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The use of cutting-edge X-Ray CT and Digital Volume Correlation techniques to visualize and quantify 4D internal deformation in otherwise opaque model materials

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Visualizing and especially quantifying the evolution of internal structures during an experiment run poses an important challenge to analogue (tectonic) modellers, since most commonly used model materials are non-transparent. Some modellers have applied X-ray computed tomography (XRCT) as a non-destructive method to gain insights into internal model deformation. A recent study (Adam et al. 2013) uses 4D digital volume correlation (DVC) methods to analyse such XRCT data from a brittle thrust model, allowing a detailed quantification of the model's internal evolution. Here, we go a step further by using DVC techniques to perform the first complete internal analysis of a brittle-viscous analogue experiment.

Our experiment set-up involves a viscous mixture of corundum sand and silicone simulating the lower crust, as well as a layer of quartz sand representing the upper crust. The model is stretched and forms rift basins above pre-determined weaknesses. Small quantities of high-density ceramic beads (Zirshot) are mixed in with these model materials, creating a distinct pattern on the XRCT images. The DVC software (DaVis by LaVision) allows the tracing of these patterns so that a 3D displacement field can be derived. These data subsequently enable various strain calculations.

The DVC results reveal the directions and rates of motion in our models. The most important displacements are parallel to the extension direction. Second come vertical motions (e.g. subsidence in the rift basins), but 3D out-of-plane motions occur as well, which are important to take into account for structural reconstructions. We also observe flow patterns in the viscous materials that are quite distinct from the displacements in the brittle parts. Strain calculations reveal further clear differences between brittle and viscous behaviour expressed as localized vs. distributed deformation, respectively. We can now also define loci of extension and contraction in both the viscous and brittle parts of the model, as well as directions of motion along fault planes.

Altogether, DVC analysis allows an unprecedented insight in the behaviour of brittle-viscous tectonic systems, illustrating and quantifying the differences between both rheological regimes in great detail. It furthermore opens an exciting possibility for thorough comparisons between analogue and numerical models.

References:

Adam et al., 2013. Quantitative 3D strain analysis in analogue experiments simulating tectonic deformation: Integration of X-ray computed tomography and digital volume correlation techniques (Journal of Structural Geology)