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Crustal-scale sheath folding at HP conditions in an exhumed Alpine subduction zone (Tauern Window, Eastern Alps)

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The Tauern Window (Eastern Alps) offers a rare glimpse of an exhumed and remarkably well preserved subduction zone that was active in Paleogene time. New cross-sections and structural data, together with new petrological data document the existence of a recumbent, crustal-scale sheath fold in the centre of the Window. The fold itself is a composite structure, comprising an isoclinally folded thrust of the former Alpine Tethyan ocean (Glockner Nappe) onto the former European continental margin (Modereck Nappe). The pervasive foliation in the area is parallel to the axial plane of the fold and carries a N-S oriented stretching lineation with top-N (to foreland) shear indicators. Opposite shear sense (top-S) in units structurally overlying the fold was not observed. Both the oceanic and continental nappes show the same peak-pressure conditions (ca. 2.0 GPa) indicating that they were stacked and subsequently folded into a crustal-scale sheath fold at approximately 60 km depth before this fold was itself emplaced as a thrust package onto proximal parts of the European margin. The amplitude of the HP sheath fold measures some 30 km from the fold hinge in the north to its attenuated limbs in the south. The stratigraphy of the former European passive margin remains intact in the fold hinge and in its upper limb, whereas it is only locally preserved in the lower limb, primarily due to intense mylonitic shearing at the base of the fold. The sheath fold is not present along strike to the east and west in the Tauern Window, where only normal-sense, passive-margin stratigraphy of the Modereck Nappe has been mapped.

The excellent preservation of passive margin stratigraphy, of early accretionary thrusts and of exhumation structures including the sheath fold, call for conditions that favoured discrete thrusting and buckling followed by a transition to more homogeneous shearing. We propose that initial thrusting of the oceanic crust onto a sliver or extensional allochthon of the European margin occurred under brittle conditions at or near the tip of the Alpine orogenic wedge. This thrusting marked the transition from Alpine subduction to Adria-Europe collision. Increasing pressure and temperature with increasing subduction suppressed brittle behaviour and favoured buckling of the composite ocean-continental units to form a large fold. The along-strike discontinuity of this sheath fold is attributed either to lateral ramping of the basal accretionary thrust or to later excision of the lower limb of the sheath fold during shearing and exhumation. In analogy with both analogue and numerical models of sheath folding, we propose that the formation and emplacement of the sheath fold during exhumation involved general non-coaxial flow at high shear strains and low viscosity contrasts between ocean crust, continental basement and its sedimentary cover. The fold is inferred to have amplified passively as a result of high-strain shearing during exhumation.

Our kinematic observations above are compatible with end-member models of nappe accretion and subduction (in a slab-top or orogenic wedge). However, to date, we are unable to explain how the high-pressure rocks were exhumed from peak conditions.