

Kyanite-muscovite-dumortierite vein mineralization mechanisms from advanced microstructural analysis using EBSD

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ABSTRACT

Dumortierite is relatively rare in Earth's crust, but it is the second most abundant aluminous borosilicate mineral after tourmaline. Boron is an element with numerous applications in modern societies worldwide, ranging from health products to wind turbine blades for clean energy, but it is limited in availability and faces a future risk of supply shortage. Only a limited number of studies have been published on dumortierite mineralization processes, and the factors that control its abundance and distribution remain poorly understood. Here we present the first comprehensive electron backscatter diffraction (EBSD) study of dumortierite mineralization mechanisms in kyanite-muscovite-dumortierite veins occurring in the metapelites of the Amgaon Gneiss Supracrustals, in the Girola Hill area, Sakoli region, Central India. Advanced microstructural and chemical analyses show that mixed-mode brittle-viscous deformation in kyanite, by fracturing and easy glide on the (100) [001] slip system, facilitates fluid-rock interactions with reactive hydrothermal fluids rich in B, F, and K and containing Na, Ti, Mg, Fe, and Pt. These interactions cause the dissolution of kyanite along fracture and cleavage surfaces and the precipitation of muscovite (F = 0.32 wt%) and topaz (F = 16.48 wt%). The motion of ripplocation defects in muscovite facilitates fluid migration along cleavage surfaces and crystallization of dumortierite needles within these surfaces. Fluid flux removes silica in solution from the system, allowing reactions to continue. The observed mineral assemblage, the microstructural signature of kyanite and muscovite, the moderate fluorine content of topaz, and low fluorine content of muscovite, together suggest that dumortierite mineralization results from hydrothermal activity, possibly in a transitional magmatic-hydrothermal environment, likely at $P > 2.5$ kbar and $400 < T < 550$ °C, which could be linked with granite intrusions in the area. Using EBSD, we demonstrate that dumortierite mineralization is focused along muscovite basal cleavage surfaces, and dumortierite needle elongation is likely controlled by the fluid flux direction. These new results enhance our understanding of the mechanisms and conditions governing dumortierite mineralization and have significant implications for understanding the distribution of this aluminous borosilicate mineral in muscovite-rich rocks.

Keywords: Dumortierite, boron, muscovite, ripplocations, vein mineralization mechanisms, EBSD, quantitative EDS