



Indentation tectonics in the Swiss Préalpes Romandes caused by the uplift of the Aar Massif: insights from high-resolution 3D structural modelling

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The Prealps represent a complex nappe system consisting of Mesozoic to early-middle Cenozoic sediments deposited in the Penninic domains, detached from its substratum during the Alpine orogeny. During subsequent phases of subduction and collision, these nappes were transported along the active plate interface between Adria and Europe far to the north. Today, they lay above the transition between the Helvetic Nappes and the Subalpine Molasse. As a result of long-term displacement and successive deformation, the Prealps exhibit a complex structural architecture that records the cumulative tectonic evolution. We developed a 3D model to yield a high-resolution visualization of the structural architecture and its spatial changes within the Préalpes Romandes. These observations allow us to correlate nappe internal deformation with movements of underlying nappes, which is the goal of this work.

The Préalpes Romandes are crosscut by predominantly north-south-oriented sinistral strike-slip faults. These structures range from large-scale faults that transect the entire Prealps nappe stack and accommodate offsets of several kilometers, to minor faults with displacements of only a few meters to tens of meters. Smaller faults are commonly linked by lateral offsets to form continuous step-over fault systems and typically terminate within the detachment horizon. In contrast, larger strike-slip faults must breach the basal detachment of the Prealps to maintain a kinematic balance and are therefore rooted in deeper structural units. Despite a regional change in stratigraphic orientation of approximately 30° from east to west, the orientation of sinistral strike-slip faults remains largely unchanged. An increasing number of NW-SE-oriented dextral strike-slip faults in the eastern Préalpes Romandes indicate a change in the regional kinematic regime.

Based on our results, we interpret that the Préalpes Romandes experienced a young (Miocene) phase of deformation following early stages of subduction related nappe transport. We relate this Miocene phase of deformation to the uplift of the Aar Massif. This caused differential motion beneath the Prealps, which is expressed by strike-slip deformation, rotation and back-thrusting within the Préalpes Romandes. We additionally invoke this motion to have controlled the

differential migration within the nappe stack, resulting in $\sim 30^\circ$ counter-clockwise rotation and a general northwestward displacement of the eastern Préalpes Romandes. In addition, the presence of a northern backstop subsequently promoted the occurrence of a lateral escape along local dextral strike-slip faults. A correlation of our 3D model with seismically active zones at greater depth discloses the occurrence of structures that were offset in response to the uplift of the Aar massif during Miocene times. These observations document a complex multistage deformation sequence associated with late-stage collision and uplift tectonics in the subsurface, where the initial sinistral movement has been disrupted and partially reoriented by the latest tectonic evolution. It also highlights the role of strike-slip structures as key elements for understanding the long-term tectonic evolution of the region.

High-resolution 3D modelling therefore provides a powerful framework to unravel internal structural relationships, integrate them with surrounding geology, and develop coherent palaeogeographic reconstructions through space and time.