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The boron isotope composition of high-pressure subducted serpentinites: constraints on tectonic setting and implications for arc magmatism

Marco Scambelluri and Sonia Tonarini
University of Genova, Dipartimento per lo Studio del Territorio e delle sue Risorse, Genova, Italy
(marco.scambelluri@dipteris.unige.it)

Serpentinites are key players in volatile and fluid-mobile element cycles in oceans, subducting slabs, fore-arc to sub-arc mantle. Their dehydration represents the main event for fluid and element flux from slabs to mantle, although no direct proof of this fact yet exists. For this purpose, boron and its isotopes are known markers of fluid-assisted element transfer during subduction. Until recently, the altered oceanic crust has been considered the dominant 11B reservoir for arc magmas, which largely display positive delta11B. However, 11B is selectively fractionated into fluids during slab dehydration below fore-arcs, and is transferred to serpentinite layers forming in the overlying mantle. This makes the residual mafic slab crust and its fluids very depleted in 11B below sub-arcs (100-120 km). Therefore, the 11B-rich composition of serpentinites, together with the very high delta11B of some arc magmas, candidate serpentinites as the B carriers for subduction. Here we present high positive delta11B of Alpine high-pressure (HP) serpentinites that experienced subduction metamorphism: our B isotope data show the connection among serpentinite dehydration, release of 11B-rich fluids and arc magmatism.

We analyzed serpentinized peridotites recording subduction metamorphism from relatively low P-T (dominant chrysotile-lizardite serpentine) to eclogite-facies (antigorite + olivine + Ti clinohumite). Formation of metamorphic olivine (+Ti-clinohumite) veins indicates release of HP fluid. In general, the delta11B of these rocks is heavy: most samples exceed 16‰ delta11B up to reach high values of + 24‰The 87Sr/86Sr ratios range from 0.7044 to 0.7065, much lower than seawater-like compositions of present-day oceanic serpentinites.

The heavy delta11B and the relatively low 87Sr/86Sr of the Erro Tobbio serpentinites are not consistent with hydration of oceanic mantle by seawater-derived fluids. The analyzed samples are similar to fore-arc Marianas serpentinites, rather than to Atlantic abyssal serpentinites. The low deltaD, high delta18O and the 87Sr/86Sr of chrysotile-lizardite serpentinites point to an origin from metamorphic fluids that exchanged with metabasalts + subordinated sediments. Moreover, the analyzed prograde suite neither shows B depletion, nor 11B fractionation with increasing grade of subduction metamorphism. This trend is unexpected for a slab-type behaviour, and two major implications for subduction geochemistry and geodynamics are suggested.

First, the Erro Tobbio serpentintes are B and 11B carriers for subduction. Independent on their origin, they maintain high 11B contents down to a first fluid release event: the olivine-veins, that fingerprint the composition of released fluids, have high delta11B well matching the arc lava signatures. Fluids released by dehydration of such high-pressure serpentinites by full antigorite breakdown have delta11B up to + 20‰The very comparable B isotope fingerprint of serpentintes and their fluids with arc lavas provides strong link between serpentinite subduction and arc magmatism, and 11B represents the spike of this process.

Second, the combination of deltaD, delta11B, 87Sr/86Sr of the Erro Tobbio serpentinite apparently favor their location above the subducting slab. This implies that such peridotites, deriving from former oceanic mantle, were early serpentinized by low-temperature metamorphic fluids likely arising from a subducting lower plate. The Erro-Tobbio mantle was then introduced, either by tectonic erosion or by down-drag, in a fore-arc subduction channel. Dehydration at sub-arc depths of this type of serpentinized mantle rocks feeds the mantle sources of arc magmas.