DENUDATION IN SOUTHERN MALAWI AND NORTHERN MOZAMBIQUE: INDICATIONS OF THE LONG-TERM TECTONIC SEGMENTATION OF EAST AFRICA DURING THE GONDWANA BREAK-UP

Daszinnies, M.C.[1,2], Emmel, B.[1,3], Jacobs, J.[1,3], Grantham, G.[4] & Thomas, R. J.[5]

[1]University of Bremen, Faculty of Geosciences, P.O. Box 330440, 28334 Bremen, Germany
[2]SINTEF Petroleum Research, N-7465 Trondheim, Norway; matthias.daszinnies@iku.sintef.no
[3]University of Bergen, Department of Earth Science, Allégaten 41, N-5007 Bergen, Norway
[4]Council for Geosciences, P/Bag X112, Pretoria, South Africa, 0012
[5]BGS, Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG, Great Britain

The Mesozoic Gondwana break-up was accompanied by the eruption of large volumes of igneous rocks during Jurassic to Cretaceous times. The oldest, Lower Jurassic volcanics cropout in South Africa (Karoo basalts) and East Antarctica (Ferrar province) and extruded in the southern part of the former supercontinent (Duncan et al. 1997; Luttinen et al. 1998). Younger Jurassic to Cretaceous igenous rocks are also found in northern Mozambique/southern Malawi (Eby et al. 1995; Lächelt 2004), eastern Sri Lanka (Takigami et al. 1999), southern India (Radhakrishna et al. 1999) and in Madagascar (Storey 1995) and reflect the northward rejuvenation of igneous activities within former Gondwana. This supports the idea that the break-up: (1) was possibly triggered by the activity of one large mantle plume (Kumar et al. 2007) or various plumes (Storey 1995); and (2) progressed northwards from southern into central Gondwana.

However, the distinct linkage between post Jurassic rift centers and locations of Late Carboniferous to Triassic intracontinental rift sediments (cf. Catuneanu et al. 2005) may suggest that crustal stretching favored the emplacement of volcanic rocks and instead relates the Gondwana break-up to the prevalence of a long lasting far-field stress regime (Ziegler and Cloethingh 2004).

In this study we focus on a small region in northern Mozambique, formerly located in the central part of the supercontinent. Here the Cretaceous Chilwa igneous province marks the visible termination of the southern Malawi rift-system (Fig. 1).

In the northern part of the Malawi rift sedimentary, thermochronological and structural studies indicate repeated crustal extension and rifting since the Late Palaeozoic (Ring 1994; van der Beek et al. 1998; Catuneanu et al. 2005). The tectonic lineaments in the southern Malawi rift link up southward to the eastern segment of Palaeozoic Zambezi Rift System (Shire Valley) and farther to the Mesozoic horst and graben structures in southern Mozambique. The pre-Cenozoic tectonic history of the southern Malawi rift system is obscured as pre-Cenozoic sedimentary rocks are absent, likely due to substantial exhumation and erosion triggered by up doming in the cause of igneous activity. We applied apatite fission track thermochronology for investigating the timing and magnitude of cooling and exhumation in the region. Samples were collected on the southern Malawi rift shoulders and the basement rocks located in the igneous region.

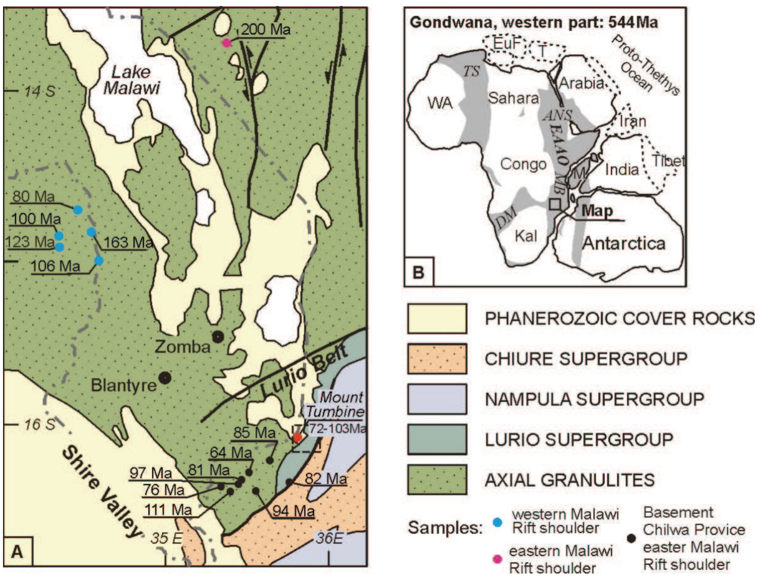

Figure 1: *Overview map (A) displaying the main lithological units and samples sites with quoted apatite fission track ages of the study area. Map was modified after Pinna et al. (1993). Map B depicts a reconstruction of western Gondwana and outlines Africa's pre-breakup setting and the study area location in East Africa (modified after Kusky et al. 2003). Abbreviations: ANS = Arabian Nubian Shield, DM = Damara Belt, EAAO = East African-Antartic Orogen, EuF = European fragments, Kal = Kalahri craton, M = Madagascar, MB = Mozambique Belt, T = Turkey, TS = Trans-Saharan, WA = West Africa craton.*

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Analyses of twenty-one samples yielded apatite fission track ages between ca. 200 Ma and 75 Ma with corresponding long to moderate mean track length of 14.3-11.5 µm. Determined kinetic parameters (D_{par}) sample mean values cluster between 2.89 µm to 1.08 µm. The results of inverse modeled apatite fission track data indicate three main cooling phases during the Early Permian, the Late Cretaceous and since Eocene times.

Early Permian cooling is related to the initiation of the Malawi rift (Zambezi pre-transform system) during a phase of intracontinental rifting within central Gondwana (Castaing 1991); synchronous with the deposition of Early Permian basal conglomerates in the northern Malawi rift segment (cf. Catuneanu et al. 2005).

Both younger episodes of rapid cooling are linked to denudation events along the evolving Malawi rift shoulders. Late Cretaceous cooling is contemporaneous with the emplacement of high level alkaline intrusions in the adjacent Chilwa province; igneous bodies derived by partial melting of the upper mantle in response crustal thinning (Eby et al. 1995). The Late Cretaceous cooling episode correlates with the deposition of the Cretaceous Red Sandstone Group in the northern Malawi rift segment (Roberts et al. 2005) and an increased sediment influx in the Zambezi Delta (Walford et al. 2005).

Cretaceous crustal thinning, transform faulting and igneous activities in southern Mozambique and in south western Madagascar and along the Davi Fracture Zone are attributed to the Late Cretaceous reorganization of the drift configuration in the proto Indic Ocean (Nairn et al. 1991; Storey et al. 1995). We link the Late Cretaceous denudation in northern Mozambique/southern Malawi to block faulting by crustal extension and transform faulting and localized up doming above high level intrusions. Crustal extension and faulting was triggered by changes in the regional intra-plate stress regime, related to the drift reconfiguration in the proto Indic. Accordingly; we propose a tectonic southward linkage of the study area into southern Mozambique. We consider the southern Malawi rift segment as a northward extension of the Mozambique Ridge transform fault into the African continent. Together with the Davi Fracture Zone, this ridge formed a set of interrelated transform faults during the Late Cretaceous. Material eroded in the southern Malawi rift segment during the Late Cretaceous denudation was transported into the Zambesi Delta via the Shire River fluviatile system (Goudi 2004).

An Eocene cooling step is inferred from some samples on the western Malawi rift shoulder and Mt. Tumbine and may be linked to regional cooling event <40-50Ma (van der Beek et al. 1998) and slightly pre-dates a second period of increased sediment influx in the Zambesi Delta in the Oligocene.

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