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Initiation of the western branch of the East African Rift coeval with the eastern branch

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Abstract

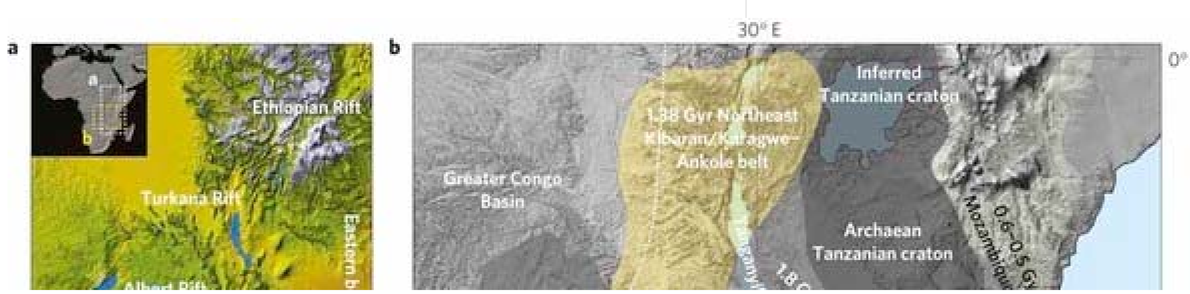
The East African Rift System transects the anomalously high-elevation Ethiopian and East African plateaux that together form part of the 6,000-km-long African superswell structure. Rifting putatively developed as a result of mantle plume activity that initiated under eastern Africa. The mantle activity has caused topographic uplift that has been connected to African Cenozoic climate change and faunal evolution. The rift is traditionally interpreted to be composed of two distinct segments: an older, volcanically active eastern branch and a younger, less volcanic western branch. Here, we show that initiation of rifting in the western branch began more than 14 million years earlier than previously thought, contemporaneously with the eastern branch. We use a combination of detrital zircon geochronology, tephro- and magnetostratigraphy, along with analyses of past river flow recorded in sedimentary rocks from the Rukwa Rift Basin, Tanzania, to constrain the timing of rifting, magmatism and drainage development in this part of the western branch. We find that rift-related volcanism and lake development had begun by about 25 million years ago. These events were preceded by pediment development and a fluvial drainage reversal that we suggest records the onset of topographic uplift caused by the

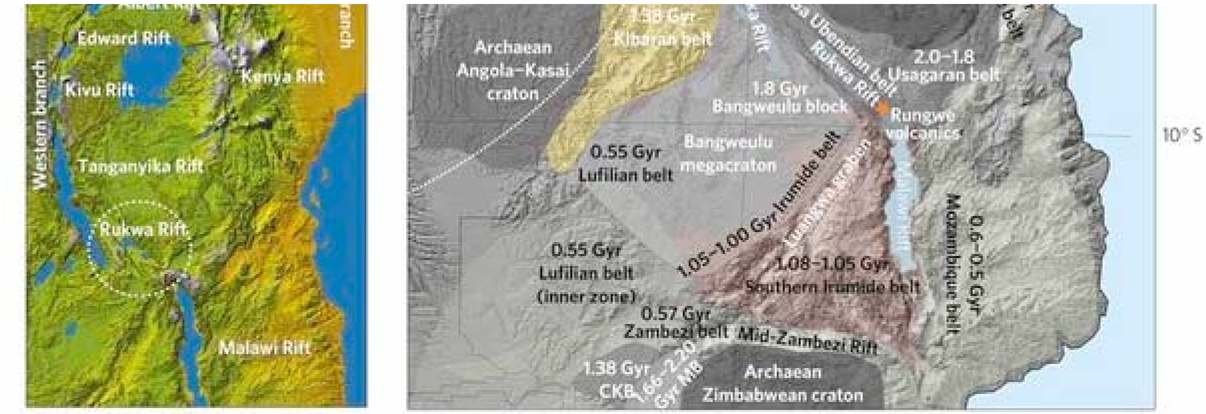
African superswell. We conclude that uplift of eastern Africa was more widespread and synchronous than previously recognized.

Introduction

The high-elevation (>1,000 m) plateaux of southern and eastern Africa are outstanding, first-order features of the African plate. Despite this, the uplift history and geodynamics of this unique topography remain a subject of debate and continue to challenge traditional plate tectonic concepts[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]. The topographic anomaly is referred to as the African superswell[4] and has been attributed to complex patterns of mantle circulation and plume development that initiated ~ 30–40 million years (Myr) ago[5, 6]. In eastern Africa, the superswell is associated with the East African Rift System (EARS), considerable sections of which are superimposed on large shear zones and sutures within Proterozoic mobile belts, reactivated as rifts during the Palaeozoic era and Cretaceous period[5] (Fig. 1a). The superswell developed in concert with the onset of Antarctic glaciation, which together fundamentally altered the African climate[7]. Regional uplift and formation of the EARS also rerouted and influenced large river systems, including the Nile, Congo and Zambezi[12, 13, 14, 15, 16]. This in turn resulted in complex and dynamic landscape fragmentation and the development of ecological corridors that, together with climatic shifts, set the stage for the evolution of Africa's unique fauna, beginning with faunal interchange with Eurasia in the latest Oligocene epoch and leading to the appearance of hominoids/hominins and other groups during the Mio–Pliocene epochs[7, 8, 9]. Within this broad template, many uncertainties remain regarding the detailed chronology of uplift, volcanism and rifting in eastern Africa, which can be addressed by investigating interior sedimentary basins along the EARS.

Figure 1: East African Rift System (EARS).





a, Image of the EARS modified from the NASA Shuttle Radar Topography Mission collection. Inset map indicates the location of the Rukwa Rift Basin study area within eastern Africa.
b, Generalized tectonic/structural map of eastern–central Africa illustrating tectonic elements and their broad ages (age data adapted from refs 48, 49). Note that colours for tectonic terranes used in this map correspond with Figs 3–4. CKB, Choma–Kalambo block; MB, Magondi belt; Gyr, billion-year-old; orange star, volcanic centre.

Here, we examine the sedimentary succession preserved within the Rukwa Rift Basin (RRB; Fig. 1), a segment of the western branch of the EARS, to: first, constrain the depositional age of these deposits; second, delimit the timing of rifting and volcanism in the western branch; and third, interpret landscape evolution and drainage development in central–east Africa since the breakup of Gondwana. Our analysis integrates U–Pb detrital zircon geochronology with palaeocurrent analysis to reconstruct sedimentary provenance and unroofing patterns in the basin, coupled with tephro- and magnetic stratigraphy of rift-fill deposits, providing a new test of the African superswell hypothesis.

Regional geology of eastern Africa

Rukwa Rift Basin

Rift stratigraphy, sedimentation and palaeontology

Volcanism and geochronology

Provenance, drainage patterns and uplift

Methods

Abstract **Introduction** **Regional geology of eastern Africa**

Standard methodologies for detrital zircon sample assessment and sorting were employed. Detrital zircon ages for all samples were obtained by SHRIMP U–Pb dating at the Australian National University. Statistical analyses of the detrital zircons were conducted using the unpublished Excel macro of J. Guynn, available on the Arizona LaserChron Centre website (https://docs.google.com/view?id=dcbpr8b2_7c3s6pxft). The carbonatite tuff samples were independently dated in three laboratories on three different minerals, resulting in concordant ages. Single-crystal, laser-fusion Ar/Ar dating of phlogopite was carried out in the Argon Geochronology for the Earth Sciences laboratory at the Lamont–Doherty Earth Observatory. U–Pb dating of zircon was conducted on the SHRIMP at the Australian National University and U–Pb dating of titanite was carried out on the LA-ICPMS at James Cook University. Oriented palaeomagnetic samples were collected by the senior author and analysed in the University of New Hampshire palaeomagnetism laboratory.

References

Acknowledgements

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Contributions

E.M.R., P.M.O., N.J.S. and M.D.G. developed the project and collected the field data. E.M.R., P.M.O., N.J.S., P.G.H.M., M.D.G. and W.C.C. developed the scientific concepts, interpreted the data and wrote the paper. R.A.A., A.I.S.K., S.H. and E.M.R. carried out the radio-isotopic dating. W.C.C. carried out palaeomagnetic analyses.

Competing financial interests

The authors declare no competing financial interests.

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Supplementary information

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