Quartz exsolution in clinopyroxene is not proof of ultrahigh pressures: Evidence from eclogites from the Eastern Blue Ridge, Southern Appalachians, U.S.A.

F. Zeb Page,* E.J. Essene, and S.B. Mukasa

Department of Geological Sciences, University of Michigan, 2534 C.C. Little Building, Ann Arbor, Michigan 48109-1005, U.S.A.

ABSTRACT

Oriented quartz needles in clinopyroxene have become one of the diagnostic indicators of ultrahigh-pressure (UHP) metamorphism. The presence of apparently exsolved quartz is taken as evidence of decomposition of a non-stoichiometric Ca–Eskola component (Ca$_{0.5}$$\square_{0.5}$AlSi$_2$O$_6$, CaEs) that is presumed to be stable only at UHP conditions. Eclogite from the Eastern Blue Ridge, North Carolina, contains clinopyroxene (Jd$_2$CaTs$_5$Ac$_5$CaEs$_0$Di$_6$Hd$_5$) with oriented needles of quartz and calcic amphibole that appear to have exsolved together. The quartz + amphibole intergrowths are surrounded by 1–5 $\mu$m haloes of neoformed pyroxene (Jd$_2$CaTs$_{10}$Ac$_{10}$CaEs$_0$Di$_{10}$Hd$_5$). The modes of quartz, amphibole, and clinopyroxene haloes were determined using BSE images, and reintegrated with the host clinopyroxene. Viewing the quartz and amphibole needles down the c-axis of the pyroxene host provides a better estimate of their proportions than in prismatic sections. Reintegrated pyroxene compositions were nearly identical to the analyzed host pyroxene with no CaEs component. Clinopyroxene with CaEs solid solution has been repeatedly synthesized at UHP conditions. However, examination of the phase equilibria usually cited as evidence for CaEs stability at conditions of ≥25 kbar shows that clinopyroxene with 10 mol% CaEs is stable well within the quartz field, and provides a pressure minimum similar to the albite = jadeite + quartz barometer. Exsolution of quartz and associated amphibole is commonplace in clinopyroxene from the Blue Ridge eclogite that lacks coesite or other evidence for UHP metamorphism. The presence of a diluted (5–10%) CaEs component in clinopyroxene does not require UHP conditions.

INTRODUCTION

Oriented quartz needles in clinopyroxene have been reported from several of the well-established ultrahigh-pressure (UHP) terranes of the world: Norwegian Caledonides (Smith 1984; Terry and Robinson 2001), Kokchetav massif, Kazakhstan (Shatsky et al. 1985; Katayama et al. 2000), Bohemian Gneis massif (Bakun-Czubarow 1992), and Dabie, China (Tsai and Liou 2000). The presence of these needles has been interpreted as an exsolution texture formed by the breakdown of a non-stoichiometric Ca–Eskola component (Ca–Eskola) to form pyroxene enriched in Ca–Tschermaks (Ca–Tschermaks) while releasing quartz, as in the following reaction:

CaEs $\Rightarrow$ CaTs + quartz

$2Ca_{0.5}\square_{0.5}AlSi_2O_6 = CaAlSiO_6 + 3SiO_2$

CaEs-bearing pyroxene is usually presumed to be stable only at UHP conditions, and the identification of exsolved quartz needles has become another line of evidence used to claim UHP metamorphism (e.g., Liou et al. 1998; Zhang et al. 2005). Quartz needles and CaEs-bearing pyroxene are indisputable features of some UHP rocks (e.g., Smith 1984; Katayama 2000). However, quartz needles also have been used in the absence of direct evidence, such as coesite or diamond, to document UHP conditions (Gayk et al. 1995; Liati et al. 2002; Zhang et al. 2002, 2003). The treatment of quartz needles and other possible indicators of UHP conditions as direct evidence thereof has recently drawn criticism (Klemd 2003).

It is clear that the CaEs component is stable at high pressures. Sobolev et al. (1968) found non-stoichiometric clinopyroxene in mantle kyanite eclogite from Siberia, and Smyth (1980) inferred up to 17 mol% CaEs in omphacite from eclogite xenoliths from South Africa. Clinopyroxene containing the CaEs component has been produced by several workers in high-pressure experiments (Mao 1971; Khanukhova and Zharikov 1976; Wood and Henderson 1978; Zharikov et al. 1984; Gasparik 1985, 1986; Harlow 1998). Although the stability of CaEs-bearing clinopyroxene at UHP conditions is not disputed, examination of the phase equilibria usually cited as evidence for CaEs stability at conditions of ≥25 kbar shows that clinopyroxene with 10 mol% CaEs is stable well within the quartz field, and provides a pressure minimum similar to the albite = jadeite + quartz barometer. Exsolution of quartz and associated amphibole is commonplace in clinopyroxene from the Blue Ridge eclogite that lacks coesite or other evidence for UHP metamorphism. The presence of a diluted (5–10%) CaEs component in clinopyroxene does not require UHP conditions.