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Holocene evolution of Itapeva Lake, Rio Grande do Sul, Brazil: Palynomorphs C_{org}, N, and S records

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Abstract

Holocene coastal environmental changes are interpreted from a 590 cm long core taken from Itapeva Lake in the northern coastal plain, Rio Grande do Sul, Brazil. The sediment core is radiocarbon dated at 211 cm depth (6460 ± 40 yr B.P.) and studied by geochemistry and palynomorph analyses. The Pleistocene–Holocene boundary is predicted at the top of a glauconitic sand layer at 330 cm depth. On the basis of C_{org}, N, S, and palynomorph data, it is possible to distinguish four zones related to the Holocene transgression–regression cycle, as well as proxies for the salinity trends and organic matter source. The start of Zone 1 represents the oldest Holocene sedimentary record in the core. Palynomorphs reveal a marsh environment with a freshwater influence. In Zone 2, Operculoclinium centrocarpum and high S values indicate brackish water and reflect a Holocene sea-level rise related to the postglacial marine transgression. The high amount of Cyperaceae pollen grains and a significant C_{org} increase in Zone 3 indicate a typical marsh environment with episodes of marine water that reflect a regression phase. *Salvinia natans* (L) All. and Cyperaceae pollen grains are the most significant palynomorphs in Zone 4, which characterizes a freshwater marsh.

Keywords: Coastal evolution; Geochemistry; Holocene; Palynology; Sea-level change; Southern Brazil

Resumo

Mudanças ambientais do Holoceno foram interpretadas na Planície Costeira do Rio Grande do Sul com base no testemunho de sondagem BOXVI da Lagoa Itapeva. Análises geoquímicas (C_{org}, N, S) e dos palinomorfos foram realizadas ao longo dos 590 cm do testemunho de sondagem datado em 6.460 ± 40 anos A.P. à profundidade de 211 cm. O limite Pleistoceno/Holoceno é inferido à profundidade de 330 cm, sobreposto à camada de areias glauconíticas. Quatro zonas correlacionadas ao ciclo transgressivo-regressivo holocênico, bem como variações da salinidade e origem da matéria orgânica, foram identificadas com base nos dados de C_{org}, N, S e palinomorfos. A Zona 1 representa o registro mais antigo da sedimentação holocênica, cujos palinomorfos indicam ambiente paludal sob influência de água doce. Na Zona 2 a ocorrência de *Operculodinium centrocarpum* e os altos teores de S indicam águas mixohalinas e uma elevação do nível relativo do mar relacionada ao máximo transgressivo holocênico (ca. 5100 anos A.P.). A quantidade elevada de grãos de pólen de Cyperaceae e o aumento no teor de C_{org} , na Zona 3, indicam ambiente paludal com influxos marinhos esporádicos, refletindo a fase regressiva. Na Zona 4 os palinomorfos com maior representatividade são *Salvinia natans* (L) All. e Cyperaceae, indicando ambiente paludal de água doce.

Palavras chave: Evolução costeira; Geoquímica; Holoceno; Palinologia; Sul do Brasil; Variações do nível relativo do mar

1. Introduction

Palynological studies in the northern coastal plain of Rio Grande do Sul state have been carried out since 1990.

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Two main research approaches have been developed to determine the origin of sediments in this area: pollen analysis, vegetation, and climate changes from continental sediments (Neves, 1991; Neves and Lorscheitter, 1992, 1995a,b) and paleoenvironmental evolution controlled by sea-level changes from lagoonal and estuarine sediments (Lorscheitter and Dillenburg, 1998; Medeanic et al., 2000; Marques-Toigo et al., 2002). A semi-arid climate has been suggested during the last glacial Pleistocene stage (Neves and Lorscheitter, 1995b), and foreset development, suggesting climate amelioration, has been recorded from the beginning of the Holocene (Neves and Lorscheitter, 1995b) or later (Bauermann, 2003).

On the basis of the marine palynomorphs, the maximum relative sea-level transgression at 5000 yr B.P. and the first evidence of another, less intense transgression at 1800 yr B.P. have been recorded in Tramandaí lagoon sediments (Lorscheitter and Dillenburg, 1998). To determine if these patterns are recorded in other places from the northern coastal plain, sediment core BOXVI was taken at the margin of Itapeva Lake.

The evolution of this shallow coastal lake, as well as other lakes in the coastal plain of Rio Grande do Sul (Tomazelli and Villwock, 1991) and Tramandaí lagoon (Dillenburg, 1994; Reichhart, 1997; Oschmann et al., 1999), is linked intimately to postglacial (post-Wisconsin) sea-level changes. Sea-level curves in the southern hemisphere during the past 7000 yr B.P. are characterized by either a falling or a fluctuating trend (Isla, 1989; Pirazzoli, 1991). For several sectors of the Brazilian coast, relative sea-level fluctuation curves during the past 7000 years have been delineated by Angulo and Lessa (1997), Martin et al. (1998), and Suguio et al. (1985). These curves show that the Brazilian coast was subject to submergence until approximately 5100 yr B.P. and emergence since then. This common feature is recorded in most parts of the Brazilian coast with local variations (e.g. Behling and Costa, 2000, 2001).

In the northern coastal plain of Rio Grande do Sul, the holocenic transgressive–regressive cycle resulted in the formation of a lagoon/barrier depositional system (Lagoon/Barrier System IV) described by Villwock (1984) and Tomazelli and Villwock (2000).

Environmental changes, such as sea level and salinity, are reflected by the variations in the composition of the palynomorph assemblage. However, the observed tolerance of some algae and plants that live in transitional environments, like lagoons and estuaries, to salinities that range from fresh to brackish water limits the use of palynomorphs as single indicator in sediments that originate in such environments.

C_{org} versus S graphs are useful tools to obtain information about paleosalinities (e.g. Berner and Raiswell, 1983). Sulphate-reducing bacteria that live in the sediment below the redox boundary use sulphate (SO_4^{2-}) from the pore water to oxidize organic matter (OM) in the sulphate-reduction process. They liberate sulphide (S^{2-}), which in a second step forms pyrite by reacting with detrital or dissolved iron. Freshwater sediments are characterized by very low sulphur and high C_{org} concentrations because of the very low amount of SO_4^{2-} in fresh water.

The weight ratios of C_{org} to sulphur and of total organic carbon to total nitrogen (C_{org}/N ratio) can be used to indicate the source of the OM in aquatic sediments. As Westrich and Berner (1984) point out, the sulphate reduction rate depends directly on the concentration of metabolizable organic carbon. Therefore, in the bacterial sulphate production process, a high fraction of terrestrial OM, mainly derived from vascular plants, can cause high organic carbon values and, in turn, low S values because such OM is barely affected by microbial decomposition, which results in high C_{org}/S values. In contrast, C_{org}/S values are lower when highly metabolizable OM (e.g. algae) decomposes.

The C_{org}/N_{org} ratio in aquatic systems is governed by mixing of terrestrial and autochthonous OM. Freshly deposited OM, derived mainly from planktonic organisms, has a C/N ratio of 6–9. In contrast, terrestrial vascular plants and their derivates in sediments have C/N ratios of 15 or higher (Sampei and Matsumoto, 2001).

Halmer (1997) identifies a Holocene lagoon for the Itapeva Lake area using sediment composition, organic carbon versus sulfur (C_{org}/S) plots, and the nitrogen content of the sediments as parameters for the paleosalinity and organic carbon source, respectively. The objective of this study is to integrate palynomorph data from core BOXVI with the C, N, and S data published by Halmer (1997), as well as with newly calculated C_{org}/N and C_{org}/S ratios, to reconstruct the evolution of Itapeva Lake during the Holocene and thereby contribute to the understanding of Rio Grande do Sul coastal plain evolution.

2. Study area

2.1. Modern physical setting

The sediment core BOXVI was obtained near the water line at the southern margin of Itapeva Lake (28°20′–29°40′S; 49°45′–50°05′W; Fig. 1). This approximately 2 m deep coastal lake is isolated from the Atlantic Ocean by a beach/foredune ridge strand plain that ranges 2–5 km wide. The Três Forquilhas River is the most important input source of terrigenous material into the lake, including pollen and spores. The river's catchment area includes the mountainous hinterland of Serra Geral plateau, where *Araucaria* (plateau), ombrophylous (mountain flanks), and lowland forest formations of the Três Forquilhas River valley are found.