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3D-model of complex km-scale fold structures using laserscanning images: The Achensee region, western Northern Calcareous Alps, Austria

H. Ortner (1) and A. Gruber (2)

(1) Innsbruck University, Geology and Paleontology, Innsbruck, Austria (hugo.ortner@uibk.ac.at), (2) Austrian Geological Survey, Vienna, Austria

The Northern Calcareous Alps (NCA) are a fold-and-thrust belt built by Permomesozoic rocks. It was affected by Early Jurassic rifting prior to Late Createceous stacking of thrust sheets. The inversion of Jurassic basins resulted in complex fold structures. One of the enigmatic areas is the Achensee region, where a major kilometric W-E trending anticline-syncline system (Montschein-anticline, Karwendel-syncline) is offset to the north east of lake Achensee (Guffert-anticline, Thiersee syncline). The anticlines and synclines west and east of the transfer zone are recumbent, but no thrust is visible. In the transfer zone, the axis of the anticline curves to a N-S orientation (Unnutz anticline), whereas the syncline evolves to a thrust with 5km offset in E-W cross section (Achental thrust) that superimposes Triassic on Cretaceous rocks.

The 3D-model in this low-budget project was constructed to understand the kinematic evolution of the fold and thrust system. Input data were: (1) a tectonic map with a dense network of orientation data, (2) a map of the trace of bedding mapped from 1m resolution laserscanning images, (3) a DEM with approximately 30m resolution.(1) and (2) were prepared in a GIS system, and then imported into the Midland Valleys Move software. Our intention was to create a data-oriented model, to prevent any model-induced bias. Thrust planes were constructed using the intersection lines with the DEM. Bedding in folds was modelled by extruding the intersection lines with the DEM parallel to the fold axis. In both cases errors were introduced into the model as the DEM has not enough resolution. Orientation data are displayed as discs in 3D space.

The 3D-model shows that the Achental thrust cuts progressively into deeper structural levels of the Unnutz anticline to the south, therefore the thrust dips shallower to the south than the fold axis. Therefore the Achental thrust superimposes pre-existing folds onto the footwall toward the north, as established from brittle structures and map-scale folds in the footwall of the thrust. The thrust is almost planar, and cuts across an E-W trending anticline north of the Karwendel syncline, but is slightly refolded south of the Guffert anticline. Therefore the Achental thrust formed during a late stage of N-S shortening.

The strongly curved folds in the hanging wall of thrust were probably localized at the margins of a Jurassic basin. A thickness difference from 200m to 800m was observed in Jurassic sediments, but the change in thickness is gradual. The importance of Jurassic faults is probably to offset the detachment for the folds in Triassic rocks and hinder further propagation. We speculate that this could be the reason to form the kinked fold axis. Brittle data indicate NW-directed shortening. The amount of shortening involved in both stages of deformation has to be selected in a way that the offset across the thrust is matched, but Karwendel and Thiersee synclines remain coherent. Localization of folding obliquely to tectonic transport and the large offset across the Achental thrust require approximately E-W and N-S striking Jurassic faults.

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