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Diffusion chronometry: state of the art, applications and future perspectives

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Elemental diffusion chronometry is a relative chronometer exploiting elements exchange within a chemically zoned crystal or within a crystal and melt and it is widely used to constrain timescales of pre-eruptive magmatic processes. The field is rapidly moving from targeting timescales related to the last pre-eruptive event, occurring shortly prior to eruption, recorded by the outermost rim of the crystal, to multiple events, recorded by the interior portions of complexly zoning crystals, potentially allowing reconstructing a core to rim sequence of magmatic events (i.e., elemental diffusion chronostratigraphy). This latter approach can provide fundamental time-constrained insights into magma dynamics, such as duration of magma mixing events.

Durations of pre-eruptive magmatic processes are quite variable and are system dependent. Timescales of magma storage between magma intrusion and eruption is relative short (from a few days to a few decades) for basaltic systems, but much longer (decades to millennia) for silicic systems. The short timescales recorded by crystals from mafic and intermediate volcanoes often match those recorded by monitoring signals (e.g., gas, seismicity, deformation, etc) and offer valuable information to inform volcano forecasting and hazards mitigation. Timescales of magma remobilisation and pre-existing crystals remobilisation, retrieved from the internal portions of chemically zoned crystals, provide information on the longevity of crystal mushes and are shedding new light particularly on basaltic crystal mushes, which may persist longer than previously hypothesised. Here, I will present the current state of the art of diffusion chronometry using recent examples from both terrestrial and extraterrestrial volcanoes. I will also focus on the challenges we face to progress diffusion chronometry, reducing uncertainties and favouring interdisciplinary approaches that link diffusion chronometry to real-time volcano observations and isotope geochemistry.