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Folding in mechanically heterogeneous rock layers and the importance of interfacial instability

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Shortening of mechanically layered rock often generates folds, which result from an interfacial instability. Interfacial instability means that small geometrical perturbations on the layer interface, which always exist on natural rock surfaces, amplify with rates that are faster than the applied bulk shortening rate so that the layer interface can locally move faster as it would do under homogenous thickening during layer-parallel shortening. Many analytical and numerical solutions quantify such folding instability for simple geometries, homogeneous material properties and uncoupled deformation, i.e. no thermo-mechanical feedback or no porous fluid flow. For such solutions, the two essential parameters that quantify the folding instability are the dominant wavelength and the corresponding maximal fold amplification rate. Many more complicated configurations and additional processes may affect folding and may require modifications of the basic folding theory based on interfacial instability. Such configurations can include material heterogeneities in the folding layer and additional processes can include fluid flow, thermo-mechanical coupling, grain size variations or fracturing. A common feature of all these additional processes is that they can cause local strength variations within the folding layer or within the surrounding rock, because rock strength can depend on fluid pressure, temperature or grain size. Here, we quantify the impact of strength variations in the folding layer and surround medium with two-dimensional numerical simulations of viscous flow. The strength variation is modelled with a weak or strong, small circular inclusion either inside or outside the layer. The layer interfaces are initially perfectly straight and shortening is parallel to the layer interfaces. Therefore, without any strength variation the layer is homogeneously shortening and thickening without any folding. The simulations show that any small variation in mechanical strength, here viscosity, causes small geometrical perturbations of the layer interface, which trigger an interfacial folding instability. The results suggest that the interfacial instability is a first-order controlling process for folding in layered rock including mechanically heterogeneous layers and additional processes. Associated with folding are always a decrease of the bulk strength of the folding rock unit and significant variations of the magnitude and orientation of stresses. These variations of stress and bulk strength should be considered in reconstructions of the deformation history of folded regions.