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Late Caledonian orogenic collapse and continental rifting in southwestern Norway: constraints from low-temperature thermochronology

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Southwestern Norway, located immediately east of the northern North Sea rift, exhibits a large population of late- to post-Caledonian brittle faults and fractures with a variety of orientations and characteristics. In the absence of an onshore sedimentary record, the age and formation of these structures are not well constrained. While some may be related to the later stages of orogenic collapse, others are onshore expressions of the continental rifting that resulted in the opening of the North Sea and ultimately the North Atlantic. In order to capture these latest stages of the Caledonian cycle, orogenic collapse and continental breakup, we employ a combination of low-temperature thermochronological techniques, such as apatite and zircon fission track and (U-Th)/He analyses and K/Ar illite dating of fault gouge samples.

While apatite fission track analyses of samples from southwestern Norway yield Permian-Jurassic, but mostly early-mid Jurassic ages, single grain apatite (U-Th)/He ages range from Triassic to Cretaceous. Thermal history modelling based on these data indicates relatively constant cooling rates of ca. 2 °C/Ma throughout Permian-early Jurassic times and slower cooling rates of < 1 °C/Ma since middle Jurassic times. Both fission track and (U-Th)/He ages are offset across faults, indicating significant vertical movements of crustal blocks during the Mesozoic. Additionally, fault-bound blocks along a profile sampled for (U-Th)/He dating show distinctly different cooling histories from their neighbours.

These findings are substantiated by K/Ar ages of illite from fault gouges, which define fault activity in Carboniferous-Permian, late Triassic-early Jurassic and Cretaceous-earliest Palaeogene times, respectively. The regional significance of these events and the applicability of the method are highlighted by good correlations with other dating methods and independent geological constraints, such as palaeomagnetic and Ar/Ar dating of fault breccias and periods of dyke intrusion.

The combined data document therefore an extended history of fault tectonics from Palaeozoic to early Cainozoic times. Extensional deformation was clearly not confined to the offshore rift systems but also affected onshore areas. The documentation of significant fault activity in the late Carboniferous-early Permian may reflect similar activity in the North Sea rift, and possibly the initiation of this rift occurred already in the early Permian, i.e. simultaneous with the formation of the Oslo Rift.