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How do basaltic magmas fragment? A numerical investigation through the ascent dynamics of the 122 BC Etna Plinian eruption

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Among the different eruptive styles that a volcano can exhibit, explosive eruptions are the most intense and violent. As magma rises through the conduit, the confining pressure decreases, causing dissolved volatile species to exsolve from the melt, forming gas bubbles. As pressure further decreases, bubbles rapidly expand and accelerate, which may lead, ultimately, to magma fragmentation, the defining feature of explosive eruptions. The high viscosity of silicic magmas favours Vulcanian, sub-Plinian or Plinian explosive activity. Violently explosive eruptions are less common at basaltic volcanoes, but Plinian eruptions of moderate intensity, are known. For example, Mt. Etna (Italy) has produced infrequent Plinian eruptions, such as the one that occurred in 122 BC, which had an inferred mass discharge rate of $\sim 10^8$ kg/s. However, the mechanisms controlling magma fragmentation during highly explosive basaltic Plinian eruptions remain unclear.

Here we investigate the conditions which lead to fragmentation of basaltic magmas by adopting a multiphase, multicomponent 1D conduit model, and using the 122 BC Etna basaltic Plinian eruption as a test case. We investigate two fragmentation criteria: the strain-rate and the inertial criteria. Our results show that, when fragmentation is achieved through the inertial criterion, it occurs just a few meters below the vent. Fragmentation can be also achieved deeper in the conduit, but only through the strain-rate criterion. Furthermore, our results highlight that a strong and rapid increase in viscosity seems to be the key condition to achieve fragmentation. 4D crystallisation experiments performed at Diamond Light Source (experiment EE12392 at the I12 beamline), at an undercooling consistent with that of basaltic Plinian eruptions, suggest that crystallization can occur within a few minutes, producing the increase in viscosity required to achieve fragmentation deeper in the conduit.