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Rift development and propagation under orthogonal versus rotational extension conditions as observed in 4D analogue models

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In natural rift settings, extension rates often increase or decrease along strike, due to the rotation about a vertical axis for small-scale settings or about an Euler pole for global scale systems, associated with the propagation of rift structures or whole ocean basins. Analogue (and numerical) modelers traditionally use a constant along-strike deformation rate, although some have applied rotational motion in their experiments. To date, however, a systematical analysis of the structures developing under these two fundamentally different modeling conditions is lacking. We therefore apply a new experimental apparatus to compare rift development and rift propagation in either a traditional orthogonal extension setting (involving constant extension rates along strike) or a rotational extension setting (involving extension rate gradients along strike), analysed with X-Ray computed tomography (XRCT or CT) and digital image correlation techniques.

Our models provide a good first-order insight in large-scale rift processes. A significant localization of deformation by means of a structural weakness (seed) is required for a rift basin to form in our experiments. Models involving a seed show best the structural differences between rifts developing in orthogonal versus rotational extension settings: in the former case, a rift basin with constant along-strike features develops, whereas rotational extension leads to an along-strike structural gradient. Rotational extension is furthermore a key factor for rift propagation. Even when rifts do propagate in our orthogonal extension models, it involves slight rotational motion, which is closely associated with significant boundary effects that should not be expected to occur in natural settings. Such boundary effects are of importance as they may lead to incorrect interpretations when for instance studying fault evolution. Rift structures near the tip of the seed are similar to features observed at locations where an oceanic rift enters continental crust. The above points are valid from a purely kinematical point of view. However, various geological processes such as magmatism and mantle plume emplacement can significantly affect a developing rift system.