Geophysical Research Abstracts
Vol. 19, EGU2017-8120, 2017
EGU General Assembly 2017

Abrupt plate acceleration during rifted margin formation: Cause and effect

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Extension rate is known to control key processes during rifted margin formation such as crust-mantle coupling, decompression melting, magmatism, and serpentinisation. Here we build on recent advances in plate tectonic reconstructions by quantifying the extension velocity history of Earth's major rifted margins during the last 240 million years. We find that many successful rifts start with a slow phase of extension followed by rapid acceleration that introduces a fast phase. The transition from slow to fast rifting takes place long before crustal break-up: approximately half of the present day rifted margin area was created during the slow, and the other half during the fast rift phase.

We reproduce the rapid transition from slow to fast extension using analytical and numerical modelling with constant force boundary conditions. In these models, rift velocities are not imposed but instead evolve naturally in response to the changing strength of the rift. Our results demonstrate that abrupt plate acceleration during continental rifting is controlled by a rift-intrinsic strength-velocity feedback. The abruptness of rift acceleration is thereby governed by the nonlinearity of lithospheric localization. Realistic brittle and power-law rheologies lead to a speed-up duration between two and ten million years. For successful rifts that generate a new ocean basin, the duration of rift speed-up is notably almost independent of the applied extensional force. Instead, the force controls the duration of the slow phase: higher forces shorten the slow phase while lower forces prolong it. If the force is too low, however, delocalisation processes prevent the rift from reaching the point of speed-up and produce a failed rift, even if the extensional system was active for many million years.