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Strain migration during multiphase extension: observations from the northern North Sea

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Many rifts develop through multiphase extension; it can be difficult, however, to determine how strain is distributed during reactivation because structural and stratigraphic evidence associated with earlier rifting is often deeply buried. Using 2D and 3D seismic reflection and borehole data from the northern North Sea, we examine the style, magnitude and timing of reactivation of a pre-existing, Permian-Triassic (Rift Phase 1) fault array during a subsequent period of Middle Jurassic-to-Early Cretaceous (Rift Phase 2) extension. We show that Rift Phase 2 led to the formation of new N-S-striking faults close to the North Viking Graben, but did not initially reactivate pre-existing, seemingly optimally aligned Rift Phase 1 structures on the Horda Platform. We suggest that, at the beginning of Rift Phase 2, strain was focused in a zone of thermally weakened lithosphere associated with the Middle Jurassic North Sea thermal dome, rather than reactivating extant faults. Diachronous reactivation of the Permian-Triassic fault network did eventually occur, with those faults located closer to the Middle Jurassic-to-Early Cretaceous rift-axis reactivating earlier than those toward the eastern margin. In addition, faults on the southern Horda Platform reactive before those in the north, leading to both an eastward and northward migration in fault reactivation in this area through time. This diachroneity in the timing of fault reactivation may have been related to flexural down-bending as strain became focused within the North Viking Graben and/or the shifting of the locus of rifting from the North Sea to the proto-North Atlantic in the Early Cretaceous. Our study shows that the geometry and evolution of multiphase rifts is not only controlled by the orientation of the underlying fault network, but also by the thermal and rheological evolution of the lithosphere and variations in the regional stress field.