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Sensitivity analysis of numerical scaled models of fold-and-thrust belts to granular material cohesion variation and comparison with analogue experiments

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Granular materials with very small cohesion values (10's of Pa) are used widely in scaled analogue experiments to simulate brittle rock deformation in the upper crust. The selection of materials with appropriate cohesion values in such experiments is important for appropriate and reproducible modeling of the dynamics of brittle rock deformation in nature. The mechanical properties of granular materials are typically determined by shear-box or ring-shear tests with results plotted on a shear stress versus normal stress diagram. The cohesion is usually determined by linear extrapolation of the low normal stress part of the failure envelope to the shear stress axis, resulting in uncertainty in its magnitude. This is compounded by measurement errors, and the physical handling technique (e.g. pouring or sifting of the materials).

Despite such uncertainties, dry granular materials (e.g. quartz sand) are still employed extensively for modeling of brittle deformation in analogue experiments. One way to evaluate the possible influence of the uncertainty in cohesion values is to carry out direct comparisons between analogue and numerical experiments

We report a series of 2-D numerical brittle-viscous shortening experiments that investigate systematically the effect of varying the cohesion value (in the range 0 to 100 Pa). We include one and two layers of viscous materials below and between the brittle materials, similar to many fold-thrust belts with single or multiple ductile decollements (evaporates and shales). The numerical models are compared to similar 3-D analogue experiments and evaluated in terms of the structural evolution of fold-and-thrust belts. We demonstrate that the numerical models are very sensitive to small cohesion changes. Specifically, the kinematics, geometry and number of structures vary, particularly in experiments that incorporate two weak viscous layers. Furthermore, these changes are not systematic with increasing cohesion. For example, in two viscous layer models with cohesion values of 80 and 90 Pa, the shear zone distribution and surface topography are markedly different, whereas in models with cohesion values of 70 and 80 Pa, they are almost identical. The closest similarity in results between the numerical and analogue experiments is observed when cohesion values 70 to 80 Pa are incorporated numerically, which is within the range of values measured in the laboratory.