Research Article
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Sedimentalogical characterization of the Bero River Estuary

Abstract

The research in question was carried out in the southwestern portion of Angola, Namibe Province, Moçâmedes Municipality, more specifically in the estuary of the Bero River. It aimed to characterize the sedimentology of the Bero River estuary, and for this purpose sedimentological analyses were carried out to understand the composition, granulometry and distribution of sediments in the studied area. For a better organization, the research was fragmented into 3 stages and the methodology was essentially varied and included a series of laboratory analyses and statistical analyses. The results revealed significant variations in the average particle sizes, with a decreasing trend towards the mouth of the river. In addition, differences in sediment selection were observed between samples, indicating variations in the uniformity of particle sizes throughout the estuary. Regarding the symmetry of the particles, there were variations among the samples, suggesting differences in the distribution and morphology of the sediments. The same results provide information for understanding the dynamics of the estuary and its influence on the coastal environment and contributing to a better understanding of the ecological and geological aspects of the area, in addition to subsidizing actions for the management and conservation of local natural resources.

Keywords: sedimentology, characterization, sediment, estuary, granulometry, coastral

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Abbreviations

IGEO, Instituto Geológico de Angola; GPS, Global Posytion System; INAMET, Intituto Nacional de Metereologia de Angola

Introduction

The sedimentological study involves the characterization, classification, and correlation of sediments with their respective occurrence areas, enabling inferences about their genesis, transportation, and deposition. When applied to analyzing the nature and the delimitation of the spatial distribution of sediments, it helps to determining the relationship between biota and their environment. Sedimentological characterization allows for the individualization of each sedimentary unit that serves as a substrate for the colonization of macro- and microphytobenthos, which function as refuges for invertebrate species and a direct and indirect source of food for the local fauna.[1]

The analysis of particle dimensions is crucial for several reasons. Firstly, it provides valuable information regarding provenance, including the availability of certain particle types and the rocks from which they originated. Two, it aids in understanding transport processes (such as textural maturity and particle resistance to abrasion and chemical alteration, based on their composition), and three, it provides insights into depositional environments.[2]

Estuarine environments are intricate and dynamic coastal configurations that play a crucial role at the interface of terrestrial and marine environments. Their longevity depends on the balance between sedimentation rates and sea level fluctuations. Therefore, understanding the sedimentary dynamics within these environments is of paramount importance.

Sedimentological characterization is essential for understanding the dynamics and sedimentary processes that occur in estuaries, which are transition zones between river and marine environments. These ecosystems are of significant ecological, economic, and social importance, supporting rich biological diversity and serving as breeding and growth grounds for various marine species. Additionally, they are favorable areas for fishing and aquaculture activities.[3]

The Bero River estuary, situated in the Moçâmedes region of Namibe Province, represents a complex system where the interaction between fresh river water and seawater leads to a variety of sedimentological processes. These processes significantly influence the distribution and composition of sediments in the area. In addition, it represents an important estuarine system that significantly influences coastal dynamics and local biodiversity. However, despite its ecological and socio-economic importance, there is a significant gap in scientific knowledge about the sedimentology of this particular estuary. Thus, a detailed understanding of the granulometry and distribution of sediments in the Bero River estuary is essential for effective management of coastal resources and for mitigating the impacts of human activities in the region.

Previous studies have emphasized that sediment granulometry in estuaries yields valuable insights into sediment sources, transportation and deposition processes, and system morphodynamics.[4,5] In the case of the Bero estuary, detailed sediment analysis reveals spatial and temporal variations that are essential for the management and conservation of this environment. Particle size, which includes analysis of the size and shape of sedimentary particles, is one of the most widely used parameters for characterizing sediments and inferring depositional processes.[6] Sediment dynamics in estuaries are influenced by various factors, including hydrodynamics, bottom topography, riparian vegetation and human activities such as dredging and infrastructure construction.[7] These activities can significantly alter deposition and erosion patterns, negatively impacting the biodiversity and environmental quality of the estuary. Understanding these processes is fundamental to developing effective management and conservation strategies, especially in the face of climate change and increased anthropogenic pressures.[8]

In this context, this study aims to characterize the grain size of the sediments in the Bero estuary. Through detailed analysis of the sediment samples collected along the estuary, the aim is to identify the main sources of sediment, the processes of transport and deposition, and the possible spatial and temporal variations in sediment composition. The results obtained are fundamental for understanding the sedimentary dynamics of the estuary and for developing environmental management policies aimed at the conservation and sustainability of this vital ecosystem.

Techniques and areas of application of sedimentological studies

Sedimenlogical properties of sediments in order to understand the origin, composition, structure and evolution of these materials. This knowledge is essential for various fields, such as geology, geography, civil engineering and oceanography.[9] In addition, sedimentological characterization has been applied in archaeological studies to investigate sediments that contain records of past human activities. For example, micromorphological analysis of sediments makes it possible to identify signs of occupation, such as fire marks, dwelling structures and buried artifacts.[10] Sedimentological characterization is also relevant for identifying and monitoring sediment contamination by chemical substances. Through techniques such as element analysis and determination of heavy metal levels, it is possible to assess environmental quality and possible risks to biota and humans.[11] There are various techniques used for sedimentological characterization. Particle size analysis, for example, is widely used to determine the distribution of grain size in sediments, allowing inferences to be made about transport energy and deposition processes.[12] In addition, mineralogical analysis can be carried out using X-ray diffractometry, allowing the different mineral phases present in sediments to be identified.[2]

It is important to note that grain size is an important part of sedimentological characterization, as it helps to analyze the size of the particles present in the sediments. It contains information about the source, mode and energy level of transport, while the grain size distribution contains information about the source and the mechanism and intensity of sediment transport.[13] The granulometric evaluation of sediments makes it possible to classify soils according to their texture, which is determined by the size of the particles.[14] Soils with different textures have different physical properties, such as water retention capacity, permeability and resistance to erosion. Grain size is the most basic physical property of a sedimentary deposit and, for this reason, the environmental interpretation of particle size distribution is extremely important.[15] In the same vein, grain size is a very important element of the clastic structure as it reflects the transportation process, as well as the distance from the source to the place of deposition. The size is determined by means of granulometric analysis, since it is inaccurate to determine it by means of delegated sections. The temporal and spatial evolution of particle size distribution is crucial information for creating models of coastal formation and evolution.[2]

Material and methods

Characterization of the study área

The size is determined by means of granulometric analysis, since it is inaccurate to determine it by means of delegated sections. The temporal and spatial evolution of particle size distribution is crucial information for creating models of coastal formation and evolution.[16]

Knowledge of particle size distribution is important for understanding the principles of coastal dynamics, as well as for understanding the regional sedimentary processes necessary for planning and decision-making in coastal projects. Another application of particle size analysis is related to the interpretation of sediment beaches along river mouths (Figure 1).[17]

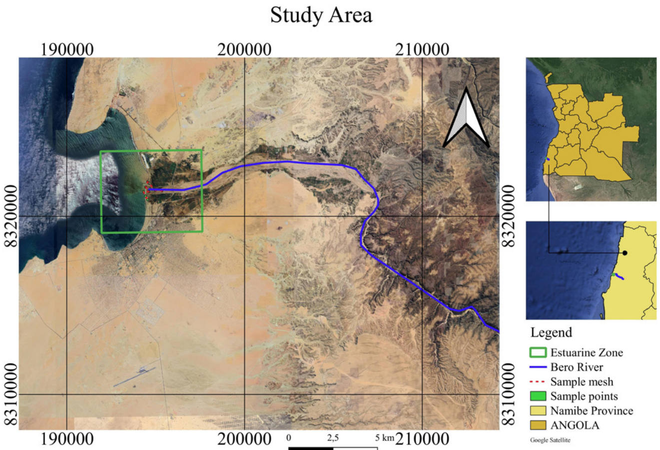

Figure 1 Study area (author, 2024).

Namibe province is generally known for having an arid and semi-arid climate. The region is also known for its high temperatures and low rainfall throughout the year. According to the National Institute of Meteorology and Geophysics, the hottest months are between November and March, with temperatures that can reach up to 40 degrees Celsius. The coldest months are between May and July, with average temperatures of around 20 to 25 degrees Celsius. The region generally receives little rainfall, with an annual average of around 50 millimeters, especially during the warmer months.[9] The climate of Namibe province is considered to be the best on the entire coast of Angola: highland tropical in the areas bordering Huíla province, desert throughout the Namibe desert and humid temperate (with variations between 17°C and 25°C) along the coast. Due to the low rainfall and the hot and dry desert climate, water plays an important role in satisfying human needs and providing water for animals. Its main rivers are: Carunjamba, Inamangando, Bentiaba, Giraúl, Bero, Catera, Cangala, Piambo, Flamingo, Curoca and the Cunene River. These rivers are periodically flowing and very dependent on the waters that fall in the Serra da Chela, except for the Cunene River.[9,18]

As for the regional geology, according to geological studies carried out in the region, the geology of Namibe is made up of three main units: the Crystalline Embayment, the Namibe Basin and the Coastal Plain. The Crystalline Embayment is the oldest unit in the Namibe and is composed of igneous and metamorphic rocks dating from the Precambrian. These rocks include gneisses, schists, granites and marble.[19] The Crystalline Basement is important in the formation of the province's relief and features mountainous and rugged reliefs. In addition to the crystalline basement, the Coastal Plain is another unit that occurs along the Namib coast and is formed by recent sediments. These sediments are mainly composed of sand, clay and gravel, which were deposited by the rivers that drain the surrounding mountains.[20]

Important geomorphological aspects are presented in studies carried out by the Angolan National Institute of Meteorology. According to these studies, the coastal region of Namibe has a morphology dominated by coastal plains, characterized by extensive flat and low areas, with the presence of sand dunes. These flat areas are formed by the accumulation of sediments brought by the action of the sea.[21] Other relevant studies on the geomorphology of Namibe province can be found in publications such as "Geomorfologia e Geomorfodinâmica da Região Litoral de Angola" by Guilherme

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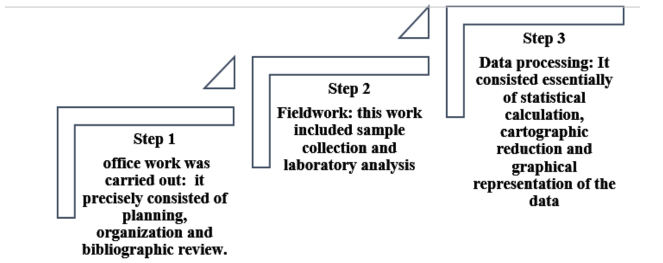
Rodrigues Castro and "Morphology and dynamics of the Namibian coastal dune field", by Luís Sousa, among others. Given that the research aims to describe the sedimentological characteristics of the Bero River estuary and acknowledging the complexity of such studies, it was necessary to divide the research into distinct stages to optimize the results. It is important to note that each of these stages involved different but complementary activities. These stages have been designated as follows: Pre-field stage, field stage and post-field stage.



Eight sampling stations were defined at random and eight shallow-water bottom sediment samples were also collected in sections spaced 100 meters apart along 9.989 square kilometers of the estuarine zone. Due to the lack of sophisticated equipment such as dredges or bottom samplers, the collection process took place with the help of adapted materials, and all the collections were carried out at low tide in a single period, i.e. in January 2024.

The collection process began in the eastern part of the channel and then samples were taken in the central part and finally in the southern part, thus completing our sampling grid. To locate the points to be sampled, we initially relied on a Garmim GPS to know their exact position. These points were created in the form of a random mesh, made in advance using software such as Google Earth and ArcGis, as shown in the map below (Figure 2) (Table 1).

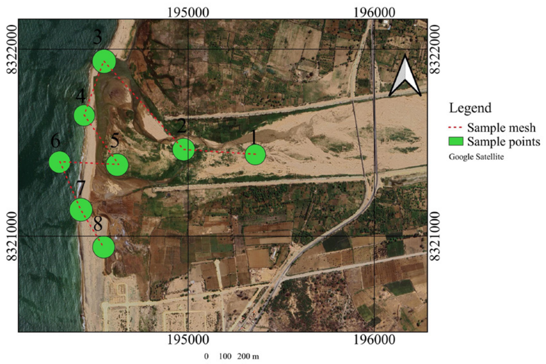


Figure 2 Sample points (Author, 2024).

Table 1 Sampling sities

Ponto (n°)	UTM X	UTM Y
P1	195361	8321438
P2	194976	8321458
P3	194547	8321653
P4	194442	8321653
P5	194617	8321383
P6	194307	8321398
P7	194422	8321139
P8	194547	8320939

Source: Author, 2024.

It is important to mention some of the constraints and limitations faced during the research. The main limitation faced was that of the 8 samples that were collected and sent to the laboratory, for financial reasons, we were only able to analyze half of them, i.e. 4 samples. Therefore, a sample was chosen from the eastern part of the channel (P2), a sample from the central part of the estuary (P5), a sample from the western part of the estuary (P6) and a sample from the southern part of the channel (P8), in order to make it as representative as possible. These samples (P2, P5, P6 and P8) were then relabeled P1', P2', P3' and P4' respectively.

Laboratory procedure

After collecting the samples, they were taken to the Geoscientific Laboratory of Huíla of the Geological Institute of Angola - IGEO for analysis. The particle size analyses were carried out in this laboratory using the instrumental dry method (Methodology EN 933-1 and 933-2) and included the steps described below (Figure 3).

Figure 3 Laboratory procedures (Author, 2024).

Sample preparation and particle size analysis

In the laboratory, the analyzed samples were subjected to the standard procedures (quartering, washing and drying) for particle size analysis using the sieving method, which evaluated the distribution of cumulative weight percentages by grain size, as suggested by Suguio in 1973.[22] The samples were then weighed. After weighing and eliminating impurities and organic matter, the samples were duly labeled and placed in the oven. It is important to note that the samples also underwent a process to remove the organic matter, which consisted of a solution of peroxide, hydrogen and distilled water. Finally, the samples underwent a dry sieving process of the sand fraction, using a set of sedimentological sieves with mesh openings corresponding to the Wentworth limits (1922).[23]

Statistical parameters

In sediment particle size analysis, a variety of statistical parameters were used to describe the size distribution of the particles present in a sample. Due to the specific needs of sediment particle size analysis, the statistical parameters used in this work were the mean, standard deviation and asymmetry.

Mean: The mean particle size is the central measure that indicates the average particle size of the 4 samples analyzed.

Standard deviation: this is the dispersion measure that indicates the variability of the particle sizes of the 4 samples analyzed in relation to the mean;

Asymmetry: is the measure of lack of symmetry in the distribution of particle sizes of the 4 samples analyzed.

Results

Sediments of the Bero River Estuary

Laboratory analysis of the samples revealed the particle size classes of the sediments found along the River Bero. These results revealed sediments such as sand, silt and clay and can be found in full in the annexes. The following table summarizes the results of the statistical parameters of the samples.

Average diameter

The average diameter reflected the average size of the sediments present in the Rio Bero estuary, represented by φ (average sediment size). In this context, the average size of the grains ranged from 0.57 to 1.51 mm and the average between them was 1.54 mm (Table 2). In this order, a total of 67% of the samples were classified as very coarse sand and there was also a small amount of silt, approximately 32%, as well as an almost unnoticeable amount of clay, 1% (Figure 4).

Table 2 Granolummetric statistical parameters (Author, 2024)

Sample	Média (mm)	Seleção (mm)	Simetria (mm)
P1 (902)	1,51	1,87	0,005
P2 (903)	1,46	1,73	-0,123
P3 (904)	1,44	1,71	0,368
P4 (905)	0,57	0,52	-0,288

Source: Author, 20224.

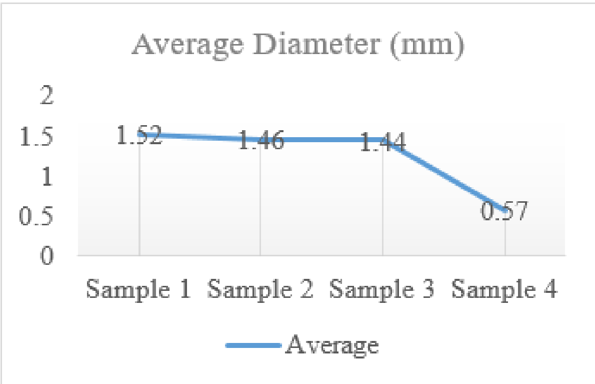


Figure 4 Average diameter of the sediments (Autora, 2024).

Particle size distribution pattern

With regard to the distribution of these sediments, it was observed that the particle size distribution pattern of the samples along their length is not completely homogeneous, i.e. it shows a slightly irregular distribution along the estuarine zone. The points sampled revealed that sand is distributed in greater proportions along the outer zone, silt is distributed in smaller proportions along the mixing zone and clays are practically non-existent along the region studied, as can be seen in the Table 3 below.

Table 3 Grain size distribution

Sample	Sand (%)	Silt (%)	Clay %)
P1 (902)	93%	7%	0,0%
P2 (903)	96,4%	3,6%	0,0%
P3 (904)	100%	0,0%	0,0%
P4 (905)	85,4%	14,2%	0,4%

Source: Author, 2024.

Textural variation

classification of the Bero River estuary was carried out. The interpretation of the results of the granulometric analysis suggested that 94.1% was sand, 6.3% silt and 0.6% clay, as shown in the graph below. In almost all the samples analyzed, the supremacy of the sand textural class over other classes such as silt and clay was evident. It is believed that this is due to the location (outer zone) of the same sediments in the estuarine zone. As presented in section 1.8 of this paper, Folk & Ward (1957)[24] present us with the estuarine sedimentary facies models in the literature, where they subdivide the estuary into three zones (internal, central and external), where the external zone is characterized by containing high energy, which favours the deposition of coarser sediments. In the case of the Bero River sediments, most of the sediments are found in this estuarine mixing zone, a place where large sediments are deposited in relation to small sediments, because sediments such as silt and clay are generally deposited in places of low energy (Figure 5).

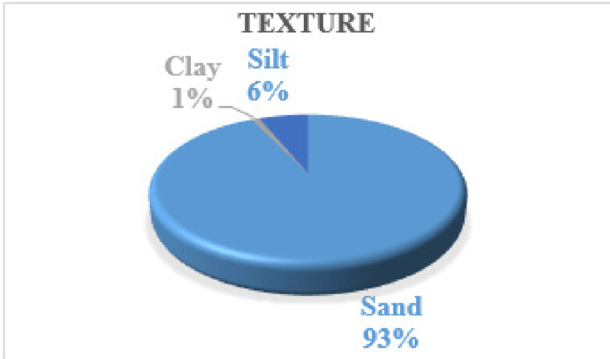


Figure 5 Textural variation (Author, 2024).

Selection

Selection, determined using the standard deviation, is a measure of dispersion that indicates how far the values are from the average and, in turn, the variability of the particle sizes. In this way, it indicates the degree of sediment selection. In the case of the sediments in the Bero estuary, as shown in the graph below (Figure 6), the sediments ranged from 0.52 to 1.87 mm, i.e. they were moderately to poorly sorted. It is believed that this is due to the low efficiency of the transportation process, as the Bero River is known to be a temporary river. Another reason for this effect may be the distance traveled by the same sediments, because sediments transported over short distances tend to be poorly sorted.

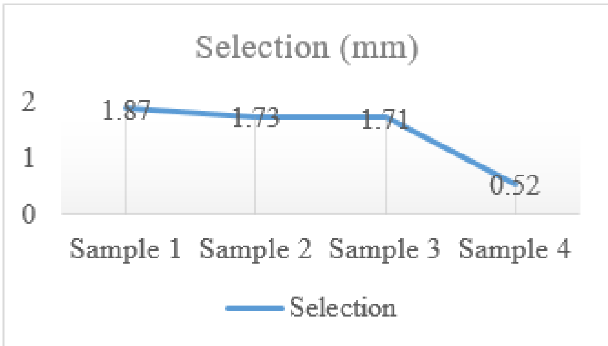


Figure 6 Selection (Author, 2024).

Asymmetry

Asymmetry indicated whether the distribution of particles was symmetrical, positively asymmetrical or negatively asymmetrical. In other words, the preponderance of coarse or fine sediments throughout the area studied. The graph below shows that the values ranged from -0.288 to 0.368 mm, i.e. very negative to positive asymmetry, with tendencies towards asymmetric sediments (Figure 7). However,

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this clearly demonstrates the predominance of coarse sediments throughout the area studied. Their essence may be linked to the lack of river discharges.

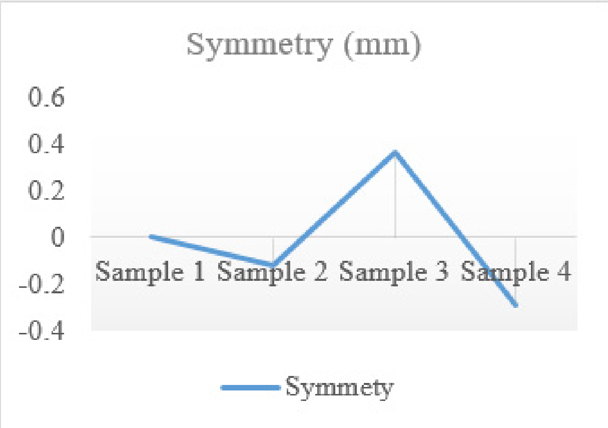

Figure 7 Symmetry (Author, 2024).

Discussion

Particle size analysis is a fundamental tool for understanding the composition and characteristics of sediments in a fluvial environment such as the Bero estuary. The results obtained provide important information on particle size distribution, sediment selection and the symmetry of the samples collected. Previous studies have emphasized that particle size is crucial for inferring transport and deposition processes in sedimentary environments.[24] Furthermore, particle size analysis can help identify the origin of sediments and the hydrodynamic processes involved in their deposition.[13,15,24–26]

The average particle sizes of the samples collected ranged from 0.57 to 1.51 mm, with a general trend of decreasing average particle size from Sample 1 to Sample 4. This trend suggests a possible variation in the source of sediment along the estuary, with a decrease in particle size towards the mouth of the river. This behavior is consistent with the theory that transport energy decreases as sediment moves downstream, resulting in greater deposition of finer particles in estuarine areas.[27] This pattern of particle size distribution is common in estuarine environments, where the mixing of fresh and salt waters creates complex conditions for deposition.[14]

Sediment selection, as measured by the selection index, also varied between the samples. Samples 1 and 2 showed the highest selection values (1.87 and 1.73, respectively), suggesting greater uniformity in particle sizes. On the other hand, samples 3 and 4 had lower selection values (1.71 and 0.52, respectively), indicating greater variation in particle sizes. This pattern may reflect the influence of different transport and deposition processes along the estuary.[28] In addition, more recent studies by Dade and Friend (1998)[12] indicate that the variation in selection may be related to the heterogeneity of sediment sources, which may include material transported from different areas of the watershed.

The symmetry of the particles, expressed by the symmetry coefficient, also showed variations between the samples. While samples 1 and 3 showed values close to zero (0.005 and 0.368, respectively), indicating a more symmetrical distribution of particles, samples 2 and 4 showed negative values (-0.123 and -0.288, respectively), suggesting an asymmetry in the distribution of particles. These differences in symmetry may be related to specific transport and deposition processes, as well as the influence of local factors such as the topography of the estuary bottom. Studies indicate that negative asymmetry may be associated with less energetic deposition conditions or localized sediment sources.[15] In addition, granulometric symmetry can be affected by phenomena such as storms and seasonal variations in river flow, which significantly alter deposition patterns.[29]

Effective sediment management in estuarine areas can help mitigate the effects of coastal erosion and protect critical habitats.[30] Furthermore, understanding the grain size of estuarine sediments is vital for assessing the impact of anthropogenic activities and climate change, which can significantly alter sediment dynamics. Thus, the results of the particle size analysis provide a comprehensive view of the composition and characteristics of the sediments in the Bero estuary.[29,31] This information is essential for understanding the ongoing sedimentological processes and is fundamental for the planning and sustainable environmental management of this important coastal area.[32–36]

Conclusion

The sedimentological characterization survey of the Bero River estuary provided valuable information on the composition, distribution and characteristics of the sediments in this important coastal area. Based on the results of the particle size analyses, it can be concluded that:

a) The variation in average particle sizes along the samples suggests a possible change in sediment source and transport processes along the estuary.

b) The difference in sediment selection between the samples indicates variations in the uniformity of particle sizes, possibly influenced by different transport and deposition processes.

c) The variation in particle symmetry suggests differences in sediment distribution and morphology along the estuary, which may be influenced by local factors and specific sedimentological processes.

These results highlight the complexity and dynamics of sedimentological processes in a fluvial environment such as the Bero estuary. Understanding these processes is fundamental for the environmental management and conservation of this region, especially considering its ecological, economic and social importance. Based on these findings, it is anticipated that further studies will be conducted to investigate sedimentological processes and to develop sustainable coastal management strategies based on the findings of this research. This will contribute to the preservation and protection of the Bero estuary and its associated ecosystems, guaranteeing their sustainable use for future generations.

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Conflicts of interest

Authors declare that there are not conflict of interest.

References

1. Costa BS, Mallmann LB, Guerra NC, et al. Sedimentological characterization of the anchoring area of two shipwrecks on the Pernambuco continental shelf. *Revista de Gestão Costeira Integrada*. 2010;10(1):49–64.

2. Dias JA. Sediment analysis and knowledge of marine systems: an introduction to geological oceanography. (Versão Preliminar). 2004.

3. Santos AF, Moraes BC, Rabelo LS, et al. Characterization of estuary sediments: importance and methodologies. *Revista Brasileira de Geografia Física*. 2014;7(3):547–556.

4. Rossetti DF. Granulometric analysis and its application in paleoenvironment studies. *Revista do Instituto Geológico*. 2001;22(1):43–53.

5. Rodrigues RS, Tassinari CG, Lima LC, et al. Analysis of surface sediments in estuaries: a case study in the state of Pará. *Geochimica Brasiliensis*. 2008;22(2):131–144.

6. Melo JM, Martins LR, Ferreira P, et al. Importance of granulometric characterization of estuarine sediments. *Revista Brasileira de Geociências.* 2005;35(1):79–88.

7. Cunha CN, Calliari LJ. Sedimentology and hydrodynamics of estuaries: the case of Guaratuba Bay, PR. *Boletim Paranaense de Geociências*. 2003;53(1):21–30.

8. Pires JM, Carvalho MA, Gonçalves AL, et al. Impacts of human activities on the sedimentary dynamics of estuaries: a comparative study. *Ciência & Tecnologia Ambiental*. 2016;11(4):189–200.

9. Instituto Nacional de Meteorologia e Geofísica. Clima da Província do Namibe. (s.d.).

10. Goldberg PM, Vance T, Holliday V, et al. Integrated archaeological investigations of sediments and soils. *Springer Science & Business Media*; 2001.

11. Lekkas TC, Unruh JD, Krol MS. Environmental change and its implications for population migrations*. Springer Science & Business Media*; 2003.

12. Schieber JZ, Bose P, Erksson PG, et al. Atlas of microbial mat features preserved within the siliciclastic rock record. *Elsevier*; 2007.

13. Liu JT, Zarillo G. Distribution of grain sizes across a transgressive shoreface. *Marine Geology*. 1989;87(2):121–136.

14. Nichols MM. Sediment accumulation rates and relative sea–level rise in lagoons. In: Perillo GE, editor. Geochemistry of Estuaries. *CRC Press*; 1999:77–92.

15. McManus J. Grain size determination and interpretation. In: Tucker ME, editor. Techniques in Sedimentology. *Blackwell Scientific Publications*; 1988:63–85.

16. Reniers A, Gallagher E, Macmahan J. Observations and modeling of steep beach grain–size variability. *Journal of Geophysical Research*. 2013;577–591.

17. Abdulkarim R, Akintoye A, Oguwuike F, et al. Sedimentological variation in beach sediments of the barrier bar lagoon coastal system, south–western Nigeria. *Aquacit*. 2011. 13 p.

18. Francisco AM. Desafios do desenvolvimento e do ordenamento do território na Província do Namibe (Angola). Dissertação de Mestrado em Gestão do Território – Especialização em Planejamento e Ordenamento do Território. Lisboa; 2013.

19. Manuel FA. Evolução tectonoestrutural da região de Moçâmedes (Namibe) sudoeste de Angola. *Geociências*. 2003;2:1–26.

20. Abreu VR, Fonseca PE. Geologia da região de Iona – Angola. *Geologia On–line*. 2012;5(2):17–35.

21. Instituto Nacional de Meteorologia e Geofísica. Características biofísicas do Namibe. INAMET. (s/d).

22. Suguio K. Introdução à sedimentologia. São Paulo, Brasil; 1973. 310 p.

23. Wentworth CK. A scale of grade and class terms for clastic sediments. *Journal of Geology*. 1922;30(5):377–392.

24. Folk RL, Ward WC. Brazos River Bar: a study in the significance of grain size parameters. *Journal of Sedimentary Research*. 1957;27(1):3–26.

25. Dade WB, Friend PF. Grain–size, sediment–transport regimes, and channel slope in alluvial rivers. *The Journal of Geology*. 1998;106(6):661–676.

26. Passega R. Grain size parameters as clues to sediment transport and deposition. *SEPM Journal of Sedimentary Research*. 1964;34(4):830–847.

27. Bridge JS, Demicco RV. Earth surface processes, landforms and sediment deposits. Cambridge University Press; 2008.

28. Blott SJ, Pye K. Gradistat: a grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surface Processes and Landforms*. 2001;26(11):1237–1248.

29. Allen JL. Sediments of the modern Niger Delta: a summary and review. In: Morgan WA, Shaver RH, editors. Deltaic Sedimentation, Modern and Ancient. *SEPM Society for Sedimentary Geology*. 1970:138–151.

30. Masselink G, Hughes MG. Introduction to coastal processes and geomorphology. Hodder Education; 2003.

31. Yang SY, Meyers PA. An overview of oceanographic and climatic controls on sediment and organic matter geochemistry in the Yellow Sea. *Marine Geology*. 1997;142(1):1–2.

32. Hunt JC, Bejamin F, Bernard M, et al. An introduction to sedimentary rocks: sedimentary environments. John Wiley & Sons Ltd; 2005.

33. Lunda DS. Apontamentos para estudantes do ensino superior do curso de geologia; 2017.

34. McLaren P, Bowles D. The effects of sediment transport on grain–size distributions. *Journal of Sedimentary Petrology*. 1985:457–470.

35. Nichols N, Gary J. Sedimentology and stratigraphy. *John Wiley & Sons*; 2009.

36. Smith D. Sedimentology and stratigraphy. John Wiley & Sons Ltd; 2010.

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