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Control of geometrical and mechanical parameters on strike-slip fault segmentation: insights from sandbox experiments.

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Abstract

Co-seismic continental strike-slip ruptures are usually segmented, separated by geometrical complexities. This segmentation affects the dynamics of earthquakes but the physical processes governing the scale of this segmentation remains unclear. Furthermore, on field, the length of segments has been shown to vary from 18km to 25km, independently of the regional tectonic setting (Klinger, 2010). These observations led the author to suggest that the thickness of the seismogenic crust could control this structural scaling. Thus, to test this hypothesis, we use analogue modelling to investigate the structural development of strike-slip faults and the physical parameters controlling this segmentation. Theoretically, the evolution from en échelon Riedel until horizontal shear segments has been thoroughly described qualitatively by Tchalenko (1970). Here we test and quantify the effect of the sand pack thickness as well as the internal and basal frictions on the length of segments. We then compare our results to natural case to conclude on their potential relationship with the seismogenic thickness. We show that ratios between the segment length and the brittle material thickness are similar for coseismic ruptures and sandbox experiments. We show also that variations of rheological properties have a minor effect on the linearly relationship between the length of segments and the brittle material thickness. Finally this study demonstrates that the inherited complexities influence the localisation of segments and relay zones observed on strike-slip faults.

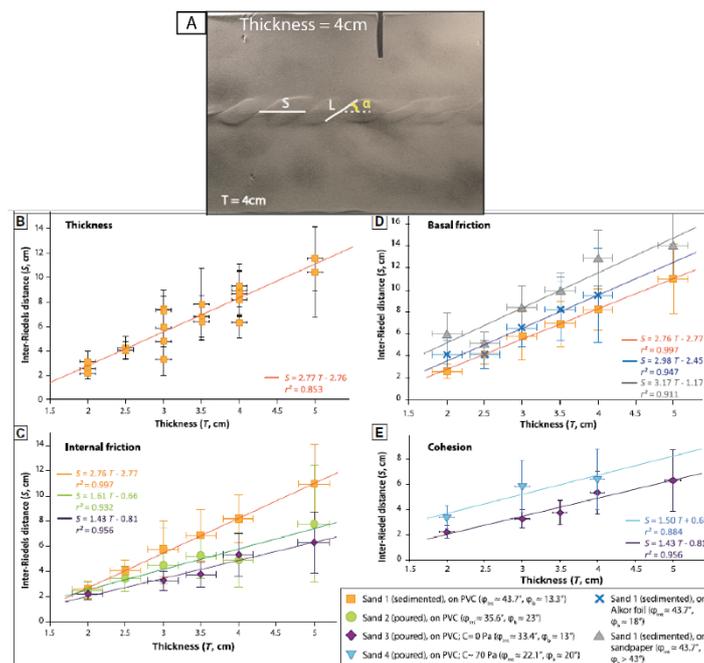


Figure 1: A – Topview of the sandbox after 11 mm of displacement highlighting the en échelon Riedel faults. [B-E] Comparison between inter-Riedel distance (S) and sand-pack thickness (T) for different frictional and cohesive properties of sand. Modified from Lefèvre et al, 2020.

Sandbox apparatus and experimental procedure

The specific sandbox for Riedel experiments is composed of two PVC plates simulating the base of the upper crust. One plate is movable and can be pushed forward to simulate a sinistral strike-slip fault at the base of the model thanks to a lead screw. The other plate is fixed. The dimensions of the box (80x210cm) are large enough to ensure that a significant part of the observations escapes boundary effects. The sand pack is flat and the edges are free. Top view photos are taken every 0.5 mm.

We test sand pack varying from 2 to 6 cm thick. To get different internal frictions, the sand is poured in two different mods: (1) sedimented with a sand distributor used to achieve a uniform sand density and a high internal friction (CV32): $\phi_{int}=43.7^\circ$ and (2) by sprinkling and scraping the sand pack for a lower friction (CV32): $\phi_{int}=35.6^\circ$. A third type of sand with a different grain size range (Ga39) is also tested: $\phi_{int}=33.4^\circ$. Two different basal frictions were tested: $\phi_b=13^\circ$ (sand/PVC) and $\phi_b=18^\circ$ (sand/Alkor foil®). For each experiment, three parameters are measured: the spacing between Riedels (S), the Riedels' length (L) and the angle (α) formed by the Riedel and the direction of the strike slip fault at the base of the model (Fig. 1). In order to obtain satisfactory statistical results and to provide a correlation between parameters, 45 experiments were run for this study.

Experimental results

The thickness of the sand pack has a significant influence on the Riedels spacing. The thicker the sand layer is, the greater the spacing is (and implicitly longer). The thickness and the average spacing between Riedels appear to be linearly correlated (slope ~ 1.5) (Fig 1).

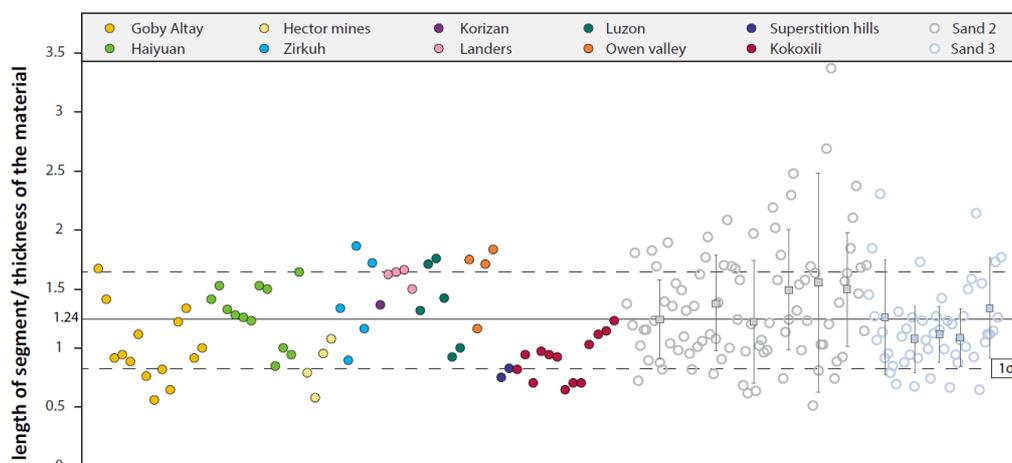


Figure 2: Normalized length of individual fault segments for several continental strike-slip earthquakes (Klinger, 2010; Lauer et al., 2018) and for individual analogue-fault segments (Sands 2 and Sand 3). From Lefèvre, 2018 (PhD Thesis).

If the sand layer thickness is constant, the larger the sand internal friction is, the longer the spacing is (Fig.1). Similarly, a linear relation relates the thickness and the average spacing between Riedels with the internal friction (slope ~ 1.5). Obviously, different internal frictions lead to various coefficients for this relation (slope and intercept): a frictional variation of 0.1 corresponds to a slope variation equal to 0.25. Furthermore, it seems that basal friction has no influence on the Riedels. Finally, considering a standard internal friction for the upper crust, this study shows that we are able to retrieve the same length over thickness ratio as for the natural cases (Fig.2).

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