Quaternary Science Reviews 155 (2017) 127–135

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Glacial-interglacial vegetation change in the Zambezi catchment

L.M. Dupont*, H. Kuhlmann

University of Bremen; MARUM — Center for Marine Environmental Sciences, Germany

ARTICLE INFO

Article history:
Received 26 August 2016
Received in revised form
14 November 2016
Accepted 15 November 2016

Keywords:
Pleistocene
Palaeovegetation
East Africa

ABSTRACT

Changes in the environment are thought to have had strong impact on human evolution. The pollen record of GeoB9311, retrieved offshore of the Zambezi River mouth, indicates glacial-interglacial changes in the vegetation of southern East Africa with enhanced forests in the coastal area during interglacials, more Afromontane forest and ericaceous bushland during glacials and an increase in mopane woodland during the transitional periods. C_4 swamps, probably with papyrus, might have spread during the more humid phases of the glacial, while mangroves responded sensitively to changes in sea level. The spread of open ericaceous bushland and Afromontane forest during glacials is found for most of Southern Africa with the exception of the extreme south and southwest regions. In contrast to the western part of the continent, forest and woodland in East Africa did not completely disappear during the glacial. It seems that on a regional scale climatic perturbations of the vegetation are less severe than in West Africa.

1. Introduction

East Africa is one of regions of paramount importance to the development of humans. Lake level studies indicate that Plio-Pleistocene climate changes and large variability in water availability in East Africa had strong impact on the evolution of hominins (e.g. Trauth et al., 2007, 2010). However, the response of biomes to climate might have been even more important than climate change itself to the people who lived in any particular environment, depending on its resources. While many pollen and isotope studies focus on their indicator value for changes in precipitation and temperature (e.g. Bonnefille and Riollet, 1988; Vincens, 1993; Vincens et al., 1993, Vincens et al., 2005; Castañeda et al., 2007, 2009; Tierney et al., 2008, 2011, 2013; Bouimetarhan et al., 2015; Singarayer and Burrough, 2015; McWethy et al., 2016), the information about biomes and vegetation change is at least as relevant (Vincens, 1991; Debusk, 1998; Bonnefille and Chalié, 2000; Vincens et al., 2007b; Ivory et al., 2012, 2014, 2016a). Many valuable studies concern East African climate and vegetation change during the Holocene and deglaciation, but few studies cover the glacial or a part of it (Debusk, 1998; Vincens et al., 2007b; Tierney et al., 2008; Singarayer and Burrough, 2015; Chevalier and Chase, 2015, 2016). Only recently, studies covering more than a glacial-interglacial cycle have been conducted on sediments of Lake Malawi (Lyons et al., 2015) and the marine core MD96-2048 off the Limpopo River (Caley et al., 2011) covering 1.3 and 0.9 Ma, respectively. Superimposed on glacial-interglacial variability, a trend towards less grasslands and more forest in the Malawi Basin since 1.3 Ma has been inferred from stable carbon isotopes of wax measured on sediments of Lake Malawi (Johnson et al., 2016). However, the lowermost part of this record contains indication of tropical marshlands, which also would have left a C_4 signal (Ivory and Russell, 2016; Ivory et al., 2016b) not related to tropical grasslands or savannah. Further south, in the Limpopo basin, a trend toward more woodland has been found for the past 400 ka (Castañeda et al., 2016). Both studies infer strong influence of Indian Ocean sea surface temperatures on climate and vegetation of southern East Africa (Dupont et al., 2011; Johnson et al., 2016; Castañeda et al., 2016).

Pollen analysis and composition of plant waxes provide complementary information about the vegetation. To assess late Pleistocene environmental variability over a glacial-interglacial cycle, we studied a 5.5 m long marine pollen record covering ca. 250 ka (Marine Isotope Stage, MIS 7-1) retrieved from the west tropical Indian Ocean in the vicinity of the Zambezi River mouth. Although marine pollen records are less detailed than terrestrial ones, they integrate a larger area and are thus less prone to local features. Dating and stratigraphy of marine cores beyond the range of radiocarbon dating are usually superior to those of terrestrial sequences. We focus on the response of the East African vegetation over a glacial-interglacial cycle in comparison with that of other parts of tropical Southern Africa.

* Corresponding author.
E-mail address: dupont@uni-bremen.de (L.M. Dupont).

http://dx.doi.org/10.1016/j.quascirev.2016.11.019

1.1. Climate

East African climate and its forcing mechanisms are complex. The modern climate of East Africa is influenced by the westerly flow of humid Congo air, and by the relatively dry NE and SE monsoons (Nicholson, 1996), whereby precipitation patterns are predominantly linked to Indian Ocean sea surface temperature variability (Appelhans and Nauss, 2016). The NE monsoon influences the region during December to February when the Intertropical Convergence Zone (ITCZ) reaches its southernmost latitude at ca. 20°S (Leroux, 1983). Precipitation ranges between 800 and 1200 mm/a. Most of the rain falls in the form of rainstorms during the wet season from November to April. The cool season from May to August is warm and dry during the day with cool nights. The third season from September to November is hot and increasingly humid. In the coastal lowlands annual precipitation is somewhat less but the dry season is less severe and relative humidity is high (White, 1983).

Past climates of East Africa are thought of as being dominated by the monsoon. The monsoon is recently recognised as a global-wide three-dimensional structure of zonal (Walker cells) and meridional atmospheric circulation (Hadley circulation) and a manifestation of the seasonal migration of the ITCZ (Trenberth et al., 2000; Wang, 2009). As the global monsoon on orbital time-scales is strongly affected by the meridional temperature gradient and the distribution of solar insolation (Schneider et al., 2014; Mohtadi et al., 2016) its variability is coherent with precessional cycles (Cheng et al., 2012). Hence, latitudinal shifts in the migration pattern of the ITCZ or meridional shifts in the Congolian Air Boundary (CAB), global and regional temperature gradients, and the Walker Circulation have been invoked to explain the variability in the hydroclimate of East Africa (see for summary Singarayer and Burrough, 2015 and references therein). Glacial-interglacial marine boundary conditions such as the position of the southern Subtropical Front and Indian Ocean sea surface temperatures probably also influenced the climate of East Africa (Caley et al., 2011; Dupont et al., 2011; Tierney et al., 2008, 2013; Truc et al., 2013; Chevalier and Chase, 2015; Castañeda et al., 2016; Johnson et al., 2016).

On shorter than orbital time-scales, perturbations of climate in relation with the variability of the Atlantic Meridional Overturning Circulation (such as Younger Dryas and Heinrich Events) have been linked to southward shifts of the ITCZ (Mohtadi et al., 2014). A southward shift of the ITCZ would have resulted in aridity north of Lake Malawi and in wetter conditions between 15 and 20°S (e.g. Garcin et al., 2006; Castañeda et al., 2007; Verschuren et al., 2009; Tierney et al., 2010; Barker et al., 2011; Schefuß et al., 2011; Bouimetarhan et al., 2015). Eastward shifts of the CAB associated with northward shifts of the ITCZ combined with the atmospheric barrier of the East African Rift System could explain the east-west humidity gradient (Tierney et al., 2011). However, a transient simulation over the deglaciation period identified greenhouse gasses and sea surface temperatures as the more important forcing mechanisms of precipitation variability in southern East Africa (Otto-Bliesner et al., 2014).

1.2. Vegetation

The natural modern vegetation along Africa's eastern coast between southern Somalia in the north and the mouth of the Limpopo in the south consists of a 50–200 km broad belt of forests and woodlands growing mostly at altitudes of less than 200 m (Fig. 1). This vegetation is phytogeographically classified as the Zanzibar-Inhambane regional mosaic, which has some affinities with the flora of the southeast coastal belt (Tongaland-Pondoland) and with the lowland rainforests of the Guineo-Congolian region (White, 1983). Mangrove swamps line the coast of Mozambique. Inland of the East Coast forest borders the eastern part of Zambezian phytogeographical region with several types of woodland. Zambezian Miombo woodland grows on well drained soils that is often stony and is dominated by *Brachystegia* (miombo tree). Zambezian Mopane woodland occupies the large river valleys and is dominated by *Colophospermum mopane*. Mopane trees mostly grow in the drier regions with precipitation down to 800 mm/a. Zambezian woodland that is neither dominated by miombo nor mopane trees has a rich flora if not degraded by disturbance or fire. Afromontane forest occurs mostly at altitudes between 1200 and 2500 m, and trees such as *Ilex mitis*, *Podocarpus falcatus*, and *Prunus africana* are widespread. Higher in the mountains, ericaceous bushland is common except for exposed rocky ridges and shallow soils where short shrubs grow together with Cyperaceae (sedges), Poaceae (grasses), lichens and bryophytes (mosses). Open vegetation also occurs on (seasonally) waterlogged soils as edaphic valley grasslands or permanent swamps with, for instance, papyrus (*Cyperus papyrus*). Outside the mountains, grasslands on dry soils are secondary. The secondary grasslands remain open while frequently burnt, and scattered fire-resistant trees from the original vegetation may occur (Vesey-Fitzgerald, 1970; White, 1983; Chapman et al., 2001).

Terrestrial pollen records indicate that during the glacial, mountainous vegetation with Ericaceae and *Podocarpus* prevailed in the mountains of the Western Rift, although the vegetation became less forested during the last glacial maximum (Bonnefille and Chalié, 2000). Similar glacial vegetation has been recorded at Mount Kenya and from Uganda (Coetzee, 1967; Marchant et al., 1997). Also around Lake Tanganyika and Lake Rukwa, glacial vegetation consisted of open woods with mountain elements such as Ericaceae and *Podocarpus*, which changed into Zambezian woodland and forest during the Holocene (Vincens, 1991, 1993; Vincens et al., 2005). Further south, at Lake Malawi, Afromontane forest retreated when both drought tolerant Zambezian woodland as well as tropical seasonal forest increased after the last glacial maximum (Ivory et al., 2012). In the small catchment area of Lake Masoko (just north of Lake Malawi), vegetation consisted of open grasslands between 42 and 23 ka. After 23 ka semi-deciduous forest established in the area, and only after 12 ka Zambezian woodland developed indicating that the later part of MIS 2 (14–29 ka) was rather humid with a short dry season, which lengthened and became more severe at 12 ka (Vincens et al., 2007b). All those records indicate that ericaceous vegetation with *Podocarpus* dominated the glacial landscape. Isotope studies on plant wax from Lake Tanganyika suggest that this vegetation did not respond to the glacial fluctuations in temperature and precipitation but rather showed internal variability (Tierney et al., 2010). Over longer time periods, a development to more woodland and increased tree cover in southern East Africa since the middle Pleistocene might have occurred (Castañeda et al., 2016), which is in contrast to the development in northern Africa over the same period (e.g. DeMenocal, 2004).

2. Materials and methods

The 7.5 m long gravity core GeoB9311-1 has been retrieved in 2005 during Meteor cruise M63/1 from 1407 m water depth at 21°33'S 36°25'E (Türkay and Pätzold, 2009, Fig. 1). The site is located about 300 km south of the Zambezi River mouth and about 150 km offshore of the Sabi River. The Zambezi River is the most important source of sediments to the Mozambique Shelf during periods of sea-level high-stands, when the main discharge is directed northwards. However, during periods of sea-level lowstands, the Zambezi River incised the exposed shelf and sediments