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Boron Isotopic Geochemistry of Metasedimentary Rocks and Tourmalines in a Subduction-zone Metamorphic Suite

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Boron is considered to be an excellent tracer of the recycling of subducted oceanic sediment and/or altered oceanic crust at convergent margins (Morris et al., 1990; Ishikawa and Nakamura, 1994). This is because of its extremely high mobility during both magmatic and fluid-related processes and its extreme enrichment in the subducted oceanic sediments and altered oceanic crust compared with unaltered mid-ocean ridge basalts (MORB) and upper mantle materials (Spivack and Edmond, 1987; Ishikawa and Nakamura, 1993). Boron may be, thus, efficiently transferred from subducted slab to arc magma source regions by aqueous fluid through metamorphic processes (Bebout et al., 1993).

Boron isotopic compositions and the concentrations of B in oceanic sediments and oceanic crustal materials are reasonably well characterized. Less is known, however, about the effects of slab metamorphism on B isotopic composition and the concentrations of B in subducted rocks. Hence, it is essential to clarify the behavior of boron and B isotope fractionation in materials such as oceanic sediments and altered oceanic crust as the result of prograde metamorphism and related devolatilization.

In order to understand the behavior of boron and its isotope fractionation during subduction zone metamorphism, B contents and isotopic compositions together with major element compositions after detailed petrographic observations were determined for metasedimentary rocks and tourmalines from the Sambagawa Metamorphic Belt, central Shikoku, Japan. B isotopic compositions of tourmalines were measured by Cameca ims 5f ion microprobe with analytical reproducibility of approximately 0.08% (2σ) using tourmaline standards precisely prepared at Misasa using TIMS (Nakamura et al., 1992). No systematic changes in whole-rock B content and isotope composition of the metasediments were observed among the different metamorphic grades, indicating the lack of a bulk fluid/rock B-isotope fractionation as a result of devolatilization.

Both modal abundance and grain size of tourmaline increase with increasing metamorphic grade. In contrast, B contents in muscovite and chlorite determined by ion microprobe decrease with increasing metamorphic grade. These observations combined with mass balance calculations of B for individual samples suggest the formation of tourmaline during progressive metamorphism from metamorphic fluids containing B mainly derived from muscovite and subordinately from chlorite without allowing significant net removal of B from the metasedimentary rocks. Tourmalines in the higher-grade metasedimentary rocks have zonal structure of B isotope and major element composition with decreasing $\delta^{11}B$ and increasing Mg/(Mg+Fe) from the core to the rim. The change of Mg/(Mg+Fe) in the tourmalines with increasing grade is paralleled by similar variation in chlorite. These observations suggest that the growing tourmalines record the progressive evolution of the B isotopic composition of the metamorphic fluid, in the outermost rims preserving the isotope signature of peak metamorphic P-T-fluid conditions.

Based on the above observations, the $\delta^{11}B$ of the tourmaline is thought to have been nearly identical to that of the metamorphic fluid resulting in the "apparent" B isotopic fractionation factor between metamorphic fluid and whole rock $\delta=(^{11}B/^{10}B)_{fluid}/(^{11}B/^{10}B)_{whole\ rock}$) which decreases from 1.007 ±0.003 to 1.001 ±0.003 from chlorite to biotite zone metamorphism. Such results together with the formation of tourmaline from (and sequestering of) B in metamorphic fluids may lead to less B-isotopic fractionation as a result of subduction-zone devolatilization than noted in suites containing less tourmaline. This, therefore, makes it possible to transport B isotopic signatures which ultimately reflect Earth's surficial to the deep mantle, perhaps resulting in mantle B isotope anomalies near convergent margins.

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