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Material instabilities and their role for the initiation of boudinage and folding structures

Manolis Veveakis (1), Max Peters (2), Thomas Poulet (1), Ali Karrech (3), Marco Herwegh (2), and Klaus Regenauer-Lieb (4)

(1) CSIRO Earth Science and Resource Engineering, Sydney, Australia, (2) Institute of Geological Sciences, University of Bern, Switzerland, max.peters@geo.unibe.ch, (3) School of Civil and Resource Engineering, The University of Western Australia, Australia, (4) School of Petroleum Engineering, The University of New South Wales, Australia

Localized phenomena, such as pinch-and-swell boudinage or localized folds, are usually interpreted to arise from viscosity contrasts. These are caused by structural heterogeneities, such as geometric or material imperfections. An alternative possibility for strain localization exists in material science, where dynamic localization emerges out of a steady state for a given critical set of material parameters and loading rates (Montési and Zuber, 2002). In our contribution, we will investigate the conditions under which this type of instabilities triggers localized deformation. Moreover, we discuss whether geological materials necessarily require structural heterogeneities, such as weak seeds, in order to generate aforementioned localized structures.

We set up a random distribution of grain sizes in a layer embedded in a matrix with a diffusion creep rheology. Deformation within the layer is accommodated by dislocation and diffusion creep as end member deformation mechanism. The grain size evolution follows the paleowattmeter scaling relationship for calcite creep (Austin and Evans, 2007), which is controlled by thermo-mechanical feedbacks (Herwegh et al., 2014). During the first strain increments in the numerical simulation, the layer establishes a viscous steady state, which is the systems' response to optimize energy following the paleowattmeter (Herwegh et al., 2014). With further loading, localization interestingly arises out of a homogeneous state. We will demonstrate the robustness of this numerical solution by identifying the natural mode shapes and frequencies of the simulated structure and material parameters, including geometric imperfections (Rudnicki and Rice, 1975). This technique aims at the determination of the spatial manifestation of the instability pattern (Peters et al., in review). The eigenvalues are thought to represent the nodal points, where the onset of (visco)-elasto-plastic localization can initiate in the structure (Rudnicki and Rice, 1975). The eigenmodes appear as sinusoidal vibrations with geometry- and material parameter-specific natural modal frequencies and shapes. In a next step, the eigenmodes are perturbed and superposed to the initial conditions.

We observe that this pattern of perturbations guides the ultimate material bifurcation. Boudinage and folding can therefore be seen as either a pure geometric problem or a fundamental material bifurcation, which evolves out of homogeneous state. The latter class offers the great possibility to extract fundamental material parameters out of localized structures directly from field observations.

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