New insights on the dynamics of the most recent Plinian eruptions of Mt. Pelée (Martinique, Lesser Antilles) inferred from noble gases

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Mt. Pelée in Martinique is one of the most dangerous volcanoes of the Lesser Antilles arc. The May 8th, 1902 eruption that destroyed the town of St Pierre and killed 28,000 inhabitants is a famous example of its hazardous explosive activity. Lacroix (1904) first defined the Pelean style as dome emplacement associated with lateral blast explosions based on his pioneering description of this eruption. Among the 22 magmatic events recorded at Mt Pelée over the last 5000 years, 6 were (Merapi-type) dome collapse eruptions and 10 were (Pelean-type) lateral blast eruptions. Furthermore, 6 eruptions were Plinian eruptions, which produced both pyroclastic flows and Plinian columns. Such a variability of eruptive regimes is a serious challenge for the management of volcanic hazards at Mt. Pelée, and past eruption deposits are a crucial insight to understand the complex dynamics of this volcano.

Here we use the information recorded by the noble gases trapped inside the vesicles of pumices to study the last three Plinian eruptions of Mt. Pelée (P1, P2, P3). During magma decompression and bubble growth, varying degrees of fractionation between the noble gases can occur because of differing diffusion coefficients and depending on the time-scale involved. A noble gas measurement in a pumice sample thus enables us to quantify the time elapsed between the onset of degassing and quenching due to fragmentation, for example. Type-1 eruptions (P1 and P3-1) are characterized by pumice vesicles with a low enrichment in neon compared to argon ($F^{22}Ne$ <400) and $^{38}Ar/^{36}Ar$ ratio close to its initial value ($\sim$0.1880). On the other hand, type-2 eruptions (P2, P3-3 and P3-2) are characterized by pumice vesicles with a high enrichment in neon compared to argon ($F^{22}Ne$ >1000) and a strongly fractionated $^{38}Ar/^{36}Ar$ ratio (<0.1860), rarely observed on Earth.

We interpret these fractionations as the result of two different durations for the dynamics of magma degassing. The strong elemental and isotopic fractionations in type-2 eruptions correspond to a short time scale of degassing, and suggest that fragmentation processes occurred shortly after the onset of degassing in the conduit. Such a rapid evolution may occur where the magma is abruptly depressurized by the collapse of a pre-existing dome, or by a sudden drop of the fragmentation level in the conduit. In type-1 eruptions, fractionations can be explained by slower degassing such that a closer approach to equilibrium between melt and bubble is achieved before quenching.

The noble gas pattern produced during magma degassing with variable time-scales can then be used as a stratigraphic marker of different Plinian eruptions. This represents a new tool for the identification and mapping of old fallout deposits imperfectly preserved in the field.