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Aluminous and alkali-deficient tourmaline from the Singhbhum Shear Zone, East Indian shield: Insight for polyphase boron infiltration during regional metamorphism

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Abstract

In the western part of the Singhbhum Shear Zone (SSZ), East Indian Shield, borosilicate-bearing veins of variable thickness (tens of micrometers to 1 m thick) are hosted in kyanite-quartzite and kyanite-mica schist. The veins have been classified into three types, which are, from oldest to youngest, generation I (tourmaline), II (dumortierite + tourmaline), and III (tourmaline) veins. Alkali- and Mg-rich tourmaline [X_{Mg} = Mg/(Mg + Fe) = 0.68 ± 0.09; X = Na, Ca, K, □ (vacancy) = 0.40 ± 0.12] is the sole borosilicate in generation I veins, which have been folded in response to regional deformation. Generation II veins were emplaced along shear bands (1 mm to 1 m thick) developed parallel to the axial planes of these folds. Long axes of fibrous dumortierite and prismatic tourmaline of generation II veins are oriented along the shear bands and have been bent around lenticular remnants of host kyanite-quartzite. Generation III veins have a dendritic pattern, crosscut generation II veins and show aggregates of fibrous to acicular tourmaline. Prismatic tourmaline in generation II veins is optically zoned with a green tourmaline core that is variably replaced and rimmed by blue tourmaline. Fibrous to acicular tourmaline in generation III veins is comprised up of blue tourmaline with compositions similar to the rim composition of prismatic tourmaline in generation II veins. Green and blue tourmaline is aluminous (Al total >7 apfu) and alkali-deficient (X = 0.71 ± 0.08). High ^{Y}Al content, high X, low X_{Mg} (0.19 ± 0.10), and excess cation charge indicate tourmaline in generation II veins is rich in an "oxy-foitite" component. Foitite-rich tourmaline in generation III veins has tetrahedral Al and a slightly lower Mg-content and X than those of generation II veins. Optical zoning in prismatic tourmaline corresponds to an abrupt compositional change with paragenetically older green tourmaline having higher Al and X_{Mg}, but lower alkali content in the X-site than the blue tourmaline rim. The compositional variation in green and blue tourmaline can be explained by a combination of coupled substitutions represented by $AlO[R(OH)]_{-1}$ and $Al(NaR)_{-1}$, where R = (Fe^{2+} + Mg). Pseudosections in the system Na_2O-K_2O-Al_2O_3-SiO_2-H_2O constructed from bulk chemical compositions of the studied rocks and the *P*-*T* slopes of two isochors computed from brine-rich inclusions trapped in quartz grains indicate that borosilicate formation in generation II and III veins occurred within 4.1 ± 0.5 kbar and 377 ± 21 °C. The mineral assemblages and textures suggest that the borosilicate-bearing veins formed from infiltration-driven alteration of host kyanite-quartzite and kyanite-mica schist along structurally controlled conduits by more than one batch of chemically distinct boron-rich aqueous fluids.

Keywords: Singhbhum shear zone, kyanite, foitite, "oxy-foitite," boron-infiltration