Textural and oceanographic aspects of the sandy beaches of South coast of *Santa Catarina*, Brazil

Aspectos texturais e oceanográficos das praias arenosas do setor Sul de Santa Catarina, Brasil

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Abstract

This study aims to describe the textural and oceanographic aspects of the foreshore zone of the beaches located between the municipalities of *Passo de Torres* and *Balneário Rincão*, at South coast of *Santa Catarina*. Oceanographic and textural parameters were collected at 41 sites, arranged on 22 beaches that extend out on 77,4 km of coastline. The field work was conducted in December 2007. The Sysgran software analyzed the textural data, revealing high homogeneity of grain size, predominance of fine sand, with quartzose sediments, reddish brown color (2.5YR5/3) in 66% of the samples and brown color (10YR5/3) in 34% of the samples, besides reducing amount of organic matter and biodetritic carbonate. In general, the sediments are well sorted, mesokurtic and with skewness approximately symmetrical. Regarding the source area, it should be noted that the coastal plain of the South coast of *Santa Catarina* comprises a wide barrier-lagoon depositional system of Holocene age, in which the sediments in general show high maturity. Regarding the coastal oceanographic aspects, the rectilinear shape of the coastline, as well as the predominant dissipative morphodynamic stage and a system of well-developed coastal dunes in most of the sites examined, corroborate with the textural and compositional homogeneity resulting from the frequency and intensity of the marine dynamic agents, winds and supply of lithoclastic sediments.

Keywords: texture; sandy beach; Santa Catarina coast.

Resumo

Este estudo tem como objetivo descrever os aspectos texturais e oceanográficos da zona litorânea das praias localizadas entre os municípios de Passo de Torres e Balneário Rincão, setor Sul de Santa Catarina. Parâmetros oceanográficos e texturais foram coletados em 41 locais, dispostos em 22 praias que se estendem por 77,4 km de costa. O trabalho de campo foi realizado em dezembro de 2007. O *software Sysgran* analisou os dados texturais, revelando alta homogeneidade do tamanho dos grãos, predominância de areia fina, com sedimentos quartzosos de cor marrom avermelhada (2,5YR5/3) em 66% das amostras e cor marrom (10YR5/3) em 34% das amostras, além de reduzida quantidade de matéria orgânica e carbonato biodetrítico. Em geral, os sedimentos são bem classificados, mesocúrticos e com assimetria aproximadamente simétrica. Em relação à área fonte, deve-se notar que a planície costeira do setor Sul de Santa Catarina compreende um amplo sistema deposicional tipo laguna-barreira do Holoceno, no qual os sedimentos em geral apresentam alta maturidade. Em relação aos aspectos oceanográficos costeiros, a forma retilínea da linha de costa, bem como o estágio morfodinâmico dissipativo predominante e a presença de dunas costeiras bem desenvolvidas na maioria dos locais estudados, corroboram com a homogeneidade textural e composicional resultante da frequência e intensidade dos agentes dinâmicos marinhos, ventos e suprimento de sedimentos litoclásticos.

Palavras-chave: textura; praia arenosa; costa de Santa Catarina.

1. Introduction

Sandy beaches are dynamic and sensitive transitional environments that adjust to energy fluctuations and undergo hydraulic, eolian and biological reworking processes. They present continuous morphological changes, resulting from variations of the energy regime (wave climate), sea level variations (storm surge events) and instability of the sediment supply caused by natural or anthropic processes (Short 1999, Klein 2004).

Depending on the location of the coast, the incidence of hydrodynamic forcing, orientation of the coastline and characteristics of the sediment, sandy beaches have a unique geography, relevant to the contemporary societies, whether as the basis of ocean circulation flows, or a place for residence, leisure, tourism, and essentially as a depository of valuable natural resources.

Located in the South region of Brazil, the coast of *Santa Catarina* presents 538 km long and has distinct beaches and diversified physiography displayed in the South, Central-south, Central, Central-north and North sectors. Its location is between two distinct sedimentary basins, *Pelotas* and *Santos*, and two distinct coasts, Meridional and Southeast (Suguio 2010). The *Santa Catarina* littoral offers a diversity of environments with their own characteristics and which enrich the coastal heritage of the state.

Continuous understanding of coastal environments makes up the studies on sedimentology on the beach systems and may indicate possible source areas and reveal marks of hydrodynamics energy. Examples include evidences of shore deposition and landward winds, caused by high and low energy events, such as wave-cut notches or trenches on the foreshore or eroded dunes.

This study describes the textural and environmental aspects of the South coast of *Santa Catarina*, encompassing five municipalities denominated from south to north of *Passo de Torres, Balneário Gaivota, Balneário Arroio do Silva, Araranguá* and *Balneário Rincão*.

2. Study area

The South coast of *Santa Catarina* is characterized by a continuous, straight, rectilinear and homogeneous coastline, whose northern and southern limits corresponding to the geographical coordinates 28°47'27,8" south/49°42'45,8" west and 29°19'31,4" south/49°10'9,5" west. The extreme south of the area along the *Mampituba river* represents the boundary between the states of *Santa Catarina* and *Rio Grande do Sul*.

Coastal lagoons and large fields of active dunes, typical of Holocene barrier-lagoon depositional system, are found in the coastal plain. The total length is 80.775 m; of which 77.480 m consists of sandy beaches (95,92%); 2.854 m of rigid structures (3,53%) and 441 m (0,56%) of river mouths. Rocky promontories have not been mapped for this segment of the *Santa Catarina* coast.

Of nine municipalities that comprise the South coast of *Santa Catarina* coastal plain, five municipalities are considered in this research, denominated from south to north of *Passo de Torres, Balneário Gaivota, Balneário Arroio do Silva, Araranguá* and *Balneário Rincão*, all facing the Atlantic Ocean (figure 1), totaling area of 949 km^2 and population of 96.893 people (IBGE 2012).

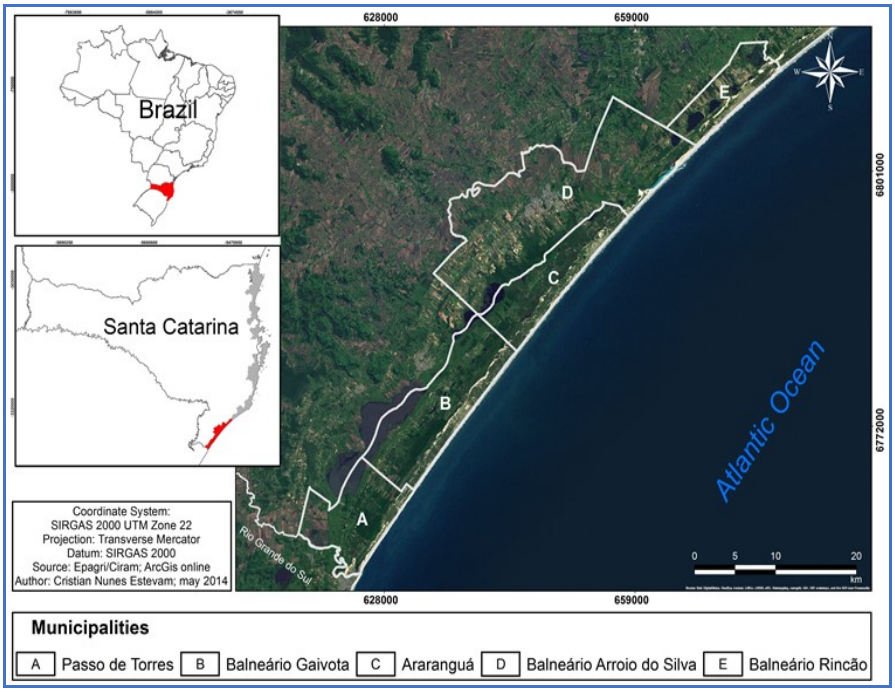

Figure 1: Geographic location of the studied area, corresponding to the South coast of *Santa Catarina*, highlighting the borders of the five municipalities: (A) *Passo de Torres*, (B) *Balneário Gaivota*, (C) *Balneário Arroio do Silva*, (D) *Araranguá*, and (E) *Balneário Rincão*.

3. Materials and methods

The methodology used in this study is part of the field survey of the project "Sedimentologic and Environmental Atlas of Sandy Beaches of the Coast of Santa Catarina, Brazil", developed by the Department of Geosciences and Graduate Program in Geography of the Federal University of Santa Catarina. For this

study, 41 sites were visited of the five municipalities, according to the figure 2. As the beaches are almost straight and very long, the sites were selected every 2 km. Sediment sampling and environmental parameters were done in December 2007.

The 41 sites are located on 22 sandy beaches, being (1) *Passo de Torres*, (2) *Bella Torres* and (3) *Rosa do Mar*, in the municipality of *Passo de Torres*; (4) *Valverde*, (5) *Areias Claras*, (6) *Sumar*, (7) *Balneário Gaivota*, (8) *Santa Fé*, (9) *Janaína*, (10) *Lagoinha* and (11) *Bill* in the municipality of *Balneário Gaivota*; (12) *Caçamba*, (13) *Arpoador*, (14) *Pescador*, (15) *Balneário Arroio do Silva* and (16) *Meta* in the municipality of *Balneário Arroio do Silva*; (17) *Paiquerê*, (18) *Morro dos Conventos* and (19) *Barra do Araranguá* in the municipality of *Araranguá*, and (20) *Barra Velha*, (21) *Rincão* and (22) *Torneiro Rincão* in the municipality of *Balneário Rincão* (table 1).

In the 41 sites of sampling of sediments, trenches were built on the foreshore zone (figure 3). On average, 200 g of sediment were sampled in the trenches at depths of up to 50 cm. The samples refer to the most superficial part of the deposit, always trying to homogenize the procedure throughout all 41 points. For each site were described the structure, color, texture, presence of carbonate or organic matter and heavy minerals of the sediments. The samples were processed at the Sedimentology Laboratory of the Department of Geosciences of the Federal University of Santa Catarina, using the standard sieving method, considering a ½ phi scale. The granulometric statistical parameters were treated with software Sysgran (Camargo 2006).

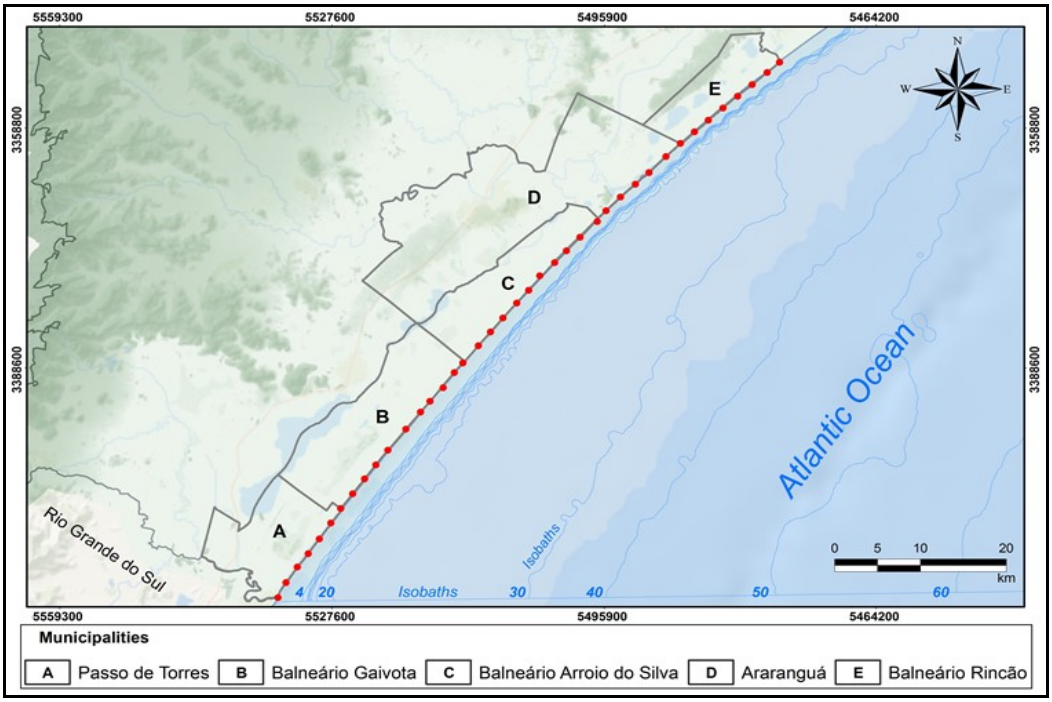

Figure 2: Geographic location of 41 sediment collection sites on the South coast of *Santa Catarina* (UTM 22J m E m S)

Table 1: Quantitative data of the field survey conducted in the South coast of Santa Catarina.

Municipality	Number of beaches	Number of sites visited
Passo de Torres (A)	3	6
Balneário Gaivota (B)	8	12
Balneário Arroio do Silva (C)	5	8
Araranguá (D)	3	6
Balneário Rincão (E)	3	9
Total	22	41

Figure 3: Example of sample collection of sediment on the foreshore zone at one of the 41 sites considered (*Passo de Torres* beach, municipality of *Passo de Torres*) (Photo by Norberto Olmiro Horn Filho, December 2007).

4. Results and discussion

The South coast of *Santa Catarina* can be characterized by its homogeneity, with the presence of long, straight, and exposed beaches. In this region, it is common the presence of coastal lagoons parallel to the coastline, extensive active dune fields, with predominance of Quaternary deposits of marine and lagoon environments, typical of the Holocene barrier-lagoon depositional system. The following section provides a description of the textural features of the sediments, complemented by orientation and slope of the coastline, direction of longshore drift, morphodynamic stage and beach width.

4.1. Textural features

Sediments of the South coast of *Santa Catarina* consist mostly of fine sand, reaching more than 95% of total texture, whose sedimentary composition consists basically of quartz, with low biodetritic carbonate content and organic matter, representing less than 1% of the total samples. It is possible to observe the morphoscopy maturity of the sediments in this coastal region, once all samples presented high level of grain reworking. Gravel or mud samples were not found.

Analysis of the textural data revealed high grain size homogeneity, with predominance of the fine sand class (average value of 2,5 Ø), well sorted (average value of 0,39 Ø), approximately symmetrical (values between -0,06 to 0,29) and mesokurtic (average value of 0,93). The color of the sediment is reddish brown (2.5YR5/3) in 66% of the samples and brown (10YR5/3) in 34% of the samples, predominating the brownish hue.

The presence of rounded to well-rounded grains suggests contributions of recycled sediments. On the other hand, assemblages of heavy minerals (maximum 10% of the total sample) present in fine sandy sediments consist of two suites: (suite 1) with concentration of zircon, tourmaline, staurolite, sillimanite, andalusite and kyanite minerals, probably indicative of granite complexes and, (suite 2) with concentration of hornblende, epidote and garnet minerals, probably indicative of metamorphic rocks, whose both suites can be attributed to Pre-Cenozoic units of the regional basement of the region.

With respect to the source area, it is worth noting that the investigated region consists of a wide barrier-lagoon depositional system, where the sediments in general show high maturity. The predominance of euhedral to subhedral grains of heavy minerals little affected by dissolution indicates first-cycle contributions, with influence of the continental chemical weathering, suggesting that the potential sources of these minerals and, therefore, of the beach sands, may be attributed to the southern zones of the *Santa Catarina* coast.

The results obtained show that the beach sediments of the investigated area are characterized by high textural homogeneity, which reveals control of the longshore drift, which is the major agent responsible for the transport and deposition of sediments along the coastline and in the inner continental shelf, which is provided by a wide dynamic system of 640 km long, between *La Coronija* in *Uruguay* and cape of *Santa Marta Grande* in *Laguna* - SC, Brazil.

4.2. Orientation and slope of the shoreline

The 41 sites have its coastline oriented predominantly in the northeast-southwest direction, exhibiting four main directions: NE-SW at 27 sites; NNE-SSW at 11 sites; ENE-WSW at two sites and N-S at one site, close to the jetties of the *Mampituba* river. The corresponding azimuths are: 11 sites with A40°, nine sites with A42°, eight sites with A45°, six sites with A47°, four sites with A50° and one site each with A4°, A52° and A55°. The slopes of the beach face vary from 2 to 5 degrees.

4.3. Longshore drift and morphodynamic stage

The South coast of *Santa Catarina* state, which corresponds to the North sector of the *Pelotas* basin presents specific characteristics regarding the action of coastal currents and waves.

Regarding longshore drift, longitudinal currents show predominant south-to-north orientation, corroborated by sandy formations in the form of spit, mostly oriented to NE, observed in the main river mouths in the study area, such as of the *Araranguá* river (figure 4). According to Horn Filho et al. (2013), wash over processes are found in the sandbar of the *Araranguá* river in high energy events.

In the studied area, the longshore drift direction is from south-to-north in 73,17% of the sites, and 24,39% of the sites from the north-to-south. In 2,44% of the sites, no significant longshore drift was recorded. Predominance of the south-to-north direction is due the current wave direction, while that from north-to-south is associated with tidal variation and backwash currents. Longshore drifts presented a mean speed of 0,21 m/s, showing considerable ability to carry sediments.

Predominates on all beaches of the South coast the dissipative morphodynamic stage dominated by wave action and microtidal hydrographic regime, with a mean tidal range of 0,3 m. In this stage, there is in general a wave train of three breaking waves (figure 5), sliding at the bottom and plunging when they approximate the beach.

Regarding the level of exposure to wave energy, all studied sites represent beaches exposed either to south-southeast ripples or to the east-northeast breakers. The wave breaking period varies greatly, from a short period associated with breakers up to a longer period associated with ripples. During the field work, the mean wave height (Hb) was 0,58 m; the mean value of

period (T) was 8,9 s and predominantly sliding breaking.

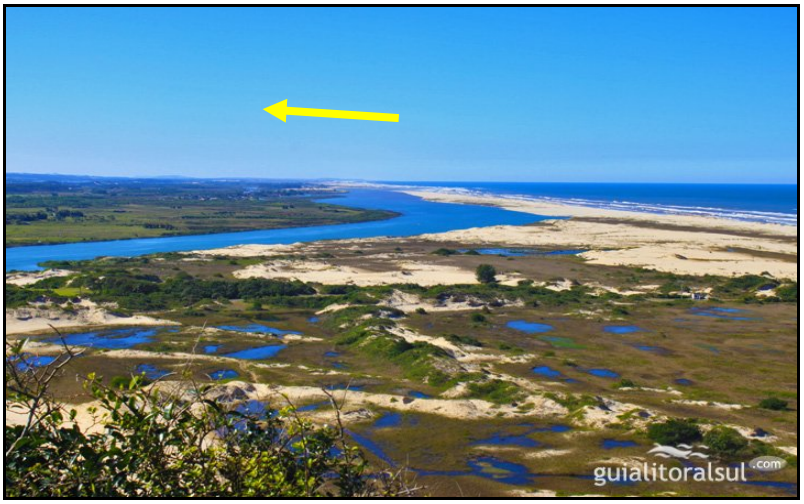

Figure 4: Northeast view of the coastal plain adjacent to the *Araranguá* river mouth, municipality of *Araranguá*, showing the inflection of the river to the northeast following the dominant direction of the coastal drift (south-to-north orientation demonstrated by yellow color arrow).

Figure 5: Northeast view of the coastline adjacent to the *Araranguá* river mouth, municipality of *Araranguá*, showing three breaking waves and erosion of the beach marine and eolic Holocene deposits demonstrated by three yellow color arrows (https://br.images.search.yahoo.com/search/images).

4.4. Beach width

The average width of the South coast beaches of *Santa Catarina* is 67,1 m, being 93 m the maximum width (site n°. 24) (at municipality of *Balneário Arroio do Silva*) and 36,6 m the minimum width (site n°1, at municipality of *Passo de Torres*) (figure 6). The width deviations are likely connected with the presence of breakwaters at the *Mampituba* river, which inhibits the arrival of sediments coming from the south, combined with the degradation of the frontal dunes in the urbanized area of *Balneário Arroio do Silva*. The presence of dunes parallel to the coastline is significant, in general little impacted by human action (figure 7). Exception is on the sectors close to beach resorts where the dunes present high levels of degradation. The presence of dunes is determined by the high amount of fine sands on the beach. Preservation and maintenance of such dunes help keep the dynamic balance of the beaches.

5. Conclusion

The data collected in this study allowed to let's say that the South coast of *Santa Catarina*, between the municipalities of *Passo de Torres* and *Balneário Rincão*, is characterized by a continuous shoreline with predominant NE-SW direction, mean azimuth angle of 46,2°, where there is predominance of quartzose fine sand, well sorted, mesokurtic, approximately symmetrical. These features are corroborated by a low slope degree, large beach width, dissipative morphodynamic stage, and fields of active dunes,

composing an environment of wide barrier-lagoon depositional system of Holocene aged, like the one observed on the North coast of the neighboring state *Rio Grande do Sul*, locates south.

Figure 6: To the left, minimum width (36,6 m) of the *Passo de Torres* beach and to the right, maximum width (93,3 m) of the *Balneário Arroio do Silva* beach (photos by Norberto Olmiro Horn Filho, December 2007).

Figure 7: Parallel and perpendicular view of the frontal dunes in the municipality of *Balneário Arroio do Silva*, which correspond to the upper limit of the backshore (photos by Norberto Olmiro Horn Filho, December 2007).

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