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Low recycling efficiency of boron into the deep mantle

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Boron is a distinctly crustal element in that it is strongly enriched in the surface reservoirs, such as continental crust, seawater, sediments, serpentinites and altered oceanic crust, relative to the mantle. These B-enriched reservoirs are also isotopically very distinct from the regular depleted upper mantle ($d^{11}\text{B} = -7.1 \pm 0.9 \text{‰}$ [10.1016/j.gca.2017.03.028]). This has encouraged the idea that boron could be an ideal tracer for subducted surface materials in the deep mantle in the form of isotopically anomalous recycled components in ocean island basalts (OIB) and enriched MORB. Yet, the potential of a geochemical tracer of this type is weakened by its extraction from the slab at the onset of subduction by dewatering and metamorphic dehydration, because this process depletes the recycled components in fluid-mobile elements. As such, this “subduction barrier” diminishes the deep recycling efficiency of incompatible, fluid-mobile tracers like B.

This study focuses on the B abundances and B isotopic compositions of glasses and melt inclusions that show low Cl/K ratios and are thought to represent the uncontaminated mantle signal from the HIMU (Tuvalu and Mangaia), EM1 (Pitcairn) and EM2 (Samoa) sources. Strikingly, all samples are depleted in boron by a factor of approximately 1.5 to 4 relative to non-fluid-mobile elements of similar incompatibility (e.g. LREE, P, Be). This negative boron anomaly is ubiquitous in OIB and is consistent with the results of previous studies [10.1016/0016-7037(95)00402-5; 10.1016/j.epsl.2018.12.005]. It also mirrors their characteristic negative Pb anomaly. These anomalies show that the mantle sources of OIB are depleted in B (and Pb) relative to non-fluid-mobile elements of similar incompatibility and relative to the MORB-source mantle. This is best explained by the presence in the OIB sources of recycled components that are enriched in all incompatible elements except for the fluid-mobile B (and Pb). The fluid mobile elements must have been preferentially extracted in the subduction barrier and returned to the surface on the short path via arc magmas. Arc magmas consistently show a general enrichment in isotopically heavy boron [10.1007/978-3-319-64666-4_9] with positive B anomalies.

Despite of the low recycling efficiency of boron into the convecting mantle, OIB still have B isotope signatures that are distinct from those of MORB. Previous studies have reported OIB signatures slightly lighter than MORB and the primitive mantle [10.1016/j.epsl.2018.12.005]. However, our study exclusively finds isotopically heavy B with a range in $d^{11}\text{B}$ from MORB-like values ($-8.6 \pm 2.0 \text{‰}$) up to $-2.5 \pm 1.5 \text{‰}$ for EM1 and HIMU lavas. The total OIB range is small but significant, and is consistent with the deep recycling of material that is strongly depleted in boron, but isotopically distinct (with isotopically heavy B in the case of our EM1 and HIMU samples). The B depletion

combined with the B isotopic anomaly in OIB shows that B is efficiently (but not quantitatively) removed from the slab during subduction, and that isotopically distinct mantle domains are thus produced. The subduction barrier for boron increases its strength as a tracer in arcs, but it diminishes its potential as a tracer of deep mantle recycling.