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Sea-level rise and sediment budget controlling the evolution of a transgressive barrier in southern Brazil

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A B S T R A C T

This paper presents an evolutionary model for a coastal barrier in the southernmost coastal sector of Brazil during the Holocene. The dataset is based on 15–20 m drill cores and ground-penetrating radar (GPR) records. The model barrier evolution has two main steps. The first step is the transgression of the barrier controlled by sea-level rise during the Postglacial Marine Transgression, which ended at approximately 6–5 cal ka. Radiocarbon dating indicates that the coastal plain began to be flooded by lagoonal waters between ∼10 and 6.7 cal ka. The second step comprises a barrier transgression controlled by a negative sediment budget of the beach system during the last 6–5 cal ka in a period of an overall slow sea-level fall of approximately 2 m. During the second step, the transgressive barrier migrated because of coastal erosion (the negative sediment budget) and the landward transference of sand by wind and lagoonal delta washout.

1. Introduction

The Holocene barrier system of Rio Grande do Sul (RS) in southern Brazil occupies the entire 620 km coast (Fig. 1). This is the longest continuous barrier system in South America. The RS Continental Margin is an ideal site for coastal barriers because of its low gradient (on average, 0.06°), significant sand availability, and moderate to high wave energy (Dillenburg et al., 2000, 2009). The entire coastline is gently undulating and consists of two large seaward projections and two landward reentrants (Fig. 1). Both features (projection and reentrance) were defined by the drowned antecedent topography (Dillenburg et al., 2000), which is represented by the surface of non-consolidated Pleistocene aeolian and marine deposits. With the exception of its southernmost sector, the geomorphology and geological evolution of the Holocene barrier coast of RS have been well studied (e.g., Dillenburg et al., 2000, 2004b, 2009; Hesp et al., 2005).

This paper presents the results of the first detailed study on the Holocene barrier at Hermenegildo, which is located close to the border with Uruguay (Fig. 1). Based on conventional lithological data from drill cores, geophysical data (ground-penetrating radar – GPR), radiocarbon dating and paleontological and palynological analysis, the evolutionary model for the Holocene barrier at Hermenegildo is presented, and the causes of the transgressive (erosional) nature of the barrier are discussed. A preliminary consideration is made about a specific and local process of landward sand transference during barrier transgression.

The study area is located in the southern half of the seaward projection between Rio Grande and Chuí (Fig. 1).

2. Regional setting

The Holocene barrier at Hermenegildo beach is located in Brazil's southernmost coastal sector near the border with Uruguay. This coastal sector belongs to the southern Brazilian Continental Margin, which is a rifted plate boundary formed in the Early Cretaceous. In the vicinity of RS (29°–34° south latitude), the deposition of a large quantity of post-rift, mainly clastic sediments produced a wide (100–200 km), shallow (100–140 m) and gently sloping (0.03°–0.08°) continental shelf.

On land, a low-relief coastal plain was formed during the Quaternary by the juxtaposition of the sedimentary deposits of four

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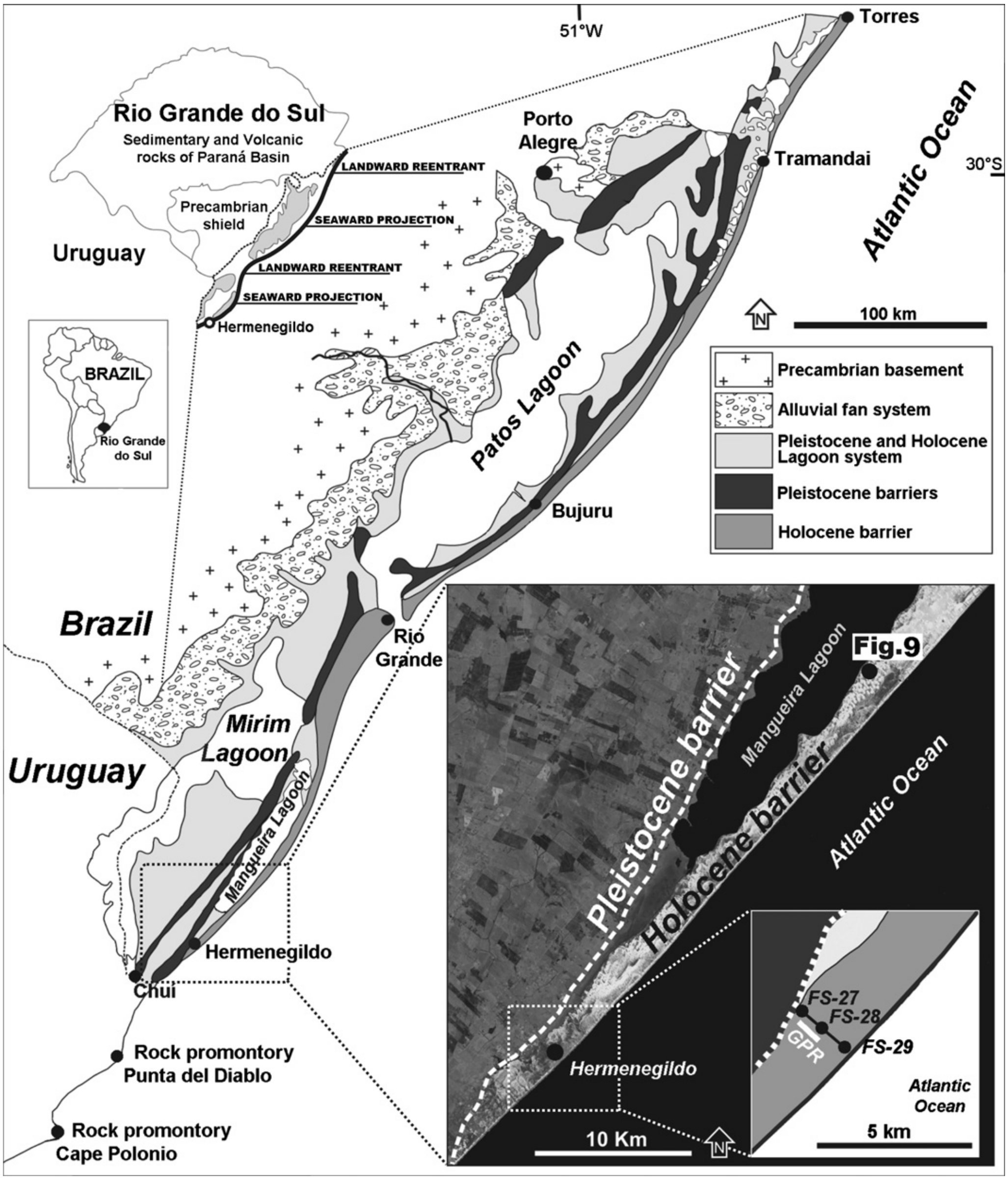

Fig. 1. The location of Hermenegildo beach and the general geology of the Rio Grande do Sul coast (modified from Tomazelli and Villwock, 1996). A Landsat 7 image of the modern barrier surface illustrates the coastal dune system that dominates the present barrier, as it did in the past. The insets present Hermenegildo's general geology, a cross-section showing the drill core locations and the GPR profile, and the area depicted in Fig. 9.

barrier/lagoon systems (Villwock et al., 1986) (Fig. 1). According to Oxygen Isotope Stages (OIS), the oldest systems (Pleistocene) were estimated to have formed at approximately 400 ka (stage 11), 325 ka (stage 9) and 125 ka (stage 5e). The modern, active system started to take form at approximately 7 ka.

The coastal plain ranges from 15 to 100 km wide (it is 50 km in the study area) and is bordered landward by bedrock highlands.

The climate is humid and temperate, characterized by warm to hot temperatures (a mean of 26 °C) in summer and cool temperatures in winter (a mean of 12 °C). Rainfall ranges from 1000 to 1500 mm and is evenly distributed throughout the year (Nimer, 1990). The prevailing wind is NE, and it changes 180° during and immediately after the passage of cold fronts (Calliari et al., 1998). These S–SW winds are the most intense (Braga and Krusche, 2000).

The southern Rio Grande do Sul coast is oriented NE–SW and subjected to dominant swell waves approaching mainly from the S–SW, which produce a net northerly longshore sediment transport, and wind-generated waves produced by strong spring–summer NE sea breezes. The average significant wave height and period are 1 m and 10–11 s, respectively (Tozzi and Calliari, 2000). During autumn and winter storms, wave height frequently exceeds 2 m and storm surges can reach up to 1.3 m above the modern mean sea level (Calliari et al., 1998; Barletta and Calliari, 2001; Parise et al., 2009). Under these conditions, intensive beach erosion occurs along the southern portion of the protruding sections of the coast, producing a high concentration of heavy minerals (up to 30%) at the fore- and backshore (Dillenburg et al., 2004a). The coast is wave-dominated (microtidal) with semidiurnal tides that have a mean range of 0.3 m. A net northward littoral transport is evident in the coastal geomorphic features (Tomazelli and Villwock, 1992). Present-day RS beaches receive little inland sand because most of the bedload carried by the few streams and rivers that drain to the coast is trapped in lagoons and other coastal plain environments (Tomazelli et al., 1998). Because of changes in the coastline