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Basement Structure Controls on the Evolution and Geometry of Rift Systems - Insights from Offshore S. Norway using 3D Seismic Data

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Rift basins form within lithosphere containing a range of heterogeneities, such as thin-skinned thrust belts and larger scale structures such as thick-skinned shear zones or crustal sutures. How the presence and reactivation of these structures during later rift events affect the geometry and evolution of rifts remains poorly understood as they are not typically well imaged on seismic data. The main reasons for this are that crystalline basement is often buried beneath thick sedimentary successions and contains small impedance contrasts. Furthermore, larger, crustal-scale, lineaments and sutures may not be imaged at all on seismic data due to their large scale and depth.

In this study, we use borehole-constrained 2D and 3D seismic reflection data located around the Egersund and Farsund Basins, offshore south Norway. In both areas, crystalline basement is exceptionally well-imaged on typical 2D and 3D reflection data due to large impedance contrasts within a highly heterogeneous, shallow basement. This allows us to map a series of intrabasement reflections and overlying rift systems.

Within the Egersund area, two main types of intrabasement structure are identified and mapped: i) thin (100 m), shallowly dipping (0-10°W) reflections showing a ramp-flat geometry; and ii) thick (1-1.5 km), low angle (c. 30°W) structures comprising of packages of reflections. These structures correlate along-strike northwards to Caledonian orogeny related structures mapped onshore Norway. The thin structures are interpreted as thin-skinned Caledonian thrusts, whereas the thicker structures represent thick-skinned Devonian shear zones formed through orogenic collapse of the Caledonides. Through seismic-stratigraphic analysis of the cover, we document multiple stages of extensional reactivation along these structures during Devonian, Permian-Triassic and Late Jurassic-Early Cretaceous extension followed by reverse reactivation during Late Cretaceous compression.

The Farsund Basin is situated above a deep crustal-scale lineament, the Tornquist zone. We also document multiple stages of reactivation and inversion within this basin, linked with motion along the underlying lineament. Reactivation of the Tornquist zone at depth leads to the formation of a deep, narrow basin at shallower levels. However, during reactivation, rift propagation may be inhibited by basement heterogeneities, such as pre-existing basement ridges.

We find that the type of reactivated structure can exert a strong control on the geometry and evolution of the overlying rift. Low-angle, thin-skinned Caledonian thrusts have negligible effect on rift evolution as these are not readily reactivated. However, reactivation of thick-skinned structures does affect rift morphology. Direct reactivation of low angle Devonian shear zones forms a series of low angle rift-bounding faults, creating a wide, shallow basin. Conversely, reactivation of deep seated crustal lineaments causes the localisation of strain fields, creating deep, narrow basins. In both cases, the presence of these thick skinned structures acts as a template for the location of later rifts; their subsequent reactivation can then control the rift geometry.