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Environmental and climatic control on seasonal stable isotope variation of freshwater molluscan bivalves in the Turkana Basin (Kenya)

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ABSTRACT

We present growth incremental stable isotope records ($\delta^{18}O$ and $\delta^{13}C$) of modern and ~2 Ma fossil bivalve shells from the semi-arid Turkana Basin (N. Kenya, S. Ethiopia). These data suggest that seasonal cyclicity in $\delta^{18}O$ and $\delta^{13}C$ recorded by modern and fossil shells is driven by wet–dry seasonal changes in host water chemistry, forced by monsoonal rainfall over the Ethiopian Highlands.

Fully lacustrine shells show lower amplitude, or even absent seasonal cyclicity in comparison with deltaic or riverine shells because of the buffering effect of the large water volume in the lake setting. Riverine shells arguably have the clearest relation to seasonally variable climate parameters. Riverine molluscs thus provide a potentially valuable proxy for varying rainfall $\delta^{18}O$ values in the Turkana Basin catchment.

Cross plots of molluscan $\delta^{18}O$ and $\delta^{13}C$ data reveal dominant environmental control on molluscan isotope values with remarkably large isotopic differences between lacustrine, deltaic and riverine environments. We interpret this isotope pattern to directly result from the different mixing proportions of Omo River source water with evaporated lake water in these environments. The interpretation of fossil molluscan $\delta^{18}O$ and $\delta^{13}C$ data in a palaeoclimatological context is not straightforward, since the potential influence of temporal changes in lake water temperature, surface evaporation or river discharge on the $\delta^{18}O$ budget of the lake is smaller than the isotopic shifts caused by shifting facies patterns in the sedimentary record.

Even though it is clear from the rich molluscan faunas that the ~2 Ma palaeo-Lake Lorenyang must have been significantly less alkaline than modern Lake Turkana and likely provided good drinking water and abundant availability of food for the different species of hominins inhabiting the region at that time, stable isotope values of molluscan bivalves are not suitable to record the difference in alkalinity between these two settings.

1. Introduction

Fluctuations in climatic and environmental conditions have been invoked as major drivers for hominin evolution and migration in Pleistocene East Africa (deMenocal, 2004; Kingston, 2007; Potts, 2007; Trauth et al., 2007; Maslin and Trauth, 2009). Especially, climate change influencing rainfall seasonality may have provided key selective forces in the evolution of the human lineage in Africa. The Turkana Basin (Kenya, Ethiopia) in the East African Rift System is well known for its rich hominin fossil record. Of particular interest in the Turkana Basin is the time period at ~2 million years ago (Ma), when palaeo-Lake Lorenyang occupied the Turkana Basin. In that climatically wet period, a hominin fauna including two early *Homo* species and *Paranthropus robustus* was present in the area (Feibel et al., 1989) (Fig. 1). To better understand the climatic and environmental context of hominin occurrence in this area, accurate palaeoclimatic and palaeoenvironmental reconstructions are required. Ideally, such reconstructions should be based on proxy records derived from local/regional climate archives.

Lake Lorenyang existed from ~2–1.7 Ma. The general hydrology of Lake Lorenyang was much like that of modern Lake Turkana, with the (palaeo) Omo River from the N as its main (~90%) water source (Yuretich, 1979; Joordens et al., 2011). In contrast with modern Lake Turkana, Lake Lorenyang had a rich molluscan fauna (Williamson, 1982; Van Bocxlaer and van Damme, 2009).

Seasonality in equatorial Africa is primarily expressed as monsoonal rainfall variation (Nicholson, 1999; Aronson et al., 2008), which is

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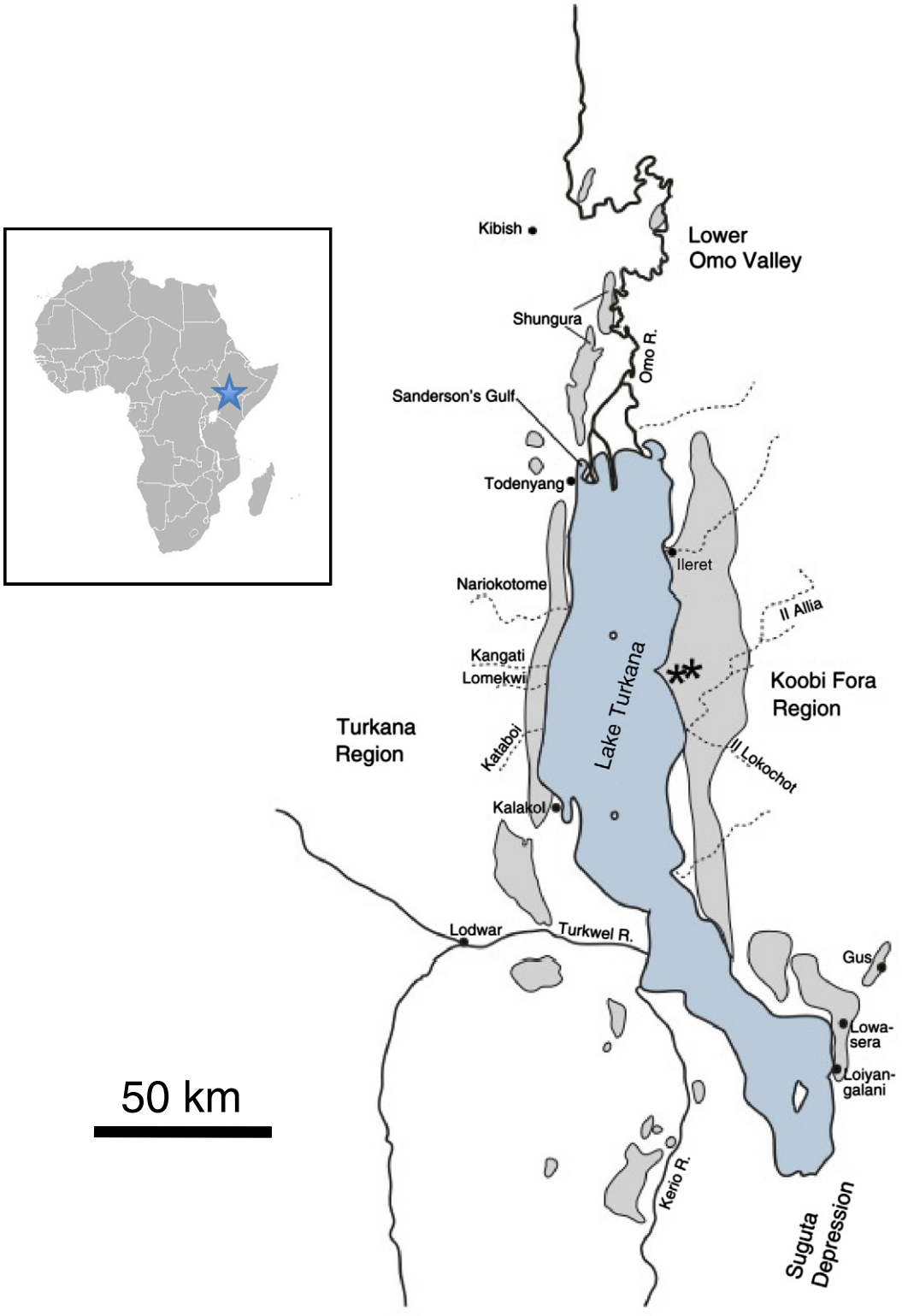

Fig. 1. Location map of Lake Turkana with collection sites of modern and fossil molluscs indicated. Grey zones mark the general areas around the lake with outcropping Pleistocene–Holocene sedimentary sequences.

reflected in strong seasonal fluctuation of Omo River discharge into the lake. Seasonal water balance changes affect oxygen isotope variation of Turkana Basin lake waters ($\delta^{18}O_w$), with lowest $\delta^{18}O_w$ values corresponding to peak Omo River discharge (typically occurring May–November; (Yuretich and Cerling, 1983). Seasonal variation in lake- and river-water oxygen and carbon isotope ratios is captured at high temporal resolution in growth incremental records of aragonitic molluscan shells ($\delta^{18}O_{ar}$ and $\delta^{13}C_{ar}$).

Generally, the conversion of (molluscan) carbonate stable isotope records into climatic or environmental parameters like temperature, rainfall amount, or lake level is a challenging task, because all these climate parameters influence molluscan stable isotope records simultaneously,