LETTER

UHP Ti-chondrodite in the Zermatt-Saas serpentinites: Constraints on a new tectonic scenario

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ABSTRACT

We focus on the key role of different Ti-humite minerals in subducted serpentinites as possible indicators of extreme pressure conditions. The occurrence of Ti-chondrodite and/or Ti-clinohumite assemblages in the eclogitized serpentinites of the Zermatt-Saas Zone (ZSZ) of the Western Alps allows the recrystallization of such rocks at UHP conditions \( (P = 2.8–3.5 \text{ GPa}, T = 600–670 \, ^\circ\text{C}) \) to be determined. Such conditions are similar to those registered by the nearby Cignana unit, a main Alpine area for UHP metamorphism, where coesite and microdiamond have been found. In ZSZ serpentinites, the new UHP assemblage predates the previously recognized HP-UHP paragenesis, which was recently dated at 65 Ma. This finding opens up a new interpretation for the petrologically and structurally well-constrained HP-UHP records, especially because all other ages for HP-UHP metamorphism in the ZSZ are much younger, and for the size of UHP units. Our findings suggest that ophiolites in the axial zone of collisional belts are a mosaic of oceanic lithosphere slices that recorded contrasted thermal and mechanical evolutions during their physical trajectories in the subduction wedge.

Keywords: Ti-clinohumite and Ti-chondrodite assemblages, integrated mineralogical and structural analysis, Alpine subduction, Western Alps

INTRODUCTION

HP-UHP mineral assemblages are the trademark of subduction zones. The most widely known are metamorphic coesite and diamond inclusions in host grains in eclogite-facies crust of the Western Alps, Norway, Central Europe, China, and Kazakhstan and majoritic garnet and Si-bearing spinel in garnet peridotite (e.g., Ernst and Liou 2008; Frezzotti et al. 2011). Recognized as upper mantle minerals from Colorado Plateau kimblerites (Aoki et al. 1976; Smith 1977), Ti-clinohumite and Ti-chondrodite are also part of HP-UHP assemblages in ultramafites from China and the Western Alps (Scambelluri and Rampone 1999; Shen et al. 2015). Shen et al. (2015) proposed conditions of 2.7 GPa and 550–660 °C for the assemblage Ti-chondrodite (Ti-Chn)+Ti-clinohumite (Ti-Chu)+Atg+Chl+Ol+Spl, demonstrating that Ti-Chn+Ti-Chu assemblages are indicators of UHP conditions in serpentinitized Ti-rich ultramafites (mineral abbreviations after Whitney and Evans 2010). The experimental demonstration of Ti-humite minerals defining HP-UHP conditions encouraged us to examine in detail fabrics and mineral assemblages in Valtournanche (Rebay et al. 2018 and references therein), to determine the microstructural relationships of Ti-Chu and/or Ti-Chn relics with the dominant HP-UHP foliation (S2) in these rocks. The occurrence of UHP rocks in the axial zones of oceanic belts has fueled debates on geodynamic environment (i.e., subduction, collision, late orogenic extension), exhumation mechanisms, and the timing of exhumation, which strongly influence the preservation of UHP assemblages (Ernst and Liou 2008). In the Alps, findings of UHP phases have led to the identification of hectometer to kilometer UHP tectonic units within HP nappes. Coesite (Reinecke 1991) and microdiamond (Frezzotti et al. 2011) relics occur in the Cignana Lake Unit (CLU) at the tectonic contact between the Zermatt-Saas Zone (ZSZ) and the Combin Zone (CZ). The shape, size, and exhumation environment of these UHP tectonic units are discussed. The occurrence of Ti-humites makes serpentinites a new key target for identification of UHP units.

The ZSZ (Figs. 1a and 1b) was derived from the internal portion of the Piedmont oceanic realm. It was trapped in the suture zone of the Western Alps during Alpine convergence. It comprises serpentinite, meta-gabbro, meta-rodinite, meta-basalt, and various meta-sediments. The metamorphism of the ZSZ is typical for eclogite facies conditions, locally overprinted by greenschist-facies mineral assemblages (commonly interpreted as exhumation-related). Peak \( P-T \) estimates range from 1.9–2.2 GPa and 500–600 °C to 2.3–2.8 GPa and 580–660 °C in different portions of the ZSZ (Bucher et al. 2005; Bucher and Grapes 2009; Zanoni et al. 2016). Such a wide \( P-T \) span suggests that different portions of the ZSZ underwent different tectono-metamorphic evolutions. In contrast, a common, and consequently uniform, evolution of the entire ZSZ was proposed by Angiboust and Agard (2010), with metamorphism peaking at 2.3 ± 0.1 GPa and 540 ± 40 °C. UHP conditions of 2.7 to >3.2 GPa and 590–630 °C have been recorded in small slices of oceanic rocks at the boundary between the ZSZ and CZ, at Lago di Cignana (Fig. 1c) (Groppo et al. 2009 and references therein). Protholith U/Pb ages range from 153–164 Ma (metabasites) to 162–168 Ma (serpentinites, Rebay et al. 2018 and references therein). Peak metamorphic ages are 71–38 Ma so that subduction might have been active already at 80 Ma (Table 1 in Rebay et al. 2018), indicating a wide time interval of re-equilibration during subduction and supporting a heterogeneous evolution of ZSZ. In particular, the dominant HP/UHP foliation (S2) of upper Valtournanche has been dated at 65.5 ± 5.6 Ma (Rebay et al. 2018).