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Tectonic nappe emplacement on low-angle shear zones triggered by kinematic strain localization

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Tectonic nappes such as the ones observed in the Helvetic nappe system (Switzerland) are often emplaced on low angle shear zones. These shear zones are usually between 1-100 m thick and can accommodate displacement of tens, up to hundreds of kilometers. In this contribution we address two questions regarding the emplacement of nappes: (1) how do low angle shear zones form? (2) Which mechanism causes strain to localize at the base of nappes? Generally, the localization of strain can have two different causes: (1) A rheological cause, here termed dynamic strain localization. Thereby, strain in a homogeneous material becomes localized because the material softens in certain regions during the deformation (strain softening) due to processes such as grain size reduction, brittle precursor controlled fluid-rock interaction or shear heating. (2) A structural cause, here termed kinematic strain localization. Thereby, the initial strength of the deformed region is heterogeneous and strain localizes due to initial differences in mechanical strength and/or due to particular geometries. Such localization of strain can occur in linear viscous materials.

We use two dimensional numerical simulations to study the emplacement of tectonic nappes over half-graben basins in a compressional wedge. We consider a linear viscous rheology and neglect temperature. The initial model configuration represents a simplified passive margin with half-grabens. We investigate (1) the control of half-graben depth on nappe emplacement and (2) the control of rheological layering in the sediments on strain localization. Results show that the viscosity contrast between basement and sediments, and the geometry of the half-graben triggers the localization of deformation at the rift shoulder of the half graben. Sediments then form tectonic nappes that are emplaced along the basement-cover interface when the topography of the basement is high (horst). The sediments that fill the half-grabens are partly sheared-off the half-graben. The resulting geometry is one where strain is localized in the sediments, forming low angle shear zones. Half-graben depth has only a minor control on strain localization. On the other hand the presence of a stronger upper sedimentary layer (i.e. rheological layering) causes significantly stronger localization of deformation in the lower sedimentary layer. Shear zones at the base of the nappes record shear strain up to 150, i.e. they accommodate $\sim$30 km displacement over a thickness of 200 m. We conclude that kinematic strain localization has a strong control on the formation and orientation of shear zones at the base of tectonic nappes. We suggest that the kinematic strain localization can trigger further strain localization caused by dynamic effects, such as due to grain size reduction or shear heating.