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Seismic imaging of a Permian-Carboniferous dyke swarm offshore southern Norway

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Dyke swarms play a fundamental role in continental rifting and breakup. Numerous studies from a range of Earth Science disciplines have demonstrated that extension, in places such as East Africa, can be driven by dyke intrusion. The lack of suitable field outcrops and the typically low-resolution of geophysical imaging techniques however, mean that the 3D structure of dyke-dominated extensional zones remains poorly constrained. Over recent decades, the widespread availability of high-quality 3D seismic reflection data has revolutionized our understanding of magma plumbing systems and the role that magmatism plays in rifting. However, while seismic reflection data is able to resolve sub-horizontal magmatic structures, such as sills, it is often unable to resolve sub-vertical structures, such as dykes.
In this study we use borehole-constrained, closely-spaced 2D seismic reflection data from offshore southern Norway to examine a dense swarm of dykes that have been imaged on seismic reflection data following post-emplacement rotation. The swarm has a WSW-ENE orientation and covers a c. 2000 km2 area along the northern margin of the Farsund Basin, a half-graben bound to the south by the N-dipping Fjerritslev Fault System. Within the seismic data dykes are interpreted as prominent high-angle reflections that cross-cut, but do not offset, Permian-Carboniferous strata. The density of these reflections decreases away from the centre of the swarm. Stratigraphically, these high angle reflections cross-cut Permian-Carboniferous strata and are truncated at the base Upper Permian unconformity, constraining the timing of their emplacement as to during the Permian-Carboniferous. We correlate this dyke swarm along-strike to the east to the Permian-Carboniferous Skagerrak-centred Large Igneous Province (LIP), and to the west to the Midland Valley dyke suite, onshore UK, both of which are dated to around 300 Ma. The resultant dyke swarm forms a system over 800 km long and, in our study area, accommodates a minimum of 10 km of extension. Furthermore, the emplacement of this dyke swarm holds important implications for the regional stress field at the time; N-S extension associated with emplacement of the roughly E-W trending swarm, incorporating the Midland Valley dyke suite, overrides regional far-field N-S compressional stresses arising from the Variscan orogeny to the south.
Two sets of faults are concentrated above the dyke swarm; one set initiates during the Triassic and is truncated above by the base Jurassic unconformity, whereas others offset the base Jurassic unconformity and tip out upwards within the Lower Cretaceous. This latter fault population also initiated in the Triassic, but were subsequently reactivated during the Early Cretaceous as a flexural response to activity along the Fjerritslev Fault System to the south. Here, we are able to image a dyke swarm on seismic reflection data, and show that this dyke swarm may represent a mechanical anisotropy and therefore act as preferential nucleation sites for later flexure-related faults.