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Quantitative analysis of fault slip evolution in analogue transpression models

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A quantitative analysis of fault slip evolution in crustal scale brittle and brittle-ductile analogue models of doubly vergent transpressional wedges was performed by means of Particle Image Velocimetry (PIV). The kinematic analyses allow detailed comparison between model results and field kinematic data. This novel approach leads to better understanding of the evolution of transpressional orogens such as the Tertiary West Spitsbergen fold and thrust belt in particular and will advance the understanding of transpressional wedge mechanics in general.

We ran a series of basal-driven models with convergence angles of 4, 7.5, 15 and 30 degrees. In these crustal scale models, brittle rheology was represented by quartz sand; in one model a viscous PDMS layer was included at shallow depth. Total sand pack thickness was 6cm, its extent 120x60cm.

The PIV method was used to calculate a vector field from pairs of images that were recorded from the top of the experiments at a 2mm displacement increment. The slip azimuth on discrete faults was calculated and visualized by means of a directional derivative of this vector field. From this data set, several stages in the evolution of the models could be identified. The stages were defined by changes in the degree of displacement partitioning, i.e. slip along-strike and orthogonal to the plate boundary.

A first stage of distributed strain (with no visible faults at the model surface) was followed by a shear lens stage with oblique displacement on pro- and retro-shear. The oblique displacement became locally partitioned during progressive displacement. During the final stage, strain was more fully partitioned between a newly formed central strike slip zone and reverse faults at the sides. Strain partitioning was best developed in the 15 degrees model, which shows near-reverse faults along both sides of the wedge in addition to strike slip displacement in the center.

In further analysis we extracted average slip vectors for individual fault segments, allowing a more quantitative analysis of fault slip evolution. It confirms the semi-qualitatively defined stages above. For the 15 degrees model, the initial faults defining the oblique shear lens have a slip angle of 15-30 degrees to the basal velocity discontinuty. In the strain partitioning stage, newly developed pro-shears show a rotation of the slip vector by $\sim$30 degrees, changing from initially oblique (60 degrees) to finally nearly orthogonal to the plate boundary. A similar progressive rotation of slip vectors has been recorded in the thin-skinned West Spitsbergen fold and thrust belt.