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2D thermo-mechanical modeling of basement-cover deformation with application to the Helvetic nappe system and the external massifs in the Western Alps

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Basement-cover deformation and its relationship to nappe emplacement and massif formation in the external Western Alps has been a subject of controversy for many years. Although it is commonly accepted that these massifs are the result of basin inversion of European margin graben-type structures, the mechanisms of basin inversion itself is still highly debated. Some studies suggested that the geometry of some external crystalline massifs is essentially a cuspate-lobate (i.e. ductile) structure while other studies interpret the geometry of those massifs as a result of brittle thrust mechanics. Furthermore, the importance of reactivation of pre-existing brittle structures during basin inversion is still debated. To better understand basement-cover deformation we use a two-dimensional (2D) thermo-mechanical finite element model to investigate both the individual and combined influence of viscous, elastic and plastic rheologies on the deformation of half-graben structures under compression. Two types of boundary conditions are used, namely pure shear and shortening combined with basal drag exhibiting a singularity point (S-point). The surface is free. The resulting geometry and finite deformation patterns in both basement and sediment model units are then compared to cross-sections, finite strain ellipses and cleavage orientation from published data. Orientation and distribution of plastic shear bands in the model are compared to fault distribution from field data and sand box analogue models. First results suggest that a dominantly ductile behavior in the lowest part of the sediment-filled basin is needed in order to reproduce finite strain patterns similar to the ones found in fold nappes such as the Morcles nappe (Western Switzerland). Ductile behavior is possible at low temperature (300 °C) using realistic flow laws for calcite. The numerical results are further applied to interpret the tectonic evolution of the Aiguilles Rouges and Mont-Blanc massifs in the Western Alps.