Structural and petrologic investigation of the subduction-exhumation history of the Modereck nappe system, central Tauern Window

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The central part of the Tauern window contains Tertiary high-pressure (HP) rocks derived from the former Alpine Tethys (Glockner nappe) and the distal European continental margin (Eclogite Zone, Modereck nappe). The HP rocks are strongly sheared and heterogeneously retrogressed, such that they only locally retain the HP fabrics and parageneses. In past work, this heterogeneity was interpreted to reflect a mélange-type structure, with blocks of eclogites surrounded by calcareous schist (Bünderschiefer) and metabasite (Prasinite) with greenschist-facies parageneses. The apparent absence of HP assemblages in these surrounding rocks was believed to support the notion that the HP rocks were tectonically injected into a lower-grade matrix that never experienced HP metamorphism.

Here we report the first evidence that HP metamorphism affected the whole Modereck nappe in the central Tauern Window. The HP assemblages occur in lozenges of less-sheared rock surrounded by a highly sheared, mylonitic calcschist and prasinite, which we found to also contain relicts of HP metamorphism. These include lawsonite pseudomorphs in garnet within early Cretaceous pelitic metasediments (Brennkogel Fm). Raman spectroscopy of quartz inclusions in garnet and on carbonaceous matter, as well as thermodynamic modelling of co-existing mineral parageneses in other Mesozoic metasediments from different parts and lithostratigraphic formations of the Modereck nappe, indicate peak-metamorphic conditions of ca. 20 kbar at 400-500 °C. Similar metamorphic conditions are also obtained in lithologies of the oceanic Glockner nappe, indicating that both distal continental and oceanic units were subducted.

Both the Modereck and Glockner nappes were affected by a multi-km-scale recumbent sheath fold, the Seidlwinkl fold, as indicated by the consistent N-S trend of stretching lineations around its entire, arcuate hinge on the map scale. The contact between these two nappes is a thrust which is affected by and therefore predates the Seidlwinkl fold. The axial plane foliation of this fold syn- to post-dates the HP metamorphism and is associated with top-N shear sense indicators parallel to the aforementioned stretching lineations. Therefore, we suggest that the formation of the sheath fold was related to the exhumation of the Modereck nappe and the overlying Glockner nappe as a composite fold nappe from ca. 60 km depth to shallower levels corresponding to greenschist-facies conditions.

HP metamorphism occurred throughout the Modereck nappe and the nappe displays a well-ordered stratigraphic succession. This indicates that it is not a mélange but a coherent HP nappe that is interpreted to have been introduced into the lower-grade neighbouring tectonic units during thrusting of the Penninic nappes beneath the Austroalpine units. During continued subduction and subsequent exhumation, they underwent extensive retrogression and structural overprinting during exhumation.

Sheath folds like the Seidlwinkl fold may be characteristic of subduction-exhumation channels, where high strain rates and temperatures favour low viscosity contrasts among the constituent continental and oceanic lithologies; this, in turn, maintains the coherence of the original passive-margin sequence. We propose that crustal-scale sheath folds nucleate along pre-orogenic structural heterogeneities of the passive margin (e.g., thickness variations in the vicinity of rift-related low-angle normal faults), then undergo explosive growth followed by homogeneous, noncoaxial shearing on their way back up. We speculate that the Seidlwinkl fold may provide an analogue for anomalous structures at the tops of downgoing slabs imaged with high-resolution seismic tomography using receiver functions.