Geophysical Research Abstracts
Vol. 19, EGU2017-8183, 2017
EGU General Assembly 2017

Comparative riftology: insights from crustal structure into the evolution of continental rifts and passive continental margins

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Continental rifts evolve to seafloor spreading and are preserved in passive margins, or fail and remain as fossil features in continents. Rifts at different stages give insight into these different evolutionary paths. Of particular interest is how volcanic passive margins evolve. These features are characterized by sequences of volcanic rocks yielding magnetic anomalies landward of and sometimes larger than the oldest spreading anomalies. Seaward-dipping reflectors (SDR) occur in stretched continental crust landward of the oldest oceanic crust and are underplated by high-velocity lower crustal bodies. How and when these features form remains unclear. Insights are given by the Midcontinent Rift (MCR), formed by 1.1 Ga rifting of Amazonia from Laurentia, that failed once seafloor spreading was established elsewhere. MCR volcanics are much thicker than other continental flood basalts, due to deposition in a narrow rift rather than a broad region, giving a rift's geometry but a LIP's magma volume. The MCR provides a snapshot of the deposition of a thick highly magnetized volcanic section during rifting. Surface exposures and seismic-reflection data in and near Lake Superior show a rift basin filled by inward-dipping flood basalt layers. Had the rift evolved to seafloor spreading, the basin would have split into two sets of volcanics with opposite-facing SDRs, each with a strong magnetic anomaly. Because the rift formed as a series of alternating half-grabens, structural asymmetries between conjugate margins can naturally occur. Hence the MCR shows that many features form prior to breakup. Because the MCR was massively inverted by regional compression long after it failed and was uplifted, its structure is better known than failed rifts that incurred lesser degrees of inversion. It provides an end member for the evolution of actively extending rifts, characterized by upwelling mantle and negative gravity anomalies, in contrast to failed and inverted rifts without upwelling mantle and positive gravity anomalies.