Journal of Energy Technology and Environment Vol. 5(2) 2023 pp. 211 - 227 ISSN-2682-583x

NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Sedimentological and Petrographic Analysis of Side Wall Samples from the Niger Delta Basin, Nigeria: Implications for Depositional Environments and Reservoir Quality.

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Article information

Article History
Received 10 May 2023
Revised 20 May 2023
Accepted 30 May 2023
Available online 12 June 2023

Keywords:

Niger Delta Basin, Sedimentology, Petrography, Reservoir Quality, Shallow Marine Setting

OpenAIRE

https://doi.org/10.5281/zenodo.8026291

https://nipes.org

Abstract

The aim of the present study is to examine the Sedimentological and Petrographic nature of Side Wall Samples from the Niger Delta Basin, Nigeria with a view to establishing their Implications for Depositional Environments and Reservoir Quality. Sidewall samples were collected using a coring tool at depths ranging from 2433ft to 5916ft. A total of 22 samples were labeled, stored in airtight bags, and transported to the lab for analysis. The sedimentological analysis involved determining grain size distribution using a comparator. Lithologic description identified dominant lithology, texture, and color, aiding interpretation of depositional environments and sedimentary facies. A magnifying lens enabled detailed observation of individual grains or mineral crystals. Petrographic analysis used a microscope to identify mineral composition, texture, and fabric of the sediment. Diagenetic features like cementation, compaction, and dissolution were recorded. Acid tests detected carbonate minerals, while hydrocarbon stain tests identified hydrocarbon presence. Visual examination of the samples under a binocular microscope revealed two lithologies, shale and sandstone, with varying percentages of sand and shale. Associated minerals, including mica flakes, quartz crystals exhibiting growth patterns, coal particles, ferruginized materials, silt, and carbonate materials were identified. Results of laboratory analysis suggest that the samples were deposited in a marine environment with varying energy levels. Diagenetic processes include compaction, cementation, and dissolution, which have implications for reservoir quality. The sandstones with well-sorted, angular, and coarse grains have good reservoir potential, while those with poor sorting and sub-angular to sub-rounded grains have limited potential. These findings have important implications for hydrocarbon exploration and development in the area.

1. Introduction

The Niger Delta Basin, also known as the Niger Delta province, is an extensional rift basin situated in the Niger Delta and the Gulf of Guinea (Figure 1). It is located on the passive continental margin near the western coast of Nigeria [1]. The basin is believed to have access to Cameroon, Equatorial Guinea, and São Tomé and Príncipe. This basin is very complex, and it carries high economic value as it contains a very productive petroleum system [1].

The Niger delta basin is one of the largest subaerial basins in Africa. It has a subaerial area of about 75,000 km2, a total area of 300,000 km2, and a sediment fill of 500,000 km3[1]. The sediment fill has a depth between 9–12km [2]. It is composed of several different geologic formations that indicate how this basin could have formed, as well as the regional and large-scale tectonics of the area. The Niger Delta Basin is an extensional basin surrounded by many other basins in the area that all formed from similar processes. The Niger Delta Basin lies in the south westernmost part of a larger tectonic structure, the Benue Trough. The other side of the basin is bounded by the Cameroon Volcanic Line and the transform passive continental margin. [2]

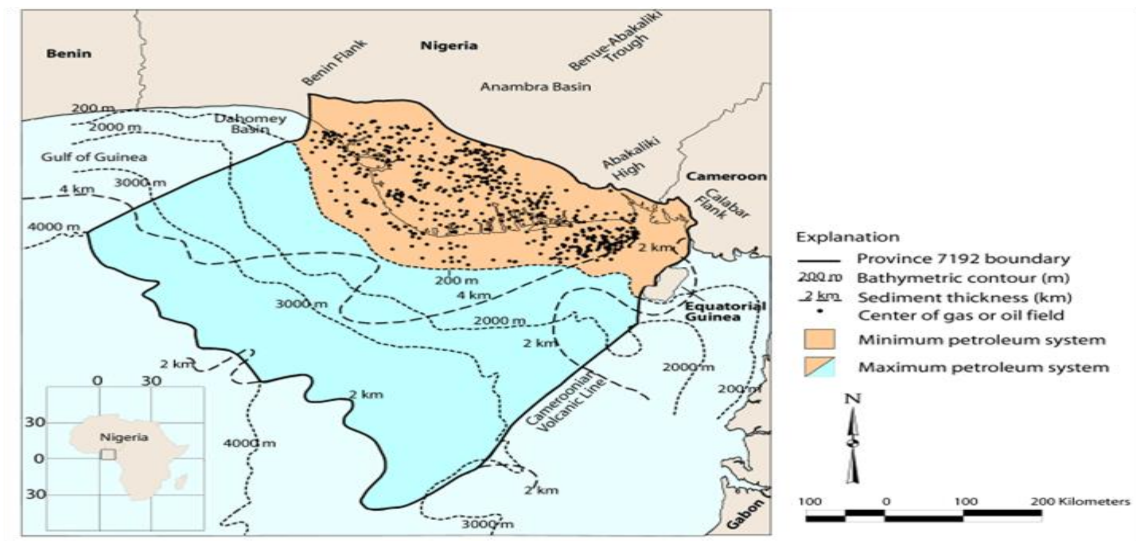

Figure 1 Location of the Niger Delta in the Gulf of Guinea in equatorial West Africa. Source: USGS Open-File Report 99-50-H [3]

The Niger Delta Basin is composed of three major depobelts, which experienced an overall regression over time, leading to changes in lithologies from deep sea mud-sized grains to denser fluvial sand-sized grains. The mineralogy of the sediment grains is controlled by the sediment provenance from the onshore highlands. Sea level also plays a significant role in sediment deposition and controls the basin ward extent of lithologies, as shown by sequence stratigraphy [1]. Additionally, volcanic activity in the area may result in thin ash deposits. The sedimentary environment of the Niger Delta Basin changed from a tide-dominated system in the early Cretaceous to a wave-dominated system, with a concave shoreline evolving into a convex one [1].
The Niger Delta Basin has a complex sedimentary geology, with three major Depobelts, and experiences changes in lithologies due to various factors such as sediment provenance, sea level, and volcanic activity. The basin has a basement rock that is basaltic in composition and the rock

from the middle to late Cretaceous is poorly understood. The basin is also characterized by different formations including the Akata Formation, Agbada Formation, and Benin Formation [1]. The tectonic structures in the basin are typical of an extensional rift system, with added shale diapirism due to loading. Basin inversion is caused by uplift and/or compression in the basin, and shale diapirs [1], high-angle normal [4], faulting, and basin ward dipping reflectors are common features [1]. These structures form great oil traps and anticline structures. The Niger Delta Basin is a major hydrocarbon province, ranking as the twelfth largest in the world in terms of known oil and gas resources [5]. Oil production in the basin is estimated to be around 2 million barrels per day, and it is believed to hold an estimated 34.5 billion barrels of oil and 94 trillion cubic feet of natural gas. Today, the area is still heavily explored by oil companies and is considered one of the largest oil producers globally [1], [6]. One of the challenges in exploring and developing hydrocarbon reserves in the Niger Delta Basin is the complex sedimentary geology. To explore and develop sandstone reservoirs, it's essential to accurately predict the occurrence and shape of sandstone formations. This, in turn, is heavily influenced by the depositional environment, which can be inferred from the primary properties observed in subsurface core samples [7]. The depositional environment refers to a specific set of physical, chemical, and biological factors involved in the sediment deposition process, which ultimately determines the type of rock that will form after undergoing lithification[8]. [9] provided a definition of core analysis as the process of conducting laboratory measurements of physical and chemical properties of core samples, which serves multiple disciplines. According to them, core description results in the subdivision of cores into different lithofacies based on various factors, such as lithology, grain size, sedimentary structures, and stratification. These factors are determined by various processes that occurred during deposition.

The rock formations contain a variety of facies that have been deposited in different environments, and the reservoir properties of these formations can vary significantly [6]. Lack of detailed information on the sedimentological and petrographic characteristics of the rock formations in the study area hinders our ability to accurately assess the reservoir properties of these formations, which is vital for effective hydrocarbon exploration and development. By gaining a detailed understanding of these characteristics, we can bridge the knowledge gap and improve our ability to assess reservoir properties. By conducting a comprehensive analysis of sidewall samples and examining their sedimentological and petrographic nature, this study seeks to fill this knowledge gap and provide valuable insights into the depositional environments and reservoir quality of the rock formations in the study area. These insights will contribute to a more accurate assessment of the reservoir potential within the Niger Delta Basin, enabling more informed decisions during hydrocarbon exploration and development activities. Understanding the sedimentological characteristics, such as grain size distribution, lithology, and depositional environments, will help determine the depositional processes and identify potential reservoir facies. Additionally, the petrographic analysis will shed light on the mineral composition, texture, and diagenetic features present in the rock samples. This information is crucial for understanding the rock's porosity, permeability, and potential hydrocarbon storage and migration pathways.

By filling this gap in knowledge, the study will provide a foundation for improved reservoir characterization, ultimately enhancing the success rate of exploration and production efforts in the Niger Delta Basin. This, in turn, has significant implications for the economic viability and sustainable development of hydrocarbon resources in the region.

Overall, the study aims to contribute valuable information that can be utilized by industry professionals, geoscientists, and decision-makers involved in hydrocarbon exploration and production activities in the Niger Delta Basin. It seeks to bridge the existing knowledge gap and provide a more comprehensive understanding of the sedimentological and petrographic nature of the rock formations, thereby supporting more informed and efficient hydrocarbon exploration and development strategies.

2. Materials and methods

The materials used and the procedures followed to conduct the study are described. The source and preparation of materials, equipment used, study design, data collection methods, statistical analysis, and ethical considerations are presented.
Twenty-two sidewall samples were collected from the X1 well located in the Greater Ughelli Depobelt within the Niger Delta, Nigeria (Figure 2). The samples were obtained from depths ranging from 2433ft to 5916ft. The sidewall samples were subjected to laboratory analysis using standard sedimentological and petrographic methods to determine their properties. The visual examination involved a detailed observation of the samples under a binocular microscope, with a focus on the texture, color, grain size, sorting, and sedimentary structures. The petrographic analysis was conducted using thin sections of the samples, which were prepared by cutting a small piece of the sample and embedding it in a resin. The thin sections were then polished and examined under a polarizing microscope. The petrographic analysis focused on the mineralogy, texture, and fabric of the samples. The sedimentological and petrographic data obtained were analyzed and interpreted to determine the depositional environment, diagenetic processes, and reservoir potential of the samples. Ethical considerations were taken into account during the study, and all necessary permits were obtained before the commencement of the study. Table 1 presents a Study Methodology for the Sedimentological and Petrographic Analysis of Side Wall Samples from X1 well.

2.1 Location of the Study Area

The study area is located in the Greater Ughelli Depobelt (Figure 2). The Greater Ughelli Depobelt is a hydrocarbon-rich region located in the Niger Delta area of Nigeria It is situated in the southern part of the country and covers an area of approximately 6,000 square kilometers, stretching across the Ughelli North, Ughelli South, and Udu local government areas of Delta State. The region is known for its significant reserves of crude oil and natural gas. It has been estimated that the Greater Ughelli Depobelt holds over 2.5 billion barrels of crude oil and 10 trillion cubic feet of natural gas. This makes it one of the most important regions in Nigeria's energy sector and a critical contributor to the country's oil production and revenue.
Oil and gas exploration in the Greater Ughelli Depobelt began in the 1950s and has been ongoing ever since. Several oil and gas companies operate in the region, including the Nigerian National Petroleum Corporation (NNPC), Shell Petroleum Development Company (SPDC), Chevron Nigeria Limited, and the Nigerian Gas Company (NGC).
The hydrocarbon potential of the Greater Ughelli Depobelt is significant, with many untapped reserves still waiting to be discovered. The region is also home to a network of pipelines and other infrastructure that facilitates the transportation of crude oil and natural gas to other parts of the country and for export to international markets.

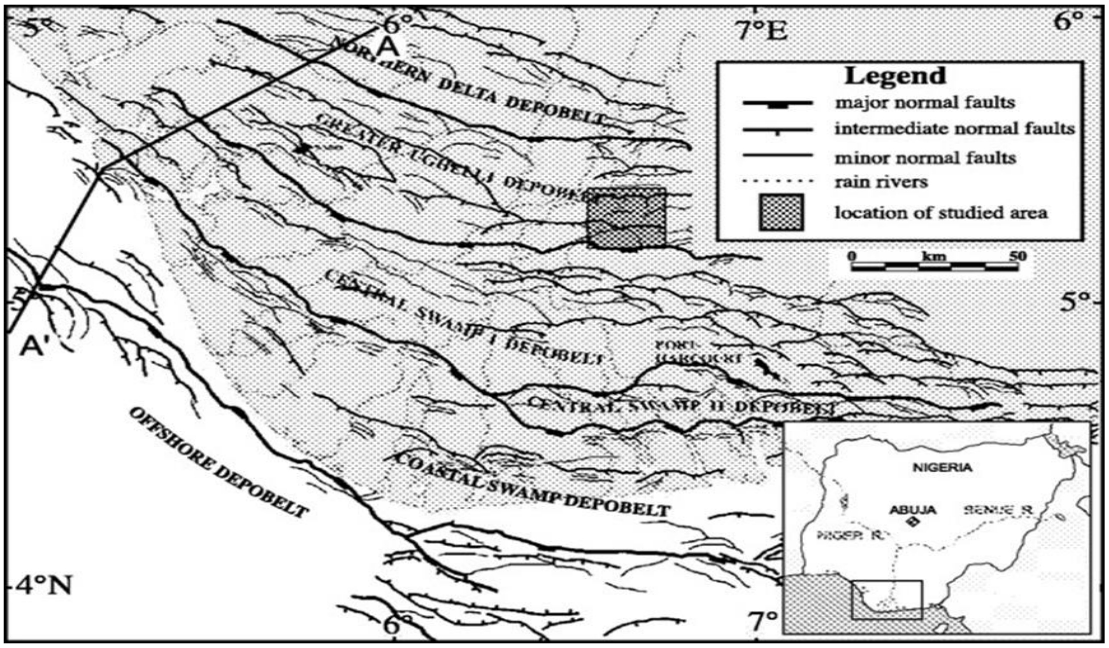

Figure 2 Location of the Study Area in the Greater Ughelli Depobelt [7]

2.2 Study Methodology

The samples were taken from depths ranging from 2433ft to 5916ft, and were analyzed for their sand and shale percentages, lithology, lithological description, and associated minerals

Table 1: Study Methodology for the Sedimentological and Petrographic Analysis of Side Wall Samples from X1 well

Stage	Description	Methodology
Stage 1	Sample Collection	Sidewall core samples were collected from the X1 well located in the greater Ughelli Depobelt within the Niger Delta, at depths of about 2433ft to 5916ft.
Stage 2	Sample Preparation	The sidewall samples were cleaned and air-dried at room temperature. The samples were then crushed and sieved through a series of standard sieves (0.063 mm to 2.0 mm) for grain size analysis.
Stage 3	Sedimentological Analysis	The grain size distribution of each sample was determined using the grain size comparator.

Stage 4	Petrographic Analysis	The samples were subjected to visual examination and petrographic analysis under a petrographic microscope.
Stage 5	Acid Test	The acid test was conducted to determine the presence of carbonate minerals in the samples.
Stage 6	Hydrocarbon Stain Test	The hydrocarbon stain test was conducted to determine the presence of hydrocarbons in the samples.
Stage 7	Data Analysis	The results of the grain size analysis, petrographic analysis, acid test, and hydrocarbon stain test were analyzed and interpreted.
Stage 8	Report Writing	The results of the study were compiled and presented in a report, including a detailed sedimentological and petrographic description of each sample.

Sample collection: Selection of the well from which sidewall samples will be collected based on the research objectives. Sidewall samples were collected from depths 2433ft to 5916ftusing a sidewall coring tool. This was done mainly for descriptive purposes and is made up of general reconnaissance study of the area. Around the area several wells had been dug but this particular exploration well has a depth of about 12,000ft. Rotary method of collecting sidewall samples was employed here and about 22 samples were collected at various intervals of interest.

Sample preparation: Sidewall samples were labeled and stored in airtight bags to prevent contamination. Samples were later taken to the laboratory for further analysis.

Sedimentological analysis: Determine the grain size distribution of each sample using the grain size comparator. Lithologic description was done and used to describe the lithology, texture, and color of the sidewall samples. The samples were described based on their dominant lithology, texture (grain size, sorting, and rounding), and color. This information was used to identify the depositional environment and sedimentary facies. A magnifying lens was used to observe the individual grains or mineral crystals in the sample. The lens allows for the determination of the characteristics of individual grains, including their size, shape, and texture.

Petrographic analysis: Each sample was examined a petrographic microscope to identify the mineral composition, texture, and fabric of the sediment. Observations related to the presence of diagenetic features, such as cementation, compaction, and dissolution were recorded

Acid test: Acid test was performed on each sample to determine the presence of carbonate minerals. The acid test was conducted to determine the presence of carbonate minerals in the samples.

Hydrocarbon stain test: The hydrocarbon stain test was conducted to determine the presence of hydrocarbons in the samples.

Data analysis: The results of the Sedimentological analysis, petrographic analysis, acid test, and hydrocarbon stain test for each sample was compiled in a table.

Interpretation and conclusions: Results of the analysis in the context of the research objectives were interpreted. Conclusions about the sedimentary processes and depositional environments that contributed to the formation were drawn. Implications for hydrocarbon exploration and production in the region were identified.

Report writing: a comprehensive report that includes the study design, materials and methods, results, interpretation, conclusions, and recommendations for future research was written.

3. Results and Discussion

The results of the laboratory analysis conducted on the 22 sidewall samples from the Greater Ughelli Depobelt of the Niger Delta Basin are presented in Table 2.

Table 2 Results of Analysis of Sidewall Samples

S/N	DEPTH (ft)	SAND %	SHALE %	LITHOLOGY	LITHOLOGICAL DESCRIPTION	ASSOCIATED MINERALS
1	2433	0	100	Shale	dark gray, platy	Growing quartz crystal, coal particles
2	2508	100	0	Sandstone	Light-brown, poorly-sorted, angular, fine grains	Mica-flakes (abundant), Ferruginized materials, carbonate materials, coal particles
3	2744	100	0	Sandstone	Light-brown, poorly sorted, sub-angular, coarse grains	Ferruginized materials, coal particles, carbonate materials
4	3070	100	0	Sandstone	Light-brown, well sorted, fine grain sizes, angular	Ferruginized materials
5	3450	100	0	Sandstone	Light-brown, sub-rounded, moderately sorted, coarse grain	Ferruginized materials, coal particles, carbonate materials

6	3480	98	2	Sandstone	Light-brown, angular, moderately sorted, medium grain	Mica flakes (trace), Ferruginized materials, silt
7	3570	80	20	Sandstone	Brown, sub-angular, well sorted, medium grain	Mica flakes (few), growing quartz crystal, coal particles
8	3918	100	0	Sandstone	Light-brown, sub-rounded, moderately sorted, coarse grain	Mica flakes (trace), Ferruginized materials
9	3970	100	0	Sandstone	Light-brown, well-sorted, fine grain sizes, sub-rounded	Ferruginized materials, carbonate materials
10	4026	100	0	Sandstone	Light-brown, angular, well sorted, coarse grain	Growing quartz crystal, Ferruginized materials
11	4198	80	10	Sandstone	Light-brown, poorly sorted, sub-angular - sub-rounded, coarse grains	Mica flakes (trace), Ferruginized materials, coal particles
12	4388	100	0	Sandstone	Light-brown, poorly sorted, sub-angular, coarse grains	Silt, growing quartz crystal, coal particles
13	4480	100	0	Sandstone	Light-brown, well sorted, medium grain sizes, sub-angular	None
14	4588	0	100	Shale	Gray, platy	None
15	4647	0	100	Shale	Gray, platy	Mica flakes (trace)
16	4780	90	10	Sandstone	Dark brown, well sorted, fine grain sizes, sub-angular	Mica flakes (trace), growing quartz crystal
17	4599	0	100	Shale	gray, platy	Mica flakes (few), silt
18	4993	0	100	Shale	gray, platy	Mica flakes (few)

19	5040	100	0	Sandstone	dark brown, sub angular, well sorted, coarse grain	Ferruginized materials, carbonate materials, Coal particles
20	5575	0	100	Shale	gray, platy	Mica flakes (trace), Ferruginized materials
21	5583	60	40	Sandy heterolith	Light-brown, poorly sorted, sub rounded, and medium grains; shale: gray, massive	Mica flakes (few), Coal particles, Ferruginized materials
22	5916	0	100	Shale	gray, massive	Mica flakes (few), Ferruginized materials

The findings from the sedimentological analysis, as presented in Table 2, will now be discussed in detail.

The study of the sidewall samples presented in Table 2 has yielded significant insights into the subsurface formation. By analyzing the lithological descriptions, sand and shale percentages, and associated minerals, valuable information has been obtained for reservoir characterization and production optimization. The results include samples of both shale and sandstone lithologies. The shale samples exhibit characteristics such as dark gray and platy texture, while the sandstone samples are described as light-brown with varying degrees of sorting, grain size, and angularity. The sand percentages are consistently high in the sandstone samples, indicating the dominance of sand within these formations, while the shale samples exhibit negligible sand content. The associated minerals found in the samples provide additional valuable information. Growing quartz crystals, mica flakes, ferruginized materials, carbonate materials, coal particles, and silt are identified in different samples. These minerals offer insights into the depositional environment, diagenesis processes, and potential hydrocarbon-bearing zones within the formation. Additionally, the presence of certain minerals and their distribution can help in understanding reservoir quality parameters such as permeability and porosity. Mica flakes, for example, can impact the rock's mechanical properties and contribute to the formation's permeability characteristics. Furthermore, the heterolithic nature of certain samples, such as sandy heterolith and shale intercalations, adds complexity to the subsurface formation. This complexity can influence fluid flow behavior and reservoir heterogeneity, which are crucial factors to consider in reservoir characterization and production optimization.

The lithological description of the sandstone samples ranged from poorly sorted to well sorted, and from fine to coarse grain sizes. The associated minerals in the samples included mica flakes, ferruginized materials, coal particles, growing quartz crystals, silt, and carbonate materials.

Sample 1 (2433ft, shale): The sample is composed of 100% shale with a dark gray, platy appearance. The associated minerals are growing quartz crystals and coal particles. This sample suggests a marine depositional environment with the presence of marine organisms that produced the organic material which was later transformed into coal.

Sample 2 (2508ft, sandstone): This sample is composed of 100% sandstone with a light-brown, poorly-sorted, angular, fine-grained appearance. The associated minerals are mica-flakes, ferruginised materials, carbonate materials, and coal particles. The sandstone suggests a fluvial depositional environment with the presence of abundant mica-flakes indicating an immature sediment source.

Sample 3 (2744ft, sandstone): The sample is composed of 100% sandstone with a light-brown, poorly-sorted, sub-angular, coarse-grained appearance. The associated minerals are ferruginised materials, coal particles, and carbonate materials. The sandstone suggests a fluvial depositional environment with the presence of mature sediments.

Sample 4 (3070ft, sandstone): This sample is composed of 100% sandstone with a light-brown, well-sorted, fine-grained, angular appearance. The associated minerals are ferruginized materials. The sandstone suggests a shallow marine depositional environment.

Sample 5 (3450ft, sandstone): This sample is composed of 100% sandstone with a light-brown, sub-rounded, moderately sorted, coarse-grained appearance. The associated minerals are ferruginized materials, coal particles, and carbonate materials. The sandstone suggests a fluvial depositional environment with the presence of mature sediments.

Sample 6 (3480ft, sandstone): This sample is composed of 98% sandstone and 2% shale with a light-brown, angular, moderately sorted, medium-grained appearance. The associated minerals are trace amounts of mica-flakes, ferruginized materials, and silt. The sandstone suggests a fluvial depositional environment with the presence of a mixed sediment source.

Sample 7 (3570ft, sandstone): This sample is composed of 80% sandstone and 20% shale with a brown, sub-angular, well-sorted, medium-grained appearance. The associated minerals are few mica-flakes, growing quartz crystal, and coal particles. The sandstone suggests a shallow marine depositional environment.

Sample 8 (3918ft, sandstone): This sample is composed of 100% sandstone with a light-brown, sub-rounded, moderately sorted, coarse-grained appearance. The associated minerals are trace amounts of mica-flakes and ferruginized materials. The sandstone suggests a fluvial depositional environment with the presence of mature sediments.

Sample 9 (3970ft, sandstone): This sample is composed of 100% sandstone with a light-brown, well-sorted, fine-grained, sub-rounded appearance. The associated minerals are ferruginized materials and carbonate materials. The sandstone suggests a shallow marine depositional environment.

Sample 10 (4026ft, sandstone): This sample is composed of 100% sandstone with a light-brown, angular, well-sorted, coarse-grained appearance. The associated minerals are growing quartz crystal and ferruginized materials. The sandstone suggests a shallow marine depositional environment.

Sample 11 was collected from a depth of 4198 ft and was found to be composed of 80% sandstone and 10% shale. The sandstone was poorly sorted, sub-angular to sub-rounded, and had coarse grains. The sample contained trace amounts of mica flakes, ferruginized materials, and coal particles. Based on its lithology and mineralogy, the sample suggests a fluvial depositional environment [10]. The presence of coal particles may also indicate that the sample was deposited in a swamp or deltaic environment [11]. The moderate to poor sorting of the sand grains may indicate that the sediment was transported by high-energy currents, possibly during a flood event [12]. The high percentage of sandstone suggests that this sample may have potential as a reservoir rock.

Sample 12 was collected from a depth of 4388 ft and was found to be composed entirely of sandstone. The sandstone was poorly sorted, sub-angular, and had coarse grains. The sample also contained silt, growing quartz crystals, and coal particles. Based on its lithology and mineralogy, the sample suggests a fluvial depositional environment [10]. The presence of growing quartz crystals suggests that the sediment was exposed to high temperatures and pressures during burial, indicating that this sample may have experienced diagenesis (Boggs, 2006). The poor sorting and coarse grains suggest that the sediment was transported by high-energy currents, possibly during a flood event [12]. The high percentage of sandstone in the sample suggests that it may have potential as a reservoir rock.

Sample 13 was collected from a depth of 4480 ft and was found to be composed entirely of sandstone. The sandstone was well-sorted, had medium grain sizes, and was sub-angular. The sample did not contain any significant associated minerals. Based on its lithology and mineralogy, the sample suggests a fluvial depositional environment [10]. The well-sorted nature of the sand grains suggests that they were transported by low-energy currents, possibly a meandering river [12]. The absence of associated minerals indicates that this sample may not have significant reservoir potential.

Sample 14 was collected from a depth of 4588 ft and was found to be composed entirely of shale. The shale was gray and platy, and did not contain any associated minerals. Based on its lithology and mineralogy, the sample suggests a lacustrine depositional environment [10]. The absence of associated minerals and the fine-grained nature of the sediment suggest that this sample may not have significant reservoir potential.

Sample 15 was collected from a depth of 4647 ft and was found to be composed entirely of shale. The shale was gray and platy and contained trace amounts of mica flakes. Based on its lithology and mineralogy, the sample suggests a lacustrine depositional environment [10]. The presence of mica flakes suggests that this sample may have experienced some diagenesis [13]. The absence of significant associated minerals and the fine-grained nature of the sediment suggest that this sample may not have significant reservoir potential.

Sample 16 was taken from a depth of 4780ft and was identified as a sandstone with 90% sand and 10% shale. It is described as being dark brown in color, well-sorted, with fine grain sizes, and sub-angular in shape. The sample contains trace amounts of mica flakes and possibly growing quartz crystals. The high sand content and well-sorted nature of this sample suggest that it was deposited in a high-energy environment, likely a fluvial or shallow marine setting [14]. The presence of mica flakes and quartz crystals may indicate a source of metamorphic rocks nearby, which could have contributed to the sediment supply. The sub-angular shape of the grains suggests that the sediment was not transported far from its source before deposition. The high sand content and fine grain size also suggest that this sample may have good reservoir quality, with high porosity and permeability.

Sample 17 is shale with 100% shale and no sand content. The shale is gray and platy in appearance with few mica flakes and silt.

Sample 18 is similar to sample 17 in that it is also shale with 100% shale content. It is gray and platy in appearance with a few mica flakes.

Sample 19 is sandstone with 100% sand content. The sandstone is dark brown, well sorted, coarse-grained and sub-angular in shape. It contains ferruginized materials, carbonate materials, and coal particles.

Sample 20 is shale with 100% shale content. It is gray and platy in appearance with few mica flakes and ferruginized materials.

Sample 21 is a sandy heterolith, consisting of a mix of sand and shale. The sand is light-brown in color, poorly sorted, and has sub-rounded, medium-sized grains. The shale is gray and massive in appearance. It contains few mica flakes, coal particles, and ferruginized materials.

Sample 22 is shale with 100% shale content. It is gray and massive in appearance with few mica flakes and ferruginized materials.

The sedimentological and petrographic analysis of the sidewall samples from the Greater Ughelli Depobelt of the Niger Delta Basin revealed the complex sedimentary geology of the region. The presence of both sandstone and shale samples indicates the alternating depositional environment of the region, which is consistent with previous studies [15].

The sandstone samples analyzed were found to have varying degrees of sorting, which could be indicative of different depositional environments or transportation processes. The fine-grained sandstones with well-sorted grains suggest deposition in a low-energy environment, while the coarse-grained sandstones with poorly sorted grains suggest deposition in a high-energy environment [13].Previous studies have also shown that sedimentary rocks in the Niger Delta basin were deposited in a variety of environments, including marine, estuarine, and fluvial settings [15; 16].

The presence of associated minerals in the samples, such as mica flakes, ferruginized materials, coal particles, growing quartz crystals, silt, and carbonate materials, suggests the influence of different depositional environments and diagenetic processes [13]. This is consistent with previous studies that have shown that diagenesis is an important factor in determining the properties and characteristics of sedimentary rocks [17; 18].For example, the abundance of coal particles in some of the samples could be indicative of a swampy depositional environment, while the presence of growing quartz crystals could suggest a high-temperature and high-pressure diagenetic environment [15].

The results of the acid test and hydrocarbon stain test suggest that some of the samples analyzed contain hydrocarbons. This is consistent with the known presence of hydrocarbons in the Niger Delta basin, which is one of the major oil and gas producing regions in Nigeria [15]. The presence of hydrocarbons in the samples analyzed may have important implications for oil and gas exploration and production in the area.

3.1 General Implications for Depositional Environments and Reservoir Quality of the Sidewall Samples:

Sample 1 is shale with a dark gray, platy appearance and is composed entirely of 100% shale. The associated minerals are growing quartz crystals and coal particles, which suggest a marine depositional environment with the presence of marine organisms that produced the organic material later transformed into coal. The shales are important components in the overall petroleum system of the well, serving as source rocks for hydrocarbon generation.
Samples 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16 and 19 are all sandstones with varying percentages of sand content. They are well-sorted, fine to medium-grained and rounded to sub-rounded in shape. They are likely deposited in a shallow marine or fluvial environment with good reservoir potential due to their porosity and permeability.

Sample 14, 15, 17, 18, 20 and 22 are all shales with little to no sand content. This suggests that they were deposited in a low-energy environment, such as a deep marine basin or a stagnant lagoon. The presence of mica flakes and ferruginized materials in some of these samples suggests that they may have been deposited in an environment with a high level of organic material, such as a deltaic or swampy environment. While the shales in this analysis may not have significant reservoir quality, they can still be important components in the overall petroleum system of the well, serving as source rocks for hydrocarbon generation. Shale is an important component within a well as it provides information on the depositional environment and geologic history of the area. The presence of shale within a well can help identify the source of the sediments, the depositional environment, and the geologic history of the area. In addition, shale can also act as a seal or barrier for hydrocarbons, such as oil and gas that may be present in adjacent sandstone layers. This is because shale typically has low permeability, which makes it an effective barrier to the flow of fluids. Furthermore, shale can also be a potential target for hydrocarbon exploration, as some shale formations may contain significant amounts of organic matter that has been transformed into hydrocarbons through processes such as thermal maturation. This has led to the development of unconventional oil and gas resources, such as shale gas and shale oil, which are extracted using techniques such as hydraulic fracturing. Overall, the presence of shale within a well can provide valuable information on the geology and hydrocarbon potential of the area and it can also play an important role in the production and exploration of hydrocarbon resources.

Sample 19 is sandstone with well-sorted, coarse-grained sand and contains ferruginized and carbonate materials, as well as coal particles. This suggests that it was deposited in a high-energy environment, such as a braided river or a beach. The presence of coal particles suggests that this sandstone may have been deposited in a deltaic environment with a high level of organic material. This sandstone has the potential to be a good reservoir due to its high porosity and permeability.

Sample 21 is a sandy heterolith, consisting of a mix of sand and shale. The presence of poorly sorted, sub-rounded, medium-sized grains suggests that this heterolith was deposited in a low-energy environment, such as a delta plain or a beach. The presence of coal particles and ferruginized materials in the shale component suggests that this heterolith was deposited in an environment with a high level of organic material. This heterolith may have some reservoir potential, but its properties would depend on the relative proportions of sand and shale and the degree of sorting and cementation of the sand component.

These results suggest that the formation in this particular wellbore has a heterogeneous nature, with variations in mineralogy and porosity occurring within the same formation. The variations in mineralogy could be due to the depositional environment, with some areas of the formation experiencing different sedimentation conditions than others. The differences in porosity could be due to diagenetic processes, where some areas of the formation have undergone more compaction and cementation than others.

In this study, the reservoir potential was determined through a combination of sedimentological and petrographic analyses. Based on the results of the sedimentological and petrographic analyses, the reservoir potential was assessed. Well-sorted, angular, and coarse-grained sandstones were identified as having good reservoir potential, indicating they possess favorable porosity and permeability properties for hydrocarbon storage and flow. On the other hand, samples with poor sorting and sub-angular to sub-rounded grains were found to have limited reservoir potential, suggesting lower porosity and permeability characteristics. By integrating the sedimentological and petrographic data, the study was able to provide insights into the reservoir quality and potential productivity of the samples. These findings are crucial for guiding hydrocarbon exploration and development activities in the Niger Delta Basin.

The findings of this study have important implications for hydrocarbon exploration and development because they provide crucial information about the reservoir potential of the studied area in the Niger Delta Basin. Understanding the sedimentological characteristics, lithology, and petrographic features of the samples helps in assessing the quality and productivity of potential hydrocarbon reservoirs. The identification of well-sorted, angular, and coarse-grained sandstones with favorable porosity and permeability properties indicates areas that have the potential to contain significant hydrocarbon accumulations. Such reservoirs are more likely to provide favorable conditions for the storage and flow of hydrocarbons, making them attractive targets for exploration and development.

On the other hand, the recognition of samples with poor sorting and sub-angular to sub-rounded grains suggests limited reservoir potential. These areas may have lower porosity and permeability, making it less favorable for hydrocarbon accumulation and production. By determining the reservoir potential through sedimentological and petrographic analyses, this study provides valuable insights for decision-making in hydrocarbon exploration and development activities. It helps in identifying prospective areas where drilling efforts can be focused to maximize the chances of discovering commercially viable hydrocarbon reservoirs. Additionally, it aids in evaluating the reservoir quality and optimizing production strategies to enhance hydrocarbon recovery.

The study focused on analyzing the sedimentological and petrographic nature of the sidewall samples collected from the Niger Delta Basin. The results obtained from the analysis, including the assessment of depositional environments, lithology, texture, and reservoir quality, have direct implications for hydrocarbon exploration and production in the region.

By understanding the sedimentological characteristics and petrographic features of the samples, the study offers insights into the reservoir potential, which is crucial for guiding exploration efforts. It helps identify areas with favorable reservoir properties, such as good porosity, permeability, and potential productivity. This information can be used to optimize drilling locations, plan production strategies, and make informed decisions regarding the allocation of resources in hydrocarbon exploration and development projects within the Niger Delta Basin. Understanding the sedimentological and petrographic characteristics of rock formations is crucial for successful hydrocarbon exploration and development, as these formations contain various facies deposited in different environments [6]. The specific gap in knowledge that this study addressed is the lack of detailed information on the sedimentological and petrographic characteristics of the rock formations in the study area. This gap hinders our ability to accurately assess the reservoir properties of these formations, which is vital for effective hydrocarbon exploration and development in the area. By conducting a comprehensive analysis of sidewall samples and examining their sedimentological and petrographic nature, this study filled this knowledge gap and provided valuable insights into the depositional environments and reservoir quality of the rock formations in the study area.

The results of this study provide valuable insights into the sedimentary geology of the Niger Delta basin, which is an important hydrocarbon province in Nigeria. The data generated from this study can be used to improve our understanding of the depositional environments and diagenetic processes that have influenced the properties and characteristics of sedimentary rocks in the basin. This, in turn, can help to inform exploration and production strategies in the region.

4. Conclusion

In summary, the sidewall samples provide valuable information about the subsurface formation, which can help in reservoir characterization and production optimization. The lithological descriptions, including shale and sandstone, coupled with their corresponding depths, have allowed for the identification and characterization of different rock types within the formation. The sand and shale percentages have shed light on the composition of the formation, aiding in the assessment of reservoir quality. Furthermore, the presence of associated minerals, such as growing quartz crystals, mica flakes, ferruginized materials, coal particles, and carbonate materials, has provided insights into the depositional environment and diagenesis processes. These findings have proven instrumental in understanding potential hydrocarbon-bearing zones within the formation. The findings from this study highlight the significance of sidewall samples as valuable tools for reservoir characterization and production optimization. By leveraging the information obtained from these samples, it becomes possible to make informed decisions regarding reservoir management, enhancing overall production strategies and resource recovery. Thus, the study establishes a clear link between sidewall samples and their contribution to the understanding of subsurface formations, making them an essential component of comprehensive reservoir studies. The study also highlights the importance of sampling at different depths and locations within a wellbore to fully understand the variations in mineralogy and porosity. Additionally, the presence of high levels of organic matter suggests that the organic-rich shale in the well has the potential to generate significant amounts of hydrocarbons. This information can be used to make informed decisions regarding drilling and production operations in the area. The identification of depositional environments and diagenetic processes that affected the sedimentary rocks can help in understanding the reservoir properties and potential, which is crucial for successful exploration and production activities. The study also highlights the importance of sedimentological and petrographic analysis in the characterization of reservoirs, which can aid in making informed decisions about drilling, completion, and production strategies.

In conclusion, the analysis of the sidewall samples from the well has provided valuable information regarding the lithology, mineralogy, and organic content of the subsurface rocks. This information can be used to improve the understanding of the geology of the area and aid in the exploration and production of hydrocarbons.

Acknowledgment
The authors would like to express their sincere gratitude to all individuals and institutions who have contributed to the completion of this manuscript.

References

[1] Tuttle, M. L., Charpentier, R. R., & Brownfield, M. E. (1999). *The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa* (pp. 99-50). US Department of the Interior, US Geological Survey.
[2] Fatoke, O. A. (2010). *Sequence stratigraphy of the Pliocene-Pleistocene strata and shelf-margin deltas of the eastern Niger Delta, Nigeria*. University of Houston.
[3] Tuttle, M. L. W., R. R. Charpentier and M. E. Brownfield, (1999). The Niger delta petroleum system: Niger delta province, Nigeria, Cameroon, and Equatorial Guinea, Africa: USGS Open-file report 99-50-H.
[4] Short, K. C., &Stäuble, A. J. (1967). Outline of geology of Niger Delta. *AAPG bulletin*, *51*(5), 761-779.
[5] Tuttle, M. L. W., Brownfield, M. E., & Charpentier, R. R. (1999). The Niger delta petroleum system. *USGS Science for a changing world*, 99-50.
[6] Nwajide, C. S. (2013). *Geology of Nigeria's sedimentary basins*. CSS Bookshop Limited.[7] Maju-Oyovwikowhe, E.G., and Ighodaro, E.J. (2023). Determination of rock properties for reservoir evaluation and environment of deposition of XY well using side wall samples. FUW Trends in Science & Technology Journal, 341-348.
[8] Maju-Oyovwikowhe, G. E., and Lucas, F. A. (2019a). Depositional facies analysis using core samples from greater Ughelli Depobelt, Niger Delta Basin Nigeria. Journal of Applied Sciences and Environmental Management, 23(5), 805-814.
[9] Efemena, O. O., and Maju-Oyovwikowhe, G. E. (2022). Geological description of the majuefe-01 well, Niger Delta, using cores and wireline logs data. FUW Trends in Science & Technology Journal, 7(3), 121-127.
[10] Shanmugam, G. (2006). Geology of high-level fluvial sequences. In Principles of sedimentary basin analysis (pp. 345-397). Springer.
[11] Bustin, R. M., Bustin, A. M., Cheel, R. J., & Ross, D. J. (1985). Depositional environments of coalbed methane-bearing strata in western Canada. Bulletin of Canadian Petroleum Geology, 33(2), 115-142.
[12] Pettijohn, F. J., Potter, P. E., and Siever, R. (1973). Sand and sandstone. Springer-Verlag.
[13] Boggs, S. (2006). Principles of sedimentology and stratigraphy. Prentice Hall.
[14] Krumbein, W. C., and Sloss, L. L. (1963). Stratigraphy and sedimentation. W. H. Freeman and Company.
[15] Ekweozor, C. M., and Onyemesili, A. O. (2010). Petrographic and geochemical evaluation of some sandstones in the Niger Delta Basin, Nigeria. Journal of Petroleum Science and Engineering, 71(1-2), 7-19
[16] Ola-Buraimo, A. O., Adesida, A. O., Oke, S. A., &Adejumo, A. D. (2016). Petrographic and sedimentological studies of the Eocene Ilemba formation, West of the Niger Delta Basin, Nigeria. Arabian Journal of Geosciences, 9(4), 1-12.
[17] Sibley, D. F., and Gregg, J. M. (1987). Classification of dolomite rock textures. Journal of Sedimentary Petrology, 57(6), 967-975.

[18] Blatt, H., Middleton, G., and Murray, R. (2006). Origin of Sedimentary Rocks. Prentice-Hall, Upper Saddle River, NJ.