Constraining pre-eruptive timescales of the 2021 Fukutoku-Oka-no-Ba eruption from magnetite and obsidian diffusion chronometry

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Quantifying the timing of magma mixing prior to eruption is particularly challenging for submarine volcanoes, where constraints from geophysical observations are limited. Here, we reconstruct the short-lived pre-eruptive history of the 2021 explosive eruption of Fukutoku-Oka-no-Ba (FOB) by integrating compositional records of obsidian and pumice glass with Fe–Mg diffusion chronometry in magnetite, together with glass water contents.

Elemental mapping of obsidian clasts collected from seafloor deposits around FOB revealed compositional banding at the 10–50 μm scale. The glass MgO–SiO_2 composition of the pumice and obsidian separated into two distinct clusters, suggesting interaction between two magma components (high-Si and low-Si series) shortly before fragmentation and quenching.

Magnetite hosted in low-Si series obsidians commonly showed disequilibrium Fe–Mg zoning, whereas magnetite from most drift pumice collected on the Okinawa islands lacked comparable zoning. We also analyzed magnetite in pumice collected by R/V *Keifumaru* at 25˚30.3N/138˚53.3E, which has been interpreted as among the earliest erupted products; some of these magnetites likewise preserved thin diffusion rims. Diffusion modelling of Mg profiles in magnetites with zoning yielded two dominant timescale populations in low-Si obsidians: an hour-scale group (~1–7 hours) and a day-scale group (~30–40 hours). Magnetite from *Keifumaru* pumice recorded similarly short timescales (~1–8 hours).

Most obsidian and pumice glass contained low total water content (H_2O_t ~ 0.2–1.0 wt%) and lacked molecular water (H_2O_m) components, whereas *Keifumaru* pumice glass was water-rich (H_2O_t ~ 1.3 wt% and H_2O_m ~ 0.5 wt%). Taken together with the major-element glass compositions and magnetite diffusion rims, these constraints allow us to infer the pre-eruptive state of the magma and to evaluate the origin(s) of the magma component(s) involved immediately prior to eruption.

We interpret these observations as evidence for multi-stage magma interaction prior to eruption: an earlier mixing/heating event on day-scale timescales followed by a late-stage hour-scale event that is consistent with having contributed to eruption initiation. Our results demonstrate that pre-eruptive mixing in submarine magma systems can occur within hours of eruption onset, and highlight the utility of combining crystal-scale diffusion chronometry with compositional and volatile constraints for time-resolved reconstruction of magmatic processes.

Keywords: Fukutoku-Oka-no-Ba, magnetite, obsidian, diffusion chronometry, crystal zoning, sumarine eruption

