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Titanium isotope insights into mass transfer during subduction initiation

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Subduction is a key geochemical process linking Earth's surface and interior. Therefore, understanding element cycling during mass transfer in subduction zones has long been a major focus within geochemistry. Boninites are highly refractory lavas that have been interpreted to denote the initiation of subduction. Thus, they can serve as geochemical archives of early subduction processes, capturing interactions between the mantle wedge and the subducting slab. While elemental and radiogenic isotope studies have traditionally been used to trace these interactions, heavy metal stable isotopes can offer a novel perspective on slab, mantle, fluid, and sediment contributions to arc magmatism.

Titanium (Ti) isotope variations (expressed as $\delta^{49/47}$Ti) are emerging as a powerful tool for investigating magmatic processes in subduction zones, including recent investigations of slab melting [1]. Here, we present new Ti isotope data for boninites and associated rocks such as high-Mg andesites from IODP Expedition 352 (Bonin Ridge) and the Oman-UAE ophiolite. We combine these new data with previously published boninite Ti isotope ratios from the Troodos ophiolite and Papua New Guinea [2]. As a whole, boninites exhibit a tenfold variation in $\delta^{49/47}$Ti (~ +0.1 to +0.2 ‰) relative to mid-ocean ridge basalts (MORB; ~ 0 ‰), and overlapping with values reported for primitive arc lavas [1]. Elevated $\delta^{49/47}$Ti compared to MORB has been attributed to eclogite-facies slab melting, where isotopically light Ti is retained in residual rutile. However, rare earth element systematics of boninites argue against a rutile- or garnet-bearing source.

Models of Ti isotope fractionation using experimental phase equilibria suggest that hydrous partial melts of refractory harzburgite yield $\delta^{49/47}$Ti similar to MORB, whereas slab melting at amphibolite facies conditions (≤1 GPa) can generate silicic melts with elevated $\delta^{49/47}$Ti (+0.16 ± 0.02 ‰) due to the preferential retention of light Ti isotopes in amphibole. The combined $\delta^{49/47}$Ti and rare earth element systematics of boninites require a substantial slab melt contribution to the mantle wedge. These findings provide direct geochemical evidence that slab melting plays a key role in mass transfer during the early stages of subduction initiation.

[1] Klaver et al., (2024), *EPSL*; [2] Kommescher et al., (2023), *G³*