ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 9, nº 2 (2023)

https://doi.org/10.21680/2447-3359.2023v9n2ID32337

Geoenvironmental Characterization of the Municipality of Baía Formosa, Eastern Coast of the State of Rio Grande do Norte, NE Brazil

Caracterização Geoambiental do Município de Baía Formosa, Litoral Oriental do Estado do Rio Grande do Norte, NE do Brasil

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Abstract: The municipality of Baía Formosa is situated on the eastern coast of the state of Rio Grande do Norte, in Northeast Brazil, as part of a series of beaches forming Z-shaped bays. This research aims to characterize the geo-environmental aspects of this area, with a specific focus on sedimentological analysis, given the absence of previous studies of this nature for this location. The primary objective of this research is to analyze and describe the sedimentary composition of the study area, spanning from Sagi Beach to Porto de Baía Formosa, while highlighting potential correlations within the results. Specific objectives include identifying the probable sediment source areas of the beach, conducting granulometric analysis, assessing carbonate and organic matter content, and ultimately, providing a geo-environmental characterization of the study area. The geo-environmental characterization encompasses both physical and socio-economic aspects, with a focus on data obtained from the municipality, which encompasses the sites where twelve (12) sediment samples were collected for sedimentological analysis, all within the estuarine relief region. It was observed that there is a notable consistency in the medium-grained sands, primarily consisting of diameters between 0.250mm and 0.350mm, which justifies the classification of this area as an exposed reflective beach, making it more conducive to the constant removal of finer sediments. Carbonate and organic matter content analyses also display a degree of uniformity; however, graphical analyses reveal differing trends among the collection points, indicating distinct sediment curve trends, kurtosis, and sorting. This study can serve as an initial foundation for continuous monitoring.

Keywords: Sedimentology; Geo-environmental characterization; Baía Formosa.

Resumo: O município de Baía Formosa está localizado no litoral Oriental do estado do Rio Grande do Norte, Nordeste do Brasil, integrante de uma sequência de praias formando baías em forma de zeta. Esta pesquisa visa caracterizar os aspectos geoambientais da área em questão com um enfoque na análise sedimentológica, visto que não existem estudos de tal cunho para o local. O objetivo desta pesquisa é fazer uma análise e descrição da composição sedimentar da área em estudo, entre as praias de Sagi e Porto de Baía Formosa, evidenciando as correlações que podem ser feitas com os resultados desta. Como objetivos específicos, pretendemos identificar a provável área fonte dos sedimentos que compõem a praia; fazer uma análise granulométrica, com verificação do teor de carbonato e matéria orgânica; e por fim, fazer uma caracterização geoambiental da área em estudo. A caracterização geoambiental aborda os aspectos físicos e socioeconômicos, com enfoque em dados obtidos do município, e que abriga os locais onde foram coletadas as doze (12) amostras para análise sedimentológica, sempre no compartimento de relevo de estirâncio. Constatamos então, uma notável uniformidade de areias de granulometria média, em sua maior parte de diâmetros entre 0.250mm e 0.350mm, fazendo jus à classificação de praia refletiva exposta, facilitando que sedimentos mais finos sejam removidos mais constantemente. As análises de teor de carbonato e matéria orgânica seguem também uma certa uniformidade, porém, as análises gráficas demonstram tendências diferenciadas entre os pontos de coleta, indicando diferentes tendências de curva, curtose e selecionamento dos sedimentos. E este estudo poderá servir como ponto de partida para um monitoramento contínuo.

Palavras-chave: Sedimentologia; Caracterização Geoambiental; Baía Formosa.

Received: 24/04/2023; Accepted: 05/10/2023; Published: 12/12/2023.

1. Introduction

Beaches are terrestrial environments with the highest dynamics and susceptibility to variations when it comes to sedimentary aspects, or in a summarized way, this can be characterized as a dynamic interface zone between the atmosphere, land and sea (Viles & Spencer, 1995, apud. PEREIRA 2018). They are subject to tidal variations, wind action, waves, currents, and littoral drift, causing their shape and sediment distribution to be constantly altered, even on a scale of days or hours, and constructed in different ways from one another.

Even though there is no global consensus regarding the granulometric scale, Suguio (2003) lists four criteria for defining the importance of granulometric analysis in sedimentology, which are: it provides a basis for a more accurate description of sediments; the distribution can be characteristic of sediments from specific depositional environments; it can provide information about physical processes such as hydrodynamics that were active during deposition; and the relationship between granulometry and other properties, such as porosity and permeability.

The analysis conducted in this study aims to establish a sedimentary profile to contribute to the better management and planning of the study area, as the results provide information about the main agent governing the sediments, their origin, and correlations with various human uses, presenting part of the coastal dynamics through sedimentary analysis

The objective of this research is to conduct an analysis and description of the sediment composition in the study area, between the beaches of Sagi and Porto de Baía Formosa, in the municipality of Baía Formosa, on the Eastern coast of the State of Rio Grande do Norte (RN), Northeast Brazil, highlighting the correlations that can be made with the results achieved, in order to propose continuous monitoring. To achieve this objective, specific goals were outlined, such as: Identifying the likely source area of the sediments that make up the beach; Grain size analysis and verification of carbonate and organic matter content; and Environmental characterization of the municipality under study.

2. Study Area Characterization

The municipality of Baía Formosa, located on the eastern coast of the State of Rio Grande do Norte, is situated in the Intermediate Geographical Region of Natal and the Immediate Geographical Region of Canguaretama (IBGE, 2022). It also belongs to the mesoregion of Leste Potiguar and the microregion of Litoral Sul. Its boundaries to the north and east are with the municipality of Canguaretama, to the south is the state of Paraíba, and to the west is the Atlantic Ocean, covering an area of 247.48 km². The municipal seat is located at coordinates 06°22'08.4" S and 35°00'28.8" W, approximately 101 km away from the capital, Natal. The main access routes are the paved highways BR-101 and RN-062 (Figure 01).

The municipality of Baía Formosa has its origins in a core of fishermen who organized themselves around the boat port and was separated from the municipality of Canguaretama in the 2010 demographic census. This municipality has a population of 8,573 inhabitants, with a population density of 34.9 inhabitants per square kilometer (IBGE, 2022).

Figure 01 – Location map of the study area.
Source: the authors (2022).

In a regional context, the municipality of Baía Formosa is geologically situated within the Borborema Province, in the Canguaretama Sub-basin, part of the Pernambuco-Paraíba Sedimentary Basin. This basin covers a narrow strip of approximately 9,000 km² along the coast of the states of Pernambuco, Paraíba, and the eastern portion of Rio Grande do Norte, encompassing an area of over 24,000 km². Along the continental shelf, it is bounded to the north by the Touros High, which marks the division with the Potiguar Basin, and to the south by the Maragogi High, delineating the boundary with the Alagoas Basin. It is considered the easternmost basin along the Brazilian coastline, as pointed out by Souza (2004).

The basin comprises five lithostratigraphic units representing different evolutionary stages of the South Atlantic rift, including the Beberibe Formation as the basal unit, along with the Itamaracá, Gramame, Maria Farinha, and Barreiras formations (FILHO et al., 2015). According to Souza (2004), the Canguaretama Sub-basin is bounded to the north by the Natal Sub-basin at the Cacerengo fault and to the south by the Miriri Sub-basin at the Mamanguape fault. Tertiary-Quaternary sedimentary covers are represented by the Barreiras Formation as well as sub-recent and recent sedimentary formations.

The study area consists of recent Holocene coastal and fluvio-marine deposits, formed by the deposition of the littoral current and the sedimentation of the Curimataú basin, respectively, taking the form of inactive dunes on the coast. There are also outcrops of the Barreiras Group in the form of reddish cliffs, which, according to EMBRAPA (2011), is composed of continental and marine terrigenous sedimentary cover.

The segment that covers Porto de Baía Formosa Beach is classified as an exposed reflective beach with live cliffs and parabolic dunes, while the more southern section, encompassing Sagi Beach, is categorized as an exposed intermediate beach on a sandy tidal plain with predominantly frontal, parabolic dunes (MUEHE et al., 2006).

Reflective beaches are characterized by high beach gradients and adjacent seabed, reducing the width of the surf zone, which is common in sheltered areas between headlands, where most of the sand reserve is in the subaerial area of the beach. Thus, even under reduced energy conditions, an erosive scenario can be induced, while intermediate beaches exhibit dissipative and reflective characteristics, characterized by a reduction in the width of the longshore trough and the migration of the submerged sandbar toward the beach. Waves dissipate energy on the sandbar when they reach the beach face, and reflective conditions prevail, which are susceptible to the formation of beach cusps, with the occurrence of rip currents being common (CALLIARI et al., 2003).

The sampling area is entirely included in the coastal dune field, being considered an accumulation of recent sandy sediments. However, considering the municipality as a whole, the most abundant and expressive soil types are Argisols, Quartzarenic Neosols and Fluvic Neosols, associated with a formation under the strong influence of alluvial sediments, with an irregular distribution of organic carbon content in depth (EMBRAPA, 2018).

Two river basins cover the municipality, in addition to the eastern strip of diffuse runoff. Of these, 35.75% of the territory is located in the areas of the Guaju river basin and 33.99% in the areas of the Curimataú river basin, leaving 26.43% in the diffuse flow band. Other tributaries of the Curimataú sub-basin have hydrological importance, such as the Pedras, Guaratuba, Outeiro, Pau Brasil rivers and the Uriúna, Taboquinha and Calvaçu streams (CPRM, 2005).

Being located on the Eastern Coast of the Brazilian Northeast, bathed by the southeast trade winds of the Hadley circulation cell, the most significant macroscale system is the Intertropical Convergence Zone (ITCZ), since cold fronts do not occur in the territory potiguar (DINIZ & PEREIRA, 2015). Another determining factor in the local climate is the sea, as it is located immediately on the coast, with a notable difference between coastal and inland municipalities in the State. The municipality is classified as having a Tropical climate, with peak rainfall during the summer, between the months of April to July, and classified as Aw (Köppen-Geiger).

The predominant type of vegetation at the site is the Pioneer Formation with Marine Influence, defined by Miura (1999) as places of unstable terrain, whether flooded or not, formed by the deposition of sediments rejuvenated by the subsequent deposition of marine sand on beaches and restingas, by alluvium fluviomarinhos in the mouths of rivers and in riverine alluvial and lacustrine soils.

3. Theoretical Framework

The coastal zone can be characterized as a dynamic interface zone between atmosphere, land and sea (Viles & Spencer, 1995; apud PEREIRA, 2018), and constitutes the transition landscape between land and sea, formed by a mosaic of coastal ecosystems , which has excessive exploitation and disordered land use, becoming a priority sector of urban management (LIMA, 2011).

According to Suguio (2003), sedimentology is the study of sedimentary deposits and their origins. It is applicable to various types of deposits, whether ancient or modern, marine or continental, including their faunal and floral contents, minerals, textures, structures, diagenesis, and temporal and spatial evolutions.

For a characterization of the various features found on the beach, Calliari et al. (2003) emphasize that it is necessary to take into account that the beach is constructed by a superposition of strata, with each stratum representing the topography of a given moment, and therefore, they will exhibit distinct grain sizes.

A characterization and monitoring of the beach, as emphasized by Lima (2011), is important for understanding the seasonal dynamics of coastal sediments and their deposition processes, analyzing quantitative data such as mean, standard deviation, skewness, and kurtosis of the sediments. Furthermore, according to Lima (2011), the mentioned skewness is represented by the dispersion of grains in relation to the central tendencies towards one of the two sides because if values are equal, the distribution will also be so. Kurtosis corresponds to the degree of peak sharpness, being the ratio between the dispersion of the central part and the ends of the curves.

Despite comprehending beyond the beach, it is defined by Cunha and Guerra (2002) as 'sediment deposits, most commonly sandy, accumulated by the action of waves, which, due to their mobility, adapt to wave and tidal conditions.' Moving on to beach features, and following the order of features as they appear from the continent to the sea, in certain locations, whether stabilized by vegetation or not, there may be the presence of frontal dunes or foredunes:

> 'The formation of this morphological unit is conditioned by a large stock of sand available to be moved by the wind. Its worldwide distribution is extensive, although it is common in coasts with a gentle gradient and strong winds blowing inland' (Lima, 2004).

Next, the backshore feature represents the highest portion of the beach, beyond the reach of ordinary waves and tides, thus subject to greater wind transport, extending from the beach crest, which is shaped by the mean spring tide level, to the foot of the beach scarp (SUGUIO, 2003).

The foreshore zone can be referred to as the region between tides, that is, between low tide and mean high tide (Ribeiro, 2010), constituting the part of the beach that is constantly wet or soaked, marking the boundaries of the tides. In terms of morphology, it can vary considerably depending on the wave power, tide range, and grain size (Reading & Collinson, 1996; cited in LIMA, 2004).

Finally, in coastal features, the shoreface corresponds to the area situated between the upper limit of high tide (beach scarp) and the line of ordinary low tide, or the front part of the beach that is typically affected by tides and the effects of wave swash after breaking (SUGUIO, 2003). These features can be observed in Figure 02.

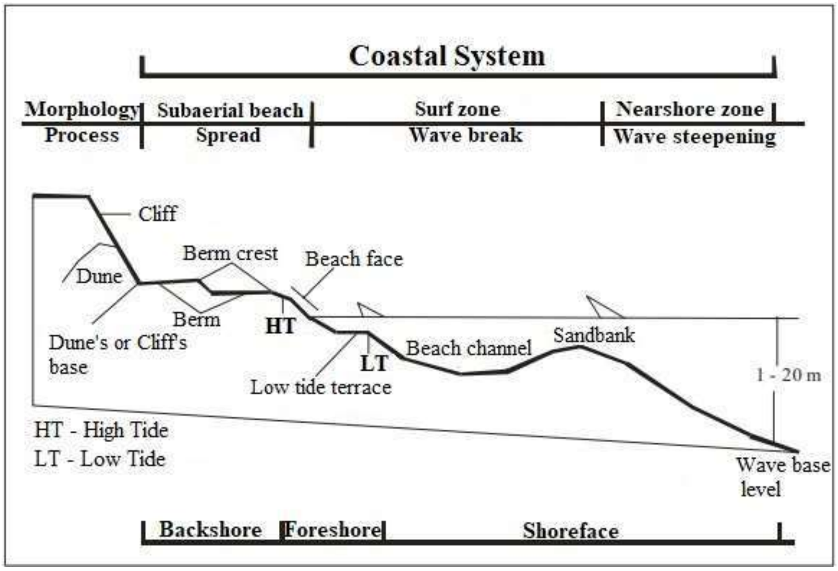


Figure 02 – Nomenclature and boundaries of the beach system.
Source: Souza, 2005 cited in CHAVES, 2005.

The study conducted here encompasses three parameters of analysis. Granulometry, which pertains to grain size, serves a descriptive function, as stated by Suguio (1973), enabling the adoption of standardized and uniform nomenclature. Scales are used as units to perform various sediment analyses. The granulometry data obtained will provide insight into the size distribution of constituent particles, allowing for comparisons and associations with the genesis of the formation, the environment in which it is situated, and porosity and permeability.

The second parameter, which includes the content of organic matter present, is essential because the interpretation of organic matter occurrence provides effective insights into the origin, nature, and final destiny of this matter in the environment (DIAS & LIMA, 2004). The last analysis involves the content of calcium carbonate ($CaCO_3$) present in the samples, which, initially, is one of the factors that is part of the textural classification of sediments by Dias & Medeiros (2005), modified from Larsonneur (1977). This factor is related to the local biota and indicates the presence of bioclastic/biogenic sediments in the environment.

4. Research Methodology

In the literature review, we used the digital collection of the UFRN Repository, where the works of Lima (2004) and Chaves (2005) were analyzed, along with the National Coastal Management Plan (PNGC, 1988) and the Tide Table (Marinha do Brasil). We also consulted the collection at the Zila Mamede Central Library (BCZM) for works by Suguio (2003) and Cunha and Guerra (2002).

Sample collection took place on March 18, 2022, during low tide on a day of spring tide (full moon). The sediments were collected in the middle foreshore. The collection was done in a single day with the assistance of a Buggy. In the field, 12 samples were collected (See Figure 01), designated as follows: Sample P1a (Guaju River wave marks), P1b (Guaju River bar), P2 (Barreiras Pinnacles), P3 (Rony's fishery), P4 (Sagi lagoon), P5 (jangada cove), P6 (ferruginous sandstones), P7 (turtle sanctuary), P8 (razed cliffs), P9 (Bacupari lighthouse), P10 (main beach of Baía Formosa), and P11 (Baía Formosa port).

These samples were analyzed at LABGEOFIS (Physical Geography Laboratory, Department of Geography, Federal University of Rio Grande do Norte). They were washed to remove all the salt. Subsequently, the samples were dried using heating plates at a temperature of 100ºC. After drying, the samples were quartered, weighed, with 100g set aside for grain size analysis, 10g for organic matter analysis, and 5g for calcium carbonate content analysis (Figure 03A).

For the grain size analysis, sieves were placed in the ROT-UP shaker, and in Phi (Φ) measure, the interval of half-Phi between the sieves was used. The following sieves with millimeter openings were used: 2, 1.4, 1.0, 0.710, 0.500, 0.355, 0.250, 0.180, 0.125, 0.090, and 0.062mm (Figure 03B).

Subsequently, the check for organic matter content in the samples was performed using a muffle furnace (Figure 03C), where the samples were subjected to a temperature of 500ºC for approximately seven hours. After cooling, the material was weighed, and the difference in percentage compared to the initial weight was determined.

The analysis of carbonate content in the samples was conducted by treating the samples with HCl (hydrochloric acid) diluted to a concentration of 10%. They were left in the solution until there was no further reaction. Subsequently, the samples were washed, dried, and weighed again to determine the difference in initial weight and calculate the percentage of carbonates (Figure 03D).

Finally, data processing for the creation of tables, graphs, and maps was performed. The granulometry data were entered into the Granulometric Analysis System (SAG), available at LABGEOFIS.

Figure 03 – Laboratory methodology. Samples in drying (A); Set of sieves on the ROT-UP device (B); Samples the muffle furnace (C); Washing of samples (D).
Source: the authors (2022).

5. Results and Discussion

According to Suguio (1973), the study of grain size analysis can have applications to characterize and classify sediments with minimal subjectivity, correlate sediments from different areas using appropriate statistical treatments, gain insights into the different values of permeability and porosity of sediments, and infer ideas about sediment genesis, as well as their mode of transport and deposition. As shown in Table 01, the study area exhibited complete homogeneity in the classification of the average grain size of the beach sediments, as determined by the Medium Sand Granulometric Analysis

System for all sampling points, with a predominant concentration of sediments with diameters between 0.355mm and 0.250mm.

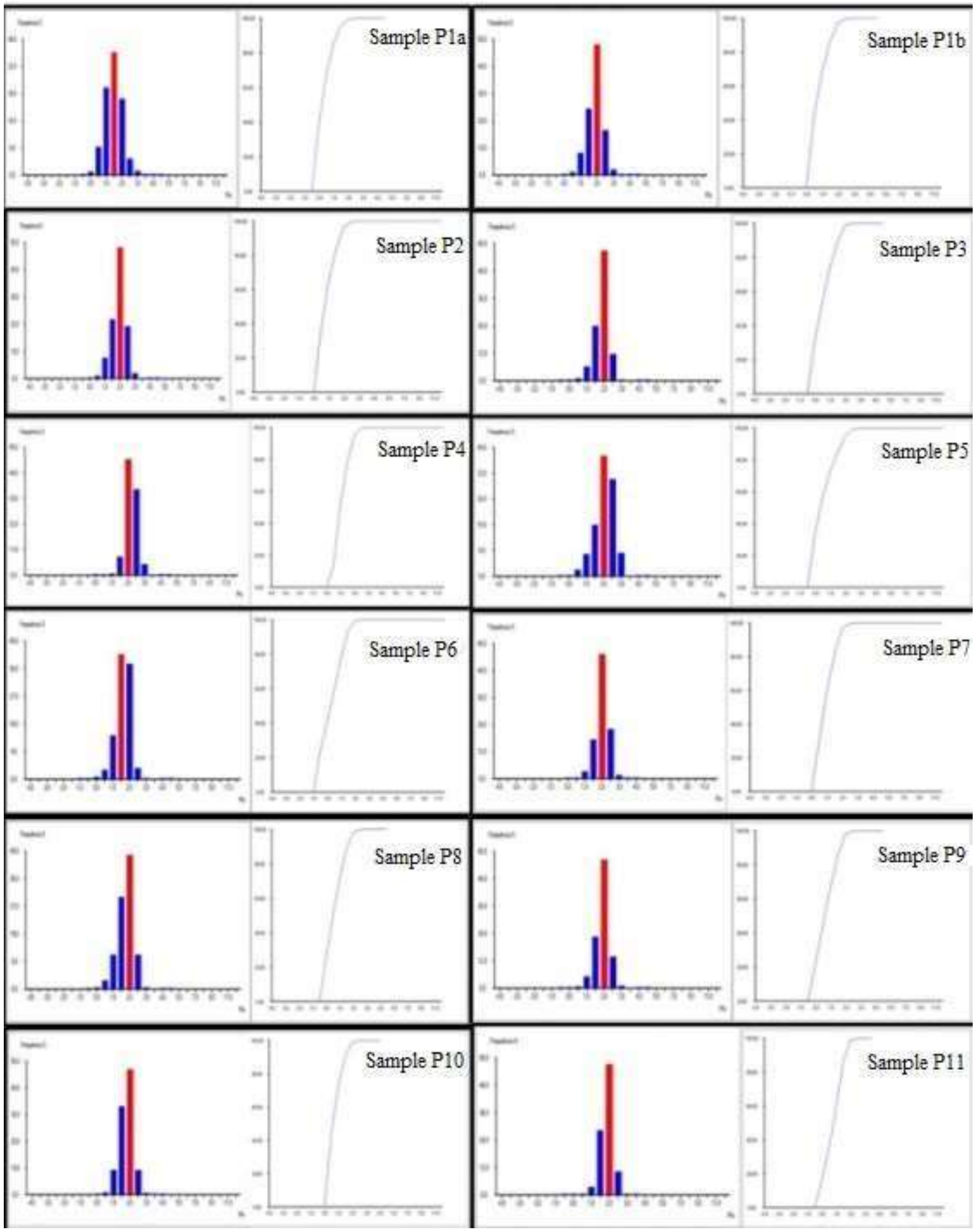
Table 01 – Overall results obtained by SAG.

	Particle-size distribution (%)							
SAMPLE	**Gravel**	**Very coarse sand**	**Coarse sand**	**Medium sand**	**Thin sand**	**Very thin sand**	**Silt**	**Average rating**
P1a	0,00	1,17	34,13	58,71	5,96	0,02	0,007	Medium sand
P1b	0,00	0,04	9,14	72,46	18,34	0,01	0,004	Medium sand
P2	0,00	0,08	8,70	70,03	21,18	0,01	0,003	Medium sand
P3	0,00	0,08	7,13	80,93	11,85	0,00	0,001	Medium sand
P4	0,00	0,00	0,56	58,01	41,42	0,01	0,002	Medium sand
P5	0,00	0,28	8,79	53,44	37,49	0,00	0,000	Medium sand
P6	0,03	0,88	17,14	78,28	3,65	0,00	0,001	Medium sand
P7	0,00	0,03	3,49	72,74	23,74	0,00	0,000	Medium sand
P8	0,00	0,62	13,92	73,74	11,72	0,00	0,001	Medium sand
P9	0,00	0,13	6,05	78,89	14,92	0,01	0,002	Medium sand
P10	0,00	0,02	10,12	80,02	9,84	0,00	0,000	Medium sand
P11	0,00	0,14	4,04	85,35	10,46	0,00	0,000	Medium sand

Source: The authors (2022).

Homogeneity was also observed in the collected samples, as shown on the left with the sample distribution curve on the sieves used, and on the right with the cumulative sediment curve (Table 02).

Table 02 – Histograms of the collected samples.



Source: The authors (2022).

The Folk & Ward (1957) classification proposal is based on the analysis and representation of two triangular diagrams, one for coarse sediments and another for fine sediments. Since there is no significant percentage of gravel for coarse sediment analysis, only the diagram for fine sediments is applicable. According to this classification, this beach segment has the character of an exposed reflective beach, causing finer sediments to be easily removed (Table 03).

Table 03 – Parameters according to the Folk & Ward (1957) classification.

Sample	Asymmetry	Kurtosis	Selection	Folk & Ward classification
P1a	Approximately symmetrical	Mesokurtic	Moderated	Sand
P1b	Negative	Leptokurtic	Well selected	Sand
P2	Negative	Leptokurtic	Well selected	Sand
P3	Negative	Leptokurtic	Well selected	Sand
P4	Approximately symmetrical	Mesokurtic	Very well selected	Sand
P5	Negative	Leptokurtic	Moderated	Sand
P6	Negative	Mesokurtic	Well selected	Sand
P7	Approximately symmetrical	Leptokurtic	Well selected	Sand
P8	Negative	Mesokurtic	Well selected	Sand
P9	Negative	Leptokurtic	Well selected	Sand
P10	Negative	Mesokurtic	Well selected	Sand
P11	Negative	Mesokurtic	Very well selected	Sand

Source: The authors (2022).

As for Central Tendency, this value is expressed through the mean value, where, if the sediment curve is symmetric, the median and the mean diameter will have equal values. If it is asymmetrically distributed, the mean will be different from the median. These values characterize the most frequent grain size class (Silva, 2012). In other words, they allow you to determine whether the particles that make up the distribution are coarser or finer compared to another distribution. The samples are predominantly classified as medium-grain sand and sand, respectively. In the sieve analysis, the sediment concentration peaks always appear in only two size classes, with diameters of 0.355mm and 0.250mm (Phi 1.5 and 2.0, respectively).

This classification reflects what was previously explained in the geomorphology section, where the beaches are classified as exposed reflective and exposed intermediate beaches for the Porto de Baía Formosa and Sagi beaches, respectively. This is a coastal feature that is strongly affected by the agents involved in sediment transport. This is also reflected in the kurtosis parameter, where the results indicate leptokurtic and mesokurtic curves. This suggests that removal processes due to the exposed morphology predominate in that environment. It's also worth noting that none of the 12 samples exhibited platykurtic curves, which would indicate a predominance of deposition processes.

Kurtosis represents the degree of sharpness of the peaks in the frequency distribution curves, indicating the average spread of the distribution tails relative to the peak (Suguio, 1973), as shown in the frequency histograms of the samples. According to the Folk & Ward (1957) method, normal curves have a value of Kg = 1.00, where Kg is the graphical angularity value. The lower the value, reaching down to 0.06, indicates a platykurtic distribution, with well-separated and distributed curves. As the value rises, samples become leptokurtic, with tall and narrow peaks (Table 04).

Table 04 – Folk & Ward´s (1957) proposed angularith designation for grains size distribution.

KG	Designation
<0,067	Very platykurtic
0,67 a 0,90	Platykurtic
0,90 a 1,11	Mesokurtic
1,11 a 1,50	Leptokurtic
1,50 a 3,00	Very leptokurtic
>3,00	Extremely leptokurtic

Source: The authors (2022).

Among the twelve (12) samples analyzed, the kurtosis values varied from 0.893 Kg to 1.253 Kg. Half of the samples exhibited leptokurtic curves (values between 1.11 and 1.50), which means that the distribution curve has shorter tails more prominent than the normal curve. The other half displayed mesokurtic curves (values between 0.90 and 1.11), indicating that their curves approach normality more closely.

The samples with leptokurtic grain size curves, mainly from the first half of the sampling area, further from the urbanized part of the beach, showed a more significant accumulation in one grain size class, indicating a predominance of a modal class, with less pronounced values in the others. These values were mostly concentrated between Phi 2.0 and 2.5, corresponding to sample P7. On the other hand, the mesokurtic grain size curves, mainly from areas closer to the urbanized part of the beach, demonstrated more evenly distributed values among the determined classes but were mainly concentrated between Phi 1.5 and 2.0, even though the mesokurtic curves had a modal class of sand.

Interpretations of the kurtosis values indicate sedimentary environmental conditions, where leptokurtic trend curves represent zones with higher energy and more significant removal of finer sediments. In contrast, platykurtic trend curves represent areas with lower sediment movement (Cunha, 1982, cited in ALMEIDA et al. 2018).

As for asymmetry, these measures indicate the enrichment of grain size in either fines or coarses, causing deviations from the normal curve. This shows the grain size distribution as either coarse or fine particles (DIAS, 2004). The values obtained varied between -0.189 (negative asymmetry) and 0.036 (approximately symmetric). Among the twelve samples, those showing negative asymmetry indicate that removal processes predominate at the location over deposition. Sample points P1a, P4, and P7 had approximately symmetric curves, but only sample P4, collected near Laguna Sagi, had a positive asymmetry value, indicating a depositional process sampling location.

As highlighted by Dias (2004), the parameter of asymmetry is reflected in the extreme parts of the frequency curve's tails. A small enrichment of fine particles at the right tail of the curve can signify the occurrence of a period of lower energy after a depositional event. Therefore, Gregório (2006, cited in SILVA, 2012) adds that there is a direct relationship between grain size and asymmetry. The more fine sediments found in the samples, the more positive the asymmetry, and the opposite holds true. This corroborates with the results for sample points P1a and P4, which have the highest values of distribution for the grain size fraction of 0.062mm, corresponding to Phi 4.0.

Another parameter is the sorting, which depends on the grain size of the material and is better in sands and coarser materials, deteriorating in finer sediments (SUGUIO, 1973). It is related to the sorting of deposits and reflects variations in flow conditions (velocity and turbulence) in the depositional environment (Ponçano, 1986, cited in DIAS, 2004). The classification leans almost predominantly towards well-sorted samples, with the exception of sample points P1a and P5, which exhibit moderate sorting. In conjunction with the asymmetry parameters, the sorting supports the previously mentioned results, indicating that removal processes predominate at the location, with medium-sized sands being prevalent, while the other fractions (finer ones) are constantly removed.

Regarding Larsonneur's Classification (DIAS & MEDEIROS, 2005), the classification obtained for the analysis proposed by Larsonneur (1977) and modified by Dias & Medeiros (2005) results in the class "Medium lithoclastic sand" (AL1d). This method uses both grain size standards and the carbonate content in the sample to classify it into one of the shown classes, as it is a parameter that associates carbonaceous organisms with distinct sedimentary classes (Aguiar Neto, 2008, cited in SILVA, 2012).

The analysis of the Calcium Carbonate ($CaCO_3$) content indicates the presence of bioclastic or biogenic sediments in that environment. It is an element fixed by organisms and gives rise to organically derived limestones. It also serves as an analysis parameter for the Larsonneur classification (1977, adapted by Dias & Medeiros, 2005). Soares (2014) and Almeida et al. (2018) emphasize that areas with higher turbidity and movement are less conducive to carbonate accumulation, which aligns with the local samples, where the presence of colonies of organisms such as corals, calcareous algae, or carbonate reefs was not observed.

Therefore, the sampling point with the highest carbonate content was sample point P1a, in the vicinity of the Guaju River. Nevertheless, even sample P1a and all others show low concentration levels, not exceeding 2%. The lowest organic matter content obtained in the analysis was in sample P10, with 0.25%, in the vicinity of the main beach of Baía Formosa (Table 05).

Finally, the analysis of Organic Matter (OM) in sediment samples provides information about its origin, nature, and fate. As noted by Soares (2014), organic matter more easily associates with finer sediments and is found in greater abundance in low-energy environments dominated by deposition. Because the environment studied is one of high energy, exposed and well-drained by predominantly sandy sediments, the results show very low values (Table 05). Note that none of the samples had organic matter levels above 1%, including an absolute zero value for sample P2. The highest value was for samples P6 and P7, both collected in nearby locations, but the values are still too low to be associated with a low-energy zone in sediment dynamics. Additionally, the samples with the highest content mentioned exhibit different asymmetry and kurtosis for their respective grain size distributions, indicating a lack of strong association between them.

Table 05 – Calcium carbonate and organic matter content in the analyzed samples.

Sample	Calcium Carbonate (%)	Organic Matter (%)
P1A	1,976	0,0041
P1B	1,318	0,0014
P2	0,47	0
P3	1,606	0,0033
P4	0,99	0,0042
P5	1,554	0,0032
P6	0,33	0,0063
P7	0,686	0,0077
P8	0,396	0,0014
P9	0,272	0,0037
P10	0,25	0,0001
P11	1,266	0,0005

Source: The authors (2022).

6. Final Consideration

Overall Analysis: The results consistently revealed a stable situation throughout the study area. The granulometry remained similar across all sampling points, primarily consisting of medium-sized sands. Additionally, low levels of organic matter and calcium carbonates were observed, with all samples showing results below 1%, and a maximum of 2%.

The kurtosis parameters, with predominantly leptokurtic curves, indicated a high-energy sediment zone characterized by the removal of finer sediments. Regarding skewness, it categorized this area as having a range of sediment from fine to coarse, with finer sediments being more intensely transported, suggesting that this section of the beach is undergoing erosion. The near absence of carbonates and organic matter points to some turbidity and sediment mobility in this area.

However, given the scarcity of literature related to the geo-environmental aspects of this study area, we found a notable lack of data on sedimentological factors. This includes information on the classification and characterization of beach sands across all relief compartments, including the backshore, foreshore, and shoreface, with adequately spaced sample collection for representativeness. It's important to note that the data presented in this study represent the first of its kind for this specific area. Furthermore, there is a dearth of information on coastal erosion aspects, such as hydrodynamics and beach profiles. Therefore, we recommend implementing a minimum one-year coastal monitoring program for the area. This will provide a comprehensive understanding of how seasonal variations, tidal changes, and shifts in climate may impact the results of future granulometric analyses.

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