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Holocene paleoenvironmental reconstruction in the Eastern Amazonian Basin: Comprido Lake

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A B S T R A C T

Two sediment cores were studied from Comprido Lake, a black water floodplain lake located near Monte Alegre City, Eastern Amazonian Basin. The total organic carbon (TOC), nitrogen content (TN), $\delta^{13}C_{TOC}$, sedimentary chlorophyll, diatom record and mineralogical composition revealed different hydrological and climatic regimes during the Holocene. Between 10,300 and 7800 cal yr BP, a dry climate was suggested by low values of TOC and chlorophyll derivatives concentrations that are related to the development of a C_4 grasses on unflooded mud banks. A gap in sedimentation due to a complete dryness of the lake occurred between 7800 and 3000 cal years BP corresponding to the Middle Holocene dry phase. From 3000 cal years BP onwards a gradual increase of the TOC, chlorophyll derivatives and *Aulacoseira* sp. suggest an increase in the productivity and in water lake level due to the high water flow of the Amazon River and the catchment area as well. The Comprido Lake record indicates that the Late Holocene in this region was characterized by a wetter climate, as also observed in other records of the Amazonian Basin.

1. Introduction

The Amazonian Basin contains the largest rainforest ecosystem, representing ~50% of the total tropical rainforest area in the world. This large area inevitably plays a significant role in modulating continental and global climate and carbon cycles (Mayorga and Aufdenkampe, 2002). In order to predict the impact of anthropogenic activities on future climate, global climate models are used and, to validate them, results of paleoclimate records are needed.

Lakes contained in closed basins experience changes in water volume and water chemistry that are mainly caused by variations in the precipitation–evaporation balance, and therefore, they are recorders of the local and regional hydrology (Vélez et al., 2006). However, floodplain lakes can also record hydrological variations in the Amazon River, although much of the Amazon history in the past has been derived from studies of lakes isolated from the hydrological dynamics of the Amazon River and thus, less is known about floodplain paleohydrology.

Growing evidence indicates that the Amazon Basin repeatedly experienced dryness during the Early and Middle Holocene (Absy, 1979; Behling and Hooghiemstra, 1999; Behling et al., 2001; Bush et al., 2007; Cordeiro et al., 1997, 2008; De Freitas et al., 2001; Desjardins et al., 1996; Irion et al., 2006; Mayle et al., 2000; Mayle and Power, 2008; Moreira et al., 2012; Saldarriaga and West, 1986; Sifeddine et al., 1994, 1998, 2001; Soubies, 1980; Turcq et al., 1998, 2002; Weng et al., 2002), shifting to a wetter condition in the Late Holocene (Behling et al., 2001; Behling and Hooghiemstra, 1998; Behling and Costa, 2000; Cordeiro et al., 2008). These Holocene climate variations appear to be influenced by orbitally driven southward migration of the Intertropical Convergence Zone (ITCZ), causing convective rainfall increase and thus more humid conditions in the Amazonian Basin (Mayle et al., 2000). Understanding how these climatic variations can affect different ecosystems in the Amazonian Basin remains a challenge.

In order to improve understanding of how the Holocene hydrology and ecosystem dynamics of a floodplain lake, mineralogical and organic geochemical parameters were analyzed in a sediment core from Comprido Lake. This black water lake is indirectly but constantly under the influence of the Amazon River, and it consequently provides information on regional Holocene climate change.

2. Study area

Comprido Lake is situated nearby Monte Alegre city on the south bank of the Amazon River 500 km from the estuary. This black

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water lake has an area of 16 km^2. During the high water periods, it is connected to the river main channel through Maracá Lake. During low water periods, the lake is completely isolated from the Amazon River (Fig. 1). The bedrock of the unflooded upland (i.e. Terra Firme) in the Comprido Lake catchment area is the Cretaceous Alter do Chão Formation (Latrubesse et al., 2010), which has been subjected to intense long-time weathering processes (Irion, 1984), being kaolinite the main clay mineral delivered by Terra Firme (Behling et al., 2001; Amorim, 2010).

The catchment area is characterized by a humid tropical climate without long dry periods. The annual mean precipitation is about 2200 mm and the annual mean air temperature is about 27 °C (RADAMBRASII, 1974). The lake is surrounded by a dense tropical rain forest (Terra Firme forest) on the southern bank and a forest–savanna transition on the northern bank is observed (RADAMBRASIL, 1974). Around the lake, there are also pioneer formations (grasslands) with the predominance of *Paspalum fasciculatum* and *Echinochloa polystachya* (C_4 plants), and *Eichornia crassipes* (C_3 plants).

3. Methodology

In order to characterize both center and margin of Comprido Lake, COM1 and COM2 core were collected by hand at S02°12′18.5″/W53°54′01.8″ and S02°12′32.0″/W53°53′52.7″, respectively (Fig. 1) at a water depth of 1.8 m. COM1 and COM2 core are about 12.5 km and 12 km from the main channel of the Amazon River, respectively, and around 600 m and 300 m from the lake margin, respectively. The cores were opened, described and sampled after arrival in the laboratory at Institut de Recherche pour Développement (IRD), Bondy, France. Soon after opening, aluminum U-channels were used to determine sediment bulk density. Sub-samples were taken every 1 cm along the core, and the water content was measured by oven drying at 50 °C for several days to obtain a final dry weight.

The mineralogical composition of 27 samples was investigated by X-ray Diffraction analysis (XRD) using a Siemens D500 diffractometer with Ni-filtered CuKα radiation operating at 40 kV and 30 mA. After grinding them with an agate mortar and pestle, bulk samples were mounted in an aluminum rotating sample-holder and scanned from 2° to 70° (2θ) on 2 s, 0.02° intervals. Clay mineralogy was determined on the <2 μm granulometric fraction and size-fractionation of bulk samples was done by settling tube using deionized water, according to Stokes' law. Oriented, air-dried, glycolated and heated (500 °C for 3 h), the samples were scanned from 2° to 15° (2θ) on 2 s, 0.02° intervals. To evaluate the quantitative variability of clay, the surface of each typical clay reflection was measured on the glycolated sample diffractogram and expressed as a percentage of the total diffracted surface, allowing for comparisons between samples.

All samples were analyzed for total organic carbon (TOC) and stable isotopic ($\delta^{13}C$) content with a CN analyzer (FISIONS NA-2000) connected to an isotope ratio mass spectrometer (Micromass Optima) at the UC Davis stable isotope facility, CA, USA. Samples were treated with 1 N HCl in order to remove carbonates prior to the analyses. The $\delta^{13}C_{TOC}$ and $\delta^{15}N$ values are reported in the standard delta notation relative to Vienna Pee Dee Belemnite (VPDB) and atmospheric N_2 standards. To calculate the C/N ratio, we used TOC and TN. The analytical precisions (as standard deviation for repeated measurements of the internal standards) for the measurements were 0.1 mg g^{-1} for TOC, 0.05 mg g^{-1} for TN, 0.06‰ for $\delta^{13}C_{TOC}$, and 0.13‰ for $\delta^{15}N$.

Chlorophyll derivatives were extracted with 90% acetone and measured as absorbance between 300 and 800 nm in Perkin Elmer spectrometer. The results were expressed, in arbitrary units, as absorbance per gram organic matter, where one unit (SPDU) is equal to an absorbance of 1.0 in a 10 cm cell, when dissolved in 100 ml of solvent (Sanger and Gorham, 1972).

Microscopical analyses were performed using the Flow Particle Image Analyzer 3000 (FPIA-3000), an automated image analysis system that measures particles from 0.5 μm to 200 μm. The samples were treated with H_2O_2 to remove organic matter prior to these measurements. In order to quantify the concentration of the diatoms from the genus *Aulacoseira*, the total number of diatoms for each sample was accessed using the FPIA-3000 software. The results were expressed as a total number of diatoms per dry weight.

^{14}C measurements were performed by an Artemis accelerator mass spectrometry (AMS) system based on a 3 MV Pelletron from National Electrostatics Corporation (NEC, Middleton, Wisconsin, USA) at "*Laboratoire de Mesure du Carbone 14 (LMC14) - UMS 2572* (*CEA/DSM CNRS IRD IRSN – Ministère de la Culture et de la Communication, France*)". The calibrated ages were calculated using the

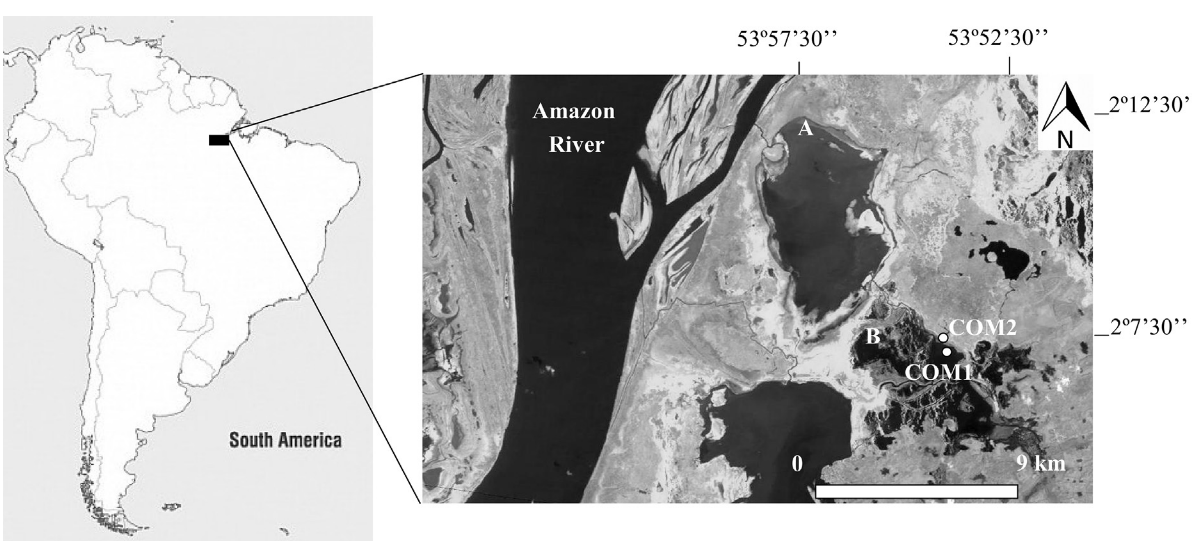

Fig. 1. South America and (A) Maracá Lake (B) Comprido Lake and the position of the cores collected. COM1 and COM2 core are about 12.5 km and 12 km from the main channel of the Amazon River, respectively, and around 600 m and 300 m from the lake margin, respectively.