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Vesicle growth during Vulcanian explosions of Soufrière Hills Volcano, Montserrat, 1997

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In 1997, the Soufrière Hills Volcano on Montserrat had two periods of repetitive Vulcanian activity, with explosions occurring on average every $\sim$10 hours. These explosions generated pumiceous pyroclastic flows by fountain collapse; synchronous fallout also took place from associated buoyant plumes that ascended to heights of 3–15 km. Explosions are inferred to have been initiated when magma overpressure behind a highly viscous, degassed plug exceeded a critical threshold. An average explosion expelled 3 x 10^5 m^3 of magma and emptied the conduit to a depth of 0.5-2 km. High-resolution vesicle size distributions, supported by helium pycnometry analyses, were performed on the explosion products in order to reveal histories of vesicle nucleation, growth and coalescence, and hence better understand the conduit dynamics during these explosions.

The vesicular interiors of breadcrust bombs derived from the degassed plug contain one population of 200-3000 μm vesicles and another of small vesicles with diameters of 2-65 μm and a mean of $\sim$20 μm. The large vesicles are spatially associated with broken phenocrysts, and formed due to locally reduced pressure during tensile fragmentation of crystals and/or to the explosion of melt inclusions. The small vesicles, a third of which are isolated, post-date fragmentation, since the glassy rinds of the bombs are practically vesicle-free. Pumices from the fallout and scoriae and pumices from the pyroclastic flows, all contain two vesicle populations: (1) a small population with a mean of $\sim$40 μm, similar to that in the breadcrust bomb but with a wider size range, (2) a larger, 300-3000 μm population. The large population, in which all the vesicles are connected, formed by vesicle nucleation, growth and coalescence at depth in the conduit during slow magma ascent between explosions. By analogy with the breadcrust bombs, the small population is interpreted to be syn-eruptive. However, unlike in the breadcrust bombs, this population was acquired *prior to* magma fragmentation, since no vesicularity gradients are present in fallout pumices, which preserve tabular forms acquired at fragmentation.

The origin of the small vesicle population is explained by the interplay between decompression and fragmentation waves in the conduit. Nucleation was triggered immediately after onset of the explosion by the rapid propagation down the conduit of a decompression wave. Decompression at shallow levels in the conduit was immediately followed by fragmentation, so that vesicles in the interiors of the breadcrust bombs grew entirely after fragmentation, protected from cooling during transport by the glassy rind. At deeper levels, the time interval between decompression and fragmentation was long enough that syn-eruptive vesicle growth and coalescence were well advanced *prior to* fragmentation. Hence the smallest vesicles in pumices are syn-eruptive, but pre-fragmentation. Syn-eruptive vesicle growth and coalescence probably took place largely in the conduit *prior to* thermal quenching, since fallout and pyroclastic flow pumices experienced different thermal histories after leaving the vent, but have the same vesicle size distributions. These hypotheses are supported by microlite analyses that allow estimation of quench pressure and hence depths of these different samples in the conduit prior to each explosion.