

## **Boralsilite, $\text{Al}_{16}\text{B}_6\text{Si}_2\text{O}_{37}$ , and “boron-mullite:” Compositional variations and associated phases in experiment and nature**

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### **ABSTRACT**

Boralsilite, the only natural anhydrous ternary  $\text{B}_2\text{O}_3$ - $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$  (BAS) phase, has been synthesized from BASH gels with Al/Si ratios of 8:1 and 4:1 but variable  $\text{B}_2\text{O}_3$  and  $\text{H}_2\text{O}$  contents at 700–800 °C, 1–4 kbar, close to the conditions estimated for natural boralsilite (600–700 °C, 3–4 kbar). Rietveld refinement gives monoclinic symmetry,  $C2/m$ ,  $a = 14.797(1)$ ,  $b = 5.5800(3)$ ,  $c = 15.095(2)$  Å,  $\beta = 91.750(4)^\circ$ , and  $V = 1245.8(2)$  Å<sup>3</sup>. Boron replaces 14% of the Si at the Si site, and Si or Al replaces ca. 12% of the B at the tetrahedral B2 site. A relatively well-ordered boralsilite was also synthesized at 450 °C, 10 kbar with dumortierite and the OH analogue of jeremejevite. An orthorhombic phase (“boron-mullite”) synthesized at 750 °C, 2 kbar has mullite-like cell parameters  $a = 7.505(1)$ ,  $b = 7.640(2)$ ,  $c = 2.8330(4)$  Å, and  $V = 162.44(6)$  Å<sup>3</sup>. “Boron-mullite” also accompanied disordered boralsilite at 750–800 °C, 1–2 kbar.

A possible natural analogue of “boron-mullite” is replacing the Fe-dominant analogue of werdingite in B-rich metapelites at Mount Stafford, central Australia; its composition extends from close to stoichiometric  $\text{Al}_2\text{SiO}_5$  to  $\text{Al}_{2.06}\text{B}_{0.26}\text{Si}_{0.76}\text{O}_5$ , i.e., almost halfway to  $\text{Al}_5\text{BO}_9$ . Boralsilite is a minor constituent of pegmatites cutting granulite-facies rocks in the Larsemann Hills, Prydz Bay, East Antarctica, and at Almgøtheii, Rogaland, Norway. Electron-microprobe analyses (including B) gave two distinct types: (1) a limited solid solution in which Si varies inversely with B over a narrow range, and (2) a more extensive solid solution containing up to 30%  $(\text{Mg,Fe})_2\text{Al}_{14}\text{B}_4\text{Si}_4\text{O}_{37}$  (werdingite). Boralsilite in the Larsemann Hills is commonly associated with graphic tourmaline-quartz intergrowths, which could be the products of rapid growth due to oversaturation, leaving a residual melt thoroughly depleted in Fe and Mg, but not in Al and B. The combination of a B-rich source and relatively low water content, together with limited fractionation, resulted in an unusual buildup of B, but not of Li, Be, and other elements normally concentrated in pegmatites. The resulting conditions are favorable in the late stages of pegmatite crystallization for precipitation of boralsilite, werdingite, and grandidierite instead of elbaite and B minerals characteristic of the later stages in more fractionated pegmatites.

**Keywords:** Boralsilite, “boron-mullite,” werdingite, boron, pegmatite, Rietveld refinement, electron microprobe, Larsemann Hills, Antarctica, Almgjøtheii, Norway