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Minimum work analysis on the critical taper accretionary wedges-insights from analogue modeling

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The Critical taper theory (CTT) is a fundamental concept for the understanding of mountain building processes. Based on force balance it predicts the preferred steady state geometry of an accretionary wedge system and its tectonic regime (extensive, compressive, stable). However, it does not specify which structures are formed and reactivated to reach the preferred state. The latter can be predicted by the minimum work concept.

Here we test both concepts and their interplay by analysing two simple sand wedge models which differ only in the thickness of the basal detachment (a layer of glass beads). While the steady state critical taper is controlled by internal and basal friction coefficients and therefore the same in all experiments, different processes can minimise work by 1. reducing gravitational work e.g. by lowering the amount of uplift or volume uplifted, or 2. reducing frictional work e.g. by lowering the load or due to low friction coefficient along thrusts. Since a thick detachment allows entrainment of low friction material and therefore lowering of the friction along active thrusts, we speculate that the style of wedge growth will differ between the two models.

We observe that the wedge with a thin basal detachment localizes strain at the toe of the wedge periodically and reactivate older faults to reach the critical topography. On the contrary, in the wedge with the thicker detachment layer, friction along thrusts is lowered due to the entrainment of low friction material from the detachment zone, subsequently increasing the lifetime of a thrust. Long thrust episodes are always followed by a fault of shorter lifetime, with the aim of reaching the critical taper. From the two experiments, we analyze the time-series evolution of the wedge to infer the work done by the two styles of deformation and predict the trend over time to differ but the maximum work to be similar

Our observations show that the critical taper theory determines the geometry of the wedge in particular the taper angle. However the path and style of deformation that the wedge adopts i.e. strain partitioning or deformation along one fault, is determined by the energetically lowest pathway. The observation is especially evident in wedges with added complexities or random changes as the wedge matures. This study combines two theories to explain variability in the results of analogue models and perhaps may aid in understanding the complexity in natural wedges. It also delineates that two different mechanics of deformation can lead to the same geometrical wedge or final topography.