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Sedimentary budgets of the Tanzania coastal basin and implications for uplift history of the East African rift system

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A B S T R A C T

Data from 23 wells were used to quantify the sedimentary budgets in the Tanzania coastal basin in order to unravel the uplift chronology of the sourcing area located in the East African Rift System. We quantified the siliciclastic sedimentary volumes preserved in the Tanzania coastal basin corrected for compaction and *in situ* (e.g., carbonates) production. We found that the drainage areas, which supplied sediments to this basin, were eroded in four episodes: (1) during the middle Jurassic, (2) during the Campanian–Palaeocene, (3) during the middle Eocene and (4) during the Miocene. Three of these high erosion and sedimentation periods are more likely related to uplift events in the East African Rift System and earlier rift shoulders and plume uplifts. Indeed, rapid cooling in the rift system and high denudation rates in the sediment source area are coeval with these recorded pulses. However, the middle Eocene pulse was synchronous with a fall in the sea level, a climatic change and slow cooling of the rift flanks and thus seems more likely due to climatic and eustatic variations. We show that the rift shoulders of the East African rift system have inherited their present relief from at least three epeirogenic uplift pulses of middle Jurassic, Campanian–Palaeocene, and Miocene ages.

1. Introduction

The volumes of siliciclastic sedimentary rocks preserved in the marginal basins represent good archives of past uplifts and topographies over the continent, and are therefore a key to constrain the timing and amplitude of vertical movements, and consequently the mechanism(s) responsible of epeirogenic movements. Here we aim to unravel the vertical motion history of the catchment area located at the East African Rift System which supplies sediment to the Tanzania coastal basin. Only few estimates of sedimentation rates in the Tanzania coastal depocentres fed by the East African Rift System are published (Macgregor, 2010). They are based on a single cross-section and have therefore a low level of confidence. Based on an interpolation between 23 exploratory wells, we carried out a volumetric study of the sediments preserved in the Tanzania coastal basin from the mid-Jurassic onwards. The presented results provide a better estimate of the sediment fluxes. We then investigate the implications of our findings for the uplift timings and the topographic building of the East African rift system.

2. Geological setting

2.1. Rifting and uplift history of the East African rift system

The East African rift system (EARS) is a major topographic feature in East Africa. It is composed of two branches: the eastern branch and the western branch separated by the East African Plateau (alternatively known as the Tanzanian plateau; Fig. 1). The mechanistic links between topography and rifting as well as the timing and magnitude of the uplift of the East African Plateau are debated (Wichura et al., 2010). Available geological and geophysical data support the presence of limited relief of less than 1000 m prior to the onset of volcanism in the EARS (Smith, 1994). The earliest recorded volcanic activity took place ~40–45 Ma in the northern Turkana depression (Fig. 1; e.g., Ebinger et al., 1993; George et al., 1998; Knight et al., 2003; Furman, 2007). This was followed by the formation of the Gulf of Aden and Red Sea rifts, which separated the Nubian Plate from Arabia at approximately ~35–27 Ma (Schilling et al., 1992; Pik et al., 1999). Intracontinental rifting in East Africa is believed to have commenced in the region surrounding Lake Turkana at ~25 Ma, with volcanism and fault propagation moving southward through the Eastern and Western Rift branches into Mozambique, while simultaneously propagating

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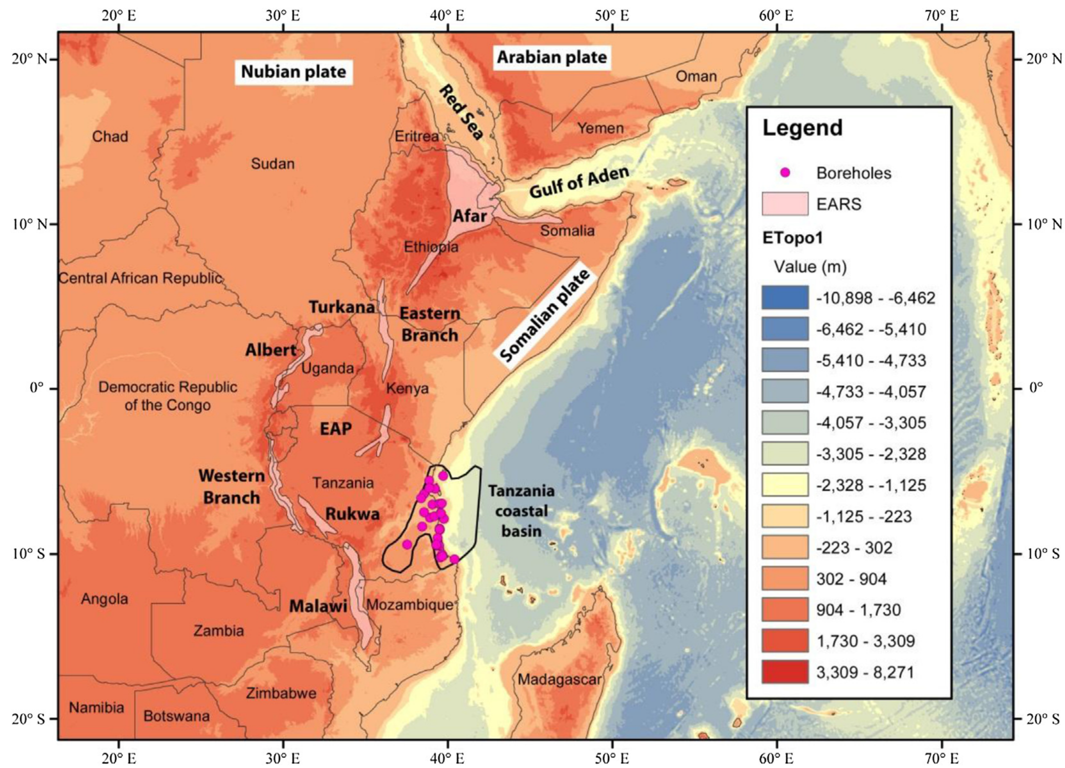

Fig. 1. Topographic/bathymetric map of the East African rift system (ETopo1; Amante and Eakins, 2009) showing its two branches (the Western branch and the Eastern branch) separated by the East African Plateau. The figure shows also the location of the Tanzania coastal basin and the boreholes used in this study. EARS: East African rift system; EAP: East African Plateau.

northwards into Ethiopia (Watson et al., 2012). The northwards propagation connected the East African Rift System with the Gulf of Aden and Red Sea spreading centers, creating the Afar Triple Junction at ~11 Ma (Smith, 1994; Chorowicz, 2005; Furman, 2007; Watson et al., 2012). The formation of this Triple junction was preceded by the arrival of the Afar plume at the start of the Oligocene (Ebinger and Sleep, 1998).

In the western rift of the EARS, Apatite fission track analysis show 3 periods of accelerated cooling and denudation (Van der Beek et al., 1998). The oldest denudation event is recorded at around 250–200 Ma and corresponds to late Karoo erosion. A second denudation phase, corresponding probably to a renewed rifting, was recorded in Late Jurassic–Early Cretaceous (~150 Ma). The youngest denudation event seems to start since ~40 Ma with a major part taking place since 20 Ma. In the Malawi and Rukwa rift flanks (Fig. 1), the denudation of the Late Karoo and the Late Jurassic–Early Cretaceous events is estimated to 2.0 ± 0.4 km each, however the Cenozoic denudation is estimated to less than 1.2 ± 0.2 km (Van der Beek et al., 1998).

In the eastern branch of the EARS, thermal history modeling of apatite fission-track and helium data (Spiegel et al., 2007) shows a rapid rock cooling during Late Cretaceous (~85–40 °C) and Late Neogene (40 °C to surface temperature). During this later period, the average denudation rates range between ~0.2 and 0.4 km/Myr. In eastern Tanzania, Noble et al. (1997) show a wide variation in apatite fission track age from 221 ± 11 to 48 ± 3 Ma, and identify three periods of accelerated cooling: during the Early Cretaceous, Late Cretaceous–Early Paleogene, and Late Eocene–Early Oligocene, In northern Tanzania, Mbede (2001) identifies three periods of rapid rock cooling: during the Early Jurassic (~195–159 Ma), Late Cretaceous (~81–75 Ma), and Early Cenozoic (~64–48 Ma).

It is widely admitted that the EARS developed above a mantle plume initiated in southwestern Ethiopia and sourcing the volcanism in the region (e.g., Duncan and Richards, 1991; Ebinger and Sleep, 1998; Ring, 2014). Most of these studies admit that the uplift of the EARS is mainly related to the plume effect. However, most of the episodes of fast rock cooling are correlated with periods of extension in the African plate and development and reactivation of high-angle faults (Noble et al., 1997; Foster and Gleadow, 1992, 1996). They are also synchronous with accelerated deposition of sediments in the East African basins like in the Selous basin (Wopfner and Kaaya, 1991). It seems that the uplift of the EARS originated from both volcanism and rifting.

2.2. Stratigraphy in the Tanzania coastal basin

The Tanzania marginal basin is composed of the Tertiary sediments associated to the fluvio-deltaic system, the underlying syn-rift Mesozoic sediments associated to the East Africa passive margin onset and the older pre break-up system (Fig. 2). This sedimentary column is characterized by several megasequences bounded by major unconformities recognized at Base Pliocene, Base Miocene, Base Middle Eocene, Base Palaeocene, Base Late Cretaceous, and Base Middle Jurassic (Break-Up Unconformity; Fig. 2). The stratigraphy of the coastal basin of Tanzania has been described by a number of authors (Kent et al., 1971; Kajato, 1982; Mpanda, 1997; Kapilima, 2003). The Triassic to Early Jurassic sediments in the coastal basin of Tanzania consists of mainly fluviatile sandstones (Fig. 2). They unconformably overlie the Precambrian gneissic basement in both Selous-Tanga and Mandawa sub-basins (Fig. 3). These two sub-basins contain Karoo rift sequences corresponding to different depositional environments. In the Selous-Tanga sub-basin, the Karoo rift sequence is represented by fluviatile sandstones resting on basal conglomerates. In the Mandawa