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The role of asthenospheric flow during rift propagation and breakup

Luke Mondy (1), Patrice Rey (1), Guillaume Duclaux (2), and Louis Moresi (3)

(1) Earthbyte Research Group, School of Geosciences, The University of Sydney, Sydney, NSW 2006, Australia, (2) Université Côte d'Azur, CNRS, OCA, IRD, Géoazur, 06560 Valbonne, France., (3) School of Earth Sciences, Melbourne University, Victoria 3010, Australia

Continental rifting precedes the breakup of continents, leading to the formation of passive margins and oceanic lithosphere. Although rifting dynamics is classically described in terms of either active rifting caused by active mantle upwelling, or passive rifting caused by far-field extensional stresses, it was proposed that a transition from passive to active rifting can result from changes in buoyancy forces due to localized thinning of the lithosphere. Three-dimensional numerical experiments of rifting near an Euler pole allow the quantification of these buoyancy forces and show that gravitational stresses are strong enough not only to sustain rifting and drive axis-parallel motion in the asthenosphere dome, but also to promote along-axis asthenospheric flow and to drive the propagation of the rift tip toward its rotation pole. We show that gradients of gravitational potential energy due to the presence of the dome of asthenosphere induce time-dependent phases of compressional and transcurrent stress regimes, despite an overall divergent plate setting. Our experiments predict overdeepened bathymetry at the tip of the propagating rift, as well as the variability of focal mechanisms of shallow seismic events similar to those observed in such a setting. We also explain the episodes of basin inversion documented in many rifted continental margins.