Investigating prograde metamorphism and pegmatites formation using tourmaline compositional and B isotopes variations. The case of the Adamello Massif (Southern Alps, Italy).

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Tourmaline is the main boron (B) host in many magmatic and metamorphic rocks. It is characterized by a complex crystalline structure, with a general formula of $XY_3Z_6T_6O_{18}(BO_3)_3V_3W$ featuring three different atomic sites that can host a great variety of elements of widely different charge and ionic radius. This, coupled with the low B diffusivities in its structure and high thermal resilience, makes tourmaline an ideal indicator of its host environment. We investigated the chemical and B isotopic composition of tourmaline in the contact aureole of the Adamello pluton intrusion. These data are used to shed light into the prograde metamorphic history of pelites from low-grade to the upper amphibolite facies where they underwent partial melting generating tourmaline-bearing pegmatites, occasionally lithium enriched. The major elements composition of tourmalines has been characterized by electron microprobe analysis and their $\delta^{11}B$ was determined in-situ by LA-MC-ICP-MS. In the low grade pelites, dravitic tourmaline rims with positive $\delta^{11}B$ (+4 to +6‰) overgrow schorlitic detrital cores ($\delta^{11}B$ between -15 and -10‰). This event may be connected to clay minerals fluid-related loss of adsorbed B during diagenesis and low-grade metamorphism. In medium grade pelites, neoblastic slightly negative dravitic tourmalines (-3 to -4‰) can be linked to white mica dehydration during prograde metamorphism. At amphibolitic facies conditions, the tourmalines are homogeneous dravites, suggesting complete recrystallization. In the contact aureole two types of partially molten metapelites have been recognized. The orbicular pelites formed in a closed system and the tourmaline B isotope composition is ca. +1‰. Banded metapelites, which recorded external fluid influx, exhibit more calcic tourmalines with lower $\delta^{11}B$ (ca. -3‰), allowing us to infer that the fluids interacted with the surrounding carbonates. In the connected anatectic system, tourmaline recorded the cooling history of the pegmatitic melts, particularly in the zoned lithium enriched pegmatites. Interestingly, the average $\delta^{11}B$ values (between 0 and -3‰) of the studied Adamello pegmatites are markedly different from the usual range of $\delta^{11}B$ values of pluton-related LCT pegmatites (e.g. Elba island, $\delta^{11}B$ from -8‰ to -10‰) suggesting a possible different origin. In the Adamello pegmatites, tourmaline composition traced the early fractionation of the most mafic and compatible elements as Mg and Fe in early dravitic cores with isotopic signature similar to that in the banded metapelites. Towards the center of the dyke, tourmaline becomes increasingly schorlitic and then elbaitic (mostly fluor-elbaite). Its $\delta^{11}B$ evolution allowed us to identify fluid exsolution events, during which the $\delta^{11}B$ of pocket tourmalines sharply increased up to 3‰ compared to the magmatic tourmalines.