Polyphase solid-inclusions formed by interactions between infiltrating fluids and precursor minerals enclosed in garnet of UHP rocks from the Dabie Shan, China

PENGLEI LIU1,2,*, JUNFENG ZHANG1, HANS-JOACHIM MASSONNE2, and ZHENMIN JIN1

1School of Earth Sciences, China University of Geosciences, 430074 Wuhan, China
2Institut für Mineralogie und Kristallchemie, Universität Stuttgart, Azenbergstrasse 18, D-70174 Stuttgart, Germany

ABSTRACT

Three types of polyphase solid-inclusions (PSIs) with distinct mineral assemblages and microstructures were found in garnet of an ultrahigh-pressure (UHP) eclogite-vein system from the Dabie Shan, east-central China. Type-1 PSI contains variable volumes of quartz, K-feldspar, plagioclase ± other phases, whereas Type-2 PSI contains variable volumes of quartz, calcite ± other phases. Both types display shapes that are compatible with those of euhedral coesite inclusions. Type-3 PSI always contains a rutile core that is surrounded by plagioclase ± quartz and generally displays the morphology of the rutile core. Variable amounts of K-feldspar are embedded within the plagioclase of Type-3 PSIs. The three PSI types developed fluid-mediated microstructures that include wedge-like offshoots and protrusion textures and inclusion-garnet interfaces controlled by the crystallographic structure of garnet. PSIs in peak minerals of UHP rocks have been previously thought to represent primary supercritical fluid or melt inclusions. Here we propose that the studied PSIs were formed under high-pressure (HP) eclogite-facies conditions during exhumation and represent reaction products between an enclosed mineral, such as coesite and rutile, and external fluids infiltrating the host garnet along fractures that have been healed later on. Two immiscible aqueous fluids (i.e., a siliceous and a carbonaceous) were involved in the formation of these PSIs. The siliceous fluid was rich in various large ion lithophile elements like Cs, Rb, Ba, K, Pb, Li, and Sr, whereas the carbonaceous fluid was rich in Pb and Sr. The new PSI formation mechanism proposed in this study brings significant implications for tracing fluid evolution and post-entrapment modifications of mineral inclusions in HP and UHP metamorphic rocks.

Keywords: Dabie Shan, ultrahigh-pressure, coesite, polyphase solid-inclusion, fluid-rock interaction

INTRODUCTION

Ultrahigh-pressure (UHP) metamorphic rocks represent relicts of deeply subducted crust and provide a natural laboratory to study the nature and behavior of metamorphic fluids in deep-seated subduction zones. The knowledge of the interaction of these fluids is important for understanding the formation, preservation, rheology, and exhumation of UHP rocks and the possible mass transfer in subduction zones (e.g., Proyer 2003; Zhang et al. 2004; Massonne 2009; Labrousse et al. 2011; Zheng et al. 2011; Hermann et al. 2013; Frezzotti and Ferrando 2015). However, there are considerable difficulties to characterize these fluids at present. One big obstacle is that the metamorphic fluids in deep-seated subduction zones usually escape from their site of interaction and leave little traces of their activity in natural rocks. Whereas experimental and theoretical studies are crucial for deciphering the physical and chemical properties of fluids in deep-seated subduction zones (e.g., Zheng et al. 2011; Hermann et al. 2013; Hermann and Rutatto 2014), polyphase solid-inclusions (PSIs) in peak minerals such as garnet have been considered in the past two decades to be a good window for peering into UHP rocks affected by fluid interaction. Such inclusions commonly display an intergrowth of several daughter minerals, negative crystal shapes, and wedge-like offshoots, and they are interpreted to represent precursor supercritical fluid or melt inclusions (e.g., Hwang et al. 2001; Stöckhert et al. 2001, 2009; Ferrando et al. 2005; Korsakov and Hermann 2006; Malaspina et al. 2006; Frezzotti et al. 2007; Frezzotti and Ferrando 2015). Similar PSIs (known as nanogranitoids), crystallized from felsic melt, have been also reported in anatectic rocks of different crustal levels (e.g., Cesare et al. 2009, 2015; Ferrero et al. 2012, 2015; Bartoli et al. 2013). In all the reported cases, PSIs were normally considered primary, i.e., they were captured during growth of the host phases.

Among the reported PSIs in UHP rocks, one group, mainly composed of quartz, K-feldspar, and/or plagioclase, has attracted substantial attention. The petrogenesis of this group of PSI has been highly debated in the literature. Such PSIs have been interpreted as the reaction products between coesite inclusions and a K-bearing omphacite host (Yang et al. 1998), although their occurrence in garnet cannot be interpreted in the same way. Another opinion refers to the former presence of composite K-cymrite + coesite inclusions (Massonne 2001; Massonne and Nasdala 2003; Song et al. 2003; Zhang et al. 2009), but it cannot account for the occurrence of larger quantities of plagioclase and/or other minerals within such PSIs. In the light of recent studies, which suggest that these PSIs could represent entrapped melts (e.g., Zeng et al. 2009; Gao et al. 2012, 2013, 2017; Liu et al. 2013; Chen et al. 2014), we present here new perspectives on the formation of