Mechanical controls on recumbent folding from 2D numerical simulations. Applications to the Eaux-Chaudes fold nappe (west-central Pyrenees)

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Tectonic nappes are typical structural features in orogenic belts worldwide and include two end members, namely thrust nappes and fold nappes. Although the geometry and kinematics of these are relatively well constrained after more than a century of studies, the mechanics are still incompletely understood.

In recent years, numerical modelling has become a powerful tool to unravel the mechanics of fold nappes. Studies have been carried out particularly with application to the Helvetic nappes of the Alps, highlighting the relevance of the mechanical stratigraphy involved in the deformation. The Helvetic nappes consist of a superposition of thrust nappes over recumbent fold nappes. It was developed due to the closure of half-graben basins and the extrusion of their sedimentary infill under dominantly ductile deformation conditions. Competence contrast between stiff (i.e. limestones) and weak layers (i.e. shales) played a key role in controlling the deformation style.

Recently, a similar structure has been reported in the Pyrenees. The Eaux-Chaudes massif (western Axial Zone, Pyrenees) is a basement-cored recumbent anticline with a kilometric, long reverse limb showing ductile deformation in Mesozoic carbonates, much in style of the Helvetic nappes of the Alps. The reverse limb is in thrust contact over an autochthonous Mesozoic cover with similar stratigraphy, and hence its development cannot be explained by basin infill extrusion. The fold structure shows a strain increase towards the reverse limb and is overlain by the Lakora basement thrust sheet. The general stratigraphic succession consists of Upper Cretaceous limestones and shales lying unconformably over Paleozoic metasediments or Lower Triassic sandstone pods and featuring inliers of Upper Triassic Keuper facies and ophites. The autochthonous succession lies on top of a late Variscan granitic pluton, both showing very low-strain during Alpine deformation.

Here, we employ the thermomechanical staggered finite difference code LaMEM (Kaus et al., 2016) to perform 2D parametric simulations in order to study changes in deformation style between thrust nappes (plastic/brittle-localisation) and recumbent fold nappes (viscous/ductile-distributed). The simulations are performed using a linear viscoelastoplastic rheology with the
Drucker-Prager criterion for plasticity. The initial setup consists of two domains separated by a basement perturbation and both overlain by a lower stiff layer, representing the Upper cretaceous limestones. In the right-bottom half domain there is a stiff body representing the Eaux-Chaudes pluton, while in the bottom-left domain there are weak layers representing the shale-rich Paleozoic basement. Over the stiff layer, there is a multilayer of weak and stiff layers mimicking the Lakora thrust sheet, which provides the overburden and confining pressure.

Preliminary results show a strong control of the cohesion and viscosity of the lower stiff layer on the deformation style developed. For simulations with low cohesion values, there is an enhancing of strain localization and thrust nappe development is favoured, whereas high cohesion values tend to spatially distribute the deformation and facilitate the development of fold nappes. Further simulations are in progress to test these preliminary results.