

A rare garnet-tourmaline-sillimanite-biotite-ilmenite-quartz assemblage from the granulite-facies region of south-central Massachusetts

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ABSTRACT

A rare lithology consisting of garnet-tourmaline-sillimanite-biotite-ilmenite-quartz has been found within the granulite-facies region of south-central Massachusetts. The homogeneous, Ti-rich oxy-dravitic tourmaline, $X_{Mg} = Mg/(Mg + Fe) = 0.72-0.77$, falls into the alkali group, and is similar in composition to lower grade tourmaline found in corresponding metapelitic rocks in Maine. Charge-balancing calculations and binary diagrams suggest that, like biotite in the region, tourmaline has undergone deprotonation by means of the exchange vectors $AlOR_{-1}(OH)_{-1}$ and $TiO_2R_{-1}(OH)_{-2}$, where R represents Fe + Mg. The restriction of a concordant tourmaline-rich horizon in otherwise tourmaline-free rocks of this granulite-facies region suggests that either: (1) B, released during prograde fluid-absent dehydration reactions of muscovite and biotite, was locally available in a fluid phase or melt for later crystallization near the peak of granulite-facies metamorphism along pathways that provided a conduit for fluid migration; or (2) that this is simply a B-rich compositional horizon (tourmalinite) that survived anatexis and granulite-facies metamorphism and that records the incipient conditions of tourmaline breakdown and subsequent recrystallization near or post-peak metamorphism.

Keywords: Massachusetts, tourmaline, granulite-facies, partial melting, deprotonation

INTRODUCTION

Metamorphic, metasomatic, and hydrothermal borosilicates include nearly fifty different minerals (Grew 1996) such as, for example, tourmaline, dumortierite, kornerupine, grandidierite, and prismaticine (Grew et al. 1990, 1996). Tourmaline is, by far, the most common borosilicate and is found as an accessory mineral in a wide range of igneous and metamorphic rocks. The B that enables growth of tourmaline may be derived from that already locally contained within the rock (as detrital or diagenetic tourmaline or from the breakdown of muscovite) or it may be introduced from an external source (metasomatism) or a combination of the two (Henry and Dutrow 1996). Regardless of the primary source of B in common metapelitic rocks, B is taken up preferentially by clay minerals, muscovite, and tourmaline during low- to intermediate-grade metamorphism.

At higher grades, sillimanite and other borosilicates may become important B sinks (Grew and Hinthorne 1983). Tourmaline is stable to at least the upper-amphibolite facies, but at higher grades, tourmaline begins to break down. In fact, tourmaline is rarely found in granulite facies rocks such as, for example, at Broken Hill, Australia (Slack et al. 1993). Tourmaline breakdown under granulite-facies conditions at low pressures has been substantiated by experiments (Bénaud et al. 1985; Holtz and Johannes 1991; Schreyer and Werding 1997; von Goerne et al. 1999), but temperatures determined in the laboratory are typically higher than in natural environments (Werdning and Schreyer 1996). Petrographic studies of tourmaline breakdown suggest that tourmaline is typically

absent in upper-amphibolite- to granulite-facies metapelites (Lonker 1988; Moran et al. 1992; Henry and Dutrow 1996; Kawakami 2001a, 2001b; Kawakami and Ikeda 2003). Temperatures of tourmaline breakdown from field studies have been estimated to be at least 620–650 °C (Moran et al. 1992) and as high as 725 °C (Kawakami 2001b). Once tourmaline breaks down, released B is then either strongly partitioned into the fluid phase or incorporated into other borosilicates like kornerupine, grandidierite, or prismaticine. Furthermore, if the rocks in which the tourmaline is breaking down are partially melted, B is preferentially incorporated into the melt (Kawakami 2001a, 2004; Kawakami and Ikeda 2003). Hydrothermal fluids and melts, therefore, are capable of transporting and redistributing B in metamorphic terranes. Kawakami and Ikeda (2003) have suggested that tourmaline grains found in granulite-facies metapelites are relics or retrograde products where removal of B-bearing fluids or melts has not gone to completion. Kawakami (2001b, 2004) presented evidence of B depletion in the migmatite zone of the Ryoike metamorphic belt as a function of tourmaline-breakdown reactions and segregation and extraction of melt.

The dominant metapelitic rocks within the Siluro-Devonian Merrimack Synclinorium of the New England Appalachians contain tourmaline at low to intermediate grades of metamorphism (Henry and Dutrow 1992; Henry and Guidotti 1985). However, in the migmatitic granulite-facies region of south-central Massachusetts, the rocks are essentially devoid of tourmaline. With the exception of rare rocks, which were originally B-rich with Mg- and Al-rich bulk compositions (Palmer and Slack 1989; Grew et al. 1990; Slack et al. 1984), the paucity of tourmaline in granulite-facies rocks is typical of several high-grade and mig-

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