Palaeogeography, Palaeoclimatology, Palaeoecology 415 (2014) 165–174

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Holocene paleohydrology of Quistococha Lake (Peru) in the upper Amazon Basin: Influence on carbon accumulation

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A R T I C L E I N F O

Article history:
Received 3 September 2013
Received in revised form 13 August 2014
Accepted 18 August 2014
Available online 27 August 2014

Keywords:
Paleohydrology
Amazon River
Carbon accumulation
Organic matter
Floodplain lake
Avulsion

A B S T R A C T

In order to study the impact of hydrological changes of the Amazon River on sedimentation process and organic matter (OM) accumulation, in an Amazonian floodplain lake during the Holocene, three sediment cores were collected from Quistococha Lake, Peru. The cores were dated with ^{14}C accelerator mass spectrometry (AMS), radiographed, and described. Bulk density, granulometry, loss on ignition (LOI), total organic carbon (TOC) and total nitrogen (TN) contents were measured, and stable isotopic composition of TOC ($\delta^{13}C$) and TN ($\delta^{15}N$) and carbon accumulation rates were determined. Two distinctive sedimentary depositional phases were identified based on the lithology, granulometry and the geochemical characteristics of sedimentary OM. Between about 6100 and 4900 cal years BP, the lake was under strong influence of the Amazon River. The river induced highest sedimentation rates (mean 0.5 cm yr^{-1}), a predominant deposition of relatively coarse particles (coarse silt), low LOI (1%), low contents of organic carbon (0.5%), low C/N ratios (~10), relatively low $\delta^{13}C$ values (−26.0‰), very laminated sediments and high carbon accumulation rates between 14 and 29 g C m^{-2} yr^{-1}. A gap in the record between about 4900 and 2600 cal years BP corresponds to a sedimentation hiatus during the dry mid Holocene. This gap is probably due to an avulsion of the main stem that induced significant changes in the lacustrine sedimentation. After 2600 cal years BP, sedimentation resumed but now the lake was isolated far from the Amazon influence. The resumption of sedimentation corresponds to wetter conditions during the late Holocene and an increase in water levels. The lake was now characterized by very low sedimentation rates (0.02 cm yr^{-1}), fine organic-rich sediments with high LOI (between 20 and 80%), TOC (between 10 and 40% of TOC), high C/N ratio (20), and lower $\delta^{13}C$ and $\delta^{15}N$ indicating a predominant deposition of C_3-plant derived OM. Carbon accumulation in this sedimentary depositional phase was about 8 g C m^{-2} yr^{-1}. These results, combined with those of studies from other isolated lakes (Cordeiro et al., 1997, 2008; Turcq et al., 2002) and from other floodplain lakes (Moreira et al., 2012; Moreira et al., 2013), point out that floodplain lakes with strong influences from the Amazon River act as important carbon sinks in the Amazon Basin despite their low carbon concentrations.

1. Introduction

Biogeochemical and hydrological processes in floodplain lakes are directly dependent on the hydrological cycle of the river (Moreira-Turcq et al., 2013). The main explanation for this intrinsic relation is the flood pulse concept (Junk et al., 1989), where river and floodplains, from a hydrological point of view, must be considered as a single unit because of their common water and sediment budget (Junk, 1997). This is more evidenced in the Amazon Basin, where the water level variation can reach ~10 m during an annual hydrological cycle. The degree of connection between the river and its floodplain depends on the water level of the river. These periodic oscillations between the terrestrial and aquatic phases of lakes are recorded in sedimentary deposits (Moreira et al., 2013). Through the sedimentary records, it is possible to detect changes in dynamics of vegetation, rivers, and lakes (Behling and Costa, 2000; Behling et al., 2001; Irion et al., 2006). Floodplains are extremely complex and dynamic systems (Moreira-Turcq et al., 2004) and their constant changes are influenced by neotectonic movements and/or hydrological changes dependent on climate and vegetation cover. These changes can have great impact on the morphology of the basin, causing avulsions, newly impeded floodplain lakes, and island development (Franzinelli and Latrubesse, 1993; Mertes et al., 1996; Costa et al., 2001; Latrubesse and Franzinelli, 2002; Horbe et al., 2011).

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http://dx.doi.org/10.1016/j.palaeo.2014.08.018
0031-0182/

The potential relevance of inland waters, especially floodplain lakes, to the global carbon budget has received more attention recently, highlighting that lakes represent an important component of the terrestrial C cycle (Cole et al., 2007). In this context, several studies discuss the role of the Amazon Basin in the global carbon cycle, but the importance of carbon storage in Amazon floodplain lakes has been suggested only recently (Moreira-Turcq et al., 2004; Cordeiro et al., 2008; Moreira et al., 2012, 2013). In addition, Lähteenoja et al. (2009) point out the important role of peat carbon accumulation in the same Amazonian region as our study. According to these authors, the carbon accumulation rates in these deposits are on the same order of the most carbon rich peatlands (Tolonen and Turunen, 1996; Page et al., 2004).

The aims of this paper are i) to provide new sedimentological data recording the dynamics of the Amazon River during the Holocene, which is still very poorly documented; ii) to understand the paleohydrological changes that controlled carbon accumulation in Quistococha Lake, and iii) to discuss the implications of this accumulation to regional and global carbon cycles.

2. Material and methods

2.1. Study area

Quistococha Lake (Fig. 1) is located near the Peruvian city of Iquitos in the western part of the Amazon Basin at a distance of some 2500 km west of the Atlantic Ocean and 400 km east of the Andes. The lake (3°49′46.87S/ 73°19′05.67W) is situated between a 15 m high terrace forming the western margin of the recent Amazon floodplain, and the River Itaya draining the alluvial plain to Iquitos (Rasanen et al., 1991). The lake is also part of the Quistococha Reserve, an environmental conservation area, located 10 km southwest of the center of Iquitos. The lake is largely surrounded by extensive *Mauritia flexuosa*, has a free water surface of 1 km^2, a depth of about 3.2 m, clear water and extremely low conductivity (Hegewald and Schnepf, 1978; Rasanen et al., 1991). The planktonic composition of the lake is mainly of desmids, which are dominated by the *Cosmarium* at 58% with the Chlorococcales representing only 1% (Hegewald and Schnepf, 1978). During this study, suspended sediments in Quistococha Lake were found to contain 38% of POC having a δ^{13}C value of −23.25‰, a δ^{15}TN value of 9.43‰, and a C/N ratio of 9.4.

According to climate records, the average annual temperature in the city of Iquitos is 26 °C and precipitation totals over 1500 mm yr^{-1} with a relatively dry season from June to September when monthly rainfall is less than 50 mm (Marengo, 1983; Figueroa and Nobre, 1990; Marengo, 1991). At Iquitos the seasonal variation in the level of the Amazon River can reach 10 m (Kalliola and Puhakka, 1993). The rainy season occurs from October to May, which is characteristic of the South American Monson climate. The flooding of floodplain lakes can happen during the rainy season, and the highest water levels occur in April–May (Lamotte, 1990). Throughout the dry season, floodplain lakes lose their connections to the rivers, and their main sources of water are rainfall and streams that drain the basin (Kaandorp et al., 2003; Espinoza Villar et al., 2008). This marked seasonal variation in precipitation leads to the formation of two distinct landscapes in western Amazonia: the "*Terra Firme*" forest (unflooded upland) and the floodplain ("*várzea*") that is partially flooded during the wet season (Kaandorp et al., 2003). The floodplain that temporarily floods areas occupies about 8% of Peruvian Amazonia (Salo et al., 1986). However,

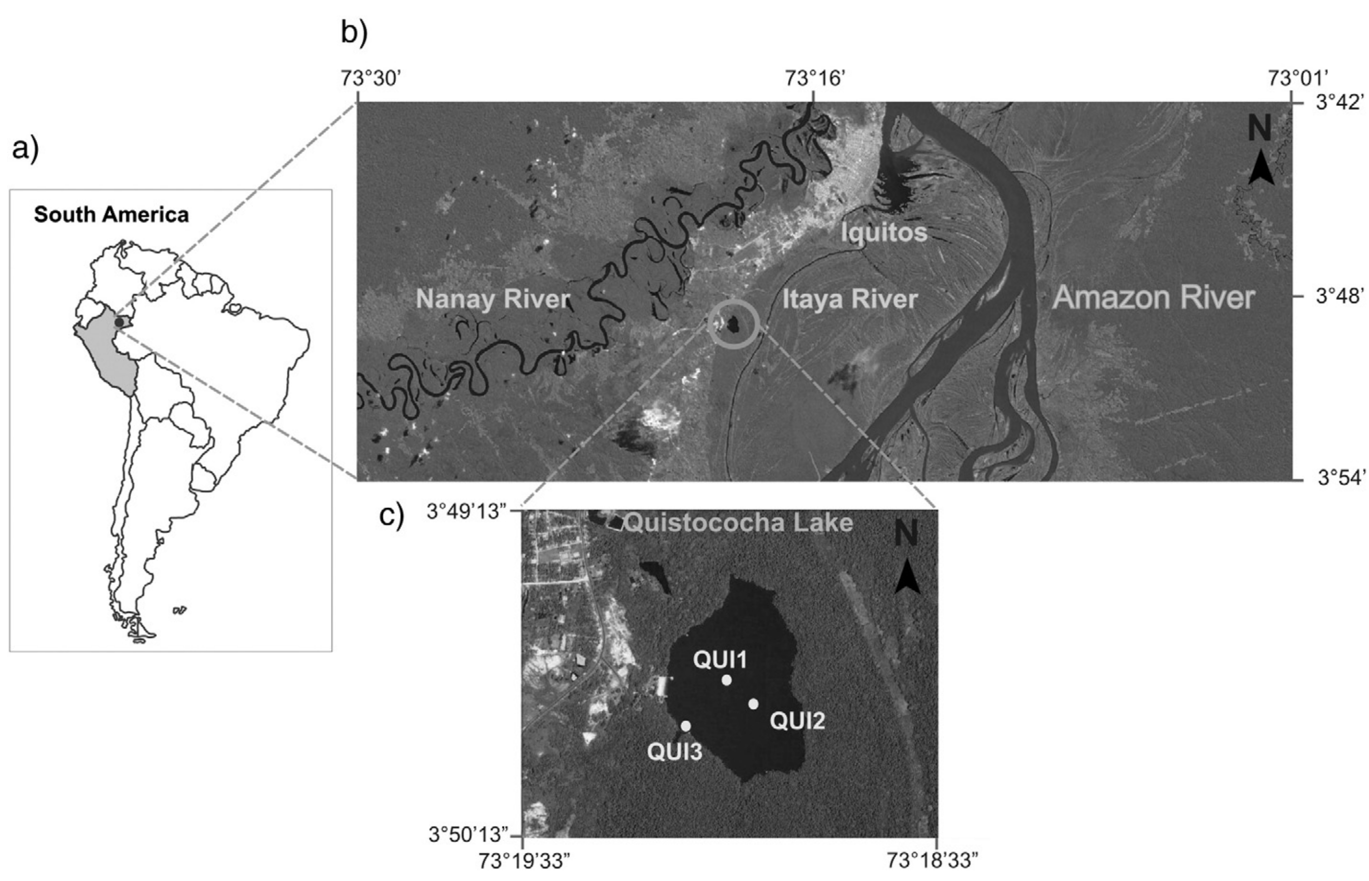

Fig. 1. Location of the study area: (a) Peru, South America, (b) Quistococha Lake with the Itaya River and the Amazon River on the on the right side and the Nanay River on the left side, and (c) locations within Quistococha Lake of the three cores used in this study.