Constraining the process of intracontinental subduction: implications from petrology and Lu-Hf geochronology of eclogites from the Austroalpine Nappes

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GEOLOGICAL SETTING

The Austroalpine nappes comprise the upper units within the nappe stack of the Eastern Alps (Fig. 1). They are derived from the continental crust of Aquila (Adria) high-grade rocks crop out along the Austroalpine (or Eoalpine) high-pressure (HP) belt, which extends over a distance of ~400 km from the Tauern complex in the west to the Sieggraben Unit in the east (Fig. 1). It comprises basement rock complexes that were subducted to eclogite-facies and partly ultrahigh-pressure (UHP) conditions in the Late Cretaceous (e.g., Janák et al. 2015, Miller & Thöni, 1997; Thöni & Miller, 1996).

RESULTS: GEOCHRONOLOGY

Several hypotheses have been proposed to explain the geodynamic evolution of the Austroalpine domain in the Eastern Alps. Janák et al. (2004) suggested the conception of intracontinental subduction. According to this model the site of the subduction zone can be traced along the east-west trending zone of Eoalpine HP metamorphic rocks. The subduction was initiated in the NW foreland of the Meliata suture, most probably within a pre-existing Permian-age rift that was reactivated when convergence across the suture continued after the closing of the Meliata Ocean (Janák et al. 2004; Stüwe & Schuster 2010).

To test this model we conducted detailed petrological and geochronological investigations on eclogites from different localities throughout the Austroalpine high-pressure belt.

RESULTS: PETROLOGY

Eoalpine HP metamorphic rocks. The subduction was initiated in the NW foreland of the Meliata suture, according to this model the site of the subduction zone can be traced along the east-west trending zone of eclogite-facies and partly UHP conditions in the Eastern Alps. Janák et al. (2004) suggested the conception of intracontinental subduction.

The Austroalpine HP belt is characterised by the presence of eclogites, which are dated using high-precision Lu-Hf geochronology. The garnet growth during pressure increase was dated using high-precision Lu-Hf geochronology. The results range between c. 100 (eclogites from Saualpe and Koralpe, Fig. 1) and c. 90 Ma (eclogite from Gries valley). The Late Cretaceous (e.g., Janák et al. 2015; Miller & Thöni, 1997; Thöni & Miller, 1996).

CONCLUSIONS

Lu-Hf dating of eclogites from the Austroalpine high-pressure belt yielded prograde garnet growth ages between c. 100 and c. 90 Ma, suggesting a short period of (ultra) high-pressure metamorphism.

The oldest eclogites are located in the Saualpe-Koralpe area, where also Permian to Triassic gneisses are widespread. This supports the hypothesis that subduction was intracontinental and was initiated within a pre-existing weak zone in the lithosphere, a Permain-aged rift.

The scattered age data from the eclogite from Saltaus valley is explained by the variable mixing between pre-Alpine and Alpine garnet. Therefore, Texel complex is interpreted to represent continental crust that contained Variscan high-grade rocks and was re-subducted during the Eoalpine orogeny.

Thermodynamic modelling indicates overall high T/P ratio and gradient with increasing temperatures and pressures from northwest to southeast. There is no continuous record of high-pressure metamorphism linking the Middle and Late Jurassic Meliata blueschist-facies metamorphism with the Cretaceous HP/UHP in the Austroalpine, but instead a gap of 50 Ma, suggesting that these are separate tectonic events.

Fig. 1. Tectonic map of the Eastern Alps, modified after Janák et al. (2004), Neubauer & Höck (2000) and Schmid et al. (2004).

Fig. 2. Compilation of measured Mn distributions in a garnet (green lines) and pyrope (blue lines; only for sample HO 2) components in garnet. Grey isopleths show volume percentage of pyrope and garnet. The ratio is represented by the position of isopleths.

Fig. 3. Equilibrium phase diagrams of the dated eclogite samples. Additionally, compositional data from in situ analysis on garnet (green lines) and pyrope (blue lines; only for sample HO 2) components in garnet were calculated. Grey isopleths show isopleth percentage of garnet. The phase diagram is characterized by the composition of garnet.

Fig. 4. (a) Compilation of Lu-Hf garnet ages established in the Austroalpine HP belt (data from Hauke et al. 2019, Janák et al. 2015, Schmidt et al. 2015, Thöni et al. 2008) and this study. (b) Compilation of estimated PT conditions (data from Hauke et al. 2019, Janák et al. 2015, Schmidt et al. 2015, Thöni et al. 2008) and this study. The yellow stars correspond to the estimated peak conditions. The green lines indicate the temperature gradient with increasing pressures and temperatures from northwest to southeast.

Fig. 5. Tectonic model illustrating the proposed evolution of the Austroalpine domain. (a) Tectonic restoration (thin black line) following the tectonic restoration of the Austroalpine HP belt. (b) Frontal convergence of the Saualpe-Koralpe complex and the craton. (c) Tectonic restoration of the Austroalpine HP belt. (d) Initial convergence of the Saualpe-Koralpe complex and the craton. (e) Tectonic restoration of the Austroalpine HP belt.

Fig. 6. Equilibrium phase diagrams of the dated eclogite samples. Additionally, compositional data from in situ analysis on garnet (green lines) and pyrope (blue lines; only for sample HO 2) components in garnet were calculated. Grey isopleths show isopleth percentage of garnet. The phase diagram is characterized by the composition of garnet.

Fig. 7. Tectonic model illustrating the proposed evolution of the Austroalpine domain. (a) Tectonic restoration (thin black line) following the tectonic restoration of the Austroalpine HP belt. (b) Frontal convergence of the Saualpe-Koralpe complex and the craton. (c) Tectonic restoration of the Austroalpine HP belt. (d) Initial convergence of the Saualpe-Koralpe complex and the craton. (e) Tectonic restoration of the Austroalpine HP belt.