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Re-equilibration of a high-pressure metamorphic fluid: evidence from tourmaline-, apatite- and quartz-hosted fluid inclusions in an Eoalpine eclogite from the Eastern Alps

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Abstract: Fluid inclusions in tourmaline, apatite and quartz from an eclogite of the Polinik Complex, as part of the Koralpe-Wölz high-pressure (H*P*) nappe system (Eastern Alps), have been investigated. All three minerals are interpreted as part of the eclogite- to post-eclogite-facies mineral assemblage which formed during Cretaceous Eoalpine metamorphism at ~ 20 kbar and ~ 650°C. Tourmaline, apatite and quartz contain two types of fluid inclusions: (1) a fluid in the system of H_2O–NaCl–$CaCl_2$–CO_2–CH_4–N_2 system, and (2) a fluid in the system of H_2O–NaCl–$CaCl_2 \pm MgCl_2$ system. Type (1) dominates in tourmaline, and type (2) in apatite and quartz. Fluid inclusions of type (1) occur individually and as clusters. In addition to isolated inclusions, type (2)-inclusions also arranged along intragranular/transgranular fluid inclusion planes – but not at grain contacts. The clear distinction in their textural occurrence enables the reconstruction of the H*P* fluid evolution from a supposed precursor fluid to stages of retrogression accompanied with re-equilibration and preferential loss of the aqueous fluid phase along a proposed exhumation path.

Calculated fluid densities of type (1) indicate conditions that reach 14 kbar in tourmaline and 12 kbar in quartz when linked with peak temperatures of ~ 650°C. Conditions are interpreted as minimum conditions during formation of the host minerals. Fluid-inclusion densities from the studied aqueous system type (2) are coherent in the studied host minerals and reach pressures of about 8–10 kbar.

A possible reason for the differences in estimated pressure between type (1) and type (2) is, beside textural arguments, the preferred loss of water during recrystallization of the studied minerals at post-peak stages. This hypothesis is supported by the same fluid chemistry of the aqueous phase (H_2O–NaCl–$CaCl_2 \pm MgCl_2$) in type (1)- and type (2)-inclusions. Additionally, different wetting behaviour of fluids containing dominantly polar [type (1)] and non-polar [type (2)] species promoted recrystallization, especially in quartz, and led to widespread decrepitation of large fluid inclusions in quartz during decompression. Hence, the fluid evolution documented in the Polinik eclogites can be reconstructed through effects of physical and chemical changes of the host minerals after peak metamorphism.

Key-words: Eastern Alps, Eoalpine eclogites, tourmaline, fluid inclusions, re-equilibration.

Introduction

Fluid inclusions (FIs) in high-pressure (H*P*) minerals like omphacite, garnet and kyanite represent the metamorphic fluid that was present at peak metamorphism (primary FIs) and during stages of retrogression (secondary FIs) (*e.g.* Touret, 2001; Fu *et al.* 2001, 2003; Krenn *et al.* 2008; Krenn, 2010). FIs in minerals that occur over a large range of metamorphic grades (*e.g.*, quartz, apatite, feldspar, tourmaline) are thought to trace the post-peak metamorphic evolution. Calculated isochores representative for those FIs, when drawn in a *P-T* field, have to be crossed during exhumation, and they are steeper for FIs with aqueous than with carbonic composition (*e.g.* Thomas & Spooner, 1988; Selverstone *et al.*, 1992; Touret & Frezzotti, 2003; Krenn *et al.*, 2008). Fluids in eclogites derived from altered oceanic crust in a water-rich environment (including hydrothermal systems) exhibit a wide range in salinity, with brines originating from pores within sediments or evaporite material (Touret, 2001; Selverstone *et al.*, 1992; Fu *et al.*, 2001). Aqueous inclusions may be subordinate in eclogites when their protoliths are related to intraplate magmatism taking place during mantle upwelling and crustal thinning (Konzett *et al.*, 2012). Chemical modifications may produce a fluid that additionally contains non-polar components like CO_2, N_2 or CH_4 (*e.g.* Touret & Frezzotti, 2003). These components may be generated during degradation of organic matter (methane) during the burial stage, decarbonation or magma degassing, but can also be formed through oxidation of, *e.g.*, graphite (Connolly & Cesare, 1993; Pattison, 2006),

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