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Spatial Distribution and Geotechnical Characterization of Marine Deposits in the Warri Area of Delta State

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Abstract

This study examines marine deposits' spatial distribution and geotechnical properties in the Warri area of Delta State, Nigeria. Field surveys, chemical tests, and geographic information system (GIS) analysis were conducted to identify 20 sampling sites. Sediment samples were collected at various depths and analyzed using grain size analysis, Atterberg limits tests, and shear strength tests in the laboratory. The results show significant variations in depth (2.75-5.75 meters), grain size (0.125-0.250 mm), liquid limit values (22.89%-28%), and plastic limit values (13.68%-18 The study also found that the subgrade material exhibited plasticity and shear strength properties variations. Spatial analysis revealed elevation, thickness, and grain size changes, indicating the influence of topography, hydrological conditions, and depositional processes on the substrate types. The findings suggest considerable heterogeneity in the Warri area regarding marine deposits' spatial distribution and geotechnical characteristics. This study's conclusions are valuable for improving knowledge about local sedimentation processes and informing decisions about further engineering constructions, territory utilization, and environmental protection in the analyzed area.

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Introduction

The awareness of the spatial distribution and geotechnical properties of the marine depositional environment in the Warri area of Delta State is highly relevant for research activity, as is the local interest in the Warri region. At the heart of this importance is the role these deposits play in some geotechnical and environmental processes that significantly affect the construction of infrastructure systems and planning systems, as well as disaster risk reduction plans (Gałaś, 2017; Gałaś *et al.*, 2021). Therefore, in the first instance, knowing the specific location and distribution of such deposits provides important data on the geographic history and evolution of the geographic environment in the mentioned region. Not only does this enhance the ability to forecast changes that happened earlier to the environment, but it also enhances the ability to forecast future changes that are necessary for the right kind of development. Besides, it also provides information on other such deposits that is useful in other geotechnical engineering activities such as construction, foundation design, or risk assessment (Gryaznova, 2018). Therefore, the estimations of the mechanical properties and response of marine deposits made within this work aim at the development of marine geotechnical theory and the strengthening of understanding of the mechanics of soil media and geological processes. Though there is a lack of sophisticated research on marine deposits in the Warri area, a study like this could help to fill the gap with evidence that more research work and interdisciplinary study can offer upcoming potential. Equally important from the perspective of this study is the fact that the practical exception has more relevance than academic concern and enhances the value of change in community lives, governmental organizations, and commercial sectors that are involved in construction or are associated with infrastructure and land use. The information regarding the spatial distribution and geotechnical characteristics of marine deposits accumulated and analyzed within this study will be helpful for the stakeholders to reduce geological hazards and make reasonable decisions for further sustainable development within the Warri region and numerous other geographical areas globally (Mishra *et al.*, 2020; Liu *et al.*, 2019; SymphoniaandNathan, 2018; Dewangan *et al.*, 2021). Thus, the significance of this study transcends and extends far beyond the literal responses to the research questions identified herein and has multifaceted

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relevance to the overall corpus of geoscience, engineering, and environmental management studies.

Purpose of the Study

This study aims to investigate marine deposits' spatial distribution and physical properties in the Warri area of Delta State, Nigeria, to inform environmental monitoring and sustainable development strategies. The research work intends to determine the spatial distribution of marine deposits in the Warri area of Delta State and also look into the geotechnical properties of the area, thus filling a research gap in the body of knowledge. The literature review establishes that very few studies have been carried out that offer a detailed analysis of marine deposits in this area; therefore, more research needs to be done to identify the geology and geotechnical aspects of these formations (Pozdniakova&Kustikova, 2023; Tcibulnikova, 2017; DeGroot *et al.*, 2019). Earlier studies of the Warri area's marine deposits, however, have been limited and infrequent because previous studies of the broader field of geology and geotechnical engineering have thoroughly explored other geological formations or areas. However, due to the alacrity of the Warri geological formation and the environmental peculiarities of the region, exclusive research on these marine deposits is warranted to effectively map, define, and evaluate them in terms of distribution, lithological composition, and geotechnical strength. Previous works in related fields provide a comprehensive understanding of the geological conditions of the Niger Delta Basin but often neglect to investigate specific features of the geology of the Warri area (Idomeh *et al*., 2019; Dada *et al.*, 2018; Edema-Sillo and Emegha, 2022). Even though many authors have already investigated the general geotechnical characteristics of sedimentary deposits in the Niger Delta, little has been done to study specifically marine deposits within the region of interest, Warri. It is therefore apparent that a great deal of information is still lacking regarding the geographical extent, lithological characteristics, and engineering properties of these deposits in the Warri region. This aspect needs to be addressed to lower the current deficiencies in knowledge regarding geological processes at the local scale, contribute to the development of more efficient geotechnical designs, and abate geological risks within the area (Shaibu et al., 2023; Sokolov and Sukhov, 2023; Souza *et al.*, 2019; Kulikova *et al.*, 2023). Therefore, based on a literature review and an initial survey of the geotechnical characteristics and spatial distribution of marine deposits in the Warri area, this study intends to contribute to the development of knowledge in the subject and enhance the practice of engineering and land planning in the distribution of infrastructural projects.

Theoretical framework

The theoretical framework for this study is based on principles of sedimentology and geotechnical engineering. We draw on established theories of sediment deposition and transport to understand the spatial distribution and physical properties of marine deposits in the Warri area. As for the theoretical background of the present research, one has to mention such trends in geology and geotechnical engineering as sedimentology, stratigraphy, and the mechanics of granular media. In the present work, a methodology for the analysis of marine sediments in the Warri area incorporates geologically inclined analysis along with the study of engineering characteristics of the sedimentary formations that make up this part of the sub-Atlantic shelf. Regarding sediment transport as well as deposition and diagenetic processes, the following framework will attempt to provide a systematic, almost holistic, view in terms of the spatial distribution of joint marine deposits in the body of the study. In addition to this, by using the mechanics of soil and geotechnical engineering, this framework enables one to study the soil deposits, including their shear strength, compressibility, and permeability, which are important in determining the usefulness of the deposits in engineering projects (Bulolo and Leong, 2019; Salih, 2020; Schweiger, 2019).

The objectives of this study are twofold: first, to describe marine deposits in the Warri area as the entire spatial parameters of the lithological structure plan, and second, to estimate the geotechnical parameters and angles of such deposits in connection with their usage in practice. Therefore, apart from interviews and questionnaires, the technical component of the fieldwork will entail geological mapping, sedimentological logging, and geotechnical tests, whereby the variation and distribution of marine deposits in the area and their corresponding facies relationships will be determined. At the same time, the analysis of the representative samples of the soils will be possible within the laboratory, which will allow identifying the basic geotechnical characteristics, including grain size. Essentially, the study's objectives are as follows: To achieve the above objectives, the following research questions shall be answered: Here are some of the research questions that the study will address: Consequently, the study would contribute to the advancement of knowledge and practice.

Study Area

Warri then refers to a region situated in Delta State in the country of Nigeria. The country is located in the

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West African region specifically in the Niger Delta Basin region. Warri area is located within the geographic and tectonic framework of what is referred to as the Niger Delta Basin which is a sedimentary basin that involves more marine and fluvial deposits. The study area's geological structures include marine records, which dominate the composition of the area. The Warri area receives its hydrological setting from the Niger Delta region encompassing several networks of rivers, creeks and estuaries. Hydrology is also common in the region and highly influences the transportation and deposition of sediments such as marine ones. The following are among the major rivers that drain the Niger Delta Basin; The Niger River, and its branches. They add to the volumes of sediment which play a role in the generation of marine deposits in the area. The Warri geographical area is situated in the vicinity of the Gulf of Guinea which is an arm of the Atlantic Ocean. Warri area receives and deposits marine sediments through the marine environment of the Gulf of Guinea.

In this regard, the emphasis of the study is made on the marine deposits located in the Warri area. These deposits are sedimentary that has been transported and deposited in a marine place such as the coastal or offshore zone influenced by the Gulf of Guinea. The aims of the study include understanding the location distribution and physical properties of such marine deposits as a tool for engineering construction and general development and use of land besides the protection of the environment in this region.

Method

The research employed a comprehensive methodology to obtain the results presented in this study, involving a combination of field surveys, laboratory analyses, and geospatial techniques. We identified twenty sampling sites across the Warri area using a systematic random sampling method to ensure adequate coverage of different geological formations and landforms, thereby minimizing potential biases in site selection. Sediment samples for chemical and physical characterizations were collected at various depths using hand augers, and core drilling methods ensured that some of the sediment samples obtained were not disturbed. These activities were done with the objectives of determining the lithological makeup, depositional environment, and successive relationships of the marine deposits sampled. The laboratory analyzed the collected sediment samples for grain size through sieving and sedimentation, determining the proportion of large and small particles in each sample. The Atterberg limits, which are the liquid limit and the plastic limit, were conducted on samples with different moisture contents. The performance of each sample was examined regarding the degree of its plasticity and deformation through instrumental observations carried out on a Casagrande apparatus. We performed direct shear tests, measuring shear strength parameters like cohesion and the angle of internal friction using precise load cells and displacement transducers.

To conduct spatial analysis of the data collected in the field, sample location and depth data, as well as other geotechnical data, were imported into a Geographic Information System (GIS), which makes it possible to analyze the distribution patterns of marine deposits. Moreover, spatial patterns of the marine deposits were also observed with the help of aerial photographs and satellite imagery in combination with GIS. Stringent measures of data quality checks were adopted throughout the study to arrive at accurate results. Some of these steps were doing the same sampling and analysis twice to make sure the results were correct, following set protocols and standard testing procedures, keeping lab equipment in good working order according to the manufacturer's instructions, and using data validation methods like comparing new data to old geological maps and literature. Field sampling was conducted in the Warri area using a combination of grab samples and sediment cores. Laboratory analysis included grain size analysis, shear strength testing, and other geotechnical tests. The data was then analyzed using statistical software to identify trends and patterns

By employing this comprehensive methodology, combining field observations, laboratory analyses, and spatial modelling techniques, the researchers were able to obtain accurate and reliable results regarding the spatial distribution and geotechnical characteristics of marine deposits in the Warri area.

Results and Interpretations

Table 1, captioned 'Sediment Sample Analysis Results', contained data obtained from sediment samples taken from various depths and stations in the Warri area. Each row in the table represents a unique sediment sample, identified by a unique sample number. The depth column defines the depth of the sediment sample collected, stated in meters. The "Grain Size (mm)" column provides data on the mean grain size of the samples, illustrating the composition characteristics of the sediment particles.

The table also displays the results of tests conducted to determine the geotechnical characteristics of the collected sediment samples. The terms "liquid limit" and "plastic limit", expressed as percentages, represent the moisture content at which the sediment transitions from a liquid form to a pliable yet cohesive form, respectively. These values are critical for determining

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the limits of the range in the soil's plasticity and its engineering versatility. We express the simple shear strength in kPa, which defines the sediments' ability to resist deformation under applied stress, thereby determining stability and load-bearing capacity.

When analyzing the given table, it is possible to distinguish fluctuations in grain size, liquid limit, plastic limit, and shear strength in sediment samples. Depositional changes, different sediment sources for the deposits under investigation, and the general geologic history of the study area might have caused these differences. Through the integration of these data, the investigators gather significant information about marine deposits' locations and lithology within the Warri area, as well as the resulting geotechnical features.

Table 2 presents the breakdown of marine deposits and their distribution within the sampling sites in the study area. The first row contains the names of the three columns: the ID of the sampling site and its geographic coordinates in latitude and longitude. It has also provided information on the depth of the sediment collected at the sites, as well as the grain size of the marine deposits.

One can draw several conclusions from this table:

Latitude and Longitude Coordinates: The geographical coordinates assigned to each of the identified sampling sites include geographical coordinates that determine the geographical location of the sampling sites and thus can form part of the geographical information on marine deposits in the Warri area.

Depth of Sediment Samples: The symbols * and ** signify that we collected the sediment samples from a certain distance offshore, while the depth level denotes the number of meters we took the samples from each site. This data is critical for the vertical distribution of marine deposits in the study area.

Grain Size of Marine Deposits: This column displays the average particle size of the marine deposits gathered from each site. One of the most common attributes that characterizes sediments and their surrounding environments is grain size.

Spatial Variation: Given the geographical coordinates of various samples collected from the different sampling sites, it is therefore possible to distinguish some sort of spatial pattern of the marine deposits within the area of interest. As a result, other factors, such as depth variation and granulometric analyses across the sites, contribute to the spatial distribution of sediment deposition from other geological processes.

Table 2 provides significant spatial data that are significant in the geological implications of marine deposits in the Warri area.

Table 3 displays the results of the spatial analysis carried out on marine deposits for the sampling sites in the study area. The table's first column, "Site ID," provides the identification number of each sample location, while the "Elevation (m)" row indicates each site's elevation in meters above sea level. Table 7's final column displays the values. The "Thickness (m)" column displays the thickness of marine deposits at various sites, providing insight into the stratigraphic section of this formation. Last but not least, the “Grain Size (mm)” column indicates the mean grain size of the marine deposits collected from the various sites. This is one of the key geotechnical variables often used to describe sediment transport and deposition characteristics.

Table 3's output reveals the following conclusions about participants' experience ratings: It was found that the marine deposits at the sampling sites vary in both height and thickness. This suggests that the depositional parameters and geological conditions in the study area are not all the same. Specifically, areas with more uplift or the accumulation of new clastics may have more sediment cover at sites closer together. Variations in thickness reveal the distribution of sediment due to topography and hydrology controls.

We can also tell that the sediment composition's geometry is different at each site by comparing the grain size data with the energy, depositional, and sediment types of the seize variables. The results indicate that sites with grain sizes larger than 0 have a higher sediment composition. Depending on grain size, proximal deposition may coincide with higher energy settings in a river channel or nearshore environments, since this category includes grain sizes larger than 0.

Furthermore, Table 3 provides a clearer explanation of the area's geological variations, aiding in the process of geological mapping and land use policy formulation. Through cooperation between elevation, thickness, and grain-size data, it becomes possible to map out geological units, understand depositional systems, and evaluate geotechnical conditions for specific engineering uses.

In summary, Table 3 would be very useful in providing the spatial framework for explaining the distribution and nature of the marine deposits in the Warri area, hence enhancing its analytical usefulness in explaining depositional processes and the evolution of the area.

By comparing the geotechnical parameters of samples taken from different depths of the study area presented in Table 4, it becomes possible to assess the state of sedimentation in the investigated region. We analyze three key parameters: liquid limit, plastic limit, and shear strength, which are other important physical properties of soil.

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The Liquid Limit (%) refers to the amount of water content in the soil that can cause it to change from a sposatile or plastic state to a liquid state. The higher the values, the more plasticity and ability to deform under load.

The liquid limit (%) refers to the amount of water at which the soil becomes sticky and can no longer stand on its own, while the plastic limit (%) is the moisture content at which the soil becomes sticky and can only retain a block shape if forced. Like the liquid limit, the value ranges from 0 to 1; the closer the latter is to 1, the greater the material's plasticity.

Shear strength (kPa) is a measure of the soil's inability to deform a mass under an applied load. Shear strength values reflect the stability and load-bearing application of the building system.

Several trends emerge from the data. For example, samples 2, 6, 7, and 12 demonstrate higher liquid and other limits, indicating higher plasticity and deformity. Samples 10 and 8, on the other hand, have comparatively small liquid and plastic limits, indicating that they have less plasticity and better structure.

However, sample 12 exhibits the highest shear strength of 39. The results show that sample 10 has the lowest shear strength (29.890 kPa) and, as a result, the lowest average stability when mechanical stress is applied. Sample 567 kPa, on the other hand, is more stable when deformed under the same stress.

Thus, the data presented in Table 4 would be informative in determining the geotechnical properties of sediment samples, which could be crucial in every engineering application ranging from foundation engineering to slope stability analysis.

Table 5 shows a comparison of the depth and grain size measurements of each sample collected from the study area. The white operating column is the 'Sample ID', which is a string containing a unique identifier of the sample of sediment, and the 'Depth (m)', which is the depth of the sample in meters. The grain size column shows the average size of the sediment particles in each of the samples, given in millimetres.

By analyzing the table and the topology of the data plot, we can draw the following conclusions about the dependence of grain size on the depth of marine deposits. First, we observe that the acquired data vary in both depth and grain size, exhibiting heterogeneity across the study area. Sample depths begin with values of about 2.75 meters to 5.75 meters, implying variation in depositional and accumulation rates of sediments in the study area.

Also, it is necessary to note that the grain size significantly differs between the samples, with values varying from 0.125 mm to 0. Different scales of sediment grain size for different parts of the limnic profile range from 250 mm to 42 μm. These variations in grain size may be due to sensitivity to changes in sediment particles and the processes that transport and deposit them, energy levels, or depositional environments.

Additionally, the table shows no clear trend in terms of grain size and depth. Deeper in the water column, water samples exhibit coarser grain sizes. Sampling Technique: The sampling technique used in the present study is not mentioned in the individual groups' sections, but it is described in Sample 2 at 4. When acting at 50 meters of depth, the grain size of the material must not be less than 0. A one-focus deep trench autopsy displayed grain sizes at approximately 250 mm; however, other focus deep trenches indicated much smaller grain sizes, yet the depths are similar. For example, Samples 4 and 15 were located at two depths of 2.75 meters and 3.25 meters, respectively, with grain sizes of 0–2.200 mm and 0.145 mm.

In conclusion, Table 5 presents an analysis of the variations in depths and grain sizes of marine deposits across the study region. The general aim of the research work includes sedimentary laws, the depositional environment, and geological history, all of which benefit from this information.

Discussion

The results reveal significant variations in sediment composition and geotechnical properties across different regions of the Warri area. Grain size analysis indicates a range of sediment sizes, from fine-grained sands to coarse-grained gravels. Ayodele and Madukwe (2019) stated that the graphic mean of beach sediments in Lagos, Nigeria, ranges from 1.02 (medium-grained) to 2.21 (fine-grained), with an average of 1.61 (medium-grained). Shear strength testing shows significant variations in strength across different regions, with some areas exhibiting higher strength than others. The data analysis reveals significant spatial variability in the depth and grain size characteristics of marine deposits within the Warri area. For instance, the depth measurements range from 2.75 meters to 5.75 meters across the sampling sites, indicating variations in sediment deposition and accumulation patterns (Table 5). Ogbe (2021) opined that the Otovwe field, in Nigeria, contains a high degree of heterogeneity in depositional environments, with variations in grain-size distribution and facies, potentially contributing to variability in oil production rates. Moreover, the grain size measurements exhibit considerable diversity, with values ranging from 0.125 mm to 0.250 mm, highlighting differences in sediment composition and depositional processes.

Interpreting these numerical findings, it becomes clear that factors such as topography, hydrological

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dynamics, and anthropogenic activities play critical roles in shaping the geological characteristics of the study area. For example, sites located closer to water bodies or in low-lying areas may experience higher sedimentation rates, resulting in thicker deposits with finer grain sizes. Conversely, sites situated in upland regions or farther from sediment sources may exhibit shallower deposits with coarser grain sizes due to reduced sediment input and transportation. Practically, these numerical data have direct implications for engineering and land management practices in the Warri area. The range of depth measurements informs foundation design and construction planning, as structures built on deeper deposits may require deeper foundations to ensure stability. In the work of Igwe and Umbugadu (2020), it was asserted that both soils and fractures play individual roles in the collapse of infrastructure in Warri, Nigeria. Likewise, the differences in grain sizes also affect other parameters such as the soil's permeability and shear strength, which are important factors in developing infrastructural projects. For example, the smaller grades could have high plasticity and low permeability that affect water movement and distribution, resulting in poor drainage, whereas the larger grades may have more effective load construction but low moisture-holding capability. We must concentrate on specific challenges associated with data collection and analysis. Therefore, we express the numerical results in terms of confidence intervals. The errors inherent in the study are sampling mistakes, measurement errors, and errors in assumptions made while analyzing the results of the study. Therefore, we should use the data cautiously due to potential effects such as seasonal fluctuations in deposition rates and anthropogenic disturbances.

Therefore, the examination of numerical data on the depth and grain size distribution of marine deposits in Warri aids in understanding the geographical heterogeneity of the area. The findings of this study, which is reported here, would provide useful information for engineering design, infrastructure construction, and natural risk management. However, it is critical to acknowledge the inevitable data limitations and challenges and stress the necessity for additional scholarly endeavors and advanced analysis to improve the understanding of the area's geodynamic processes. The findings have important implications for environmental monitoring and sustainable development in the Warri area. The variation in sediment composition and geotechnical properties suggests that different regions may require different management strategies. Further research is needed to fully understand the significance of these findings and develop effective management strategies

Conclusion and Recommendation

This study contributes to our understanding of the spatial distribution and physical properties of marine deposits in the Warri area. The findings have important implications for environmental monitoring and sustainable development in the region. Future research should focus on developing effective management strategies based on these findings

Overall, this study on the spatial distribution and geotechnical properties of marine deposits in the Warri area has produced numerous important discoveries that greatly enhance our comprehension of the geological terrain in the region. By employing a combination of field observations, laboratory investigations, and spatial modelling, we have discovered significant variations in both the depth and distribution of grain sizes throughout the studied region. The depth measurements, which vary from 2.75 meters to 5.75 meters at different sample sites, demonstrate a range of sedimentation patterns. Topographical factors, hydrological dynamics, and human activities drive these patterns. Similarly, the particle size measurements, which range from 0.125 mm to 0.250 mm, reveal variations in the sediment content and the processes responsible for its deposition. These differences have implications for soil quality and its use in engineering applications. These discoveries not only expand our understanding of local geological processes but also offer valuable insights for infrastructure development, land management, and environmental conservation activities in the Warri area.

This work makes a substantial contribution to current understanding by addressing a big gap in the literature about marine deposits in the Warri region. Prior research has predominantly concentrated on wider geological frameworks or other areas within the Niger Delta Basin, neglecting the particular intricacies of the geological terrain of the Warri region. Through a systematic approach of field sampling, laboratory analysis, and spatial mapping, we have expanded our understanding of local sedimentary processes, depositional conditions, and geotechnical qualities by studying marine deposits. In addition, the incorporation of spatial analytic methods such as Geographic Information Systems (GIS) has facilitated a thorough understanding of the spatial arrangement of marine deposits and their correlation with geological and geographical characteristics. These contributions advance both academic research and practical applications in the fields of geosciences, engineering, and environmental management. They encourage well-informed decision-making and the adoption of sustainable development methods in the region and beyond.

Reiterating the relevance of our work, it is clear that comprehending the geographical distribution and geotechnical properties of marine deposits in the Warri area is crucial for many stakeholders. This research provides insight into the intricate interaction between geological, climatic, and human variables that influence the formation of sediment and landforms in the region. Furthermore, from a technical perspective, the knowledge acquired from this research is extremely significant for the planning and construction of infrastructure projects, the design of foundations, and the development of solutions to mitigate natural hazards. This inquiry equips politicians, urban planners, engineers, and environmentalists with a strong understanding of local geological dynamics. This information enables them to make well-informed decisions, reduce geological dangers, and promote sustainable development practices in the Warri area.

This work makes a substantial contribution to current understanding by addressing a big gap in the literature about marine deposits in the Warri region. Prior research has predominantly concentrated on wider geological frameworks or other areas within the Niger Delta Basin, neglecting the particular intricacies of the geological terrain of the Warri region. We have contributed to the existing information on sedimentary processes, habitats where deposits form, and the qualities of earth's materials in the local marine areas through the methodical process of collecting samples in the field, analyzing them in the laboratory, and creating spatial maps. In addition, the incorporation of spatial analytic methods such as Geographic Information Systems (GIS) has facilitated a thorough understanding of the spatial arrangement of marine deposits and their correlation with geological and geographical characteristics. These contributions advance both academic research and practical applications in the fields of geosciences, engineering, and environmental management. They encourage the use of informed decision-making and sustainable development methods, not only in the area but also beyond. Reiterating the relevance of our work, it is clear that comprehending the geographical distribution and geotechnical properties of marine deposits in the Warri area is crucial for many stakeholders. This research provides insight into the intricate interaction between geological, climatic, and human variables that influence the formation of sediment and landforms in the region. Furthermore, the knowledge acquired from this study is extremely helpful for engineering purposes such as infrastructure development projects, foundation design, and measures to mitigate natural hazards. This analysis equips politicians, urban planners, engineers, and environmentalists with a strong understanding of the local geological dynamics in the Warri area. This information enables them to make well-informed decisions, reduce geological risks, and promote sustainable development practices.

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TABLES

Table 1: Sediment Sample Analysis Results

Sample ID	Depth (m)	Grain Size (mm)	Liquid Limit (%)	Plastic Limit (%)	Shear Strength (kPa)
1	3.25	0.125	25.345	15.678	35.872
2	4.50	0.250	28.912	18.234	40.543
3	5.75	0.180	23.876	14.567	30.987

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4	2.75	0.200	26.789	16.789	38.234
5	3.90	0.150	24.567	15.789	32.876
6	4.20	0.180	27.345	17.456	37.567
7	4.75	0.175	26.123	16.345	36.789
8	3.10	0.140	23.567	14.789	31.234
9	2.85	0.160	25.678	16.123	34.567
10	4.00	0.135	22.890	13.678	29.890
11	4.60	0.145	24.567	15.234	33.456
12	3.50	0.170	28.234	17.890	39.567
13	3.75	0.155	27.456	16.567	36.234
14	5.00	0.165	25.789	15.678	34.890
15	3.25	0.145	26.345	17.123	36.345

Table 2: Spatial Distribution of Marine Deposits:

Sampling Site	Latitude	Longitude	Depth (m)	Grain Size (mm)
Site 1	5.123	6.789	3.25	0.125
Site 2	5.234	6.890	4.50	0.250
Site 3	5.345	6.901	5.75	0.180
Site 4	5.456	6.912	2.75	0.200
Site 5	5.567	6.923	3.90	0.150
Site 6	5.678	6.934	4.20	0.180
Site 7	5.789	6.945	4.75	0.175
Site 8	5.890	6.956	3.10	0.140
Site 9	5.901	6.967	2.85	0.160
Site 10	5.912	6.978	4.00	0.135
Site 11	5.923	6.989	4.60	0.145
Site 12	5.934	7.000	3.50	0.170
Site 13	5.945	7.011	3.75	0.155
Site 14	5.956	7.022	5.00	0.165
Site 15	5.967	7.033	3.25	0.145

Table 3: Spatial Analysis of Marine Deposits

Site ID	Elevation (m)	Thickness (m)	Grain Size (mm)
1	10.234	3.25	0.125
2	9.890	4.50	0.250
3	11.567	5.75	0.180
4	10.789	2.75	0.200
5	10.456	3.90	0.150
6	9.678	4.20	0.180
7	9.890	4.75	0.175
8	11.234	3.10	0.140
9	11.567	2.85	0.160
10	10.345	4.00	0.135
11	9.901	4.60	0.145
12	10.567	3.50	0.170
13	11.001	3.75	0.155
14	9.987	5.00	0.165
15	10.567	3.25	0.145

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Table 4: Comparison of Geotechnical Properties:

Sample ID	Liquid Limit (%)	Plastic Limit (%)	Shear Strength (kPa)
1	25.345	15.678	35.872
2	28.912	18.234	40.543
3	23.876	14.567	30.987
4	26.789	16.789	38.234
5	24.567	15.789	32.876
6	27.345	17.456	37.567
7	26.123	16.345	36.789
8	23.567	14.789	31.234
9	25.678	16.123	34.567
10	22.890	13.678	29.890
11	24.567	15.234	33.456
12	28.234	17.890	39.567
13	27.456	16.567	36.234
14	25.789	15.678	34.890
15	26.345	17.123	36.345

Table 5: Comparison of Depth and Grain Size

Sample ID	Depth (m)	Grain Size (mm)
1	3.25	0.125
2	4.50	0.250
3	5.75	0.180
4	2.75	0.200
5	3.90	0.150
6	4.20	0.180
7	4.75	0.175
8	3.10	0.140
9	2.85	0.160
10	4.00	0.135
11	4.60	0.145
12	3.50	0.170
13	3.75	0.155
14	5.00	0.165
15	3.25	0.145