Crystal chemistry and origin of grandidierite, olinelite, boralsilite, and werdingite from the Bory Granulite Massif, Czech Republic

Jan Cempírek, 1,* Milan Novák, 2 Zdeněk Dolníček, 3 Jana Kotková, 2,4 and Radek Škoda 2

1Department of Mineralogy and Petrography, Moravian Museum, Zelný trh 6, 65937 Brno, Czech Republic
2Department of Geological Sciences, Masaryk University, Kotlářská 2, 61137 Brno, Czech Republic
3Department of Geology, Palacký University, třída 17. listopadu 12, 77146 Olomouc, Czech Republic
4Czech Geological Survey, Klárov 3, 118 21 Prague 1, Czech Republic

Abstract

A mineral assemblage involving grandidierite, olinelite, boralsilite, werdingite, dumortierite (locally Sb,Ti-rich), tourmaline, and corundum, along with the matrix minerals K-feldspar, quartz, and plagioclase, was found in a veinlet cutting leucocratic granulite at Horní Bory, Bory Granulite Massif, Moldanubian Zone of the Bohemian Massif. Zoned crystals of primary grandidierite to olinelite enclosed in quartz are locally overgrown by prismatic crystals of boralsilite and Fe-rich werdingite. Boralsilite also occurs as separate cross-shaped plume aggregates with Fe-rich werdingite in quartz. Grandidierite is commonly rimmed by a narrow zone of secondary tourmaline or is partially replaced by the assemblage tourmaline + corundum + hercynite. Grandidierite (XFe = 0.34–0.71) exhibits dominant FeMg substitution and elevated contents of Li (120–1890 ppm). Boralsilite formula ranges from \( \text{Al}_{13.97}\text{B}_{2.23}\text{Si}_{1.80}\text{O}_{17} \) to \( \text{Al}_{15.6}\text{B}_{2.26}\text{Si}_{3.75}\text{O}_{17} \) and the formula of werdingite ranges from \( \text{Fe}_{1.44}\text{Mg}_{4.00}\text{Al}_{2.64}\text{Si}_{3.55}\text{O}_{17} \) to \( \text{Fe}_{1.22}\text{Mg}_{1.88}\text{Al}_{2.73}\text{Si}_{3.36}\text{O}_{17} \). Dumortierite and Sb,Ti-rich dumortierite occur as zoned crystals with zones poor in minor elements (≤0.12 apfu Fe+Mg) and zones enriched in Sb (≤0.46 apfu) and Ti (≤0.25 apfu). Secondary tourmaline (XFe = 0.44–0.75) of the schorl-magnesiofoitite-foitite-olenite solid solution occurs as a replacement product of grandidierite, rarely boralsilite. Other accessory minerals in the veinlet include monazite-(Ce), ilmenite, rutile, ferberite, srilankite, lollingite, arsenopyrite, and apatite. Formation of the borosilicate-bearing veinlet post-dates the development of foliation in the host granulite and is related to the decompressional process. The assemblage most probably originated from a H2O-poor system at \( T \sim 750 ^\circ\text{C} \) and \( P \sim 6–8 \text{kbar} \). Textural relations as well as geological position of the borosilicate veinlet suggest that it represents the earliest intrusion related to pegmatites in the Bory Granulite Massif. Younger granitic pegmatites in the area are characterized by high contents of B, Al, P, Fe, and minor concentrations of W, Ti, Zr, Sc, and Sb. All pegmatite types probably formed within a short time period of ~5 Ma.

Keywords: Boron, grandidierite, olinelite, werdingite, boralsilite, granulite, partial melting, Moldanubicum, Bohemian Massif

Introduction

Anhydrous borosilicates with mullite-type structure represent an uncommon but very distinct group of minerals associated with rocks of a specific peraluminous composition, in most cases metamorphosed under high-temperature and low- to medium-pressure conditions (Grew 1996). Grandidierite is the most common, as it is known from more than 40 occurrences worldwide in peraluminous metamorphic rocks (rarely in calc-silicate rocks) as well as in abyssal (metamorphogenic) pegmatites, commonly in Precambrian terrains [e.g., Madagascar, Antarctica, Norway, Canada; see review in Grew (1996)]. On the other hand, olinelite—the Fe-analog of grandidierite—is rare, as it has been known only from five localities so far (Hiroi et al. 2001; Dzikowski et al. 2007; Buick et al. 2008). Other rare anhydrous borosilicates include werdingite, boralsilite, and boromullite. Werdingite occurs in granulite-facies metamorphic rocks in South Africa, Zimbabwe, and Australia (Moore et al. 1990; Grew et al. 1997; Buick et al. 2008) and in abyssal pegmatites in Madagascar, Norway, and Antarctica (Grew et al. 1998b, 2008). Boralsilite has been found in two localities so far, in Antarctica and Norway (Grew et al. 1998a, 2008), whereas boromullite is known only from a single locality in granulitic rock in Australia (Buick et al. 2008). The anhydrous borosilicates are commonly associated with or replaced by hydrous borosilicates, e.g., minerals of kornerupine-prismatine series, tourmaline or dumortierite (e.g., Huijsmans et al. 1982; Grew 1996; Grew et al. 1998a, 1998b).

Borosilicate occurrences are also important for petrological and geochemical considerations, as borosilicates commonly store light elements under high-grade conditions. For this reason, stability fields of the most common borosilicates (e.g., tourmaline, dumortierite, kornerupine, grandidierite, werdingite) were experimentally studied (e.g., Schreyer and Werding 1997).