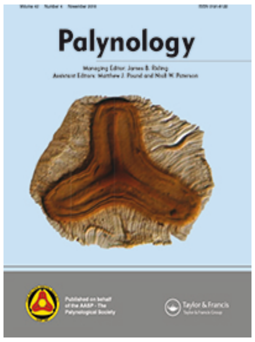

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Late Holocene palynology of a saline lake in the Pantanal of Nhecolândia, Brazil

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ABSTRACT

This work presents the first description of a palynological assemblage preserved in sediments deposited in a saline lake (*salina*) in the Nhecolândia area of the Brazilian Pantanal. Pollen studies from salinas have been underappreciated due to inferred taphonomic issues related to elevated alkalinity. We have found a well-preserved assemblage that allowed the reconstruction of the history of local vegetation. Radiocarbon dating revealed a constant deposition since ∼3760 calibrated years before present (cal yrs BP), and pollen analyses suggested two main phases of vegetation and environmental development. From 3760 to 1510 cal yrs BP, the site was a swamp to shallow lake dominated by cattails (*Typha domingensis*) and Poaceae. From 1510 cal yrs BP to the present the herbaceous community is enriched with Cyperaceae and Bromeliaceae, and with tree taxa such as the Arecaceae (palm trees), evidencing the local development of a fringe vegetation. These two phases were interpreted as a change from drier to wetter settings, largely in agreement with regional lake and speleothem records, as well as pollen and carbon isotope studies from other locations in central South America during the latest Holocene. Given that salinas are non-floodable and pollen was found to be well preserved, we highlight the potential of palaeopalynology in these environments as a source of palaeoecological information for the Pantanal Basin.

KEYWORDS

pollen; saline lake; Quaternary; Taquari megafan; wetland; environmental change

1. Introduction

The Brazilian Pantanal is the largest tropical wetland on Earth (Por 1995), still a pristine environment (Assine 2015). It is located in west-central Brazil, where it covers an area of 148,000 km^2 in the upper Paraguay River basin, with altitudes ranging from 80 to 200 m above sea level (Silva & Abdon 1998). The Pantanal is commonly divided into geographic sub-regions according to hydrology, geomorphology, climate and vegetation. The latter is formed by a complex mosaic of biomes that contain cerrado, chaco and amazonia elements. A novel classification scheme is based on the geomorphology, hydrological regime and sedimentary dynamics of these fluvial systems, which are determined by the geology and geomorphology of the source areas (Assine et al. 2015a, 2015b).

The Nhecolândia covers an area of 24,000 km^2 of the abandoned lobes in the south portion of the fluvial Taquari megafan, in the state of Mato Grosso do Sul, Brazil (Assine & Soares 2004; Assine 2005). The main characteristic of this Pantanal subdivision is the presence of saline lakes, locally known as *salinas*, which represent around 10% of the small freshwater lakes found in the region; the remaining 90% of the nearly 10,000 lakes are fresh water (Padovani 2010; Assine et al. 2015b).

Nhecolândia saline lakes are bounded by 2–5 m high marginal sandy ridges locally called *cordilheiras*. There are few, small perennial streams in the Nhecolândia and the flooding waters are drained through large and shallow waterways known as *vazantes*. Unlike most of the freshwater lakes in the region, the saline lakes are not subject to flood pulses and are supplied by groundwater flow and direct rainfall. This hydrological regime, combined with high rates of ion precipitation, causes alkalinity and high electrical conductivity in many of these lakes (Barbiero et al. 2002, 2008; Medina-Junior & Rietzler 2005; Rezende-Filho 2006; Almeida et al. 2009; Furquim et al. 2010; Assine et al. 2015b). Saline lake formation is traditionally explained by shifts in the Taquari river drainage during the Holocene (Ab'Saber 1988); however, some evidence suggests the action of aeolian processes (Assine & Soares 2004; Assine et al. 2015b).

The sedimentology, geochronology and sponge spicules of lakes from Nhecolândia have recently been studied by McGlue et al. (2017). These authors describe convergent lithostratigraphy in three different lakes, composed of basal sands dated from the Early to Middle Holocene and massive organic muds from the Late Holocene (ca. 3200 cal yrs BP onwards). Facies and geochemical analysis revealed the presence of an ephemeral freshwater wetland or shallow lakes prior to ∼3200 cal yrs BP, reflecting the more arid climate of the Early–Middle Holocene, and the formation of permanent lakes from ∼3200 cal yrs BP, reflecting increased rainfall (McGlue et al. 2017). High water pH was attained later, in the latest Holocene (after ∼900 cal yrs BP) (McGlue et al. 2017).

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Because of the flood-pulse system dynamic (explained in detail by Junk et al. 1989), one of the major challenges in conducting Quaternary palynological studies in the Pantanal is to find closed sedimentary basins, where the pollen record is most closely related to the surrounding vegetation (Oliveira et al. 1999). Cordilheiras isolate saline lakes from the surrounding depositional environments, which are driven by the discharge of major rivers and the duration of the rainy season (Junk et al. 1989). Thus, the salinas provide the opportunity to access a more reliable historical pollen record and infer historical vegetation shifts in the Pantanal during the Holocene with more precision.

The aim of this paper is to describe the palynological assemblage of a Nhecolândia saline lake. To date, no palynological assemblage has been described from these systems. Our study is an important step in understanding the historical dynamics of the Pantanal and saline lake vegetation.

2. Material and methods

2.1. Study area

We studied a saline lake called Salina da Ponta (core NM1), located at Fazenda Nhumirim in Nhecolândia, Mato Grosso do Sul, Brazil (18°59'1.91"S, 56°39'44.82"W; Figure 1). The climate of this region is tropical sub-humid, with a mean annual temperature of 25.5 °C, mean annual rainfall of 1100 mm, and mean annual evapotranspiration of 1400 mm (Alho et al. 1988; Soriano 1999). The surrounding vegetation is a mosaic of open grassland, cerrado (a type of savanna) and forest physiognomies (Figure 1). The studied salina is bounded by a strip of grassland vegetation, which is surrounded by a variety of cerrado that covers the cordilheiras. The vegetation of the cordilheira is intermingled with vegetation indicative of the vazante formations, which are lower than the cordilheiras and associated with humid grasslands (Figure 1; Pott et al. 1986; Sakamoto 1997; Almeida et al. 2009; Pott & Silva 2015).

2.2. Core description

Core NM1 was obtained with a vibracorer device and reached a depth of 170 cm. Here we focus on the top 75 cm, where radiocarbon dates and pollen recovery were possible. The core contains a basal unit of massive fine to very fine sand (from 170 to 60 cm) and is overlain by massive organic muds from 60 cm to the top (Figure 2). The core is archived in the Laboratório de Estudos do Quaternário (LEQ/IGCE) of the Instituto de Geociências e Ciências Exatas da Universidade Estadual Paulista, Rio Claro-SP, Brazil. Three samples (corresponding to 30, 50 and

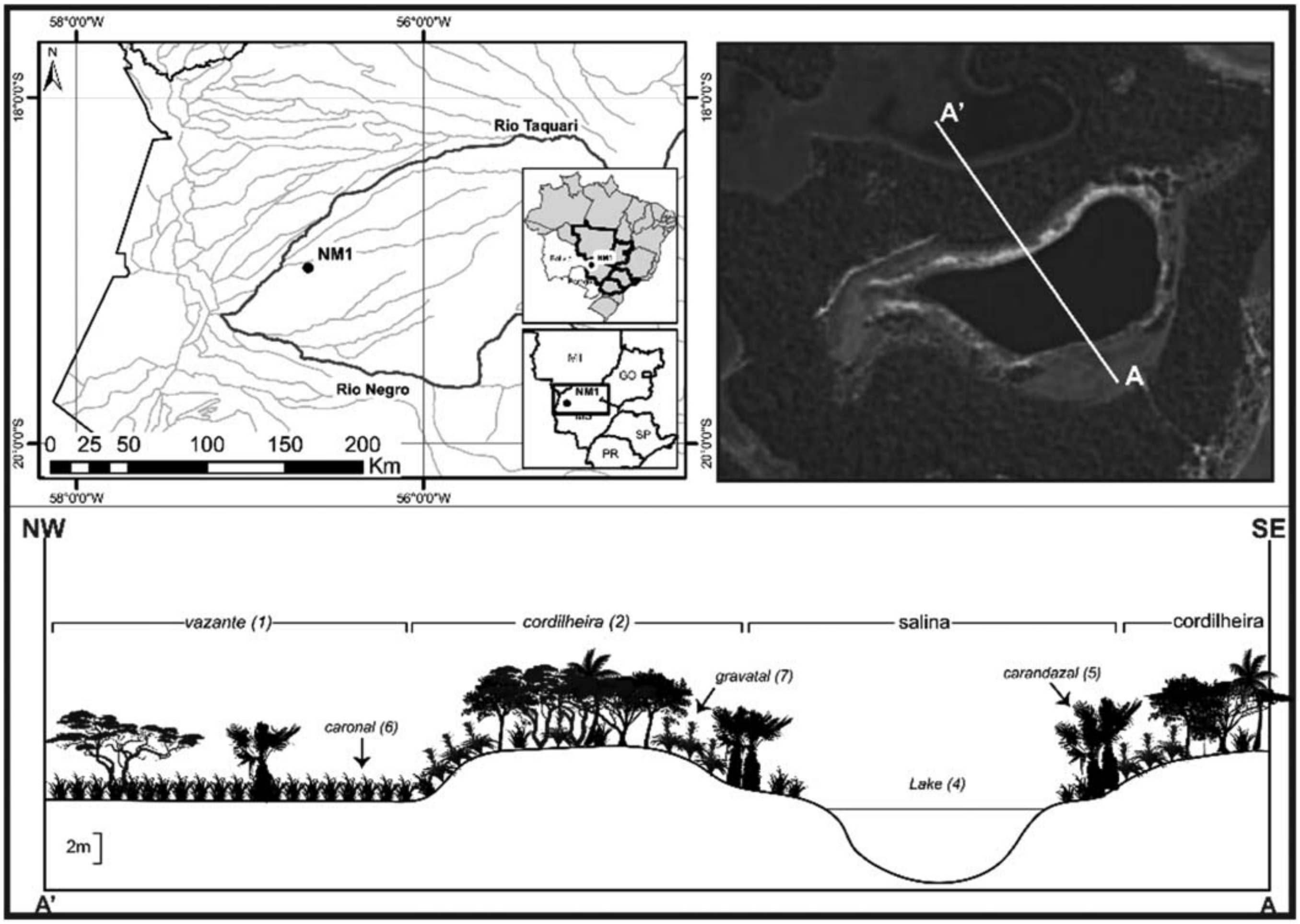

Figure 1. A, Location of the studied salina in the Nhecolândia region, state of Mato Grosso do Sul, Brazil. B, An idealised transect showing the vegetation formation of the Nhecolândia region (see also Table 2).

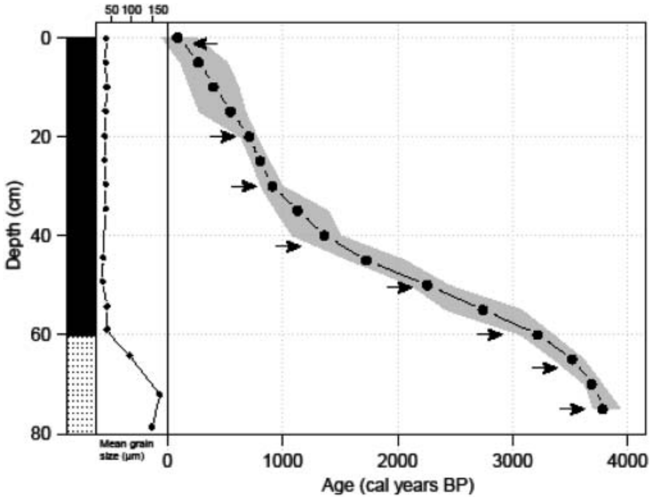

Figure 2. Lithology, mean particle size and depth–age model for core MN1, Nhecolândia, Brazil. Grain size data from McGlue et al. (2017). Age model: gray shading is 95% confidence interval (CI), solid circles are all samples processed for pollen analysis, and arrows are dated horizons (see Table 1). From 0 to 60 cm: dark clay, from 60 to 80 cm: sand.

75 cm depths) were sent to Beta Analytic labs for radiometric age dating using the accelerator mass spectrometry (AMS) method and for determination of δ^{13}C values. Additionally, five dates using the same method and laboratory were used from the study of McGlue et al. (2017) (Figure 2; Table 1). Calibration of conventional ^{14}C ages followed the SHcal13 curve (Hogg et al. 2013) and was performed with the Bchron package in R (Parnell 2016). Bchron was also used for the construction of an age–depth model using the algorithm of Haslett & Parnell (2008).

2.3. *Palynology*

We collected 16 samples of organic-rich sediments at 5-cm intervals. We processed 5 g of each sample following the methodology of Ybert et al. (1992) for Quaternary sediments: (i) 1 mg of the exogenous pollen of *Kochia scoparia* (L.) Schard (1809), with an estimated content of 60,543 grains (Salgado-Labouriau & Rull 1986) was added to each sample to allow concentration values to be calculated; (ii) carbonate dissolution with 10% hydrochloric acid (HCl); (iii) sieving with 250-µm mesh; (iv) acetolysis; and (v) silicate dissolution with 40% hydrofluoric acid (HF). We mounted the residues in glycerin jelly, covered them with a cover glass, and sealed them with paraffin. Slides are archived in the Palynological Laboratory of Instituto de Geociências, Universidade Federal de Mato Grosso, Cuiabá-MT, Brazil – PALMA (Silva-Caminha et al. 2014). We used a Nikon Eclipse E200MVR optical microscope to count and identify the palynomorphs, and an England Finder slide to record the coordinates of pollen grains on the slide.

We compared the pollen obtained from the saline lake with example pollen types from PALMA and the Graham Palynological Collection (Smithsonian Tropical Research Institute, CTPA, Panama), as well as a specialised bibliography (Salgado-Labouriau 1973; Faegri & Iversen 1989; Rubick & Moreno 1991; Colinvaux et al. 1999). We counted at least 300 grains on each slide, including locally abundant elements such as Poaceae and Cyperaceae, representative of families endemic to Nhecolândia (Chambers et al. 2011). Samples with fewer than 100 grains (n = 3) were excluded from the pollen diagrams and analyses. Relative abundance of spores and freshwater algae was calculated based on the 300-grain counts. We built the palynological diagrams using the rioja package in R (Juggins 2015). Due to overrepresentation of herbaceous elements growing locally (see Results), a regional-scale biome reconstruction was not possible. Therefore, the pollen diagram was not divided into ecological groups but into those taxa more abundant in and/or restricted to one of the two zones.

Table 1. Radiocarbon dates from Lake NM1, Nhecolândia region of Pantanal, MS, Brazil. All dates are based on accelerated mass spectrometry (AMS). Calibrated ages are 1-sigma means.

Sample depth (cm)	Laboratory code	Conventional ages (^{14}C yrs BP)	Calibrated age (cal yrs BP)	δ^{13}C (‰ PDB)
1	ß-417761	104 ± 0.3	130 ± 8	−21.3
20	ß-429478	850 ± 30	720 ± 60	−21.3
30	ß-353950	1030 ± 30	920 ± 30	−20.6
43	ß-429479	1670 ± 30	1510 ± 95	−21.5
50	ß-403549	2300 ± 30	2320 ± 30	−18.5
60	ß-427472	3080 ± 30	3310 ± 40	−18.9
67	ß-427473	3460 ± 30	3650 ± 100	−17.7
75	ß-353952	3510 ± 30	3760 ± 110	−19.0

2.4. *Data analysis*

A multivariate approach was taken in order to evaluate possible palynofloristic gradients and zones. A detrended correspondence analysis (DCA) and a CONISS cluster (Grimm 1987) were carried out on a log-transformed matrix of the pollen data, to avoid noise from over-represented taxa. Analyses were performed in R using the Vegan (Oksanen et al. 2017) and Rioja (Juggins 2015) packages, respectively. Additionally, to assess the statistical significance of taxa creating possible multivariate gradients, an indicator value analysis (IndVal; Dufrêne & Legendre 1997) was carried out using the R package labdsv (Roberts 2016). The IndVal ranges from 0 to 1, with higher numbers pointing to higher specificity and/or fidelity (i.e. those taxa that are restricted to or significantly more abundant in one zone when compared to other zones).

3. Results

3.1. *Chronology*

Calibrated ages revealed that deposition of the upper 75 cm of the NM1 core occurred in the Late Holocene, with a basal age of 3760 ± 110 cal yrs BP (Table 1; Figure 2). The depth–age model (Figure 2) revealed a constant sedimentation rate of 0.020 cm/yr on average. Considering the constant deposition trend (see confidence intervals in Figure 2) plus the lack of stratigraphic discontinuities, significant variations in the accumulation history are unlikely, making the NM1 record a reliable archive.

3.2. *Palynology*

We counted 4365 grains from 16 sample slides representing 26 pollen and seven spore types (Figure 3). Additionally, 3653 algal

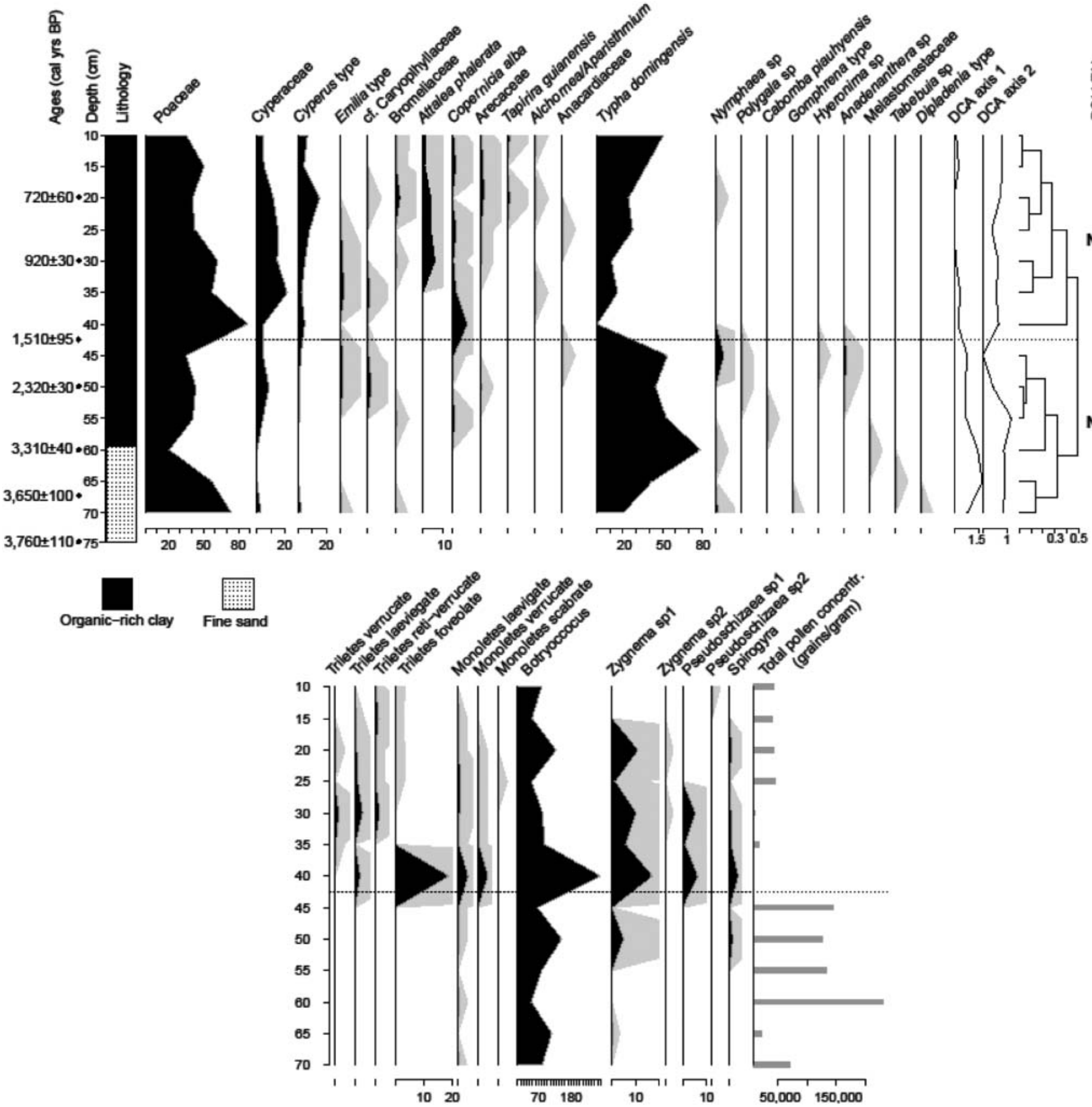

Figure 3. Palynological diagram of core NM1 from Nhecolândia, Pantanal, Brazil. The x-axes are percentage of the pollen sum, unless otherwise noted. Note axis width differences due to over-abundant taxa (upper diagrams: pollen, DCA axis and CONISS cluster; lower diagrams: spores, algae and total pollen concentration).

cells from six different taxa were counted in parallel. The pollen assemblage is heavily dominated by the herbaceous plants, with accessory shrub/tree taxa (Figure 3). The identified types correspond to common species occurring in the cerrado/Pantanal biome, in either open or wooded physiognomies. Common taxa from various vegetation formations in the Pantanal are represented by *Attalea phaleratha*, Arecaceae, Melastomastaceae, Polygalaceae, Anacardiaceae, *Anadenanthera* sp. and *Tapirira guianensis*. Two types, *Gomphrena* sp. and Asteraceae correspond to grassland physiognomies common on vazante formations, while *Copernicia alba* occurs surrounding the saline lakes in the cordilheira formation. The unique species that shares three physiognomies is *Tabebuia alba*, found in forests and cerrado physiognomies of cordilheiras as well in vazantes. Bromeliaceae occurs in forest-cerrado provinces bounding the saline lakes. *Typha domingensis* and *Cabomba piahuiensis* are restricted to aquatic or semi-aquatic freshwater environments. Poaceae and Cyperaceae are found in all samples from the core, and are widely distributed in the modern Pantanal habitats (Table 2).

Multivariate statistics (DCA and CONISS dendrogram) suggest a change in the local physiognomy occurred around a depth of 42 cm, or ~1510 cal yrs BP (Figure 3). The two pollen zones defined by this change (MN1-A and MN1-B) and are described and interpreted below. The IndVal analysis revealed only four taxa as significant indicators of zone MN1-B, namely

Table 2. Main characteristics and key taxa of the vegetation groups in Nhecolândia. (Data compiled from Adámoli 1986; Pott et al. 1986, 1989, 2011a; Pott & Pott 1994, 1997; Santos et al. 1997; Nunes da Cunha & Junk 1999, 2001; Rebellato & Nunes da Cunha 2005; Junk et al. 2006; Rezende-Filho 2006; Cardoso 2008; Ribeiro & Walter 2008; Almeida et al. 2009; Assine et al. 2015b; Pott & Silva 2015). Numbers in parentheses correspond to those in Figure 1.

Vegetation group	Characteristics	Key taxa
(1) Vazantes	Trees and bushes over grass/humid grassland (floodable)	Poaceae; Cyperaceae; Asteraceae; Arecaceae; *Copernicia alba*; Melastomastaceae; *Polygala* sp.; *Gomphrena* sp.; *Anadenanthera* sp.; *Tabebuia* sp.; Anacardiaceae; *Tapirira guianensis*
(2) Cordilheiras	Trees and bushes from forest formations/cerrado or forest (non-floodable)	Poaceae; Cyperaceae; Anacardiaceae; *Anadenanthera* sp.; *Tabebuia* sp.; *Attalea phaleratha*
(3) Salina border vegetation	Cerrado vegetation close to saline lakes/cerrado or forest (non-floodable)	*Copernicia alba*; *Tabebuia* sp.; *Gomphrena* sp.; Bromeliaceae; Asteraceae
(4) Lake or swamp	Herbs or bushes adapted to moist soils or aquatic environments/humid grassland/macrophytes	Cyperaceae; Poaceae; *Typha domingensis*; *Cabomba piahuensis*
(5) Carandazal	Monodominance of *Copernicia alba* surrounding sand bands/forest	*Copernicia alba*; Poaceae; Cyperaceae

Note: 75 to 42 cm or 3,760 to 1,510 cal yrs BP (Figure 3); 42 to 0 cm or 1,510 cal yrs BP to present (Figure 3).

Cyperus type, *Attalea phalerata*, Cyperaceae and Arecaceae, all with indicator values > 0.76 and p-values < 0.026.

3.2.1. Zone MN1-A

This zone is characterised by the dominance of *Typha domingensis* and Poaceae; a few other elements are present, some of which are aquatic plants (*Nymphaea* and *Cabomba piahuensis*). No species is an indicator of this zone. This zone is characterised by a lack of fern spores and a less diverse freshwater algae community when compared to zone MN1-B. Total pollen concentration values are rather high, with 20,000–230,000 grains per gram, with a mean of 120,000 grains per gram. The dominance of *T. domingensis* and Poaceae, a low-diversity tree, spore and algae assemblage, leads to the interpretation of a local swamp or low water-level lake. The δ^{13}C values are on average -18 ± 0.6‰ and the sedimentation rate is 0.014 cm/yr^{-1}.

3.2.2. Zone NM1-B

This zone is characterised by the dominance of Poaceae, Cyperaceae and Arecaceae (*Attalea phalerata*, *Copernicia alba*). Cyperaceae and Arecaceae are indicator taxa of this zone. Additionally, Bromeliaceae seem to be an important constituent of zone NM1-B, as are *Tapirira guianensis* and *Alchornea/Aparisthmium*. In addition, fern spores occur almost exclusively in zone NM1-B, and freshwater algae are more diverse and abundant. Total pollen concentration values are lower than in zone NM1-A, with 6000 to 140,000 grains per gram, with an average of 40,000 grains per gram. The pollen assemblage recovered in this zone is indicative of a local cordilheira forest (Table 2), pointing to higher moisture availability, which is needed to support a forest structure. The presence of fern spores and freshwater algae is in agreement with this interpretation. The δ^{13}C values are on average -21 ± 0.4‰ and the sedimentation rate is 0.027 cm/yr^{-1}.

4. Discussion

Pollen preservation in alkaline soils and sediments is generally low. Traverse (1988) and Faegri & Iversen (1989) state that only grains with a thick exine layer would be likely to be preserved in this setting. However, recovery from such settings was made by Potter & Rowley (1960), Bryant et al. (1994) and Salgado-Labouriau (2007), who showed that even thin-walled grains, such as Poaceae, may be preserved in alkaline settings. Campbell & Campbell (1994) found high preservation potential of grains in saline aggregate sediments in strongly seasonal climatic systems. Palynomorph preservation in sediments from Lake NM1 in Nhecolândia is good. Grains retain their shape, wall structure and aperture characteristics, which permitted accurate identification. Moreover, particulate organic matter and diverse non-pollen palynomorphs were found to be well preserved and abundant, although these were not counted.

Anemophilous taxa, like Poaceae and Cyperaceae, are strong components of all samples obtained from the core. These families produce 75% of the pollen in palynological assemblages from the Pantanal (Salgado-Labouriau 1973; Ledru 1993) and represent 31% of the terrestrial plants in the region today. The vegetative province called *caronal*, which is dominated by *Elyonorus muticus* (Cyperaceae), currently covers wide extensions of the vazante and open cerrado biomes in Nhecolândia (Pott et al. 1986, 2011a, 2011b; Junk et al. 2006) (Table 2). Although the modern saline lakes do not have macrophytes, we detected *Cabomba pihauyensis*, *Nymphaea* and aquatic or semi-aquatic Cyperaceae and Typhaceae (up to 78% of the palynological assemblage), which indicates that freshwater environments were present in the past (Figure 3). Tree pollen that is indicative of the regional cerrado occurs throughout the NM1core, and includes *Dipladenia*, *Tabebuia*, *Anadenanthera* and *Tapirira guianensis*. Overall, the pollen spectrum is dominated by herbaceous and aquatic/semi-aquatic plant groups, and this constrains our vegetation and palaeoenvironmental reconstructions to a local scale.

4.1. Environmental reconstruction

The vegetation evolution described in sediments of Lake MN1 in Nhecolândia follows two main phases. From 3760 to 1510 cal yrs BP (zone MN1-A), a swampy environment, rich in *Typha domingensis*, is present. This species is a rhizomatous macrophyte that tends to be monodominant in disturbed flooded areas, temporary ponds and swamps (Pott et al. 2011b). Additional aquatic macrophytes such as *Nymphaea* and *Cabomba* also indicate swampy/lake conditions. The lack of a developed tree community, no fern spores, and lowered algal diversity were interpreted as indicating a lower water table in a drier climatic setting. Herbaceous elements such as *Gomphrena* sp. (Amaranthaceae) are in agreement with this interpretation as the taxon is related to arid or saline habitats (Pott et al. 1986,

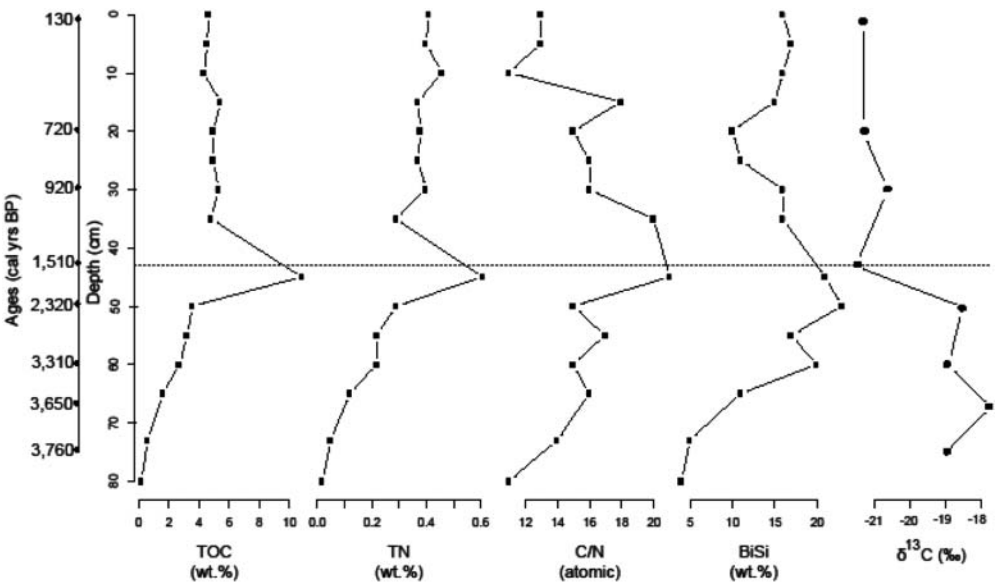

Figure 4. Geochemistry of core NM1, data from McGlue et al. (2017). TOC: total organic carbon; TN: total nitrogen; C/N: carbon-nitrogen ratio; BiSi: biogenic silica; δ^{13}C: stable carbon isotopes (from bulk organic sediments; see Table 1).

2011a; Marchant et al. 2002; Mendonça et al. 2008). Sedimentological and geochemical data for lake NM1 (McGlue et al. 2017) are also indicative of drier conditions, particularly as indicated by low preservation of total organic carbon and nitrogen (Figure 4). Presence of the sponge *Corvoheteromeyenia* sp. indicates freshwater conditions, agreeing with the evidence of macrophytes *Nymphaea* and *Cabomba*. A drier climate locally during this phase would be in line with other regional records, for instance from 3800 to 2500 cal yrs BP in the region of Bonito-MS (Bertaux et al. 2002), only ~240 km south of Nhecolândia; between 3500 and 1400 cal yrs BP in the Argentinean Chaco and Pampa (Iriondo 1990; Iriondo & Garcia 1993); and the depositional hiatus between 5300 and 2600 cal yrs BP in the Paraguay river basin, which all provide strong evidence for drier climate in this period (McGlue et al. 2012).

Zone MN1-B starts at 1510 cal years BP and extends to the present. This phase is reconstructed as a higher water table lake, reflecting more moisture availability. In contrast with zone NM1-A, the upper part of the record is dominated by a less restricted community of herbaceous plants, and includes a more diverse tree, fern and freshwater algae community (Figure 3). Poaceae and *T. domingensis* are still well represented, but Cyperaceae appears as an indicator group. More abundant trees, especially palm trees that are significant indicators of zone NM1-B, as well as Bromeliaceae and the early successional stage tree *Alchornea* all together are interpreted as indicative of a wetter period that supported the development of the cordilheira vegetation (Table 2; Figure 1). *Tapirira guianensis* and *A. phalerata* also support this interpretation; the first is a common species in floodable forests or associated with moist soils (Lorenzi 1992; Marchant et al. 2002), and the second is typical of cordilheiras (Figure 1; Pott & Pott 1994, 1997; PCBAP 1997; Marques et al. 2001; Junk et al. 2006). Geochemical data from core NM1 also support a higher water table, indicating a persistent setting that led to higher production (increased biogenic Si, TOC [total organic carbon], C/N) and organic carbon preservation (Figure 4; McGlue et al. 2017).

Total pollen concentrations are significantly lower in zone NM1-B than in zone NM1-A (t-test, df = 5.5, $p < 0.02$; Figure 3). This is consistent with higher productivity of the lake system and its surroundings as well as increased sedimentation rates after 1510 cal yrs BP (Figure 4; McGlue et al. 2017) – more organic matter produced by the lake system, and increased run-off into the lake due to higher precipitation would dilute pollen in the bottom lake sedimentation, result in lower concentration.

Stable carbon isotopes (δ^{13}C) indicate a significant change from less to more negative values (-18.5 ± 0.6 to -21.1 ± 0.4; t-test, df = 5.2, p-value < 0.001). Although values in both zones are in the range of C4 plants (Meyers 2003), a lighter carbon contribution after 1510 cal yrs BP could be pointing to a higher contribution of C3 plants, which is in agreement with pollen data that shows cordilheira vegetation development in the later part of the record.

A wetter phase in the last 1510 cal yrs BP in Nhecolândia would be in agreement with records from various locations. In the north Pantanal basin, since at least ~3000 yrs BP, more humid conditions have prevailed (Whitney et al. 2011). Speleothem records from Bonito-MS (~240 km from Lake MN1, Bertaux et al. 2002) and Rosário Oeste-MT (~300 km from Lake MN1, Novello et al. 2016) point to higher humidity after ~2500 and 1510 yrs BP, respectively, largely in agreement with our inferred lake record from Nhecolândia. In addition, more humid climates are recorded in the Argentine and Chaco-Pampa after 1400 yrs BP (Iriondo 1990; Iriondo & Garcia 1993); forest expanded following the mid-Holocene dry period from ~3000 yrs BP in southern Amazonia (Pessenda et al. 1998a, 1998b; Mayle et al. 2000), and in south-east Brazil (Gouveia et al. 1999). This latest Holocene increased humidity can be correlated with a gradual monsoon system enhancement in the latest Holocene as documented in pollen records depicting a southward expansion of the Amazon-cerrado ecotonal region (Mayle & Power 2008). Therefore, the latest Holocene wetter phase recorded in

Lake NM1 agrees with continental-scale records of climatic evolution in South America.

5. Conclusion

The pollen record obtained from a saline lake in the Nhecolândia region of the Pantanal Basin allowed the definition of two important periods – a drier one from ~3760 to 1510 cal yrs BP, and a wetter one from 1510 cal yrs BP to the present. The two phases are marked by a change from swampy/shallow lake conditions and impoverished fringe vegetation to a higher lake level with more diverse fringe vegetation. These inferences are in close agreement with the sedimentological and geochemical record of the saline lakes from Nhecolândia (McGlue et al. 2017) and other regional palaeo-archives, which altogether show the potential for palaeoenvironmental records preserved in these alkaline lakes. This work presents the first pollen record from a saline lake and provides an important step in understanding more precisely the environmental shifts that occurred in the Quaternary in the Pantanal.

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