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Control of structural inheritance on thrust initiation and material transfer in accretionary wedges

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Faults in the incoming sediment layer are commonly observed in subduction zone settings and well developed in the incoming plate off Sumatra. To investigate how they affect the structural development of the accretionary wedge, we conducted a series of 2D analogue tectonic experiments in which a 2 cm thick quartz sand layer on top of a thin detachment layer of glass beads was pulled against a rigid backstop by a basal conveyor belt in a 20cm wide box with glass walls. A gap at the base of the back wall avoids entrainment of the glass beads. At regular spacing of either 2.3, 5.5 or 7.8 cm (fractions of the thrust sheet length in the reference model), conjugate pairs of weakness zones dipping 60deg were created by cutting the sand layer with a thin (1 mm) metal blade. Both the undisturbed sand and the pre-cuts have an angle of internal friction of ∼29o, but their cohesion is different by 50 Pa (110 Pa for the undisturbed material, 60 Pa along the pre-cuts). Friction of the glass beads is ∼24deg. The experiments are monitored with high resolution digital cameras; displacement fields derived from digital image correlation are used to constrain fault activity.

In all experiments, a critically tapered wedge developed with a surface slope of 7.5deg. In the reference model (no weakness zones in the input section), the position of new thrust faults is controlled by the frontal slope break. The average length of the thrust sheets is 11 cm and the individual thrusts accommodate on average 8 cm displacement each. The presence of weakness zones causes thrust initiation at a position different from the reference case, and affects their dip. For a fault spacing of 7.8 cm (or 75% of the reference thrust sheet length), every single incoming weakness zone causes the formation of a new thrust, thus resulting in thrust sheets shorter than the equilibrium case. In addition, less displacement is accommodated on each thrust. As a consequence, the frontal taper is smaller than expected from known basal and internal friction. This ultimately leads to continuous out-of-sequence reactivation of selected thrust faults in the wedge to restore the taper, and as a result the development of splay faults or nappe-like structures. The other two models - with smaller spacing of inherited structures - show similar behavior, but less pronounced.

In general terms, the results show that the formation of long-lived out-of-sequence thrusts (splay faults) may be the result of internal wedge reorganization due to a different equilibrium at the wedge front (mechanisms lowering the effective basal friction at the front of the wedge), and does not require local rheological contrasts.