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Comparing various analogue set-ups for modelling extensional tectonics

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Analogue modellers have historically used various methods, involving a range of experimental machines and model materials, to investigate a wide variety of tectonic settings. These methods have provided the scientific community with highly valuable insights in tectonic processes and the evolution of geological structures. However, only few studies directly compare different experimental set-ups for investigating similar tectonic settings. Here we present a systematic overview of structures forming in analogue models with different mechanisms for achieving extensional deformation.

We use either a rubber base, a foam base, basal plates or basal sheets to deform overlying model materials. The rubber and foam base apply a distributed extension field to the model materials, whereas the basal plates and sheets apply sharp velocity discontinuities which are migrating (basal plates) or not (basal sheets). For each set-up we test brittle-only (sand) and brittle-viscous (sand and silicone) material layering. Our standard brittle-viscous models use, a 1:1 thickness ratio and an extension velocity of 8 mm/h. We deform the models to 13%. In selected set-ups, we add a viscous weakness within the brittle sand layer as a further mechanism to localize faulting. We systematically vary the extension velocity and viscous layer thickness for a specific experimental sub-set. We use X-ray computed tomography (XRCT) and digital volume correlation (DVC) for a highly detailed 3D analysis of internal and external model evolution.

We find a strong difference in faulting distribution between brittle-only models with a basal plate or sheet compared with a foam or rubber base set-up. Rubber/foam base models develop distributed faulting and show a migration of faulting towards the model centre. Pre-defined viscous weaknesses do not strongly influence these general results. However, a rubber base can cause strong boundary effects (conjugate strike-slip faulting) due to lateral contraction of the rubber sheet, which may be reduced by using low width-to-length ratios. Basal plate/sheet models produce strongly localized rift structures with little boundary effects along the plate/sheet edges.

Brittle-viscous experiments show mainly deformation along the model sidewalls, although the foam base set-up produces the least boundary effects. Rift basins only develop when pre-defined weaknesses are used. In contrast to the brittle-only models, the basal plate/sheet models do, therefore, not localize deformation under our standard boundary conditions. However, at higher extension velocities (80 mm/h or higher), basal plate/sheet set-ups produce flexural basins along the model central axis. Only when applying high brittle-to-viscous thickness ratios (4:1, compared to the standard 1:1 ratio) do we obtain localized rift structures above the velocity discontinuity imposed by the basal sheets/plates in the centre of the model.

Our models clearly illustrate the strong influence experimental set-ups can have on tectonic simulations and show the importance of including information on model boundary conditions when comparing experimental results from different studies.