Apatite as a powerful tool of tracking melt volatile (H_2O, CO_2) abundances

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The volatile abundances and composition in melts are a key parameter of controlling eruptive styles of volcanoes, however they are not always feasible to constrain using the common "melt inclusion" method. Here we study two eruptions at Merapi Volcano (Indonesia): the effusive one in 2006, and the larger explosive one in 2010. H_2O, CO_2, Cl, F and S concentrations were measured using secondary ion microprobe for apatite that occurs in various textural positions, i.e. as inclusions in other phenocrysts, or microphenocrysts/microlites in the groundmass. We use a new apatite thermodynamic model (Li and Costa, 2019, *in review*), which constrains the partitioning of volatiles between apatite and the melt via considering non-ideal mixing of F-Cl-OH in apatite to calculate the melt volatile compositions.

We find that apatite crystals from both deposits show mainly a bimodal distribution of H_2O-CO_2 concentrations: apatite included in amphibole crystals has higher volatile contents (0.9~1.0 wt.% H_2O, and ≥2400 ppm CO_2) than those in plagioclase/clinopyroxene/groundmass. Apatite included anhydrous mineral or groundmass grew or reequilibrated with shallow melts (H_2O: 1~3 wt.%; CO_2: 50~2000 ppm) at depths of ≤9 km, whereas those in amphibole show much higher volatiles (H_2O: 4~10 wt.%; CO_2: ≥1.0 wt.% for 2010) and grew much deeper locations (near Moho). Our results thus imply the existence of two well defined storage areas below Merapi that are roughly consistent with geophysical images. Moreover, summit fumaroles show increasing C/H value of the gas towards the eruption. Calculation of fluid compositions using the deep and shallow melts calculated from apatite match with those measured from the gas. We propose that before the 2010 explosion, the deep volatile-rich magmas migrated from depths (near Moho) to the shallow reservoirs (≤ 9km), and transferred much of their fluids to the pre-existing melts (from 2006) at the upper reservoir, which was quickly remobilized and erupted explosively.