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3D numerical model of the plume-lithosphere interactions near cratonic blocks: Implications for the Tanzanian craton

Alexander Koptev (1,2), Evgueni Burov (1,2), Eric Calais (3), Sylvie Leroy (1,2), and Taras Gerya (4)

(1) Sorbonne Universités, UPMC Univ Paris 06, UMR 7193, Institut des Sciences de la Terre Paris (iSTeP), F-75005 Paris, France (alexander.koptev@upmc.fr), (2) CNRS, UMR 7193, Institut des Sciences de la Terre Paris (iSTeP), F-75005 Paris, France, (3) ENS Geologie, UMR CNRS 8538, Paris, France, (4) ETH-Zurich, Institute of Geophysics, Sonnegstrasse 5, 8092 Zurich, Switzerland

We explore the evolution of plume-activated rifting in a heterogeneous continental lithosphere containing embedded cratonic blocks, with a particular focus on the impact of horizontal position of a plume with respect to the craton. We also study the influence of a preexisting far-field stress/strain field on the «active» rifting style by implementing a slow far-field extension during the plume-lithosphere interaction. In the experiments, a «cratonic» block (cold, thick depleted mantle) is embedded into a «normal» lithosphere roughly mimicking the configuration of the Tanzanian craton and of its surroundings. We next varied the far-field extension rates, the thickness of the craton as well as the thermo-rheological profile and the position of the plume with respect to the center of the craton (placed either strictly under the center of the «Tanzanian» craton or slightly shifted in the NE direction). Despite significant disparities in style and timing of rifting process observed in models with different parameters, the common feature for all cases with central plume position refers to the development of largely symmetric diverging rift branches embracing the craton. The models with shifted initial plume position demonstrate a fundamentally different behavior because in this case the cratonic block deflects plume material to one side of the craton, leading to a strongly asymmetric spreading of plume-head material under the bottom of the lithosphere. This asymmetry results in development of two different rift branches: the first one is more pronounced and develops right above the plume head at the north-east of the craton, with a lot of magmatic material arriving to the surface. The second branch appears almost simultaneously but is less pronounced, amagmatic, and propagates northward over the western part of the craton. This evolution resembles the one inferred for east (warm and magmatic) and west (cold and amagmatic) rift braches in the East African rift system. The cratonic micro-plate embraced by two rift branches undergoes a counter-clockwise rotation about a pole located somewhere to the north, in close similarity to the rotation of the Victoria micro-plate craton revealed by GPS data. Thus, the agreement of key model features with the evolution of the East African Rift System demonstrates the possibility of emergence of two asymmetric simultaneous rifts at the opposite borders of a craton, as result of interaction with a single mantle plume. The model also demonstrates the possibility of development of both magmatic and amagmatic rifts in identical geotectonc environments without necessity of premature diking events. It also sheds some new light on the mechanisms of «survival» of small cratons.