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# Episodes of environmental stability versus instability in Late Cenozoic lake records of Eastern Africa

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ABSTRACT

Episodes of environmental stability and instability may be equally important for African hominin speciation, dispersal, and cultural innovation. Three examples of a change from stable to unstable environmental conditions are presented on three different time scales: (1) the Mid Holocene (MH) wet–dry transition in the Chew Bahir basin (Southern Ethiopian Rift; between 11 ka and 4 ka), (2) the MIS 5–4 transition in the Naivasha basin (Central Kenya Rift; between 160 ka and 50 ka), and (3) the Early Mid Pleistocene Transition (EMPT) in the Olorgesailie basin (Southern Kenya Rift; between 1.25 Ma and 0.4 Ma). A probabilistic age modeling technique is used to determine the timing of these transitions, taking into account possible abrupt changes in the sedimentation rate including episodes of no deposition (hiatuses). Interestingly, the stable-unstable conditions identified in the three records are always associated with an orbitally-induced decrease of insolation: the descending portion of the 800 kyr cycle during the EMPT, declining eccentricity after the 115 ka maximum at the MIS 5–4 transition, and after ~10 ka. This observation contributes to an evidence-based discussion of the possible mechanisms causing the switching between environmental stability and instability in Eastern Africa at three different orbital time scales (10,000 to 1,000,000 years) during the Cenozoic. This in turn may lead to great insights into the environmental changes occurring at the same time as hominin speciation, brain expansion, dispersal out of Africa, and cultural innovations and may provide key evidence to build new hypotheses regarding the causes of early human evolution.

## 1. Introduction

The possible influence of environmental variability, both temporally and spatially, on human evolution and dispersal is an intensely debated topic in the scientific community (Potts, 1996; Trauth et al., 2005, 2007; Maslin and Christensen, 2007; Maslin and Trauth, 2009; Potts, 2013; Maslin et al., 2014). However, recent evidence indicates that episodes of stable environmental conditions play an equally important role for human evolution, dispersal, and technological innovation (e.g., Grove, 2013; Shultz and Maslin, 2013). Periods of reduced environmental variability may encourage the growth of hominin populations, sympatric evolution, and dispersal, whereas episodes of less favorable conditions, pronounced droughts, or rapid shifts between wet and dry climates could result in geographical isolation and allopatric speciation (Maslin and Trauth, 2009).

The sedimentary record of Eastern African lakes is rich in examples of both environmental stability and instability in the course of climate change (e.g., Trauth et al., 2003, 2005; Foerster et al., 2012; Junginger and Trauth, 2013; Junginger et al., 2014; Fig. 1). These lakes, particularly those that occur in the rift basins, are amplifiers of moderate climate change (Olaka et al., 2010; Trauth et al., 2010). As an example, the water level of the Early Holocene paleo-Lake Suguta rose to 300 m during a +25% change in precipitation during the African Humid Period (ca. 15 ka–5 ka; Garcin et al., 2009; Borchardt and Trauth, 2012; Junginger and Trauth,

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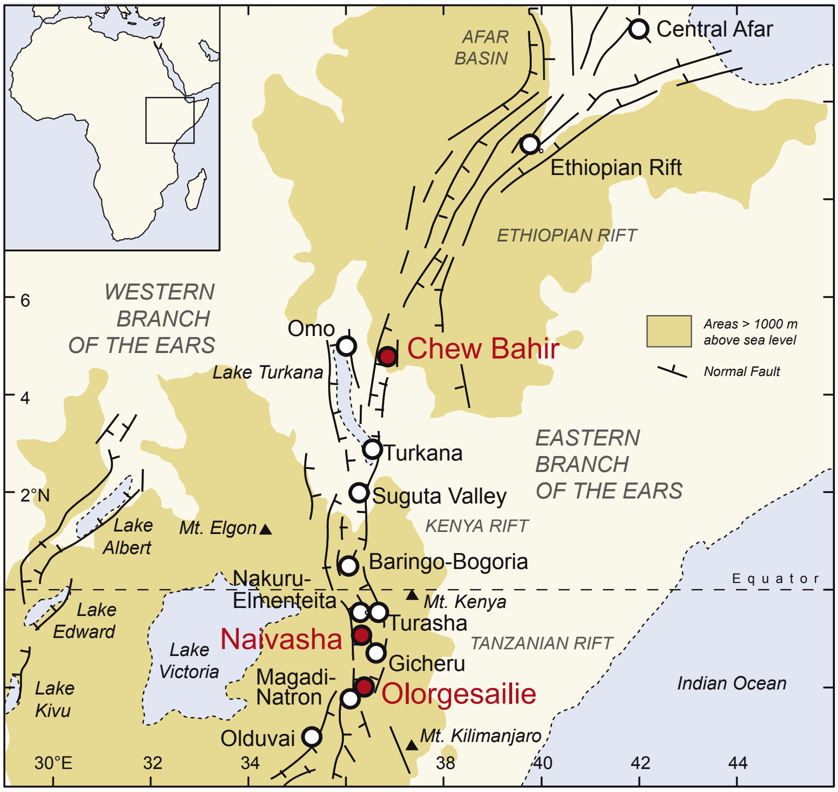

**Figure 1.** Map of Eastern Africa showing topography, faults, and lake basins. Note the location of the studied sites Chew Bahir, Naivasha and Olorgesailie (modified from Trauth et al., 2005).

2013). On the other hand, as hydrological modeling suggests, large water bodies buffer rapid shifts in climate due to their delayed response to changes in the precipitation-evaporation balance (Borchardt and Trauth, 2012). The identification and correlation of episodes of stability versus instability between lake basins, however, is unfortunately hampered by ambiguous interpretation of environmental indicators or proxies within the sediments (Owen et al., 2008, 2009; Trauth and Maslin, 2009). Furthermore, fluctuating sedimentation rates and hiatuses between radiometric age dates, which themselves contain errors, complicates the assessment of the actual timing of environmental stability versus instability (e.g., Sadler, 1999; Blaauw, 2010; Schumer and Jerolmack, 2009; Trauth, 2014).

This manuscript attempts to meet this challenge and presents three examples of stability versus instability on three different time scales in lake records in Eastern Africa: (1) the Mid Holocene (MH) wet–dry transition in the Chew Bahir basin (Southern Ethiopian Rift; between 11 ka and 4 ka), (2) the MIS 5–4 transition in the Naivasha basin (Central Kenya Rift; between 160 ka and 50 ka), and (3) the Early Mid Pleistocene Transition (EMPT) in the Olorgesailie basin (Southern Kenya Rift) (between 1.25 Ma and 0.4 Ma). First, we re-analyze the three lake records using a probabilistic technique to determine the best age model for stratigraphic sequences (Trauth, 2014). Second, we interpolate the published lake records on the new age model and distinguish episodes of environmental stability versus instability in the records. Third, we put together plausible mechanisms that cause stable or unstable conditions in the course of climate change. Last, the results are discussed in light of the importance of both stability and instability for human evolution and dispersal, providing a basis for further discussions of the influence of the environment on early humans.

## 2. Detecting episodes of stability and instability in lake records

In our analysis of episodes of environmental stability and instability, we use published lake records, which include critical episodes of Eastern African climate change and human evolution, dispersal, and cultural innovation. We use the amplitudes of water level changes as published, without revising or reinterpreting the proxies of lake levels and climate used by the authors of the original works. While the amplitudes have been left untouched, we have subjected all age models to a critical review because the timing and rate of climate change as well as its correlation with orbital forcing is essential for our analysis. Having developed consistent age models for the three records, we defined episodes of relative stability and instability by visual inspection and correlated these with orbital forcing (Laskar et al., 2004). We have not used any more sophisticated method to determine the degree of variability for two reasons: (1) the quantitative significance of the records is not sufficient to analyze them statistically, and (2) an arbitrary definition of a critical value of the variability would be necessary to separate stable from unstable episodes, which we wanted to avoid.

### *2.1. The Mid Holocene (MH) wet–dry transition in the Chew Bahir basin*

The Mid Holocene (MH) wet–dry transition in the Chew Bahir basin (Southern Ethiopian Rift) is reconstructed from five up to ~20 m long sediment cores (CB01, CB03–06) collected along a ~20 km long NW–SE transect across the basin (Foerster et al., 2012, 2014). The composite age model of the sediment cores is based on 32 AMS $^{14}$C ages derived from biogenic carbonate, fossilized