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Modeling of B concentrations and isotopic compositions in subducted slabs and dehydration fluids

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The oceanic lithosphere plays a key role regarding global scale element cycles. Seawater-rock interaction at the ocean floor causes intense chemical modification of the basaltic oceanic crust and possibly also the upper parts of the oceanic mantle. Later subduction of the modified oceanic lithosphere leads to dehydration, which again enables redistribution of major and trace elements in the subducted slab. This dehydration process is responsible for arc volcanism, subduction-related ore formation but also controls the distribution of elements that are recycled into the upper plate and the atmosphere and those that are incorporated into refractory minerals and are recycled into the deeper mantle.

Regarding the water budget and thus the element transport in a subduction zone, the potentially hydrated oceanic mantle plays a major role as it can store large amounts of water in hydrous minerals, such as chlorite and serpentine. The pressure and temperature conditions as well as the fluid-rock interaction within the subducted slab controls whether water – and elements solved therein – can escape the slab or are deeply subducted and recycled into the Earth's mantle.

Boron concentrations and isotopic compositions are excellent tracers for the contribution of oceanic lithospheric mantle to the water and trace element budget in subduction zones: boron is incorporated at significant amounts in serpentine, it is highly fluid mobile and its two stable isotopes (^{10}B and ^{11}B) undergo equilibrium fractionation between fluid and solid phases.

In this contribution, thermal and thermodynamic models of subduction of oceanic lithosphere are combined with trace element and isotope partitioning data in order to quantify boron concentrations and its isotopic composition in coexisting fluid and solid phases during devolatilisation, fluid migration and fluid-rock interaction in a subducted slab. The results show that fluid-mobile elements undergo complex liberation and resorption processes during fluid migration in a dehydrating slab, which leads to re-enrichment of previously leached lithologies. Such internal redistribution of trace elements within the slab enables recycling of fluid mobile elements beyond the dehydration interval into the deep mantle beyond sub-arc depths.

Further, this study shows that across arc variations of the isotopic composition of boron in arc volcanics can be used as indicator for the hydration state of the subducted oceanic mantle lithosphere. Increases in boron concentrations and $\delta^{11}B$ in rear- and back-arc volcanic rocks, as observed for example in Kamchatka and Northern Japan, can be explained by dehydration of serpentinized upper oceanic mantle.This release occurs over a small pressure and temperature range and, despite intense fluid-rock interaction in the slab crust, the associated trace element signal is transferred to the slab surface and into the mantle wedge. The position of the serpentinite-out reaction and thus the associated trace element signal is dependent on the thermal structure within the slab. Consequently complex across-arc variations in boron concentrations and boron isotopic compositions can be used as constraining parameters in thermomechanical subduction zone models.