Geophysical Research Abstracts
Vol. 12, EGU2010-9756, 2010
EGU General Assembly 2010

Dynamics of fold nappe formation

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Fold nappes are large-scale recumbent folds that have most likely formed by dominantly ductile deformation. In the Western Swiss Alps, the Middle and Lower Penninic basement nappes as well as the Helvetic ones display, in most cases, the typical geometry and stratigraphy of fold nappes with a normal flank, a frontal part and an overturned limb. The core of fold nappes often consists of metamorphic basement surrounded by a sedimentary cover. Examples are the Morcle-Mont-Blanc nappe or the Antigorio nappe.

Although fold nappes are a prominent tectonic structure in the Alps and in many other past and present mountain belts, there are only few studies that investigated the dynamics of the formation of fold nappes. Therefore, there are still many open questions concerning the controlling forces (gravity or horizontal compression), the far-field deformation field (simple and/or pure shear), the effective rheology (e.g. Newtonian viscous, power-law or viscoplastic) and the impact of geometrical and material heterogeneities (e.g. effective viscosity ratio or initial geometry).

In this study, numerical results of finite element models simulating the formation of fold nappes in ductile multilayers are presented. In these models, the sedimentary cover is modelled with ductile multilayers exhibiting a power-law rheology and the basement is modelled with one thick layer having also a power-law rheology. The far-field deformation field is assumed to be simple-shear. The applied finite element method employs a Lagrangian formulation with re-meshing where the numerical grid is deformed with the calculated velocity field. This method ensures that the boundaries between the different layers (i.e. sedimentary units and basement) are accurately resolved during the entire large strain deformation. Although the presented models are basic, the results already show several interesting features: a) the sedimentary layers are detached from the basement at several locations, b) folds of different size and order are formed, c) fold axial planes with different orientations are formed during one continuous deformation phase and d) recumbent folds with overturned limbs more or less parallel to the far-field simple shear direction are formed. Furthermore, in the middle of the model the multilayers formed a fold nappe which has an overturned limb, a frontal part and a normal limb.

The applicability of the presented numerical models to natural fold nappes in the Alps is discussed. Also, modelling approaches for a more realistic numerical modelling of fold nappes in the Alps are presented.