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How do lower and upper crustal intrabasement structures influence the geometry and evolution of rift systems?

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Pre-existing structures within crystalline basement occur across a range of scales and at a range of depths, playing a fundamental role in the evolution of overlying rift systems. Determining how these structures may influence rift evolution requires a detailed understanding of the three-dimensional relationship between the intrabasement structures and the overlying rift-related faults. Constraining the 3-D geometry of intrabasement structures is often hampered by poor seismic imaging in crystalline basement, particularly at depth. However, in areas where crystalline basement is at shallow depths and highly heterogeneous, intrabasement structures along with the overlying rift-related fault systems can be well-imaged on seismic reflection data.

Here, we use borehole constrained 2-D and 3-D seismic reflection data from offshore southern Norway to examine how large-scale lower crustal lineaments influenced the evolution of the overlying rift in the east, and contrast this with the role of km-scale shear zones present at upper crustal levels in the west. In the east, the E-trending Farsund Basin is situated atop the NW-to-W-trending Sorgenfrei-Tornquist Zone (STZ), a lower crustal lineament that separates the stable cratonic lithosphere of Baltica from the amalgamated terranes of Central and Western Europe. We constrain the geometry and evolution of the upper-crustal rift-related fault population and use these findings to infer the geometry and kinematic behaviour of the underlying STZ. We argue that the STZ locally perturbed the regional stress field, creating a local NE-directed stress field within the upper crust, oblique to the main E-trending regional extension direction.

To the west, the influence of the STZ appears to fade, with faults striking largely N-S. Here, a series of km-scale structures within crystalline basement are mapped in 3-D across the study area. We first outline evidence to suggest that the intrabasement reflectivity may represent mylonitic shear zones, before correlating the discrete intrabasement structures to Devonian shear zones and the Caledonian thrust belt as mapped onshore. These shear zones act as a template for the initiation and reactivation of rift-related faults; during later tectonic events they may: i) directly reactivate along mechanical anisotropies within the structure; ii) locally perturb the regional stress field, causing rift-related faults to align with and merge along the intrabasement structure; or iii) remain passive and be cross-cut by rift-related faults.

In the east we show that the geometry and evolution of the overlying rift is predominately controlled by the lower crustal STZ. In contrast, to the west, Devonian shear zones control the first order rift structure, with only minor faults aligned with the STZ. The STZ appears to have a secondary influence in this area, controlling minor faults, and influencing along-strike segmentation and splays associated with major faults. Overall, we show that large-scale lower crustal structures, such as the STZ, have the propensity to alter regional stress fields, controlling the geometry and kinematic evolution of superposed rifts. However, the influence from deeper crustal levels is superseded by the presence and reactivation of shallower intrabasement structures, which dominate the structural style of the superposed rift where present.