Same initial volatile budget but different ascent paths led to contrasting eruptive styles at Merapi Volcano in 2006 and 2010

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Eruptions at Merapi Volcano (Indonesia) flipped from effusive in 2006 to explosive in 2010, without significant change in magma composition or mineralogy. In such case, the contrasting eruptive styles are controlled by two principal parameters: pre-eruptive volatile budget and/or magma ascent rate. It is often difficult, however, to constrain the two parameters or to establish which plays a larger role in an eruption. For example, it is difficult to apply the "melt inclusion" approach, if the deposits cooled slowly and inclusions are not quickly quenched into glass. Here we show that volatiles in apatite can preserve a temporal and evolutionary record on magma, and thus used to address this problem. We determined the pre-eruptive volatile budgets and magma ascent rates of the 2006 and 2010 eruptions at Merapi, to better understand what controls the eruptive styles.

F, Cl, OH and S concentrations in apatite were measured using secondary ion mass spectrometry and electron microprobe. Point analyses and chemical maps were obtained for apatite crystals in different textural context. We found that amphibole-hosted apatite inclusions in 2006 and 2010 deposits have similarly high volatile contents, indicating similar initial volatile budgets in magmas of the two events, despite the difference in their eruptive styles. Besides, apatite inclusions in clinopyroxene and plagioclase and apatite in the matrix have distinctly low volatile contents. Thus we propose at least two reservoirs in the plumbing system of Merapi: a deep reservoir where amphibole crystallized from volatile-rich magma, and a shallower one where magma was more degassed and crystallized clinopyroxene and plagioclase.

In addition, the 2006 apatite crystals in the matrix show increasing Cl content towards the rim, possibly resulting from an increase in partition coefficient with decreasing pressure, and/or increasing Cl concentration in the residual melt due to microlite growth during slow ascent. In contrast, Cl zoning is not observed in apatite of 2010 deposits. Diffusion modelling of Cl concentrations indicate that the ascent rate of 2010 magma was >25 times faster than that of 2006, consistent with extrusion rates obtained from monitoring data. We propose that the faster magma ascent rate in 2010 is responsible for the greater explosivity of this event, rather than higher pre-eruptive volatile budget, compared to 2006.