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Limits to large-scale fault strength: going directly from geometry to strength using wedge mechanics

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It is of course difficult to obtain direct *in-situ* constraints on present-day fault strength and crustal stresses at great depth. However in the special case of critical failure represented by active accretionary wedges and fold-and-thrust belts we can directly constrain the large-scale limiting strength and critical far-field stress of the basal sliding surface and overlying deforming wedge directly from the wedge geometry observed in seismic images. These results indicate that the basal detachments are very weak with effective friction of 0.1-0.02, whereas the overlying deforming crust is much stronger.

Recent advances in wedge mechanics provide remarkably simple relationships between the surface slopes α and detachment dips β of accretionary wedges and fold-and-thrust belts and their limiting basal and internal strengths F and W, without strong assumptions about deformation mechanisms. For example, in the case of homogeneous compressive wedges $F = C\alpha + (\alpha + \beta)W$, where $F = \sigma_\tau/\bar{\rho}gH$, which can be considered an effective coefficient of friction, $W = (\sigma_1 - \sigma_3)/\bar{\rho}gH$ and the buoyancy term $C = [1 - (\rho_f/\bar{\rho})]$ is 1 for subareal wedges and 0.6 for submarine wedges, with ρ_f being the density of the overlying air or sea water. Thus if we have independent constraints on W we can immediately constrain F. For example, borehole and other constraints suggest that W is typically in the range 0.5-1. Furthermore, in the case of wedges with low taper $\alpha + \beta$, the range of possible detachment strengths F depends largely on the surface slope α and is only weakly dependent on wedge strength W. Analysis of a set of active wedges world-wide, including, including Nankai, Barbados, Cascadia, New Zealand, Gulf of Alaska, western Taiwan, Niger delta, and Mexican Ridges, indicate that they have exceedingly weak fault strengths F in the range 0.1-0.02.

Furthermore, many accretionary wedges can be shown to be mechanically heterogeneous based on their variable taper, typically with steeper surface slope near the toe. Application of heterogeneous wedge theory to the Barbados accretionary wedge shows that lateral variation in basal fault strength dominates the variation in wedge taper, with an increasing basal fault strength towards the toe.

Finally, *in situ* observations in the Chelungpu scientific borehole after the Chi-Chi earthquake indicate the Chelungpu thrust ramp is also exceedingly weak, similar to the basal detachment of the western Taiwan thrust belt $F = 0.09$ whereas the wedge is strong $W = 0.6$, implying that off-fault strength dominates the crustal wedge strength. These results from critical-taper wedge mechanics are consistent with the weak-fault–strong crust perspective, with a variety of dynamical and quasi-static mechanisms contributing to large-scale critical fault weakness.