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# Formation of metasomatic tourmalinites in reduced schists during the Black Hills Orogeny, South Dakota

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## Abstract

Tourmaline is a common mineral in granites and metamorphic rocks in collisional orogens. This paper describes graphite-bearing, metasomatic tourmalinites in sillimanite-zone schists of the Proterozoic Black Hills Orogen, South Dakota. The tourmalinites bound quartz veins and beyond about 1 m grade into schists with disseminated tourmaline, and ultimately tourmaline becomes only a trace, intrinsic phase in the schists. Next to the quartz veins, tourmaline has almost completely replaced schist minerals, including biotite, muscovite, and plagioclase. The tourmaline is generally anhedral and follows the original foliation direction of the schist. However, tourmaline is euhedral in quartz veinlets cutting through the tourmalinites. Tourmaline is compositionally zoned from having about 22 to 2% of apparent Al occupancy on the Y sites. There are very good negative correlations of $^{Y}(Fe^{2+}+Mg^{2+})$, $^{X}Ca^{2+}$, and $^{Y}Ti^{4+}$ with $^{Y}Al^{3+}$, and a very good positive correlation of X-site vacancies with $^{Y}Al^{3+}$. Mg# [molar $Mg^{2+}/(Mg^{2+}+Fe^{2+})$] is fairly invariant at approximately 0.5, which is somewhat higher than that in the precursor biotite. This is in contrast to tourmaline in the neighboring peraluminous Harney Peak leucogranite where the range of Y site occupancy of Al is small at about 20%, but the Mg# ranges from 0.12 to 0.5.

The compositional trends in the metasomatic tourmaline are dominated by the exchange $^{X}\square + 4\ ^{Y}Al^{3+} = {}^{X}Ca^{2+} + 3\ ^{Y}(Fe^{2+}+Mg^{2+}) + {}^{Y}Ti^{4+}$. Mass-balance calculations suggest the metasomatizing fluid brought in $H^+$ and $B(OH)_3$ and removed $K^+$, $SiO_2$, and some $Fe^{2+}$ during tourmalinization. Other elements in the tourmaline largely reflect the bulk composition of the replaced schist. The calculations show that silica in the quartz veins was locally derived, not brought in by the metasomatizing fluid. Interstitial graphite in the tourmalinites shows precipitation of carbon from the methane-bearing fluid. The study demonstrates an important effect of boron transfer by fluids during metamorphism and magmatism in the Earth's crust.

**Keywords:** Tourmalinite, metasomatism, tourmaline, schist; Black Hills, South Dakota