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Interactions between propagating rifts and pre-existing linear rheological heterogeneities: insights from 3D analogue experiments of rotational extension

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Propagating rifts are a natural consequence of lithospheric plates that diverge with respect to each other about a pole of rotation. This process of "unzipping" is common in the geological record, but how rifts interact with pre-existing structures (i.e. with a non-homogeneous lithosphere) as they propagate is poorly understood. Here we report on a series of lithospheric-scale three-dimensional analogue experiments of rotational extension with in-built, variably oriented linear weak zones in the lithospheric mantle, designed to investigate the role that inherited structural or thermal weaknesses play in the localisation of strain and rifting. Surface strain and dynamic topography in the analogue models are quantified by high-resolution particle imaging velocimetry and digital photogrammetry, which allows us to characterise the spatio-temporal evolution of deformation as a function of the orientation of the linear heterogeneities in great detail.

The results show that the presence of a linear zone of weakness oriented at low angles with respect to the rift axis (i.e. favourably oriented) produces strain localisation in narrow domains, which enhances the "unzipping" process prior to continental break up. Strong strain partitioning is observed when the linear heterogeneity is oriented at high angles with respect to the rift axis (i.e. unfavourably oriented). In these experiments, early sub-parallel V-shaped basins propagate towards the pole of rotation until they are abandoned and strain is transferred entirely to structures developed in the vicinity of the strongly oblique weak lithosphere zone boundary. The modelling also provides insights on how propagating rift branches that penetrate the weak linear zone boundary are aborted when strain is relayed onto structures that develop in rheologically weaker areas.

The experimental results are summarised in terms of their evolution, patterns of strain localisation, and dynamic topography as a function of the lithospheric heterogeneity obliquity angle, and compared to ancient and modern examples in nature.