Displacement-length scaling relationships for a fault array reveal that faults grow via alternating phases of lengthening and localisation

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Rifting of the continental lithosphere is accommodated by the development of large, linked, normal fault arrays. However, the timescales over which fault arrays develop - from the interaction of small, isolated faults towards localisation of through-going fault systems, has not been well constrained from observations in natural systems. Our limited knowledge of timescales over which fault arrays develop has also resulted in the development of different and debated fault growth models. While scaling relationships between fault displacement and length have been extensively used to understand fault evolution, the scaling exponent value is still not resolved due to significant scatter in global displacement-length profiles.

Here we use 3D seismic reflection and borehole data from the Exmouth Plateau, NW Shelf of Australia to investigate the timescales of faults growth within an array. The excellent quality seismic data allows for the entire Jurassic to Early Cretaceous fault array to be analysed over a large areal extent (~1200 km$^2$), and the fault activity can be dated using biostratigraphy from wells. Our study is novel in that we reconstruct and quantify the length and throw on faults back through time to investigate how fault populations evolve. We find that the early stage of rifting was characterised by distributed faulting, where fault trace lengths were established early within the first 7.2 Myrs of rifting (out of a total rifting duration of 85.5 Myrs). By 28.5 Myrs of rifting (33% of the total rifting duration), strain localises on major west dipping faults as a fully linked system. Localisation continues on major faults until the cessation of rifting where strain is accommodated with maximum throw in the centre of faults decreasing towards its tips. Our results suggest that fault displacement and length may scale linearly, but grow in alternations of fault lengthening and fault displacement phases. The growth of active fault systems and death of inactive faults located in stress shadow zones is responsible for the scatter of data points frequently observed in global displacement-length profiles.