Earth and Planetary Science Letters 449 (2016) 79–88

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

A new perspective on West African hydroclimate during the last deglaciation

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ARTICLE INFO

Article history:
Received 20 November 2015
Received in revised form 22 May 2016
Accepted 23 May 2016
Available online 7 June 2016
Editor: M. Frank

Keywords:
West African Monsoon
African humid period
deglacial climate
foraminiferal geochemistry
X-ray fluorescence

ABSTRACT

Widespread drought characterized the Heinrich 1 and Younger Dryas cold periods of the last deglaciation throughout much of Africa, causing large increases in dust emissions from the Sahara and Sahel. At the same time, increases in wind strength may have also contributed to dust flux, making it difficult to interpret dust records alone as reflecting changes in rainfall over the region. The Niger River has the third largest drainage basin in Africa and drains most of the Sahara and Sahel and thus preserves and propagates climatic signals. Here, we present new reconstructions of Niger Delta sea surface salinity and Niger River discharge for the last 20,000 years in order to more accurately reconstruct the onset of the Western African Monsoon system. Based on calculated $\delta^{18}O_{SEAWATER}$ ($\delta^{18}O_{SW}$) and measured Ba/Ca ratios in planktonic foraminifera, these new records reflect changes in sub-Saharan precipitation across the Niger River Basin in West Africa and reveal that the West African Monsoon system began to intensify several thousand years after the equatorial Monsoon system in Central Africa. We also present new records of primary productivity in the Niger Delta that are related to wind-driven upwelling and show that productivity is decoupled from changes in Niger River discharge. Our results suggest that wind strength, rather than changes in monsoon moisture, was the primary driver of dust emissions from the Sahara and Sahel across the last deglaciation.

1. Introduction

Prolonged droughts across West Africa impart significant socio-economic hardships on developing nations. Complex interactions between the ocean, land, atmosphere, and local solar insolation result in non-linear feedbacks that make understanding past and future climate changes in this part of the world extremely difficult (deMenocal et al., 2000). These complexities are exemplified in paleo-hydrological reconstructions from West Africa, where the deglacial history of precipitation varies as a function of both proxy and location. Northwest African proxy reconstructions of continental aridity, including dust flux and grain size records from continental slope sediment cores, point to a severe and widespread drought that characterized Heinrich Event 1 (H1, 16.7–15.1 kyr) (Collins et al., 2013; Mulitza et al., 2008; Stager et al., 2011; Tjallingii et al., 2008). During this time, dust emissions from the Sahara and Sahel were on average five times higher compared to the early Holocene humid interval (McGee et al., 2013). In contrast, previously published records of sea surface salinity (SSS) and river discharge from the eastern Gulf of Guinea, which have been interpreted to reflect West African precipitation runoff, suggest little or no change in West African runoff during H1 (Weldeab et al., 2007). A second discrepancy between regional precipitation proxies occurs during the deglacial cold reversal known as the Younger Dryas (YD, ∼11.2–12.9 kyr). During this period, records from northwest Africa record much smaller increases in dust flux relative to H1, implying less intense drought conditions (Mulitza et al., 2008; Tjallingii et al., 2008), whereas SSS and river discharge records from the Gulf of Guinea suggest a severe reduction in riverine discharge during the YD (Weldeab et al., 2007). Clearly, questions surrounding the drought history of West Africa remain.

Another uncertainty in the interpretation of published dust records regards the extent to which wind speed versus aridity influences dust fluxes. During the H1 and YD cold reversals, steepened meridional temperature gradients in the North Atlantic resulted in stronger trade winds over West Africa (McGee et al., 2010). Intensified winds have the ability to increase dust mobilization, resulting in drought-like dust signals independent of hydroclimate change across the Sahara and Sahel during H1 and

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http://dx.doi.org/10.1016/j.epsl.2016.05.038
0012-821X/

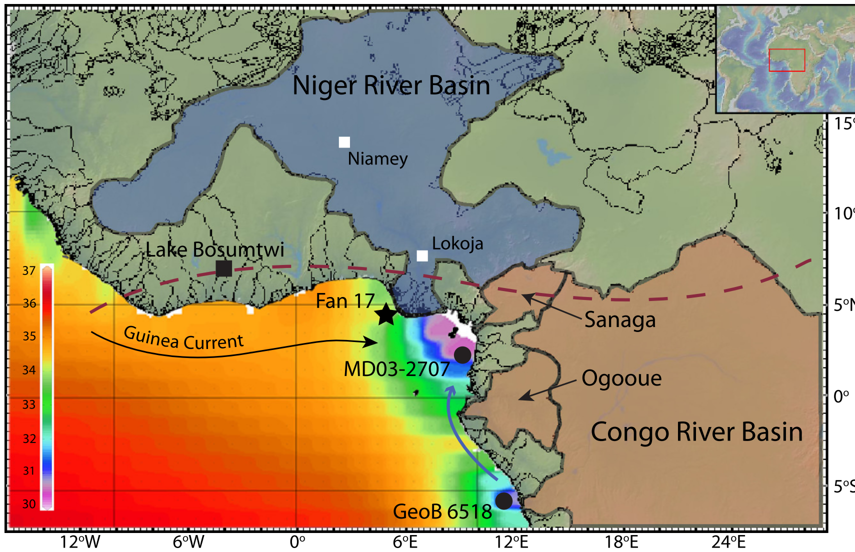

Fig. 1. Regional map of major West and Equatorial African river basins that drain into the Gulf of Guinea. Niger Delta core Fan 17 (black star) was recovered in 1178 m of water and less than 100 km equidistant from the two major Niger River distributaries. MD03-2707 (black circle) is located 400 km southeast of the Niger River Delta in the low salinity core for the Gulf of Guinea, where freshwater from the Niger and other major Central Africa rivers including the Congo River (blue arrow) also contribute to the low SSS. Red dashed line represents the approximate position of surface wind convergence during boreal winter. The Niger and Congo River drainage basins are outlined by shaded blue and brown, respectively. GeoB-6518 (black circle) is located near the mouth of the Congo River. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the YD. Recently, observations linked wind strength, not aridity, as the most significant source of inter-annual to decadal variability of Saharan aerosol emissions (Ridley et al., 2014; Rodriguez et al., 2015), and modeling studies support the role of wind as a driver of enhanced deglacial dust flux (Murphy et al., 2014). Nevertheless, there is limited evidence of sub-Saharan hydroclimate change during the deglaciation to confirm aridity patterns, making it difficult to determine whether changes in continental aridity or wind strength played a more important role in driving deglacial dust emissions from the Sahara and Sahel.

In order to more accurately reconstruct temporal changes in the West African Monsoon (WAM) system across the last deglaciation, we present new records of hydrologic change in the Niger River drainage basin from sediment core Fan 17 (4.81°N, 4.45°E, 1178 m water depth) over the last 21 kyr based on stable oxygen isotopes and trace metal analyses on the planktonic foraminifera *Globigerinoides ruber*. We combine Mg/Ca-sea surface temperature (SST) estimates with measured $\delta^{18}O_{calcite}$ ($\delta^{18}O_{c}$) values to calculate $\delta^{18}O_{sw}$ values, a proxy for SSS. In addition, we measure Ba/Ca ratios in *G. ruber* as a proxy for past discharge variability from the Niger River. We then compare our results with $\delta^{18}O_{sw}$ and Ba/Ca records from a core located in the Gulf of Guinea, MD03-2707 (Weldeab et al., 2007), to explore subtle differences in the timing of regional monsoon development during the deglaciation. Core MD03-2707 is located farther east of Fan 17 in the low salinity core of the Gulf of Guinea, very close to equatorial river runoff. Using the differences between the Fan 17 and MD03-2707 Ba/Ca records, we show that monsoon onset over West Africa and the Sahel was more gradual than previously thought, and has important implications for the interpretation of deglacial dust records from the northwest coast of Africa.

2. Oceanographic setting

Sediment core Fan 17 was collected by Shell Oil in 2007 and donated to Texas A&M University for research purposes (Fig. 1). An intraslope sandy turbidite lobe deposit exists to the northwest of Fan 17, but seismic data indicates that Fan 17 is not disturbed by mass wasting or turbidity currents depositing sand on the intraslope lobe. Mean annual SST at the core location is 27.8 °C with less than 1 °C of seasonal variability. SSS in the Niger Delta ranges from 32 during the wet summer months to 34.5 during the dry winters, with an annual average of 33.4. The low SSS during the summer months is a direct result of the monsoon that develops across West Africa (Fig. 1). The Guinea Current running along the Guinea Coast moves discharge from the Niger River eastward. The location of Fan 17 close to the shelf break and roughly 100 km equidistant from the two main distributaries of the Niger River make it ideal for continuously monitoring river runoff regardless of changes in sea level or delta lobe avulsion. The current shelf break depth for the Niger Delta is ~90 m. Given global sea level was 120 m lower during the LGM, the shelf would have been exposed until after meltwater pulse-1A (MWP-1A) when sea-level abruptly rose 20 m to ~90 m below present. Thus, the freshwater plume would have been located even closer to the Fan 17 core site prior to the YD.

During boreal summer, differential heating between the land and ocean creates an onshore wind that transports moisture rich air from the Gulf of Guinea to a zone of ascent caused by the juxtaposition between the axes of two mid-level atmospheric jets (Nicholson, 2008). The resultant tropical rainbelt sets up over the Niger River Basin and is responsible for producing most of the rains associated with the seasonal monsoon throughout much of sub-Saharan West Africa, including the Sahel. Hydrographic data along the Niger River show that precipitation falling in the Sahelian latitudes of the Niger River Basin (12–18°N) is the main determinant of the magnitude of discharge at the Niger Delta, and riverine flow is therefore strongly related to the intensity of the rainbelt (Itiveh and Bigg, 2008). This discharge contributes to the very low salinities of the modern Gulf of Guinea (Fig. 1). However, the Niger River is not the only river that contributes to the low salinities in the Gulf of Guinea. Freshwater from the Ogooue and Congo rivers also contribute large amounts of runoff to the Gulf of Guinea along with other smaller equatorial rivers (Fig. 1).

3. Methods

3.1. Age model development

The age model for Fan 17 is based on 11 radiocarbon-dated intervals measured using accelerator mass spectrometry at Lawrence