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A model of tectonic extension and the evolution from rifted basins to margins

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When continental lithosphere is initially extended it thins and subsides forming rifted sedimentary basins like the North Sea basin. However, if lithospheric extension continues to final break up, giving birth to a spreading center, the greatly thinned continental plates subside deep below sea level forming a conjugate pair of margins.

When intense lithospheric extension occurs with little associated magmatism, it forms the so-called ‘non-volcanic rifted margin’ (NVRM). Conjugate sets of NVRMs are found worldwide, including examples like West Iberia-Newfoundland, South Labrador Sea-Greenland, Armorican-Flemish Cap, South Australia-Antarctica, and Nova Scotia-Morocco. Previous work in those deep margins has recognized two apparent paradoxes:

A widely recognized apparent first paradox is that one margin shows steady crustal thinning and large-scale faulting, whereas the conjugate displays far abrupter crustal thinning but little large-scale faulting. Previous explanations of this asymmetry invoked simple shear extension during much of the rifting along crustal- or lithospheric- detachment faults. However, seismic data have only convincingly imaged potential detachment faults near the continent-ocean transition, where the crust has been thinned to less than ∼6 km, so the potential detachments could not explain the large-scale asymmetry of conjugate margins.

A second apparent paradox, found in both conjugate margins, is the discrepancy between an apparently small extension by faulting (measured as horizontal stretching) compared to a greater crustal thinning (measured as thinning factor). Invoked explanations range from depth-dependent crustal stretching to superposition multiple phases of widespread faulting.

We present seismic images of conjugate margins that show the structure created by faulting and crustal thinning as extension progressed from the rift flanks to the area of continental break-up. The observations support a model of the temporal evolution of fault activity during rifting that resolves both apparent paradoxes described above.