

## **Oriented multiphase needles in garnet from ultrahigh-temperature granulites, Connecticut, U.S.A.**

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### **ABSTRACT**

This study investigates distinctive oriented, needle-shaped multiphase inclusions found within cores of garnets from felsic granulites of the Upper Member of the Bigelow Brook Formation and the Brimfield Schist (northeastern Connecticut, U.S.A.). The rocks crop out in the southern end of the Central Maine Terrane and thus are a part of the Acadian/Neocadian Orogen. The typical mineral assemblage is garnet + sillimanite + K-feldspar + plagioclase + quartz + cordierite + biotite ± spinel. The sillimanite is commonly pseudomorphous after kyanite.

The multiphase needle inclusions and associated exsolved needles of rutile and ilmenite are mostly oriented parallel to  $\langle 111 \rangle$  of garnet. The multiphase needles contain various combinations of quartz, micas, chlorite, rutile, graphite, a siliceous compositionally variable phase (“Phase-CV”), Zn-spinel, apatite, zircon, and rare ilmenite. We hypothesize that they represent inclusions of fluid that adhered to exsolving Ti±Fe oxide needles (mostly rutile) or extended along zones of weakness in garnet. This requires that multiphase needle formation occurred in response to cooling and/or decompression. The needles ultimately decrepitated during retrogression. We note that micaceous needle-shaped multiphase inclusions are rarely described; the closest analogs of which we are aware are found in UHP garnets of the Erzgebirge (Perchuk 2008).

The Brimfield Schist in this area underwent ultrahigh-temperature metamorphism (UHTM) of ~1000 °C at a minimum pressure of ~1 GPa (Ague et al. 2013). Here we provide new temperature estimates for the adjacent Upper Member of the Bigelow Brook Formation. Ternary feldspar reintegration using the activity model of Benisek et al. (2004) and Zr-in-rutile thermometry (Tomkins et al. 2007) give average temperatures of ~990 and ~1010 °C, respectively, at 1 GPa for this unit. Therefore, the recently discovered UHT zone in the Brimfield Schist of northeastern Connecticut extends to the east to include the Upper Member of the Bigelow Brook Formation. Consequently, the first confirmed regional UHT locality in the United States is larger than initially recognized, and is at least 25 km long and 5–10 km wide. The oriented, elongate multiphase inclusions and petrographically obvious oriented Ti±Fe oxide needles may be useful indicators of extreme temperature and/or pressure rocks in other field areas.

**Keywords:** Ultrahigh temperature, multiphase inclusions, garnet, metamorphism, Connecticut, rutile