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# How do normal faults grow over a range of spatial (experiment to full-rift) and temporal (seconds to 100s Myr) scales?

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A large body of research has led to the development of two contrasting models that both attempt to describe the growth of normal faults. The propagating model claims that normal faults grow via synchronous increase in displacement and length (also known as the 'isolated fault model'), whereas the constant-length fault model claims that normal faults grow by rapid length establishment and subsequent displacement accrual. Here we address two problems: i) the understanding of normal fault growth has been muddled by the fact that it is unclear how the two competing fault growth models apply in nature; and ii) the two fault growth models have largely been developed at the segment to array scale of normal faults, whereas we know of no attempts to investigate whether the fault growth models apply at the scale of entire rifts. In this contribution we first interrogate time-series displacement (D) and length (L) data from natural and experimental faults at segment to array scale, to elucidate growth styles and D-L trajectories throughout fault life, and to assess the applicability of the two fault models. We show that the growth of most faults is characterized by a hybrid of the two growth models, following two stages, the first defined by fault lengthening (20-30% of fault lifespan) and the second by displacement accrual (70-80% of fault lifespan). Although broadly adhering to the constant-length model, fault growth throughout the lengthening stage, during which significant displacement (10-60% of the total end-of-life fault displacement) may also accumulate, is achieved through rapid tip propagation, relay breaching, and segment linkage, characteristics perhaps most intuitively thought to reflect growth in accordance with the propagating model. The subsequent growth stage is dominated by displacement accrual with limited lateral tip propagation, a phenomenon best described by the constant-length model. We also show that, despite being used primarily in support of the propagating model, global displacement-length (D-L) datasets are equally compatible with the constant-length model.

Having investigated fault growth at segment to array scale, we turn to the East Greenland rift system where the time scales of rift propagation, border fault growth, and rift length establishment is examined. Reviewing historical geochronological and stratigraphic evidence along with new K-Ar fault dating from the Dombjerg segment of the rift border fault system, we determine that the East Greenland rift system established itself along its full length within the initial 10-20 Myrs (4-20% of rift life), which appears consistent with the predictions of the constant length model for normal fault growth. Comparison with other rift systems (e.g. Corinth) suggest, however, that the early lengthening stage of rifts, albeit rapid, is characterised by tip propagation, relay breaching, and fault linkage. This implies that hybrid growth behaviors likely also apply at rift scale, whereby (i) a rapid stage of fault (or, in this case, rift) length establishment achieved through tip propagation, relay breaching, and fault linkage (i.e. propagating fault/rift growth) is followed by (ii) a stage of displacement accumulation and subsidence without significant further tip (or rift) propagation.