Fault kinematics and tectonic stress in the seismically active Manyara–Dodoma Rift segment in Central Tanzania – Implications for the East African Rift

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Abstract

The Eastern Branch of the East African Rift System is well known in Ethiopia (Main Ethiopian Rift) and Kenya (Kenya or Gregory Rift) and is usually considered to fade away southwards in the North Tanzanian Divergence, where it splits into the Eyasi, Manyara and Pangani segments. Further towards the south, rift structures are more weakly expressed and this area has not attracted much attention since the mapping and exploratory works of the 1950s. In November 4, 2002, an earthquake of magnitude Mb = 5.5 struck Dodoma, the capital city of Tanzania. Analysis of modern digital relief, seismological and geological data reveals that ongoing tectonic deformation is presently affecting a broad N–S trending belt, extending southward from the North Tanzanian Divergence to the region of Dodoma, forming the proposed "Manyara–Dodoma Rift segment". North of Arusha–Ngorongoro line, the rift is confined to a narrow belt (Natron graben in Tanzania) and south of it, it broadens into a wide deformation zone which includes both the Eyasi and Manyara grabens.

The two-stage rifting model proposed for Kenya and North Tanzania also applies to the Manyara–Dodoma Rift segment. In a first stage, large, well-expressed topographic and volcanogenic structures were initiated in the Natron, Eyasi and Manyara grabens during the Late Miocene to Pliocene. From the Middle Pleistocene onwards, deformations related to the second rifting stage propagated southwards to the Dodoma region. These young structures have still limited morphological expressions compared to the structures formed during the first stage. However, they appear to be tectonically active as shown by the high concentration of moderate earthquakes into earthquake swarms, the distribution of He-bearing thermal springs, the morphological freshness of the fault scarps, and the presence of open surface fractures. Fault kinematic and paleostress analysis of geological fault data in basement rocks along the active fault lines show that recent faults often reactivate older fault systems that were formed under E–W to NW–SE horizontal compression, compatible with late Pan-African tectonics. The present-day stress inverted from earthquake focal mechanisms shows that the Manyara–Dodoma Rift segment is presently subjected to an extensional stress field with a N080°E direction of horizontal principal extension. Under this stress field, the rift develops by: (1) reactivation of the pre-existing tectonic planes of weakness, and (2) progressive development of a new fault system in a more N–S trend by the linkage of existing rift faults. This process started about 1.2 Ma ago and is still ongoing.

Keywords

- Tanzania;
- East African Rift;
- Manyara–Dodoma Rift segment;
- Fault kinematics;
- Tectonic stress;
- Seismotectonics