Abstract

The Helvetic nappe system in Western Switzerland is a stack of fold nappes and thrust sheets emplaced at low grade metamorphism. Fold nappes and thrust sheets are also some of the most common features in orogens. Fold nappes are kilometer scaled recumbent folds which feature a weakly deformed normal limb and an intensely deformed overturned limb. Thrust sheets on the other hand are characterized by the absence of overturned limb and can be defined as almost rigid blocks of crust that are displaced sub-horizontally over up to several tens of kilometers. The Morcles and Doldenhorn nappe are classic examples of fold nappes and constitute the so-called infra-Helvetic complex in Western and Central Switzerland, respectively. This complex is overridden by thrust sheets such as the Diablerets and Wildhörn nappes in Western Switzerland. One of the most famous example of thrust sheets worldwide is the Glarüs thrust sheet in Central Switzerland which features over 35 kilometers of thrusting which are accommodated by a ~1 m thick shear zone.

Since the works of the early Alpine geologist such as Heim and Lugeon, the knowledge of these nappes has been steadily refined and today the geometry and kinematics of the Helvetic nappe system is generally agreed upon. However, despite the extensive knowledge we have today of the kinematics of fold nappes and thrust sheets, the mechanical process leading to the emplacement of these nappe is still poorly understood. For a long time geologist were facing the so-called 'mechanical paradox' which arises from the fact that a block of rock several kilometers high and tens of kilometers long (i.e. nappe) would break internally rather than start moving on a low angle plane. Several solutions were proposed to solve this apparent paradox. Certainly the most successful is the theory of critical wedges (e.g. Chapple 1978; Dahlen, 1984). In this theory the orogen is considered as a whole and this change of scale allows thrust sheet like structures to form while being consistent with mechanics. However this theory is intricately linked to brittle rheology and fold nappes, which are inherently ductile structures, cannot be created in these models. When considering the problem of nappe emplacement from the perspective of ductile rheology the problem of strain localization arises.

The aim of this thesis was to develop and apply models based on continuum mechanics and integrating heat transfer to understand the emplacement of nappes. Models were solved either analytically or numerically. In the first two papers of this thesis we derived a simple model which describes channel flow in a homogeneous material with temperature dependent viscosity. We applied this model to the Morcles fold nappe and to several kilometer-scale shear zones worldwide. In the last paper we zoomed out and studied the tectonics of (i) ductile and (ii) visco-elasto-plastic and temperature dependent wedges. In this last paper we focused on the relationship between basement and cover deformation. We demonstrated that during the compression of a ductile passive margin both fold nappes and thrust sheets can develop and that these apparently different structures constitute two end-members of a single structure (i.e. nappe). The transition from fold nappe to thrust sheet is to first order controlled by the deformation of the basement.