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Interplay of near surface rift evolution and deep-seated lower crustal flow: New findings from fully quantified crustal-scale analogue models

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Here we present new results and findings from an analogue modelling series using an extension gradient to simulate continental rifting in rotational settings. We study the effect of a pressure-gradient driven, rift-axis parallel lower crustal flow on rift propagation. The dynamically scaled two-layer models represent a brittle upper and a ductile lower crust. To simulate different crustal setups, we use variable ductile/brittle ratios R_{DB} , where increasing values indicate a hotter crust with the brittle-ductile transition at relatively shallower depth. An additional package of sand on one part of the model simulates tectonic loading to provoke a pressure-gradient driven lower crustal flow.

Several factors play a role in dynamic rift propagation such as extension rates, fault evolution and the interplay of vertical motions at the surface as well as model-internal rift-axis parallel horizontal flow. We combine surface and internal deformation analysis using stereoscopic Digital Image Correlation and Digital Volume Correlation applied on surface stereo images and XRCT images, respectively to obtain the fully quantified model deformation.

Our results show that rift propagation occurs in two consecutive stages: (i) bidirectional step-wise growth in fault length by linkage and (ii) unidirectional linear fault growth. Strain partitioning of bulk extension causes episodic alternative fault growth on conjugate rift margin faults. Over time, fault activity abandons rift boundary faults and migrates inward creating intra-rift faults. This process occurs segment-wise along the rift axis, where different fault generations are simultaneously active. We quantify increasing lower crustal flow parallel to the rift axis with increasing R_{DB} as the result of tectonic loading. In return, such lower crustal flow causes vertical and horizontal motions at the surface expressed by dynamic topography and deformation features.

These results give insights into deformation processes of rifting and highlight the important role of extension gradients on fault growth and strain partitioning in segmented rotational rift systems. Rift-axis parallel lower crustal flow in rotational rift settings may be of relevance when dealing with restorations of 2D crustal seismic sections across rifts.

