3D FEM modeling of fold nappe formation in the Western Swiss Alps

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Fold nappes are recumbent folds with amplitudes exceeding 10 km and have been presumably formed by heterogeneous simple shear. They often exhibit a constant sense of shearing and a non-linear increase of shear strain towards their overturned limb. The fold axes of the Morcles fold nappe in western Switzerland plunges to the ENE whereas the fold axes in the more eastern Doldenhorn nappe plunges to the WSW. These opposite plunge directions characterize the Wildstrubel depression (Rawil depression, Ramsay, 1981). The Morcles nappe is mainly the result of layer contraction and shearing (Ramsay, 1981). During the compression the massive limestones were more competent than the surrounding marls and shales, which led to the buckling characteristics of the Morcles nappe, especially in the north-dipping normal limb.

There are still no 3D numerical studies which investigate the fundamental dynamics of the formation of the large-scale 3D structure including the Morcles and Doldenhorn fold nappes and the related Wildstrubel depression. Such studies require a numerical algorithm that can accurately track material interfaces for large differences in material properties (e.g. between limestone and shale) and for large deformations. We present a numerical algorithm based on the finite element method (FEM) which can simulate 3D fluid flow for a power-law viscous rheology. Our FEM code combines a numerical marker technique and a deformable Lagrangian mesh with re-meshing (Poliakov and Podladchikov, 1992) and is used to study the formation of 3D fold nappes similar to the ones in the Western Swiss Alps. The numerical method requires the interpolation of material properties to the integration points because the layer interface can lie within a finite element. To guarantee accuracy the number of integration points in the finite elements is increased considerably. The interpolation is only performed during several re-meshing steps when the deformed Lagrangian mesh is too distorted. During the re-meshing the global coordinates of the contour points specifying the interface between different materials remain unchanged and the new local coordinates of the contour points are interpolated from the element nodes of the new mesh. Our new FEM code is tested for large strain density driven diapirism and single-layer folding of power-law viscous layers by comparing numerical results with analytical solutions. Also, the results of the new 3D algorithm are compared with results of existing and tested 2D algorithms for cylindrical folding.

We present first results for the formation of fold nappes in 3D. We further present preliminary numerical results for the formation of the Morcles-Doldenhorn fold nappe system.

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