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Vesiculation processes during the 1997 Vulcanian explosions of Soufrière Hills Volcano, Montserrat

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Soufrière Hills Volcano had two periods of repetitive Vulcanian activity in 1997, during which 88 explosions occurred. Each explosion discharged the contents of the upper 0.5-2 km of the conduit, two thirds as pyroclastic flows and the rest as fallout from 3-15 km high buoyant plumes: frothy pumices from a deep, gas-rich zone, lava and breadcrust bombs from a degassed lava plug, and dense pumices from a transition zone.
Vesicles constitute 1-66 vol% of breadcrust bombs and 24-79% of pumices, all those larger than a few tens of μm being interconnected. Small vesicles (< few tens of μm) in all pyroclasts are interpreted as having formed syn-explosively, as shown by their presence in breadcrust bombs formed from originally non-vesicular magma. Most large vesicles (> few hundreds of μm) in pumices are interpreted as pre-dating explosion, implying pre-explosive conduit porosities up to 55%. About 15% of large vesicles in pumices, and all those in breadcrust bombs, are angular voids formed by syn-explosive fracturing of amphibole phenocrysts. An intermediate-sized vesicle population formed by coalescence of the small syn-explosive bubbles. Nucleation took place heterogeneously on titanomagnetite, number densities of which greatly exceed those of vesicles, and bubble growth took place mainly by decompression. Growth took place under disequilibrium conditions largely by decompression-driven expansion; diffusive outgassing of melt was limited by the short timescale of the explosions, accounting for the high water contents preserved in matrix glasses.
Development of vesicle textures was controlled by the time interval between decompression and onset of clast-surface cooling. Plug fragments entered the air quickly after fragmentation ($\sim$10 s), so interiors continued to vesiculate once the rinds had quenched. A larger time interval for deep-derived pumices ($\sim$50 s) allowed complete vesiculation prior to quench, accounting for the textural similarity between flow and fall pumices, despite different thermal histories after leaving the vent. This also allowed syn-explosive coalescence to proceed further in pumices than in the breadcrust bombs. Uniaxial boudinage of some amphiboles implies significant syn-explosive vesiculation of pumices even prior to magma fragmentation and suggests that vesiculation in pumices have been largely confined to the conduit. Syn-explosive decompression rates estimated from vesicle number densities are consistent with those predicted by numerical models. These decompression rates are also consistent with the idea that syn-explosive bubble nucleation during the 1997 explosions was initiated during rapid decompression of conduit magma in a zone of steep pressure gradient beneath the descending fragmentation level.