EGU26-17661, updated on 26 Aug 2026
https://doi.org/10.5194/egusphere-egu26-17661
EGU General Assembly 2026
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3D geomodel of the Eastern Tauern Dome (Tauern Window - Eastern Alps)

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The Tauern Window in the Eastern Alps represents an ideal natural laboratory to investigate the three-dimensional architecture due to deformation processes related to continental collision and indentation. It exposes deeply subducted and subsequently exhumed European crust and remnants of the Alpine Tethys ocean beneath nappes derived from the Adriatic upper-plate, which frame the window (Austroalpine units). South of the Tauern Window, the Austroalpine Rieserferner and Drau–Möll blocks acted as indenting wedges during Oligocene-Miocene Adria–Europe convergence, while the Southern Alps form the leading edge of the Adriatic indenter. Lower-plate units exposed in the Tauern Window record a complex tectono-metamorphic evolution from Late Cretaceous to Miocene times, including accretion and subduction (D1-D2), exhumation and isoclinal folding of the Alpine Tethys ophiolites of the Penninic nappes (D3), formation of the crustal-scale Venediger duplex and nappe stacking of the European crust (D4), and overprint of earlier duplex structures by late-stage indentation, doming and lateral escape (D5). The final configuration of the Eastern and Western Tauern domes is then represented by several doubly plunging, upright antiforms deforming the D4 roof thrust of the Venediger duplex and the overlying units. In order to validate these nappe-scale structures, three-dimensional modelling was performed using the open-source software PZero (https://github.com/gecos-lab/PZero).

Geological 3D modelling in such metamorphic belts is hindered by both mathematical and geological complexities, including the interpolation of polydeformed surfaces and the definition of a consistent geological legend. Traditional explicit modelling approaches often generate inconsistencies, while fully time-aware implicit modelling is difficult to apply due to poorly constrained or heterogeneous ages of tectono-metamorphic boundaries. In this project we use the Structural Topology model (STm) approach that integrates conceptual geological interpretation with topological analysis of these units (i.e. volumes) and their boundaries (i.e. surfaces), systematically classifying (i) units as tectono-metamorphic, tectono-stratigraphic, or intrusive, and their boundaries (ii) as being conformal or discordant with the internal foliation of units, and (iii) according to crosscutting relationships that reveal the tectonic evolution. For all these model entities, a polarity is defined that, in addition to constrain stratigraphic and structural relationships, allows constraining the gradient of the scalar field used for implicit interpolation.

We believe that this strategy allows reconstructing topologically and geologically consistent 3D models despite polyphase deformation and reactivation of structures. The resulting 3D geomodel also provides new insights into the architecture and exhumation history of the Eastern Tauern Dome and offers a transferable framework for geological 3D modelling in complex orogenic belts.