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The critical role of extension-orthogonal shears in oblique rift development

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We use high-resolution three-dimensional thermomechanical modeling to investigate the relative timing and distribution of geologic structures during oblique rift development. The obliquity of the rift is prescribed in the models using a wide oblique heterogeneous weak zone allowing intra-rift shear zones to form freely.

We found that after a short distributed deformation phase strain localization starts at the model edges. There, antithetic grabens nucleate and propagate toward the center of the model orthogonally to the extension direction. Meanwhile, extension-orthogonal shears develop within the rift, isolating en échelon basins. Oblique shears form mainly on the rift borders. The coalescence of oblique and extension-orthogonal shears fosters the development of a complex anastomosing shear zone within the rift. Strain is preferentially accommodated on extension-orthogonal shears, while oblique shears form accommodation zones between extending blocks. Lithosphere breakup also initiates from the model edges. The necking caused by the uplifting mantle propagates at an acute angle toward the center of the model and forces the linkage of the isolated rift basins. Active deformation becomes limited to the newly formed oceanic ridge oriented at an intermediate angle halfway between the extension direction and the normal to the oblique zone trend. Breakup ultimately leads to the development of asymmetric conjugate passive margins segmented by pre-existing extension orthogonal en-échelon basins.

We show that strain localization and the evolution of the deformation pattern in oblique rifts foster the development of complex transtensional systems in which extension-orthogonal shears play a critical role. Comparison with observations from natural oblique continental rift and passive margins confirms the importance of extension-orthogonal shears in accommodating pre-breakup extension.