Geophysical Research Abstracts
Vol. 18, EGU2016-11205, 2016
EGU General Assembly 2016

Non-robust numerical simulations of analogue extension experiments

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Numerical and analogue models of lithospheric deformation provide significant insight into the tectonic processes that lead to specific structural and geophysical observations. As these two types of models contain distinct assumptions and tradeoffs, investigations drawing conclusions from both can reveal robust links between first-order processes and observations. Recent studies have focused on detailed comparisons between numerical and analogue experiments in both compressional and extensional tectonics, sometimes involving multiple lithospheric deformation codes and analogue setups. While such comparisons often show good agreement on first-order deformation styles, results frequently diverge on second-order structures, such as shear zone dip angles or spacing, and in certain cases even on first-order structures.

Here, we present finite-element experiments that are designed to directly reproduce analogue "sandbox" extension experiments at the cm-scale. We use material properties and boundary conditions that are directly taken from analogue experiments and use a Drucker-Prager failure model to simulate shear zone formation in sand. We find that our numerical experiments are highly sensitive to numerous numerical parameters. For example, changes to the numerical resolution, velocity convergence parameters and elemental viscosity averaging commonly produce significant changes in first- and second-order structures accommodating deformation. The sensitivity of the numerical simulations to small parameter changes likely reflects a number of factors, including, but not limited to, high angles of internal friction assigned to sand, complex, unknown interactions between the brittle sand (used as an upper crust equivalent) and viscous silicone (lower crust), highly non-linear strain weakening processes and poor constraints on the cohesion of sand. Our numerical-analogue comparison is hampered by (a) an incomplete knowledge of the fine details of sand failure and sand properties, and (b) likely limitations to the use of a continuum Drucker-Prager model for representing shear zone formation in sand. In some cases our numerical experiments provide reasonable fits to first-order structures observed in the analogue experiments, but the numerical sensitivity to small parameter variations leads us to conclude that the numerical experiments are not robust.