Structural development and fault kinematics of the Western Branch of the EARS and their controls on geothermal resources

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The Western Branch of the East African Rift System (EARS) extends from South Sudan to Mozambique in a general S-shape, with, from North to South, the NE-trending Kivu and Albertine rift segments, the N-S northern half of the Tanganyika rift, the NW-trending South Tanganyika-Rukwa-North Malawi (TRM) rift segment, and the N-S Malawi rift segment and its prolongation into Mozambique.

It developed with relatively discrete basin initiation and volcanism at various times since the since the Mid Miocene, widespread rifting in the Late Miocene (5-9 Ma) and a last phase of accelerated rifting during the Quaternary (last 2 Ma) (Ebinger, 1989; Chorowicz, 2005; Roberts et al., 2012; Mc. Gregor, 2015).

The Western Branch is one of the two branches of the EARS which separate the Eastern costal Africa (Somalian plate) from the rest of Africa (Nubian plate). These two branches surround and isolate two the Tanzanian craton in the North (Victoria microplate) and the Mozambique part of the East African Orogen in the South (Ruvuma microplate plate) (Fernandes et al., 2013; Saria et al., 2014).

Different kinematic models have been proposed for the opening of the EARS (Fig. 1). Based on remote sensing interpretation and fault-slip data, Chorowicz (2005) suggest a NW-SE opening in a pull-apart mechanism guided by transcurrent wrench fault zones. In this model, the NW- trending central portion of the Western branch (TRM zone) acts as an intracontinental right-lateral fault zone. Instead Delvaux et al. (2012) show after detailed neotectonic and fault kinematic analysis that the TRM segment is currently opening in pure normal faulting, with principal extension orthogonal to the fault trend. Evidence for right-lateral faulting have been also found along the major border faults, but this is related to an earlier, pre-Cretaceous tectonic stage.

On the basis of earthquake slip vector and GPS data, Calais et al. (2006) proposed a new kinematic model and defined the Victoria and Rovuma microplates rotating in an opposed way between the Eastern and Western branches of the EARS in a general WNW-ESE extension. This model was later refined Fernandez et al., 2013) and the last model, based on more and longer GPS time series constrain the opening in a more strictly E-W direction (Saria et al., 2014). The associated stress field determined from stress inversion of earthquake folcal mechanisms (Delvaux and Barth, 2010) suggest a general, second-order orthogonal opening of the rift basins in a first-order E-W extension between the Nubian and Somalian plates. It defines a radial pattern of directions of horizontal principal extension, away from the Tanzanian craton. The second-order stress field appears strongly influenced by the presence of existing crustal discontinuities inherited from the earlier tectonic history of the mobile belts that surrounds the Tanzanian craton.

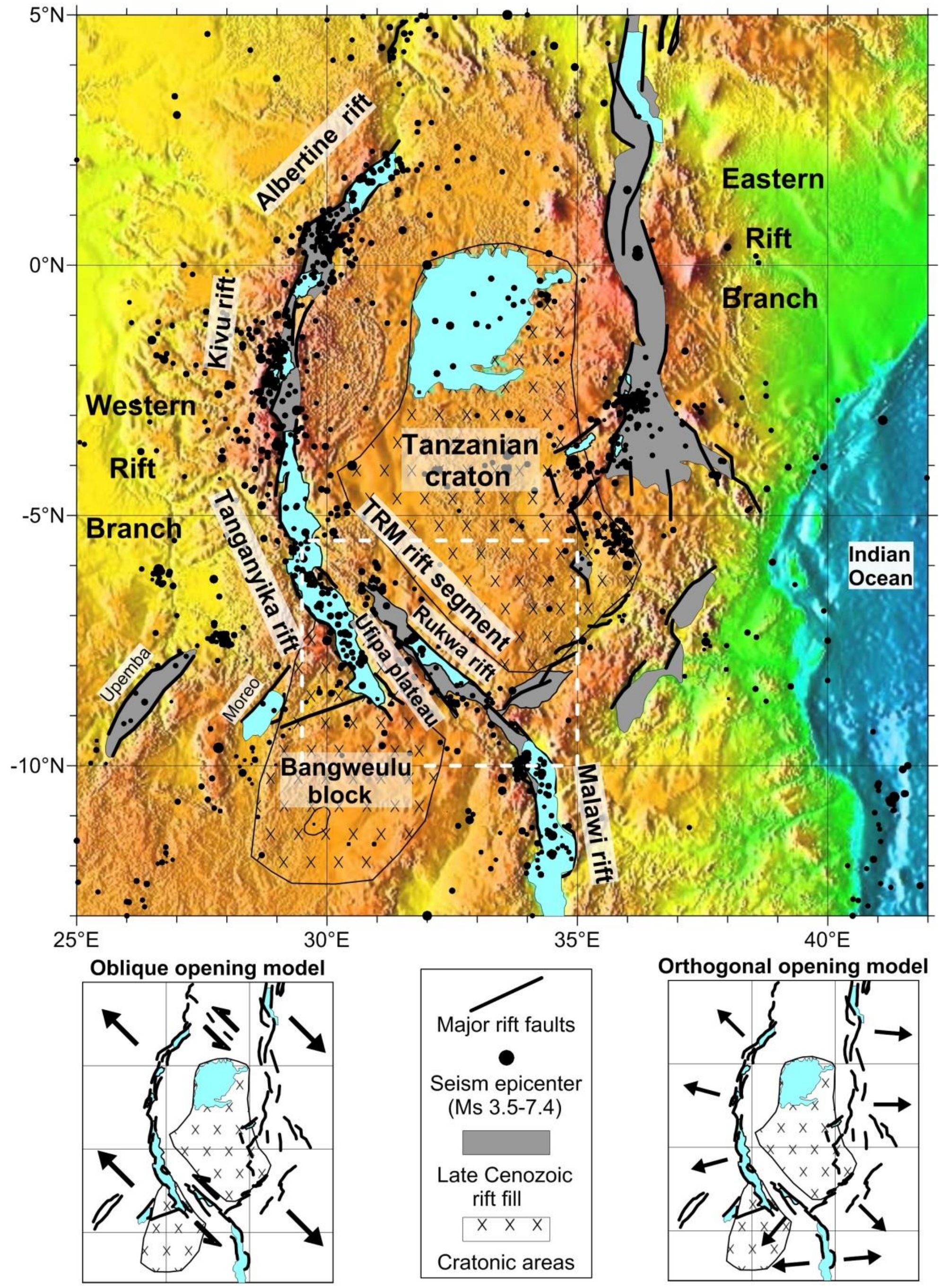

Figure 1: East African Rift System with the two branches surrounding the Tanzanian craton with the two major kinematic models of opening.

The Western branch has a long-lived tectonic evolution, with frequent reactivations, first in ductile conditions and then in brittle conditions since the late Neoproterozoic - early Palaeozoic (Klerkx et al., 1998; Delvaux, 2001). The brittle faults recorded along the TRM rift segment (Delvaux et al, 2012) and also in the Kivu rift segment (ongoing investigation), suggest that thrusting and reverse faulting occurred in the area of the future Western branch during the Late Pan African amalgamation of Gondwana, as a consequence of the E-W convergence and collision of the Eastern and Western Gondwana along the eastern margin of the Tanzanian craton. Later, probably during the Triassic, the same area was affected by strike-slip reactivations in response to far-field ~N-S oriented compressional stresses generated at the southern margin of Gondwana which was in the situation of an active compressional margin at that time.

The neotectonic and active deformation on the entire EARS is illustrated by the distribution of neotectonic faults, volcanoes, earthquake epicentres and thermal springs (Fig. 2).

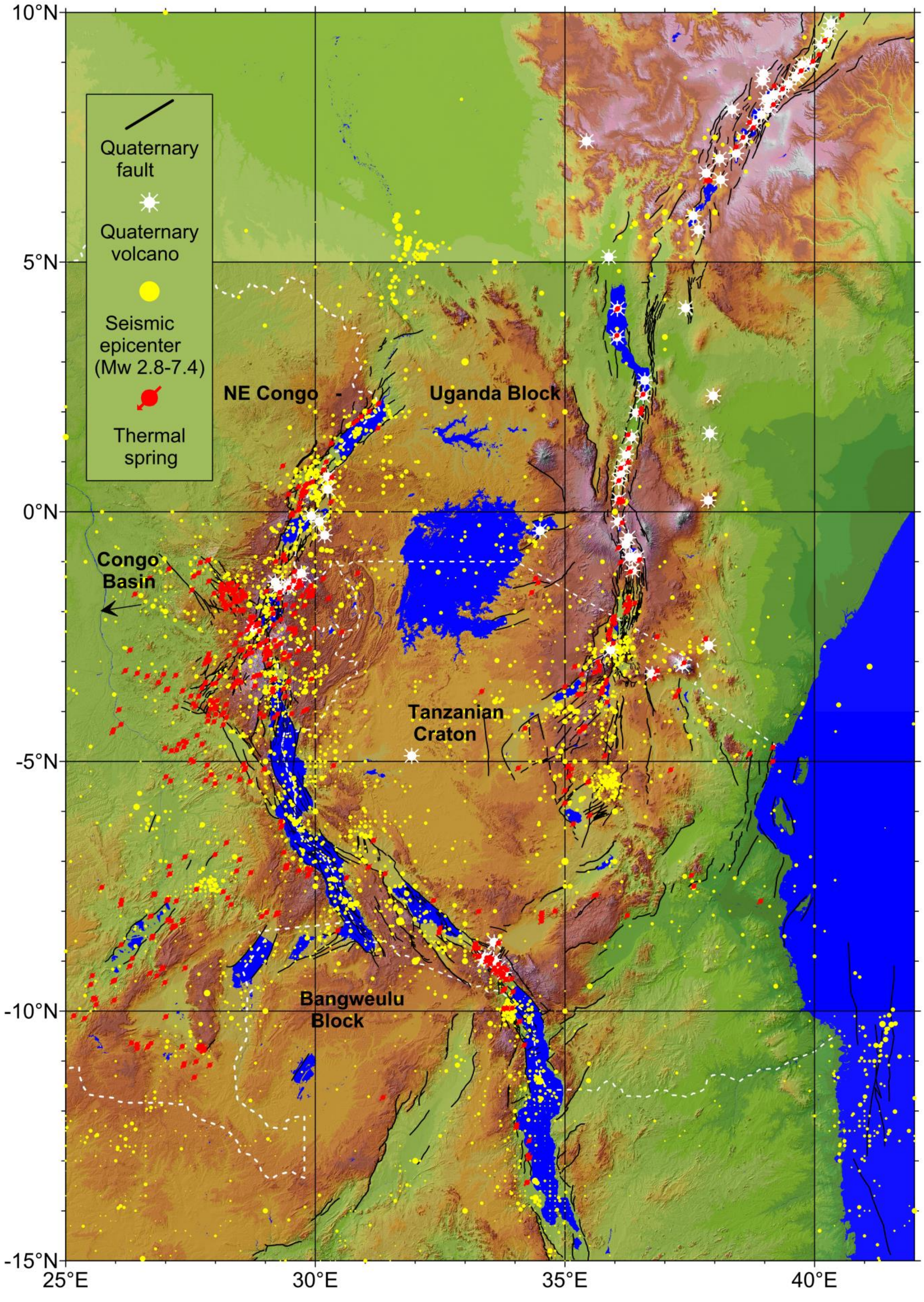

Figure 2: Distribution of quaternary neotectonic faults, volcanoes and thermal springs in both branches of the EARS surrounding the Tanzanian craton.

The thermal springs have long been considered as marker of active deformation as they generally occur along faults that are seismically active (at least for those with advective hydrothermal system). In the DRCongo, they have attracted the attention of the early geologists and explorers and mapped extensively. We compiled all information available to us on the thermal springs in the EARS and adjacent parts. It appears that the location of the thermal systems along the volcanic part of the Eastern Branch are well concentrated to the axial zone of the rift, often related to volcanism. But on the non-volcanic parts of the EARS (most of the Western Branch and the southern termination of the Eastern Branch), the thermal springs as the seismicity and active faults are distributed over a much wider area than the major rift basins.

The internal architecture of the rift basins has been particularly well studied in the Western Branch, especially in the Tanganyika, Rukwa and Malawi rift basins. It has been shown to be composed of a series of half- and full-grabens that form the building blocks of the rift basins (Rosendahl et al., 1992; Morley and Wescott, 1999). The architecture of the different rift segments along the Western Branch will be detailed to illustrate the various modes of extension, with special attention to the accommodation zones between the different basins. From North to South, we will consider successively the Albertine rift, the Kivu rift, the TRM rift segment, the Mbeya triple junction with the Rungwe volcanic province, the non-magmatic southern extremity of the Eastern Branch in Central Tanzania (Manyara-Dodoma region) and the isolated rift basins of the incipient South-Western branch of the rift.

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