Possible fragmentation in a lava fountain at the temperature lower than the glass transition

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The 2018 LERZ eruption of Kilauea Volcano, Hawaii, was one of the rare opportunity to observe a lava fountain erupting the highly porous pyroclasts of reticulite or golden pumice. The pyroclasts covered the neighborhood as fall deposits, over the lava flow outside the spatter cone. The pyroclasts in fall deposits are usually generated by fragmentation, which is a key process to cause explosive eruption by enhancing the mobility of viscous magma. Viscous silicic magma can fragment in a brittle manner by rapid deformation. However, the fragmentation mechanism of less viscous basaltic magma is still controversial.

We here show that the magma in a lava fountain surrounded by high-temperature volcanic gas is relatively colder and generates smaller and numerous pyroclasts. The size distribution of the pyroclasts produced in the colder fountain obeys the power law with an exponent of -1.7, which is a power law for the fragmentation of solid materials. From this observation, we infer that volcanic gas, which had confined in the bubbles, expands rapidly to be cooling. The adiabatically expanding gas, in turn, cools the contacting melt surface below the glass transition temperature. The solidifying magma foam is fragile, resulting in that the magma foam fragmented into small pieces further. The small pyroclasts are entrained by the upwelling flow of the volcanic gas locating above the fountain and then deposit as tephra. Our hypothesis solves the question of how a low viscous magma without crystals fragments in a brittle manner.