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Quaternary stress evolution in East Africa from data of the western branch of the East African rift

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ABSTRACT: The Quaternary kinematic evolution of the north Malawi rift area has been determined from paleostress and paleostrain data, by previous works. The similar results obtained for both the Tanzanian and the Malawian side of Lake Malawi allow to present common horizontal stress trajectories for north Malawi rift and to integrate them in the stress trajectories already proposed for the western branch of the East African rift system and adjacent areas. Therefore, the western branch of the East African rift can also be intergated in the geodynamic context proposed for the eastern branch, in which the East African continent is actually under compressional stress field, dominated by ridge-push from the Red Sea - Gulf of Aden spreading centers.

INTRODUCTION AND GEOLOGICAL SETTING

Kinematic analysis of minor faults has been recently conducted in the northern half of the Malawi rift, in the Tanzanian side (Delvaux & al., 1992) and in the Malawian side (Ring & al., 1992). The Cenozoic kinematic history appears to be polyphase, as it has been also demonstrated for the Kenya rift (Strecker & al., 1990). A correlation of kinematic evolutions is presented here, in relation to the geodynamic setting of the East African rift system, outlined recently by Bothworth & al. (1992).

The western branch of the East African rift system (Fig. 1) developed in a sigmoidal shape on Proterozoic mobile belts which surround the Tanzanian Archean craton. The central part of the western branch has a general NW-SE orientation and is occupied by the Tanganyika, Rukwa and Malawi (Nyasa) rift valleys, along which the Cenozoic basins and major faults are largely superimposed on an older Permo-Triassic (Karoo) rift system (Dypvik & al., 1990; Morley & al., 1992).

In the north Malawi area, Tertiary sedimentation started in upper Miocene, until late Pliocene. After a major erosional and structural unconformity of Plio-Pleistocene age, Quaternary lake beds were deposited (Ebinger & al., submitted; Ring & Betzler, submitted). For the whole Cenozoic period, volcanogenic deposits are interbedded with lacustrine and fluviatile sediments and their K-Ar and Ar-Ar dating (Ebinger & al., 1989) provides good age constraints for the stratigraphic succession.

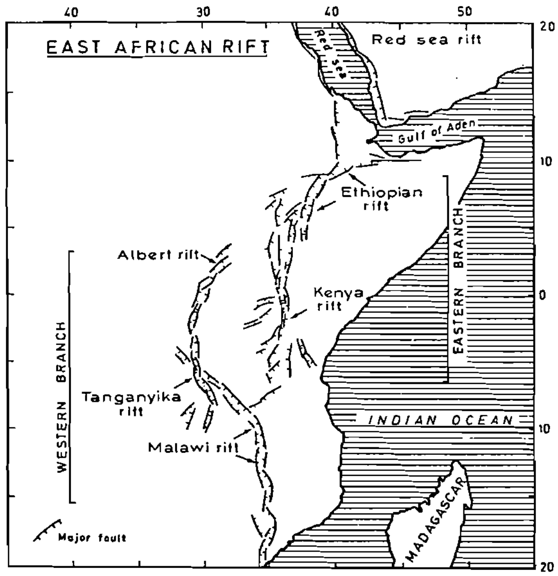

Fig. 1. General map of the east-African Cenozoic rift system.

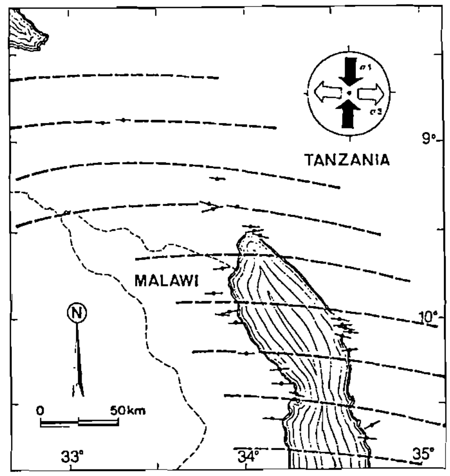

Fig. 2. Interpretation of minimum horizontal stress trajectories for early-middle Pleistocene in the north Malawi rift.

NORTH MALAWI QUATERNARY PALEOSTRESS AND KINEMATICS

For the Cenozoic period, several kinematic phases were identified in the north Malawi area, by analysing Neogene and Quaternary faults in relation to well dated sediments and volcanics. For the Tanzanian part of this area, paleostress tensors were determined by minimisation of the angular deviation between observed slip lines and computed shears (Delvaux & al., 1992). For the Malawian side, fault data were used to constrain the orientation of principal strain axes (Ring & al., 1992). The correlation of strain and stress axis is generally though to be non-coaxial, but the resulting strain axes of Ring & al. (1992) correlate well with the stress axis of Delvaux & al. (1992), and the kinematic histories deduced from the two methods are very similar and, therefore, can be compared.

The Cenozoic kinematic history of this area is characterized by a stress inversion from an extensive regime (upper Miocene - Pliocene), into a strike-slip regime (Pleistocene - Recent). The latter regime established after a late Pliocene to early Pleistocene period of stability. It started at about 0.57 Ma (early Pleistocene), together with a new pulse of volcanic activity and renewed sedimentation, and it is accompanied by an important uplift in the Rungwe volcanic area. This new kinematic phase is characterized by horizontal principal compression and extension axes, typical of a strike-slip regime. For the early-middle Pleistocene period, the dominant extension direction was E-W, with a N-S principal compression (Fig.2). It then evolved by clockwise rotation of the extension direction from E-W to NW-SE, in middle Pleistocene, at about 0.42 Ma (Fig. 3). This last paleostress regime observed from fault measurements is compatible with the present stress field, as deduced from earthquake focal mechanisms, with a common NW-SE extension direction (Delvaux & al., 1992).

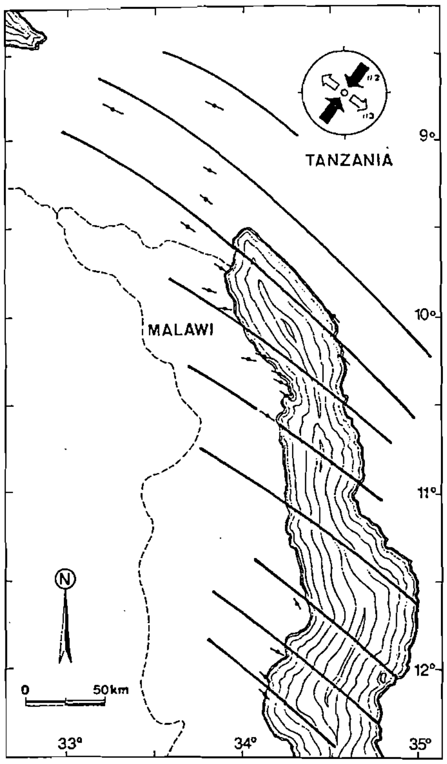

Fig. 3. Interpretation of minimum horizontal stress trajectories for late Pleistocene - Recent in the north Malawi rift.

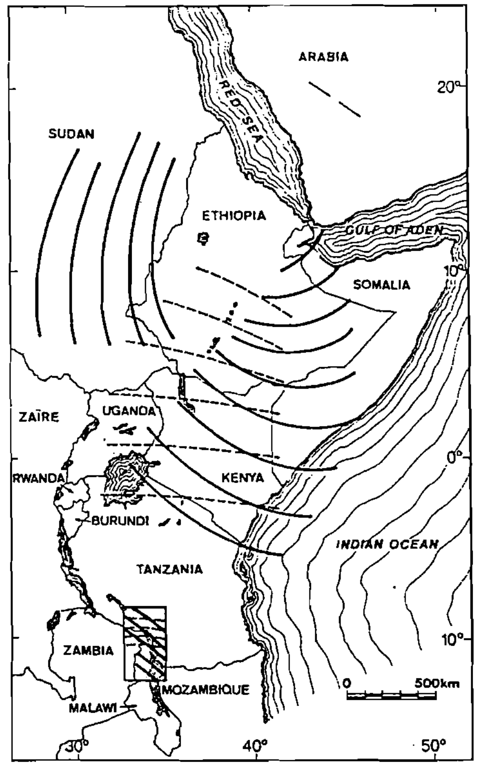

Fig. 4. Minimum horizontal stress trajectories for the north Malawi rift, compared with the interpreted trajectories of Bosworth & al. (1992) for the western branch of the east African rift. Doted lines: pre-middle Pleistocene, solid lines; late-Pleistocene to present-day.

KENYA RIFT QUATERNARY PALEOSTRESS AND KINEMATICS

In the Kenya rift, Strecker & al. (1990) evidenced a rotation of extension direction from E-W to NW-SE at about 0.4 Ma, which is contemporaneous to the one described for the north Malawi rift. For the north-eastern part of the East African rift, a recent compilation of paleostress and present-day stress data indicates that Kenya, Sudan and Ethiopia area underwent significant clockwise rotation of about 45° for the regional stress trajectories in middle Pleistocene (Bothworth & al., 1992). This rapid rotation is thought to be related to an abrupt change in plate tectonics at the Red Sea - Gulf of Aden plate boundary.

Similarities in the kinematic history for both the western and eastern branches of the East African rift allow the integration of paleostress data from the north Malawi area with the data of the eastern branch, already synthetised in the map of stress trajectories presented by Bothworth & al. (1992). The resulting map (Fig. 4) evidences the existence of homogeneous stress fields for the whole East Africa, for the two last periods of deformation. In Kenya, the first period corresponds to pre-middle Pleistocene (older than 0.4 Ma), but for north Malawi it corresponds to the

0.55 - 0.4 Ma time span. For both areas, the second regime is younger than 0.4 Ma and is still active.

CONCLUSIONS

It is meaningful that the middle Pleistocene modification of the kinematic regime was recorded simultaneously in the Kenya rift and in the Malawi rift. This suggests that the causes are not local and that they are most likely linked to significant changes in the plate tectonic regime at the Red-Sea - Gulf of Aden boundary.

The East African rift lies in the middle of the African continent which is entirely surrounded by mid-oceanic spreading ridges and a continental collision to the north. As a result, East Africa is actually under a compressional stress field, dominated by ridge-push from the spreading centers of the Red Sea - Gulf of Aden (Bothworth & al., 1992; Zoback, 1992). The correlation of both the horizontal stress trajectories and the timing of the clockwise stress rotation between the two branches of the East African rift allows to propose a common geodynamic model for whole East Africa, and emphasize the continental-scale character of the stress pattern. Thus, the causes of the Quaternary kinematics of the East African rift are related to external forces, linked to the general dynamics of the plate tectonics.

REFERENCES

Bothworth, W., M.R. Strecker & P.M. Blisniuk 1992. Integration of East African Paleostress and Present-Day Stress Data: Implications for Continental Stress Field Dynamics. - *J. Geophys. Res.*, 97 (B8): 11851-11865.

Delvaux, D., K. Levi, R. Kajara & J. Sarota 1992. Cenozoic paleostress and kinematic evolution of the Rukwa - North Malawi rift valley (East African rift system). - *Bull. Centres Rech. Explor.-Prod. Elf Aquitaine*, 16, (2).

Dypvik, H., H. Nestby, F. Rudent, P. Aagaard, T. Johansson, J. Msindai & C. Massay 1990. Upper Paleozoic and Mesozoic sedimentation in the Rukwa-Tukuyu Region, Tanzania. *J. Afr. Earth Sci.*, 11: 437-456.

Ebinger, C.J., A.L. Deino, R.E. Drake & A.L. Thesa 1989. Chronology of volcanism and rift basin propagation : Rungwe volcanic provinces, East Africa. *J. Geophys. Res.*, 94: 15783-15803.

Ebinger, C.J., A.L. Deino, A.L. Tesha, T. Becker & U.Ring (submitted). Regional tectonic controls on rift basin geometry: Evolution of an East African Lake Basin. *J. Geophys. Res.*

Morley, C.K., S.M. Cunningham, R.M. Harper & W.A.Wescott 1992. Geology and geophysics of the Rukwa rift, East Africa. - *Tectonics*, 11: 68-81.

Ring, U. & C. Betzler (submitted). Architecture, Tectonics and Sedimentation of the Malawi Rift (East Africa). *Zeitschrift Deutsche Geologische Gesellschaft.*

Ring, U., C. Betzler & D. Delvaux 1992. Normal vs. strike-slip faulting during rift development in East Africa: the Malawi rift. *Geology,* 20 (12).

Strecker, M.R., P.M. Blisniuk & G.H. Eisbacher 1990. Rotation of extension direction in the central Kenya rift. *Geology*, 18: 299-302.

Zoback, M.L. 1992. First- and Second-Order Patterns of Stress in the Lithosphere: the World Stress Map Project. *J. Geophys. Res.*, 97 (B8): 11703-11728.