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Birth of a bubble: sub-second 4D in-situ synchrotron tomography reveals role of silicate crystals in degassing of andesitic magmas

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Bubbles in silicate magmas are one of the main controls on eruption explosivity. Previous investigations of bubble dynamics in magmatic systems were generally conducted on natural post-eruption samples or quenched experimental charges; both types of studies provide only a view of the final state of a dynamic system, with little information on how that state was achieved. One of the most important and most elusive parameters, the exact location of bubble nucleation sites, cannot yet be directly observed in natural volcanic systems.
We present a 4D X-ray microscopy study of bubble behaviour using experiments that simulate natural conditions as close as is currently possible with the aim of revealing the initial nucleation dynamics and growth of water bubbles in a magma. 4D in-situ synchrotron X-ray tomography experiments were conducted on hydrous, crystal-bearing andesitic run products produced at 1 GPa to observe bubble nucleation and track bubble growth and movement. The high-pressure run products were heated at 1 atm to above the solidus and observed in 3D at a resolution of 3 μm3 every 0.5 s for a total of 50 s. We discovered that bubbles nucleated heterogeneously on plagioclase/melt interfaces and on clinopyroxene crystals. Heterogeneous nucleation on oxides and homogeneous nucleation within the melt occurred significantly after bubble nucleation on silicates. The 3D bubble-crystal contact angle was not constant but changed with time; initially the contact angle was very large and decreased with bubble growth. Bubbles grew much larger than their associated crystal, producing textures similar to some natural volcanic samples. After each experiment the bubbly samples were scanned at sub-micron spatial resolutions to confirm that bubbles nucleated at the silicate crystal/melt interface.
Our results show that the presence of silicate phases in magmas must be taken into account when discussing vesiculation in natural systems. We also demonstrate the power and utility of 4D experiments and the need for their wider application in verification and potential re-evaluation of heterogeneous bubble nucleation.