Effect of pre-eruption storage on estimates of magmatic $\delta^{18}O$ from minerals

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Melt $\delta^{18}O$ is frequently calculated from analyses of individual minerals in volcanic rocks. Due to the large range in oxygen diffusivities in phases that comprise magma, disequilibrium is likely to arise among minerals in magmas that have experienced long intervals of pre-eruption storage. Minerals where diffusion is slow are more likely to preserve a record of oxygen isotopic fractionation at crystallization temperatures. With the recognition that many silicic magmas spend a significant portion of their pre-eruption history as crystal mush prior to remobilization and eruption, minerals with faster oxygen diffusivity will be affected to a greater degree and thus give erroneous results, particularly for long-lived evolved magmas.

We analyzed mineral phases from rhyodacite domes at Parinacota Volcano, Chile, where the crystallization T (700-800°C) and pre-eruptive crystal residence times (<230 ka) are well constrained using several geothermometers and U-Th disequilibrium dating [1]. Calculated temperatures based on $\delta^{18}O$ of mineral pairs (where diffusivities are different) are highly scattered and likely not meaningful. However, if melt $\delta^{18}O$ is calculated from the most retentive phase (titanite), temperatures obtained from pairing the other minerals with that model melt yield ranges in T that reproduce (a) initial crystallization conditions for minerals where diffusion is slow, and (b) lower eruption/cooling temperatures for minerals where diffusion is fast.

We propose that in order to assure maximum accuracy of melt $\delta^{18}O$ calculated from minerals in silicic magmas that experienced prolonged near-solidus storage, (a) closure temperatures for oxygen isotopic exchange should be calculated for all minerals based on typical grain sizes and an assumed cooling rate, in order to determine which mineral is most likely to already be closed to oxygen isotope exchange at crystallization conditions (e.g. zircon or titanite) and (b) crystallization temperature be independently determined, preferably on the same phases (e.g. via Zr-in-titanite or Ti-in-zircon thermometry). Our analyses shows that quartz may not be a reliable mineral to detemine melt $\delta^{18}O$ in silicic magmas.

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