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Inheritance of pre-existing weakness in continental breakup: 3D numerical modeling

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The whole process of continental rifting to seafloor spreading is one of the most important plate tectonics on the earth. There are many questions remained related to this process, most of which are poorly understood, such as how continental rifting transformed into seafloor spreading? How the curved oceanic ridge developed from a single straight continental rift? How the pre-existing weakness in either crust or lithospheric mantle individually influences the continental rifting and oceanic spreading?

By employing the state-of-the-art three-dimensional thermomechanical-coupled numerical code (using Eulerian-Lagrangian finite-difference method and marker-in-cell technic) (Gerya and Yuen, 2007), which can model long-term plate extension and large strains, we studied the whole process of continental rifting to seafloor spreading based on the following question: How the pre-existing lithospheric weak zone influences the continental breakup?

Continental rifts do not occur randomly, but like to follow the pre-existing weakness (such as fault zones, suture zones, failed rifts, and other tectonic boundaries) in the lithosphere, for instance, the western branch of East African Rift formed in the relatively weak mobile belts along the curved western border of Tanzanian craton (Corti et al., 2007; Nyblade and Brazier, 2002), the Main Ethiopian Rift developed within the Proterozoic mobile belt which is believed to represent a continental collision zone (Keranen and Klemperer, 2008),the Baikal rift formed along the suture between Siberian craton and Sayan-Baikal folded belt (Chemenda et al., 2002). The early stage formed rift can be a template for the future rift development and continental breakup (Keranen and Klemperer, 2008). Lithospheric weakness can either reduce the crustal strength or mantle strength, and leads to the crustal or mantle necking (Dunbar and Sawyer, 1988), which plays an important role on controlling the continental breakup patterns, such as controlling the breakup order of crust and mantle (Huismans and Beaumont, 2011). However, the inheritance of pre-existing lithospheric weakness in the evolution of continental rifts and oceanic ridge is not well studied.

We use 3D numerical modeling to study this problem, by changing the weak zone position and geometry, and the rheological structure of the model. In our study, we find that:
1).3D continental breakup and seafloor spreading patterns are controlled by (a) crust-mantle rheological coupling and (b) geometry and position of the pre-existing weak zones.
2).Three spreading patterns are obtained: (a) straight ridges, (b) curved ridges and (c) overlapping ridges.
3).When crust and mantle are decoupled, abandoned rift structures often form.