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How to predict deformation for geometrically and mechanically non-uniform accretionary wedges

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The mechanical understanding of fold-and-thrust belts and accretionary prisms strongly relies on the critical taper theory (CTT). The latter considers their mechanics as analogous to sand pushed by a moving bulldozer along a frictional décollement. The wedge evolves into a critical geometry, corresponding to a point of internal state of stress for which the whole wedge including the basal décollement is on the verge of Coulomb failure. If the de´collement is planar and material properties are homogeneous and cohesionless, the critical wedge is triangular. The force of the CCT relies on the fact that conditions for stress equilibrium, Coulomb yielding of the wedge and basal frictional sliding have an analytical solution.

However, this theory suffers from several limits. As stated above, the analytical solution applies for perfectly triangular wedges. However, the critical taper is shaped by internal thrusts that lead to a non-uniform topographic slope. What is then the scale of topographic variability for which the CCT will stand? The second limit is that CCT applies for homogeneous frictional properties in the wedge and as well as along the décollement. We can also wonder if there is a scaling parameter for which variations of properties along the decollement would impact the topography.

We here show how the limit analysis, an efficient semi-analytical approach, can help us to overcome these limits. We aim to provide simple analytical solutions to structural geologists to evaluate the critical state of their field study cases.

We first show that the effect of topographic slope variability relies on a competition between the surface of potential hanging-walls and the surface of theoretical critical hanging-walls. Dips of thrust and backthrust are controlled by the frictional parameters. Along a wedge with a non-regular topography, an out-of-sequence system will appear if there is a position along the wedge for which the hanging-wall will have a lower surface than the critical one. The impact of basal friction variations on the topography can be resolve in the same manner but by comparing force balances and not only surfaces.

To validate our findings, analytical solutions are compared to sandbox experiments. We will also compare our results to natural cases such as the Jura (France) fold-and-thrust belt. Finally, we will discuss how the same approach can be applied to variations of the décollement geometry.