International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

Check for updates

# Sedimentary facies and grain size distribution; Insights into Ogwashi-Asaba Formation, Niger Delta Basin

Eghele Akpere * and Anthonia N. Asadu

*Department of Earth Sciences, Federal University of Petroleum Resources, Effurun 330102, Delta State, Nigeria.*

International Journal of Science and Research Archive, 2024, 13(02), 2769–2778

Publication history: Received on 02 November 2024; revised on 11 December 2024; accepted on 13 December 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.2.2464

## Abstract

The Niger Delta is renowned for being one of the most productive hydrocarbon provinces globally. This productivity is primarily attributed to its complex geological history, which is marked by intricate stratigraphy and various sedimentary facies. These sedimentary facies, which are distinct bodies of sediment with specific characteristics, provide essential information about past environments and sedimentary processes, about the complex stratigraphy and diverse sedimentary facies. Stratigraphic sequences in the Niger Delta include alternating layers of sandstones, shales, and siltstones. Sediment samples were collected with cores too, from the Ogwashi-Asaba formation, and a detailed field analysis was documented. Grain size, petrographic, and geochemical analysis were carried out in the lab, from the samples collected. The analyzed parameters suggest that the sandstone samples from the Ogwashi-Asaba Formation are predominantly fluviatile. Graphic Mean (Mz) ranges from 1.4 to 2.1 phi. Grain Size Composition 2-20% very fine sand, 6-66% fine sand, 45-87% medium to coarse sand, and 70-100% very coarse sand. Sorting (σ1) ranges from 1.1 to 2.1 phi, with 64.71% of sediments being very poorly sorted and 35.29% poorly sorted. Graphic Skewness (Sk) ranges from -0.6 to +0.5, indicating varying energy conditions. Graphic Kurtosis (KG): Ranges from 0.8 to 1.9, with curves varying from leptokurtic to platykurtic. These sedimentary processes shaping the Ogwashi-Asaba formation creates a diverse stratigraphy and a variety of sedimentary facies. Each provides valuable insights into past environmental conditions and sedimentary dynamics. A comprehensive understanding of these processes enhances the potential for hydrocarbon exploration and the reservoir characterization of the province.

**Keywords:** Facies; Sequences; Niger Delta; Ogwashi-Asaba; Formation

## 1. Introduction

The Niger Delta, situated on the southern coast of Nigeria, stands as one of the world's most prolific hydrocarbon provinces, renowned for its substantial oil and gas reserves. This deltaic system, located on the passive continental margin of West Africa, has been a focal point of geological and sedimentological studies due to its complex stratigraphy and diverse sedimentary facies. Since the Eocene epoch, the Niger Delta has prograded southward into the Gulf of Guinea, resulting in the deposition of a thick sequence of sediments influenced by a dynamic interplay of fluvial, deltaic, and marine processes.

Understanding the sedimentary facies of the Niger Delta is crucial for comprehending the sedimentological processes that have shaped this region. Sedimentary facies refer to distinct bodies of sediment that possess specific characteristics, such as grain size, composition, and sedimentary structures, which reflect the conditions under which they were deposited. Analyzing these facies provides valuable insights into the depositional environments, sediment transport mechanisms, and the factors controlling grain size variations.

* Corresponding author: Akpere E

The Niger Delta's sedimentary record reveals a complex stratigraphy that includes alternating layers of sandstones, shales, and siltstones. These layers represent various depositional settings, from high-energy fluvial channels to low-energy marine environments. Detailed facies analysis of these sediments helps reconstruct the geological history of the delta, providing a clearer picture of past environmental conditions and sedimentary processes.

The findings of this study will contribute to a deeper understanding of the sedimentological processes that have shaped the Niger Delta. They will provide valuable insights for geologists and petroleum engineers involved in hydrocarbon exploration and production, aiding in the development of more accurate models for predicting reservoir quality and distribution. Ultimately, this research aims to enhance our knowledge of one of the world's most important hydrocarbon provinces, supporting more efficient and sustainable resource extraction.

The aim of this study is to analyse the sedimentary facies of the study area to infer the sedimentary processes that occurred during deposition and identify the factors that influenced grain size distribution. The main objectives of this study include are to identify and describe the sedimentary facies in the study area, to analyse the grain size distribution within these facies, to interpret the sedimentary processes that control facies development and grain size distribution and to provide insights into the implications of these findings for hydrocarbon exploration.

## 2. geology of the study area and literature review

The delta began forming in the Eocene epoch, around 56 to 34 million years ago. During this period, sedimentation started in the region, primarily influenced by the rivers draining the West African hinterland. The delta has since prograded, or advanced, southward into the Gulf of Guinea. This progradation is the result of the continuous supply of sediments from rivers, especially the Niger River, which transports a vast amount of sediments derived from weathering and erosion of the continental interior (Doust, H.; Omatsola, E., 1990).

The delta plain is characterized by distributary channels, levees, and interdistributary bays, where sediments are deposited in a relatively calm environment. The delta front is more dynamic, with sediments being reworked by waves and tides, creating sand bars and mouth bars. The prodelta is the furthest seaward part of the delta, where finer sediments settle out in a more tranquil marine setting (Short & Stauble, 1967). During the Palaeocene the older Akata Formation was deposited. The Agbada Formation was deposited during the Eocene. While during the Oligocene the younger Benin Formation was deposited.

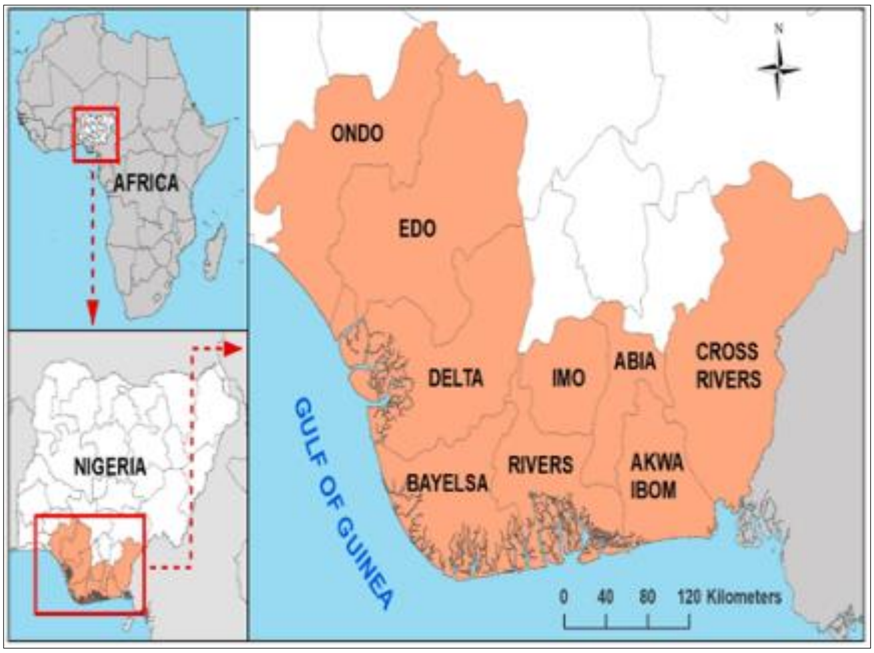


**Figure 1** Map of Africa showing the part where Nigeria is situated, the map of Nigeria showing the area Niger Delta Region is located, and the map of Delta state showing Aniocha South the location of Ogwashi-Asaba. *((Ebhuoma, et al., 2020) (Amanna, Illoegbunam, & Dike, 2016)*}.

Short & Stauble in 1967 in their research titled Outline of Geology of Niger Delta in AAPG Bulletin provided a comprehensive overview of the geology of the Niger Delta, discussing the stratigraphy, structural framework, and depositional environments.

Onyebuchi, I.A., & Adebayo, 2022 studied the facies Architecture and Sequence Stratigraphy of the Niger Delta: Implications for Reservoir Characterization. They focused on the facies architecture and sequence stratigraphy of the Niger Delta, analysing high-resolution seismic and well log data. Their research discussed the identification of key sedimentary facies and their depositional environments, along with the factors controlling grain size variations. The study emphasizes the importance of understanding sediment transport mechanisms and the role of sea-level changes in shaping the delta's stratigraphy. The findings have significant implications for reservoir characterization and hydrocarbon exploration.

Udoh & Ekpo, 2023 in the research titled Advances in Sedimentological Studies of the Niger Delta: Techniques and Applications. The paper reviews recent advances in sedimentological studies of the Niger Delta, focusing on new techniques and their applications. It discussed the use of advanced sedimentological tools, such as digital outcrop models, high-resolution imaging, and sedimentary facies modelling, to enhance the understanding of grain size distribution and depositional processes. The study underscores the importance of integrating various datasets to achieve a holistic view of the delta's sedimentary architecture, which is essential for effective hydrocarbon exploration and production.

In 2024, Ndubuisi & Chukwu researched on the Impact of Climatic Variability on Sedimentary Processes in the Niger Delta. They examined the impact of climatic variability on sedimentary processes and facies distribution in the Niger Delta. By analyzing sediment cores and climate data, the authors demonstrate how changes in precipitation and sea-level rise over the past few decades have affected sediment deposition and grain size distribution. The study highlights the implications of these changes for sedimentary facies analysis and the future of hydrocarbon exploration in the region.

Obi & Eze, 2024 in the study about the Modern Techniques in Sedimentary Facies Analysis: Case Study from the Niger Delta highlighted the application of modern techniques in sedimentary facies analysis, with a case study from the Niger Delta. They discussed the use of digital outcrop models, high-resolution imaging, and geostatistical methods to analyse sedimentary facies and grain size distribution.

## 3. Material and methods

- Literature Review
- Field Preparation
- Field Data Collection
- Sample Preparation and Laboratory Analysis
- Data Interpretation and Facies Classification.
- Sedimentological Analysis
- Reconstruction of Depositional Environments
- Hydrocarbon Exploration and Reservoir Characterization
- Reporting and Dissemination

## 4. Data analysis and result interpretations

The exposed section is categorized into various lithofacies based on field measurements, lithological variations, and the megascopic properties of the sedimentary rocks. These include friable, massive, fine-grained sandstones with thin to thick bedding that are cross- and parallel-bedded, displaying whitish to yellowish colours. There are also thinly bedded pebble mantled bottom and top lithofacies, lateritic cap lithofacies, and medium to coarse-grained ferruginous sandstone lithofacies. One notable lithofacies is a reddish-brown/purple sandstone that is highly ferruginous and frequently used for building materials.

## 5. Discussion of Results

### 5.1. Granular and Textural Analyses of the Study Area

The sedimentary analysis of the Ogwashi-Asaba area reveals varied granular and textural properties.

Graphic Mean (Mz)

- Ranges from 1.4 to 2.1 phi.
- Grain size composition:
- 2-20% very fine sand
- 6-66% fine sand
- 45-87% medium to coarse sand
- 70-100% very coarse sand

Graphic Standard Deviation (Sorting, σ1)

- Ranges from 1.1 to 2.1 phi
- 64.71% very poorly sorted
- 35.29% poorly sorted

Graphic Skewness (Sk)

- Ranges from -0.6 to +0.5
- Variation in skewness indicates changing energy conditions in the sedimentary environment

Graphic Kurtosis (KG)

- Ranges from 0.8 to 1.9
- Leptokurtic: More peaked than normal distribution
- Platykurtic: More sagged than normal distribution

The statistical parameters obtained from the textural studies are applied to understand the transportation history, sedimentary processes, and characteristics of depositional environments as shown in table 23.

Bivariate Plots:

- Mean Grain Size vs. Standard Deviation (Sorting)
- Skewness vs. Standard Deviation
- Simple Skewness vs. Standard Deviation

The collective analysis of these parameters suggests that the sandstone samples from the Ogwashi-Asaba Formation are predominantly fluviatile. This interpretation aligns with the findings of (Friedman, 1967) and (Moiola & Weiser, 1968), supporting the view that the sediments were influenced by fluvial processes.

This implies that the comprehensive analysis aids in understanding the depositional history and the sedimentary environment of the Ogwashi-Asaba area, contributing valuable insights for sedimentological and hydrocarbon exploration studies.

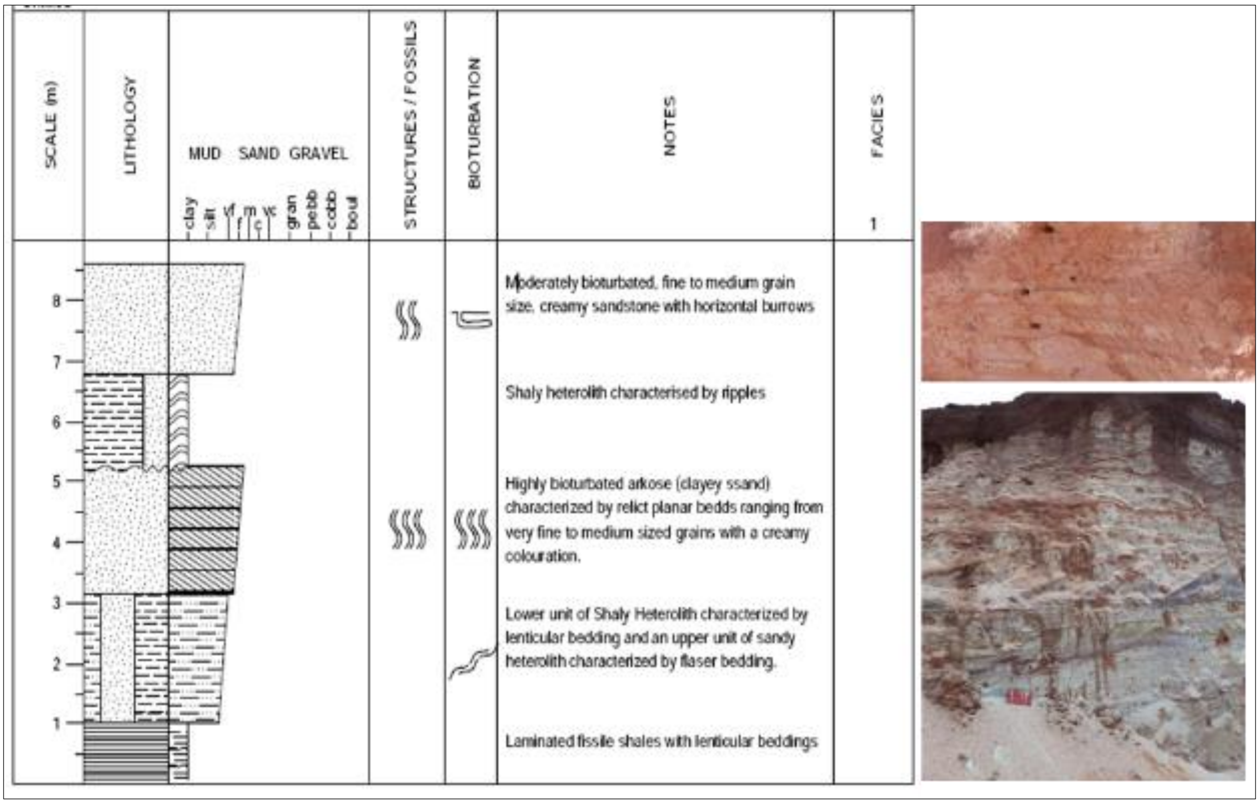


**Figure 2** Outcrop 1 Lithologic section of the Ogwashi-Asaba Formation

**Table 1** Findings and analysis of statistical characteristics derived from GSA data of the beds in Outcrop 1 Location 1 for the Ogwashi-Asaba Formation sandstone samples.

| Outcrop 1 Location 1 | Me an | Standard Deviation | Skewness | Kurtosis | Simple Skewness Measure | Simple Sorting Measure |
|---|---|---|---|---|---|---|
| BED A | 2.0 | 2.0 | -0.1 | 1.0 | -0.1 | 3.4 |
| BED B | 1.8 | 1.9 | -0.1 | 1.1 | -0.4 | 3.4 |
| BED C | 2.1 | 2.1 | 0.03 | 1.5 | 0.7 | 3.0 |
| BED D | 1.4 | 1.6 | 0.1 | 1.1 | 0.2 | 2.7 |

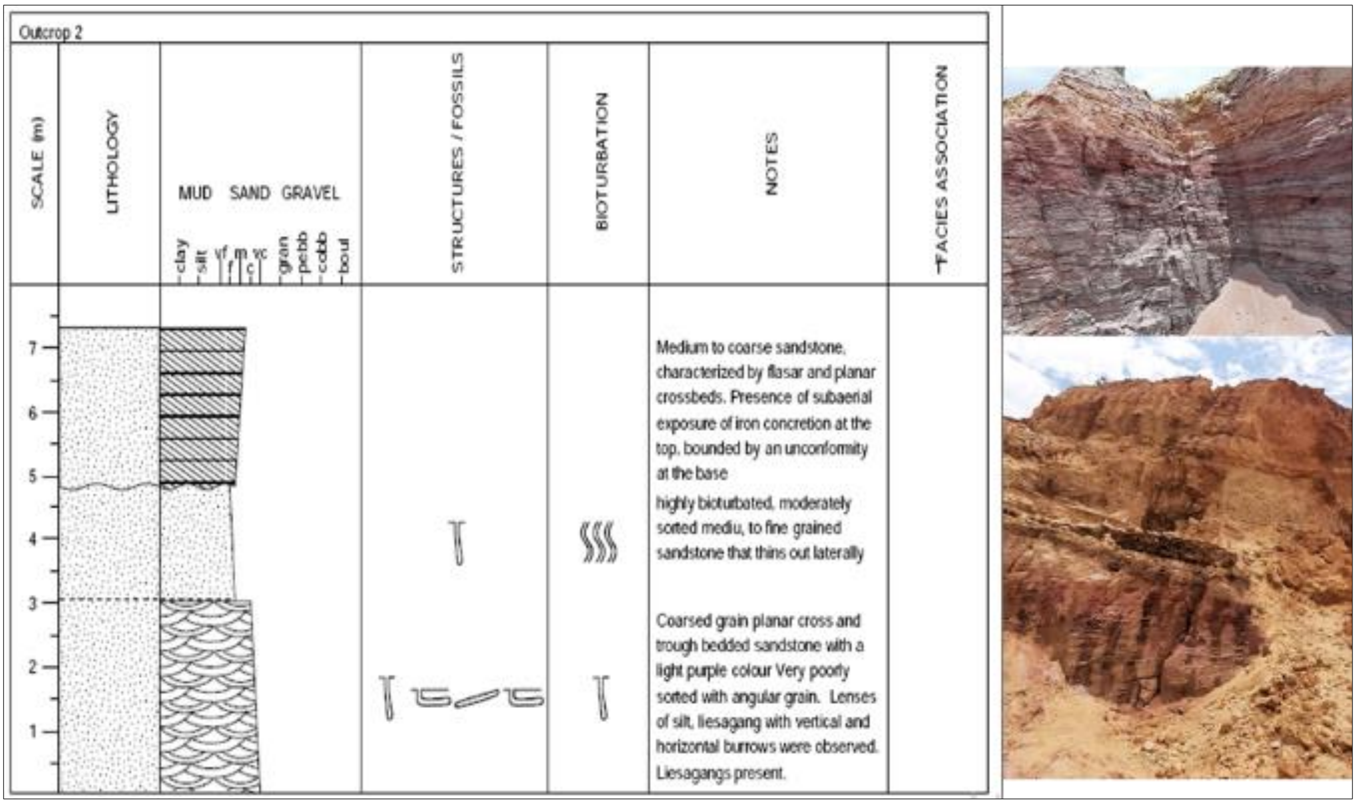


**Figure 3** Outcrop 2 Lithologic section of the Ogwashi-Asaba Formation

**Table 2** Findings and analysis of statistical characteristics derived from GSA data from Outcrop 1 Location 1 Bed A for the Ogwashi-Asaba Formation sandstone samples

| Sieve sizes (ml) | Phi Scale φ | Retained Weight (g) | Weight % | Cumulative Weight % | % Passing |
|---|---|---|---|---|---|
| 10 | -1.0 | 1.1 | 4.47 | 4.47 | 95.53 |
| 20 | 0.25 | 3.3 | 13.42 | 17.89 | 82.11 |
| 30 | 0.75 | 2.9 | 11.79 | 29.68 | 70.32 |
| 40 | 1.25 | 1.2 | 4.88 | 34.56 | 65.44 |
| 60 | 2.0 | 2.4 | 9.76 | 44.32 | 55.68 |
| 80 | 2.50 | 1.6 | 6.50 | 50.82 | 49.18 |
| 100 | 2.75 | 1.5 | 6.10 | 56.92 | 43.08 |
| 120 | 3.0 | 2.0 | 8.13 | 65.05 | 34.95 |
| 250 | 4.15 | 3.8 | 15.45 | 80.50 | 19.50 |
| PAN | | 4.8 | 19.50 | 100 | 0 |
| | | 24.6 | 100 | | |

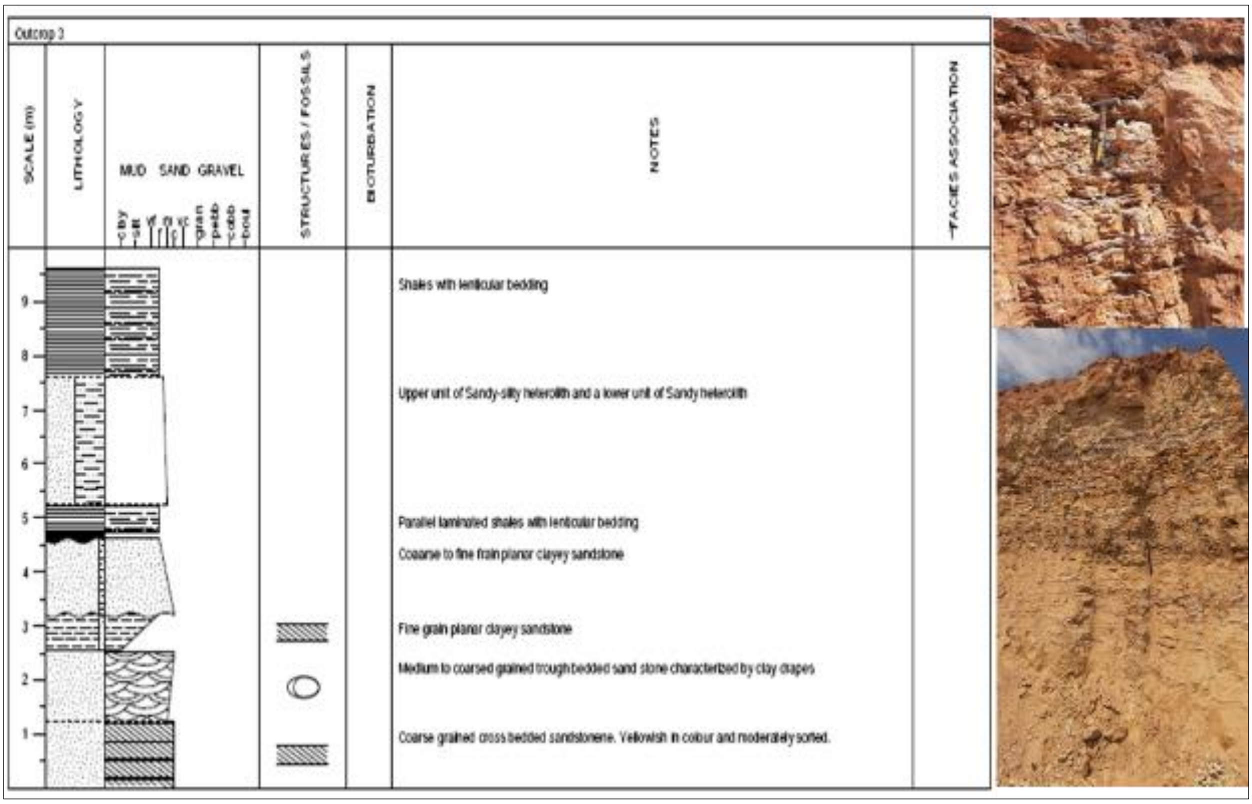


**Figure 4** Outcrop 3a Lithologic section of the Ogwashi-Asaba Formation

**Table 3** Findings and analysis of statistical characteristics derived from GSA data from Outcrop 1 Location 1 Bed B for the Ogwashi-Asaba Formation sandstone samples

| Sieve sizes (ml) | Phi Scale φ | Retained Weight (g) | Weight % | Cumulative Weight % | % Passing |
|---|---|---|---|---|---|
| 10 | -1.0 | 2.0 | 8.0 | 8.0 | 92 |
| 20 | 0.25 | 3.2 | 12.8 | 20.8 | 79.2 |
| 30 | 0.75 | 2.4 | 9.6 | 30.4 | 69.6 |
| 40 | 1.25 | 1.6 | 6.4 | 36.8 | 63.2 |
| 60 | 2.0 | 2.3 | 9.2 | 46 | 54 |
| 80 | 2.50 | 1.5 | 6.0 | 52 | 48 |
| 100 | 2.75 | 2.4 | 9.6 | 61.6 | 38.4 |
| 120 | 3.0 | 4.5 | 18 | 79.6 | 20.4 |
| 250 | 4.15 | 2.6 | 10.4 | 90 | 10 |
| PAN | | 2.5 | 10 | 100 | 0 |
| | | 2.5 | 100 | | |

## 5.2. Functions that discriminate linearly

To further distinguish the depositional environment, additional textural statistical measures (mean, standard deviation, skewness, and kurtosis) were used in conjunction with discriminant function analysis. The sandstones in the research area were deposited under a variety of continental settings, according to an analysis of the data generated by the linear discriminant functions (LDF). Fully beach situations are represented by Y1, generally beach and largely shallow agitated marine settings are represented in Y2, with examples suggesting shallow marine and fluvial (deltaic) environment by Y3.

Using discriminant function analysis, additional textural statistical metrics (mean, standard deviation, skewness, and kurtosis) were employed to further differentiate the depositional environment. The sandstones in the research area were deposited under a variety of continental settings, according to an analysis of the data produced by the linear discriminant functions (LDF). The table displays the findings of the LDF analysis. Y1 corresponds to fully beach habitats, Y2 to primarily shallow, agitated marine settings with one sample suggesting a beach environment, and Y3 to mostly fluvial-deltaic settings with some shallow elements.

### 5.3. Sedimentary Facies and Depositional Environments

The Ogwashi-Asaba Formation exhibits a range of sedimentary facies, each representing different depositional environments. The identified facies include:

- **Channel Sandstones:** These are coarse-grained, well-sorted sandstones with cross-bedding, indicating high-energy fluvial channels.
- **Delta Front Sands:** Medium to coarse-grained sandstones deposited in deltaic settings, showing features like ripple marks and graded bedding.
- **Prodelta Shales:** Fine-grained shales and siltstones, representing low-energy environments where fine sediments settle from suspension.
- **Marine Clays:** Deposited in the distal parts of the delta, these are characterized by fine laminations and high organic content.

The colour variations, particularly the reddish-brown hues observed in some sandstones, provide additional evidence of the depositional environment. These colors result from the oxidation of iron-bearing minerals in well-oxygenated settings, typical of continental and deltaic environments.

### 5.4. Implications for Hydrocarbon Exploration

The detailed analysis of sedimentary processes and facies in the Ogwashi-Asaba Formation has significant implications for hydrocarbon exploration. The variability in grain size, sorting, and cementation affects the porosity and permeability of the rocks, critical factors for reservoir quality. Understanding the depositional environments helps predict the distribution of reservoir and non-reservoir rocks, aiding in the efficient development of hydrocarbon resources.

The sedimentary processes shaping the Ogwashi-Asaba Formation are complex and interrelated, involving weathering, erosion, transportation, deposition, compaction, and cementation. These processes create a diverse stratigraphy and a variety of sedimentary facies, each providing valuable insights into past environmental conditions and sedimentary dynamics. The comprehensive understanding of these processes enhances the potential for hydrocarbon exploration and reservoir characterization in one of the world's most prolific hydrocarbon provinces.

## 6. Conclusion

The study of sedimentary facies and grain size distribution in the Ogwashi-Asaba area of the Niger Delta Basin provides significant insights into the sedimentary processes that have shaped this region. The Ogwashi-Asaba area is characterized by a complex stratigraphy comprising multiple layers of sandstones, shales, and siltstones, which have been deposited over millions of years through various geological processes such as subsidence, sedimentation, and tectonics. Coarse-grained and well-sorted, indicative of high-energy fluvial channels. Medium to coarse-grained sandstones with features like ripple marks and graded bedding, representing deltaic environments. Fine-grained shales and siltstones deposited in low-energy settings where fine sediments settle from suspension. Fine laminations and high organic content, deposited in the distal parts of the delta. The colour variations in these rocks, such as reddish-brown hues, are indicative of iron oxidation in well-oxygenated environments like floodplains and deltas. Graphic Mean (Mz) ranges from 1.4 to 2.1 phi. Grain Size Composition 2-20% very fine sand, 6-66% fine sand, 45-87% medium to coarse sand, and 70-100% very coarse sand. Sorting ($\sigma 1$) ranges from 1.1 to 2.1 phi, with 64.71% of sediments being very poorly sorted and 35.29% poorly sorted. Graphic Skewness (Sk) ranges from -0.6 to +0.5, indicating varying energy conditions. Graphic Kurtosis (KG): Ranges from 0.8 to 1.9, with curves varying from leptokurtic to platykurtic. These parameters help in understanding the depositional environments, with bivariate plots suggesting a predominantly fluviatile environment. Linear discriminant function (LDF) analysis further refines this understanding, indicating environments ranging from beach habitats to shallow marine and fluvial-deltaic settings. The detailed study of sedimentary facies and grain size distribution aids in reconstructing the depositional history of the Ogwashi-Asaba area. This understanding is crucial for hydrocarbon exploration, as it helps predict the distribution of reservoir and non-reservoir rocks, thus enhancing the potential for efficient resource development in one of the world's most prolific hydrocarbon provinces.

### *Recommendations*

Comprehensive Mapping and Sampling

- Conduct detailed geological mapping and systematic sampling across the Ogwashi-Asaba area to obtain a more granular understanding of the spatial distribution of different sedimentary facies.
- Implement high-resolution seismic surveys and core sampling to better delineate subsurface stratigraphy.

Advanced Analytical Techniques

- Utilize advanced grain size analysis techniques, such as laser diffraction and image analysis, to improve the precision of sedimentological data.
- Apply X-ray diffraction (XRD) and scanning electron microscopy (SEM) for mineralogical and textural analyses to enhance the understanding of sediment composition and diagenetic alterations.

Integrating Modern Sedimentological Models

- Integrate modern sedimentological models and simulation software to predict sedimentary processes and depositional environments more accurately.
- Develop three-dimensional geological models of the Ogwashi-Asaba area to visualize and interpret the complex stratigraphy and facies relationships.

Environmental and Climate Considerations

- Investigate the influence of past climatic conditions and sea-level changes on sediment deposition in the Ogwashi-Asaba area.
- Consider the role of vegetation and organic content in shaping the sedimentary facies, particularly in fluvial and deltaic environments.

Collaborative Research Efforts

- Foster collaboration between academic institutions, industry experts, and government agencies to leverage diverse expertise and resources.
- Encourage multidisciplinary approaches that combine sedimentology, geochemistry, paleontology, and geophysics for a holistic understanding of the region.

Hydrocarbon Exploration and Reservoir Characterization

- Focus on identifying and characterizing potential hydrocarbon reservoirs within the sedimentary sequences, emphasizing the role of grain size distribution in porosity and permeability variations.
- Implement reservoir modeling and simulation techniques to optimize exploration strategies and enhance recovery rates.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

## References

[1] Amanna, C. E., Illoegbunam, A. K., & Dike, H. O. (2016). Bioaccumulation of Zn in Muscle and Brain Tissues of the African Catfish— Clarias gariepinus. Journal of Geoscience and Environment Protection, 04(05), 12-20. doi:10.4236/gep.2016.45002

[2] Ebhuoma, E., Simatele, M. D., Leonard, L., Ebhuoma, O. O., Donkor, F., & Tantoh, H. B. (2020). Theorising Indigenous Farmers' Utilisation of Climate Services: Lessons from the Oil-Rich Niger Delta. Sustainability MDPI, 12(18). doi:10.3390/su12187349

[3] Friedman, G. M. (1967). Dynamic process and statistical parameters compared for size frequency distribution of beach and river sands. Jour. Sed. Petrol, 37, 327–354.

[4] Doust, H.; Omatsola, E. (1990). Niger Delta; Divergent/passive margin basins. (J. D. (Eds.), Ed.) American Association of Petroleum Geologists, 201-238.

[5] Moiola, R., & Weiser, D. (1968). Textural parameters: An evaluation. . Journal of Sedimentology Petrol., 38(1), 45-53.

[6] Ndubuisi, J. O., & Chukwu, L. (2024). Impact of Climatic Variability on Sedimentary Processes in the Niger Delta. Journal of Sedimentary Research.

[7] Obi, C. G., & Eze, P. U. (2024). Modern Techniques in Sedimentary Facies Analysis: Case Study from the Niger Delta. Sedimentary Geology.

[8] Onyebuchi, I. A., & Adebayo, S. O. (2022). Facies Architecture and Sequence Stratigraphy of the Niger Delta: Implications for Reservoir Characterization. Marine and Petroleum Geology.

[9] Short, K. C., & Stauble, A. J. (1967). Outline of geology of Niger Delta. . AAPG Bulletin, 51(5), 761-779.

[10] Udoh, F. E., & Ekpo, B. (2023). Advances in Sedimentological Studies of the Niger Delta: Techniques and Applications. Journal of Sedimentary Geology.