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The role of discrete intrabasement shear zones during multiphase continental rifting

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Rift systems form within areas of relatively weak, heterogeneous lithosphere, containing a range of pre-existing structures imparted from previous tectonic events. The extent to which these structures may reactivate during later rift phases, and therefore affect the geometry and evolution of superposed rift systems, is poorly understood.

The greatest obstacle to understanding how intrabasement structures influence the overlying rift is obtaining detailed constraints on the origin and 3D geometry of structures within crystalline basement. Such structures are often deeply buried beneath rift systems and therefore rarely sampled directly. In addition, due to relatively low internal acoustic impedance contrasts and large burial depths, crystalline basement typically appears acoustically transparent on seismic reflection data showing no resolvable internal structure.

However, offshore SW Norway, beneath the Egersund Basin, intrabasement structures are exceptionally well-imaged due to large impedance contrasts within a highly heterogeneous and shallow basement. We use borehole-constrained 2D and 3D seismic reflection data to constrain the 3D geometry of these intrabasement reflections, and examine their interactions with the overlying rift system. Two types of intrabasement structure are observed: (i) thin (c. 100 m) reflections displaying a characteristic trough-peak-trough wavetrain; and (ii) thick (c. 1 km), sub-parallel reflection packages dipping at c. 30°. Through 1D waveform modelling we show that these reflection patterns arise from a layered sequence as opposed to a single interface. Integrating this with our seismic mapping we correlate these structures to the established onshore geology; specifically layered mylonites associated with the Caledonian thrust belt and cross-cutting extensional Devonian shear zones.

We observe multiple phases of reactivation along these structures throughout multiple rift events, in addition to a range of interactions with overlying rift-related faults: (i) Faults exploit planes of weakness internally within the shear zones; (ii) faults initiate within the hangingwall and subsequently merge along the intrabasement structure at depth; and (iii) faults initiate independently from and cross-cut intrabasement structure. We find that reactivation preferentially occurs along the thicker, steeper intrabasement structures, the Devonian Shear Zones, with individual faults exploiting internal mylonite layers.

Using a detailed 3D interpretation of intrabasement structures, correlated with the onshore geology, we show that large-scale Devonian shear zones act as a long-lived structural template for fault initiation throughout multiple rift phases. Rift-related faults inherit the orientation and location of underlying intrabasement structures.