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Experimental determination of fragmentation efficiency for Plinian and Pelean eruptions of Mt. Pelée, Martinique

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Mt. Pelée is a historically active volcano, situated on the island of Martinique (Lesser Antilles), that has shown a variety of explosive styles in the recent past, ranging from dome-forming (Pelean) to open-vent (Plinian) eruptions. The 1902-1905 eruption is infamous for the pyroclastic density currents (PDCs) that destroyed the towns of St. Pierre and Morne Rouge, killing 30 000 residents. Since the last eruption (dome-forming) in 1929-1932, Mt. Pelée was quiet and considered dormant until recently. In late 2020, the local Volcanological Observatory (OVSM) raised the alert level following a noticeable increase in seismicity, bringing into effect a reinforcement of monitoring resources. As St. Pierre is long since re-established, along with several other towns along the volcano's flanks, it is of utmost importance to understand the possible range of eruptive activity to improve the preparedness strategies of local communities.

The precise controls on eruption dynamics vary across volcanic systems and cannot be constrained via direct observation. However, crucial inferences can be made based on petrophysical properties and mechanical behaviours of erupted materials. For this study, we collected samples from PDC deposits of Mt. Pelée, from the two historic Pelean (1902-1905, and 1929-1932) and three pre-Columbian Plinian eruptions (1300 CE P1, 280 CE P2, and 79 CE P3). We measured petrophysical properties (density, porosity, permeability) of cylindrical samples drilled from bomb-sized clasts and investigated their fragmentation behaviour via grain size and high-speed video analysis. These results are used in comparison with field data of grain-size distribution (GSD) of individual outcrops and calculated total GSD data. We investigated the effects of transport-related sorting or fining.

The "Pelean" samples are found to be denser (32-47% open porosity) than the pumiceous "Plinian" samples (55-66% open porosity). Moreover, these two classes are distinctly different in their crystallinity as samples underwent different ascent conditions. In our experiments, distinct fragmentation behaviour and resulting GSDs are observed for samples from each eruption style, regardless of experimental pressure conditions (5-20 MPa). Our results show the paramount

importance of open porosity on fragmentation efficiency in pumiceous samples, alongside a strong influence of crystallinity. The fractal dimension of fragmentation calculated from weight fractions, independent of grain shape, shows clear differences in fragmentation efficiency as a function of sample properties and experimental starting conditions.

Our results suggest that (i) the variability in porosity and permeability is too low to cause the increased explosivity exhibited during the 1902 eruption compared to the 1929 event, (ii) open porosity has a major control on fragmentation efficiency in pumiceous samples, (iii) fragmentation efficiency can be effectively evaluated by calculating the fractal dimension of the cumulative weight fractions of experimental products.

The influence of crystallinity and pore textures on fragmentation efficiency must be further investigated to aid hazard model development for future eruptions of Mt. Pelée. Future work will constrain these textural parameters of naturally and experimentally fragmented materials from Mt. Pelée, to further elucidate the controls on eruptive dynamics at this hazardous volcano.