Geophysical Research Abstracts
Vol. 19, EGU2017-4832-4, 2017
EGU General Assembly 2017

The challenges of numerically simulating analogue brittle thrust wedges

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Fold-and-thrust belts and accretionary wedges form when sedimentary and crustal rocks are compressed into thrusts and folds in the foreland of an orogen or at a subduction trench. For over a century, analogue models have been used to investigate the deformation characteristics of such brittle wedges. These models predict wedge shapes that agree with analytical critical taper theory and internal deformation structures that well resemble natural observations. In a series of comparison experiments for thrust wedges, called the GeoMod2004 (1,2) and GeoMod2008 (3,4) experiments, it was shown that different numerical solution methods successfully reproduce sandbox thrust wedges. However, the GeoMod2008 benchmark also pointed to the difficulties of representing frictional boundary conditions and sharp velocity discontinuities with continuum numerical methods, in addition to the well-known challenges of numerical plasticity. Here we show how details in the numerical implementation of boundary conditions can substantially impact numerical wedge deformation.

We consider experiment 1 of the GeoMod2008 brittle thrust wedge benchmarks. This experiment examines a triangular thrust wedge in the stable field of critical taper theory that should remain stable, that is, without internal deformation, when sliding over a basal frictional surface. The thrust wedge is translated by lateral displacement of a rigid mobile wall. The corner between the mobile wall and the subsurface is a velocity discontinuity. Using our finite-element code SULEC, we show how different approaches to implementing boundary friction (boundary layer or contact elements) and the velocity discontinuity (various smoothing schemes) can cause the wedge to indeed translate in a stable manner or to undergo internal deformation (which is a fail). We recommend that numerical studies of sandbox setups not only report the details of their implementation of boundary conditions, but also document the modelling attempts that failed.

References

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