EGU25-6051, updated on 21 May 2025
https://doi.org/10.5194/egusphere-egu25-6051
EGU General Assembly 2025

High-resolution digital outcrop models of low-angle normal faulting: the fossil distal Adriatic rifted margin (SE Switzerland)

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Low-angle normal faults (LANFs), characterized by dips of less than 30°, are frequently observed in rifted margins. Despite extensive research, the mechanical processes governing LANFs remain poorly constrained, raising critical questions about the angle at which they initiate, their evolution during extension, their three-dimensional geometry, and related deformation in the hanging-wall and footwall. Addressing these issues is essential for understanding extensional processes in such tectonic settings, including thinning of the continental crust and the exhumation of mantle material in rifted margins.

The Err and Bernina extensional detachment systems, within the lower Austroalpine nappes of the Central Alps, offer a rare natural laboratory for studying LANFs. Formed during the Jurassic rifting in the distal Adriatic rifted margin preceding the formation of the Alpine Tethys, these LANFs are exceptionally well-preserved despite the subsequent deformations from the Alpine orogeny.

This study presents results from extensive field campaigns conducted between 2022 and 2024, during which high-resolution data were collected over a ~100 km² area using Unmanned Aerial Vehicle (UAV) surveys supplemented by field mapping. Rigorous quality control and processing ensured the generation of 3D high-resolution digital outcrop models (DOMs) of the Err and Bernina extensional detachment systems, implementing differential positioning and SwissTopo terrain data for a resulting spatial error of less than 1 meter. The DOMs provide centimetre to decimetre-scale details that facilitate mapping of the spatial evolution of LANFs and the tectono-sedimentary architecture of the overlying allochthonous blocks. Detailed interpretations reveal their internal structure, including lithological changes, deformation patterns, and fault structures at various scales. Additionally, we characterized the sedimentary basins formed during the Jurassic extension, shedding light on their development and spatial relationships with the detachment systems. Comparison of our findings with seismic data across present-day low-angle normal fault systems bridges the scale-gap between detailed field-based analyses and large-scale seismic interpretations, providing crucial new insights to the evolution of LANFs.