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 Apulia (Adira). High-grade rocks crop out along the Austroalpine (or Eoalpine) high-pressure (HP) belt, which extends over a distance of ~400 km from the Texel 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).

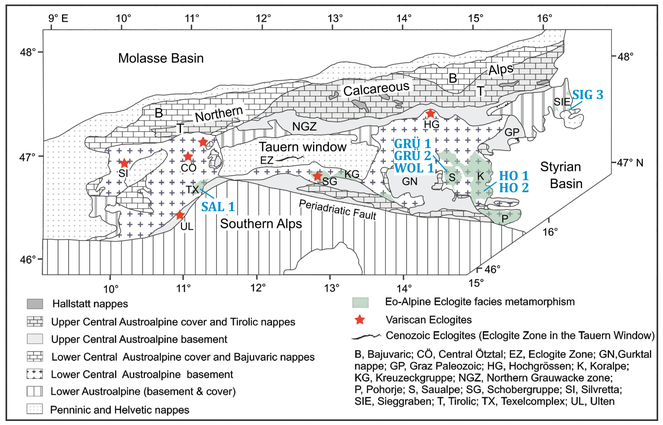
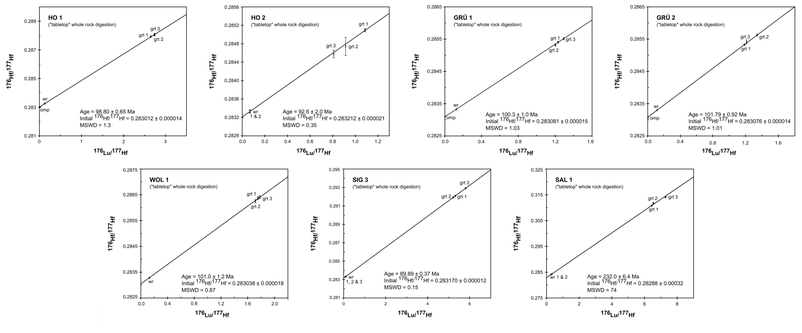


Fig. 1. Tectonic map of the Eastern Alps, modified after Janák et al. (2004), Neubauer & Höck (2000) and Schmid et al. (2004). Dated eclogite samples are marked in blue.

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 (Janäk 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: GEOCHRONOLOGY



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 Sieggraben, Fig. 1), indicating a short period of subduction. The Lu-Hf "age" of the eclogite from Texel indicates a variable mixing of Alpine (Grt 2) and relic pre-Alpine garnets (Grt 1) (Fig.)

RESULTS: PETROLOGY

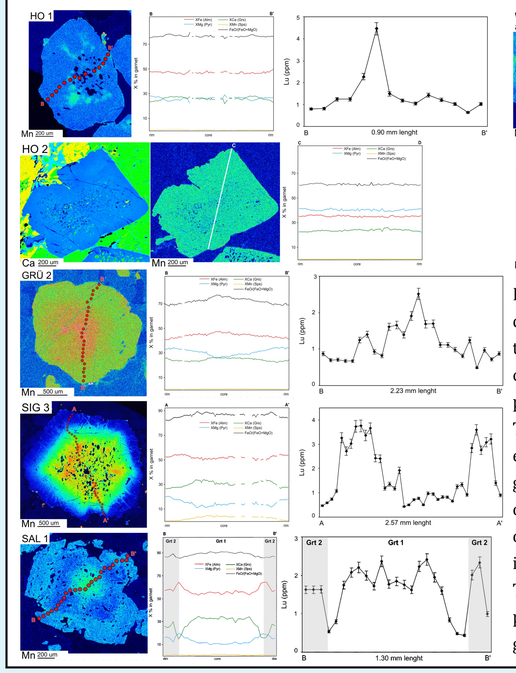


Fig. 2. Compilation of Mn distribution maps, compositional and Lu concentration profiles for the dated eclogites, with the exception of sample HO 2. The profiles follow the traces marked on the separate garnets.

Eclogite samples HO 1 and GRÜ 2 display compositional zoning with high Ca and Mn distributions as well as bell-shaped Lu concentrations in the cores (Fig. 2). This indicates that the garnets have preserved their prograde growth zonation pattern for Lu-Hf. In contrast, the garnets in sample HO 2 show homogeneous major element distribution probably related to equilibrium during the thermal stage of metamorphism.

The garnets from sample WOL 1 also display prograde growth zonation with Mn enrichment in the cores. However, the distribution of Lu differs in the smaller and larger garnet crystals (Fig. 2). Similarly to sample SIG 3, in the large garnets Lu is concentrated only close to the rims. This pattern may be well explained by a model where incorporation of Lu is controlled by diffusion, whereas the overall garnet growth is dominated by interface-controlled mechanism.

The garnets in sample SAL 1 show two growth stages (Fig. 2). Idiomorphic Grt 1 displays prograde growth zoning. An abrupt change in chemical composition marks the second garnet growth stage (Grt 2). The distribution of Lu mimics well the Mn zoning of in garnet.

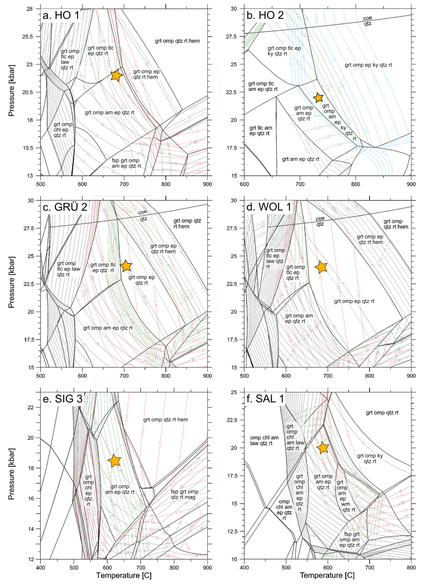


Fig. 3. Equilibrium phase diagrams of the dated eclogite samples. Additionally, compositional isopleths for almandine (red lines), grossular (green lines) and pyrope (blue lines; only for sample HO 2) components in garnet were calculated. Grey isopleths show volume percentage of garnet. The yellow stars correspond to the estimated peak conditions.

CONCLUSIONS

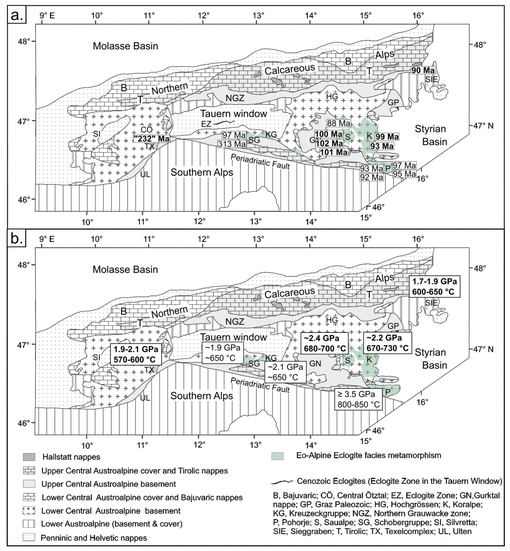


Fig. 4. (a) Compilation of Lu-Hf garnet ages established in the Austroalpine HP belt (data from Hauke et al. 2019, Sandmann et al. 2016, Thöni et al. 2008 and this study). (b) Compilation of the estimated P-T conditions (data from Hauke et al. 2019, Janák et al. 2015, Konzett et al. 2012 and this study). Bold numbers represent the data obtained in this study.

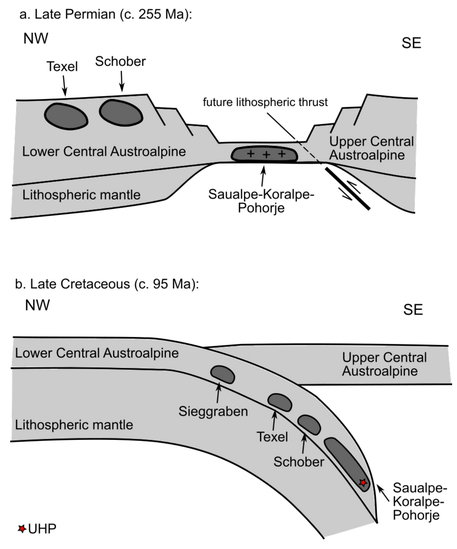


Fig. 5. Tectonic model illustrating the proposed evolution of the Austroalpine domain. (a) Gabbroic intrusions embedded within the thinned crust of a rift zone during extension in the Late Permian. (b) Progressive subduction of the Saualpe-Koralpe-Pohorje terrane and the Variscan eclogites from Schobergruppe and Texel complex during the Late Cretaceous.

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 localized in the Saualpe-Koralpe area, where also Permian to Triassic gabbros are widespread. This supports the hypothesis that subduction was intracontinental and was initiated within a pre-existing weakness zone in the lithosphere, a Permian-age rift.

The scattered age data from the eclogite from Saltaus valley is explained by the variable mixing between pre-Alpine and Alpine garnets. 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.

References:

Hauke et al. 2019, Int. J. Earth Sci., 108, 1317–1331. Janák et al. 2004, Tectonics, 23, TC5014. Janák et al. 2015, J. Metamorph. Geol., 33, 495-512. Konzett et al. 2012, J. Petrol., 53, 99-125. Miller & Thöni 1997, Chem. Geol., 137, 283-310. Neubauer & Höck 2000, Mitt. Österr. Geol. Ges., 92, 7-14. Sandmann et al. 2016, Lithos, 262, 576-585. Schmid et al. 2004, Eclogae geol. Helv. 97, 93-117. Stüwe & Schuster 2010, Geology, 38, 175-178. Thöni & Miller 1996, J. Metamorph. Geol., 14, 453, 466. Thöni et al. 2008, J. Metamorph. Geol., 26, 561-581.