EGU21-6916
https://doi.org/10.5194/egusphere-egu21-6916
EGU General Assembly 2021

Using apatite records of volatile budget and magma ascent rates to investigate eruption dynamics

Olivier Bernard[1,2], Weiran Li[1], Fidel Costa[1,2], and Caroline Bouvet de Maisonneuve[1,2]
[1]Earth Observatory of Singapore, Nanyang Technological University, Singapore
[2]Asian School of the Environment, Nanyang Technological University, Singapore

One of the major challenges faced by volcanologists to investigate controls on eruption dynamics is to quantify both pre-eruptive volatile budgets and timescales of magma ascent. Indeed, petrological investigations of the two parameters usually rely on different methods/analytical techniques that are not always applicable/accessible. Recent studies have shown that the abundance and zoning pattern of F, Cl, and OH in apatite can be used to determine both pre-eruptive volatile budget and magma degassing rates that can, under some conditions, be related to magma ascent rates ([1],[2]).

Here we apply the two methods to apatite in the Rabaul 2006 eruption deposits (Papua-New-Guinea). This was a VEI-4 eruption and occurred in three main phases: (1) a sub-plinian onset followed 12h after its start by (2) a mixed strombolian-effusive phase, which subsequently evolved into (3) discrete vulcanian explosions. We sampled deposits of the three phases: (1) pumices, (2) fragments of lava flow, and (3) fragments of cow-pad bombs.

We calculated pre-eruptive water contents using apatite included in clinopyroxene as they keep a better record of reservoir conditions from the time of entrapment. We found that the magma that fed the sub-plinian phase contained the highest water content of about 2 wt.%, while magmas that fed the lava flow and the vulcanian phase were drier, with 0.2 to 0.5 wt.% less H_2O. X-ray maps acquired with an EPMA show that only apatite crystals in the groundmass of the vulcanian and effusive deposits are zoned in F and Cl at the crystal rims, whereas those from the sub-plinian deposits and included in clinopyroxenes are not zoned. This indicates that the zoning is related to syn- or immediately pre-eruptive changes of Cl-F-H_2O during magma ascent towards the surface and can thus be modelled as diffusive reequilibration of the crystal and the melt. We obtained maximum diffusion timescales of <8 hours for the unzoned apatite in sub-plinian deposits, timescales of 20–22 hours for apatite in vulcanian deposits, and 600–1500 hours for those in the lava flow. Thus, the time scales increase with decreasing explosivity of the eruptions, as it could be expected if magma ascent rate played the key role of eruption dynamics. However, the degassing timescales of the effusive phase are significantly longer than the eruption duration itself, which can be explained if the magma started rising in the system 1–3 months prior to the onset of the eruption. The volatile-rich, fast-rising magma that fed the initial sub-plinian phase propagated through, disturbed and remobilized the shallower, more degassed batch of magma, which was erupted during the following effusive phase. Deeper, volatile-poor magma that kept moving up the open conduit, was responsible for the late vulcanian explosions.

Our results show that apatite is a powerful tool for probing slight changes in magma volatile chemistry and ascent rates that can vary between different phases of the same eruption and produce different eruption styles.

[1] Li and Costa, 2020, GCA [2] Li et al. 2020, EPSL