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Serpentinites and Boron Isotope Evidence for Shallow Fluid Transfer Across Subduction Zones

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In subduction zones, fluid-mediated chemical exchanges between subducting plates and overlying mantle dictate volatile and incompatible element cycles in earth and influence arc magmatism. One of the outstanding issues is concerned with the sources of water for arc magmas and mechanisms for its slab-to-mantle wedge transport. Does it occur by slab dehydration at depths directly beneath arc front, or by hydration of fore-arc mantle and subsequent subduction of the hydrated mantle? Historically, the deep slab dehydration hypothesis had strong support, but it appears that the hydrated mantle wedge hypothesis is gaining ground. At the center of this hypothesis are studies of fluid-mobile element tracers in volatile-rich mantle wedge peridotites (serpentinites) and their subducted high-pressure equivalents. Serpentinites are key players in volatile and fluid-mobile element cycles in subduction zones. Their dehydration represents the main event for fluid and element flux from slabs to mantle, though direct evidence for this process and identification of dehydration environments have been elusive. Boron isotopes are known markers of fluid-assisted element transfer during subduction and can be the tracers of these processes. Until recently, the altered oceanic crust has been considered the main 11B reservoir for arc magmas, which largely display positive delta11B. However, slab dehydration below fore-arcs transfers 11B to the overlying hydrated mantle and leaves the residual mafic crust very depleted in 11B below sub-arcs. The 11B-rich composition of serpentinites candidate them as the heavy B carriers for subduction. Here we present high positive delta11B of Alpine high-pressure (HP) serpentinites recording subduction metamorphism from hydration at low gades to eclogite-facies dehydration: we show a connection among serpentinite dehydration, release of 11B-rich fluids and arc magmatism. In general, the delta11B of these rocks is heavy (16‰ to + 24‰ delta11B). No B loss and no 11B fractionation occurs in these rocks with progressive burial: their high B and 11B compositions demonstrate that initially high budgets acquired during shallow hydration are transferred and released to fluids at arc magma depths, providing the high-boron component requested for arcs. Interaction of depleted mantle-wedge with de-serpentinization fluids and/or serpentinite diapirs uprising from the slab-mantle interface thus provide an efficient self-consistent mechanism for water and B transfer to many arcs.

The boron compositions documented here for Erro-Tobbio serpentinites are unexpected for slabs, deputed to loose much B and 11B during subduction dehydration. Their isotopic compositions can be achieved diluting through the mantle the subduction-fluids released during shallow dehydration (30 km) of a model slab. Moreover their delta11B is close to values measured in Syros eclogite blocks, hosted in mélanges atop of the slab and metasomatized by uprising subduction-fluids. The nature of serpentinizing fluids and the fluid-transfer mechanism in Erro-Tobbio is further clarified integrating B isotopes with O-H and Sr isotopic systems. Low deltaD (-102‰, high delta18O (8‰ of early serpentinites suggest low-temperature hydration by metamorphic fluids. 87Sr/86Sr ranges from 0.7044 to 0.7065 and is lower than oceanic serpentinites formed from seawater. Our data indicate that alteration occurred distant from mid-ocean ridges: we propose metamorphic environments like the slab-mantle interface or the fore-arc mantle fed by B- and 11B-rich slab fluids. We therefore provide field-based evidence for delivery of water and 11B at sub-arcs by serpentinites formed by subduction-fluid infiltration in mantle rocks atop of the slab since the early stages of burial, witnessing shallow fluid transfer across the subduction zone.