. Superimposed on the waveform is a HF-wave component excited upon bursting, and a low frequency (f of the order of 10 Hz) air flow which vents out when the aperture grows. This transition of bubble bursting style and airwave excitation mechanism can be explained by bubble film being stretched above a critical strain rate such that the film rutpures by brittle failure. We also study the case where the fluid level is lowered such that an air column (length L) resonance is excited in addition to Helmholtz resonance. When L exceeds critical, air column resonance continues longer than the Helmholtz resonance, because the decay rate of the former becomes smaller than that of the latter. Our experiments indicate that whenever Helmholtz resonance is excited, we may use the frequency and decay rate to constrain the bubble volume and aperture radius, and also to infer the change of magma rheology.

Keywords: crystal-bearing magma, viscoelasticity, non-Newtonian rheology, bubble bursting, airwave, resonance

