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Fault behavior in convergent analogue sand wedges and its implications on the evolution of orogenic belts

Tasca Santimano, Matthias Rosenau, and Onno Oncken

GFZ German Research Center for Geosciences, 3.1- Lithosphere Dynamics, Potsdam, Germany (tsanti@gfz-potsdam.de)

In an orogenic belt, fault planes are important first order structures along which deformation occurs and subsequently affects the initial geometry of an orogenic wedge. Moreover, wedge growth and fault activity are related to the principles of the Critical Taper Theory (Davis et al, 1983). The Critical Taper Theory states that a sand wedge evolves towards a critical state characterized by a stable geometry and no internal deformation. In a sub- or supra-critical state, the wedges have an unstable geometry and internal deformation occurs in order to adjusts its geometry accordingly to reach the critical taper. This adjustment to reach criticality is made by creating new faults especially if new material is added to the wedge, or reactivating old faults, in order to change the length or height of the wedge respectively. Fault reactivation seems to allow the wedge to adjust its geometry more sporadically. To observe the temporal evolution of the faults, a series of simple analogue experiments were performed where sand wedges are created. In the experiments one parameter-basal frictional coefficient is varied from <0.4 to >0.6. The growth of the sand wedge and formation of the fault planes is recorded using Particle Image Velocimetry (PIV). Analysis of the PIV data consists of quantifying the fault spacing and lifetime of a fault i.e. first order deformation and reactivation of older faults i.e. second order deformation. Our experiments show that the magnitude of fault spacing follows a periodic pattern over time and fault dip is consistent for all the faults. Second order deformation or fault reactivation is only observed in wedges with the lowest basal friction and presumably controlled by fault weakness (faults planes filled with low friction material from the basal detachment) and favorable stress conditions (shallow dipping maximum principal stress axis). Moreover, only in wedges with a weak base reverse faults remain steep and therefore are more effective in contributing to growth in height when reactivated. The magnitude of displacement in the vertical and horizontal component, of a reactivated fault is controlled by the critical taper. Specifically, for weak wedges the rate of displacement over time is constant in the vertical component but increases in the horizontal component. In addition, fault reactivation is not a continuous event but occurs episodically with increased frequency towards the end of an accretion cycle. These preliminary observations in the sand box experiments may shed light on the deformation in fault networks or the evolutionary stage of a natural orogenic belt.

References

Davis, D., Suppe, J., Dahlen, F.A., 1983: Mechanics of Fold-and-Thrust Belts and Accretionary Wedges. Journal of Geophysical Research 88, 1153-1172.