Geophysical Research Abstracts
Vol. 19, EGU2017-6561, 2017
EGU General Assembly 2017

Studying scissor tectonics with 4D analogue models

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Although tectonic modellers generally apply constant deformation velocities throughout their models, natural settings can involve along-strike velocity variations. In extensional regimes (e.g. the Woodlark Basin, Papua New Guinea), we often observe the propagation and associated “scissor-like” opening of a rift, with older rift parts more evolved than the rift tip. In some cases, this extension is accompanied by compression on the other side of the rotation (or scissor) axis resulting in a full scissor tectonic system (e.g. the Taupo Ridge and Wanganui Basin, New Zealand).

To model scissor tectonics, we apply a foam base that allows distributed deformation at the base of overlying brittle-ductile model material. Quartz sand and a viscous PDMS/sand mixture represent the upper and lower crust respectively (8 cm thick model, 1 cm = 5 km). Rotation of the model sidewalls around a rotation point induces extension at one end of the model and compression at the other end. Seeds of ductile material (ø ca. 1 cm) are placed on top of the basal model layer, serving as weak zones that control where faulting occurs in the overlying brittle sand. Surface- and X-Ray CT scans allow a detailed 4D analysis of the model topography and internal structures.

Our models develop rifting in the extensional domain, no visible deformation near the scissor axis and thrusting in the compressional domain. The topography analysis indicates the localized subsidence along the rift and uplift occurring over a relatively wide area in the compressional domain. Rift structures initiate at the edge of the model before propagating towards the scissor axis, with rift sections farther away form the rotation axis, where extension is largest, being more developed than sections close to it.

4D CT-images reveal the formation of a pop-up forms in the compressional domain (instead of the single thrust that appears on the surface scans). Away from the scissor axis in the extension domain, increasing degrees of extension lead to complex rift-internal structures as the model evolves. At the end of the model run, a 36 mm wide, 8 mm deep rift basin with internal horst structures and a strongly deformed seed occur near the model edge, while only a simple symmetrical graben structure develops near the scissor axis. In contrast with the extensional domain, the compressional pop-up has a more cylindrical appearance: its structure does not change significantly along-strike.

In short, the scissor tectonics model produces structural variations in space (along-strike) and time (structural evolution), that can be analysed with CT-scans and surface scans. Future modelling will involve syn-rift sedimentation and various seed geometries, while particle-tracing methods will allow us to quantify both surface and internal model deformation.