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The Congo basin: an example of failed rift

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The Congo basin (CB), considered as a typical intracratonic basin, due its slow and long-lived subsidence history and the largely unknown formation mechanisms, occupies a large part of the Congo craton, derived from the amalgamation of different cratonic pieces. It recorded the history of deposition of up to one billion years of sediments, one of the longest geological records on Earth above a metamorphic basement. The CB initiated very probably as a failed rift in late Mesoproterozoic and evolved during the Neoproterozoic and Phanerozoic under the influence of far-field compressional tectonic events, global climate fluctuation between icehouse and greenhouse conditions and drifting of Central Africa through the South Pole then towards its present-day equatorial position. Since Cretaceous, the CB has been subjected to an intraplate compressional setting due to ridge-push forces related to the spreading of the South Atlantic Ocean, where most of sediments are being eroded and accumulated only in the center of the basin.

In this study, we first reconstructed the stratigraphy, the depths of the main seismic horizons, and the tectonic history of the CB, using geological and exploration geophysical data. In particular, we interpreted about 2600 km of seismic reflection profiles and well log data located inside the central area of the CB (Cuvette Centrale). We used the obtained results to constrain the gravity field data that we analyzed, in order to reconstruct the depth of the basement and investigate the shallow crustal structure of the basin. To this purpose, we used a gravity inversion method with two different density contrasts between the surface sediments and crystalline rocks.

The results evidence NW-SE trending structures, also revealed by magnetic and seismic data, corresponding to the alternation of highs and sediments filled topographic depressions, related to rift structures, characterizing the first stage of evolution of the CB. They also show a general good consistency between the seismic and gravity basement along the seismic profiles and evidence the presence of possible high-density bodies in the shallow to deep crust. The identified structures are prevalently the product of an extensional tectonics, which likely acted in more than one direction.

Therefore, we performed 3D numerical simulations to test the hypothesis of the formation of the CB as multi-extensional rift in a cratonic area, using the thermomechanical I3ELVIS code, based on a combination of a finite difference method applied on a uniformly spaced Eulerian staggered grid with the marker-in-cell technique. To this purpose, the numerical tests have been conducted considering a sub-circular weak zone in the central part of the cratonic lithosphere and applying a velocity of 2.5 cm/yr in two orthogonal directions (N-S and E-W). We repeated these numerical tests by increasing the size of the weak zone and varying its lithospheric thickness. The results show the formation of a circular basin in the central part of the cratonic lithosphere, characterized by a series of highs and depressions, consistent with those obtained from geophysical/geological reconstructions.

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