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Geology of Owelle, South Eastern Nigeria

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Abstract
This study examines the geology of Owelle and its environs in Awgu Local Government Area, Enugu State, situated within the Lower Benue Trough of southeastern Nigeria. Integrated methods, including field mapping, sedimentological and petrographic analyses, grain-size statistics, and hydrogeochemical assessment, were applied to characterize lithology, depositional environments, water quality, and resource potential. The Owelli Sandstone and Nkporo Shale are the dominant formations. Sandstone units are medium- to coarse-grained quartz arenites, ferruginized in places, with cross-bedding and bioturbation indicative of fluvio-deltaic to shallow marine depositional settings. Statistical analysis of grain-size distributions supports a transition from beach to shallow marine environments with fluvial influence. Hydrogeological results show that the Owelli Sandstone provides a productive aquifer, though water quality is slightly acidic with elevated iron content, necessitating treatment before use. Engineering tests revealed variable soil plasticity, influencing construction suitability. Economically, sandstone, clay, laterite, and ironstone deposits present opportunities for industrial and construction applications. However, environmental hazards such as erosion, deforestation, and pollution, primarily driven by anthropogenic activities, threaten sustainable exploitation. This work enhances understanding of the stratigraphy and depositional framework of the Anambra Basin and underscores both the resource potential and environmental challenges of the study area.

Keywords: Owelle, Owelli Sandstone, Nkporo Shale, Depositional Environment, Hydrogeology, Anambra Basin, Resource Potential, Environmental Geology

1. Introduction

Owelle and its environs, located in Awgu Local Government Area of Enugu State, southeastern Nigeria, lie within the Lower Benue Trough between longitudes 7°25′–7°30′E and latitudes 6°10′–6°15′N, covering an estimated 45 km². The area is significant geologically as it exposes the Owelli Sandstone and Nkporo Shale, two major lithostratigraphic units of the Anambra Basin. These formations are important for understanding sedimentological evolution, hydrogeological potential, geotechnical properties, and economic resources in southeastern Nigeria.The Lower Benue Trough developed during the Cretaceous opening of the South Atlantic, with tectonic phases controlling sedimentation patterns (Murat, 1972; Burke, 1976). The Owelli Sandstone, a coarse-grained deltaic facies deposited during the Campanian, is laterally equivalent to the Nkporo Shale (Reyment, 1965) [12]. Despite extensive regional work, localized studies are required to unravel depositional environments, aquifer characteristics, and resource implications.This study aims to (i) carry out detailed geological mapping of the study area, (ii) interpret depositional environments from sedimentological and statistical analyses, (iii) assess water quality and aquifer potential, (iv) evaluate soil properties for engineering purposes, and (v) identify economic resources and environmental challenges.

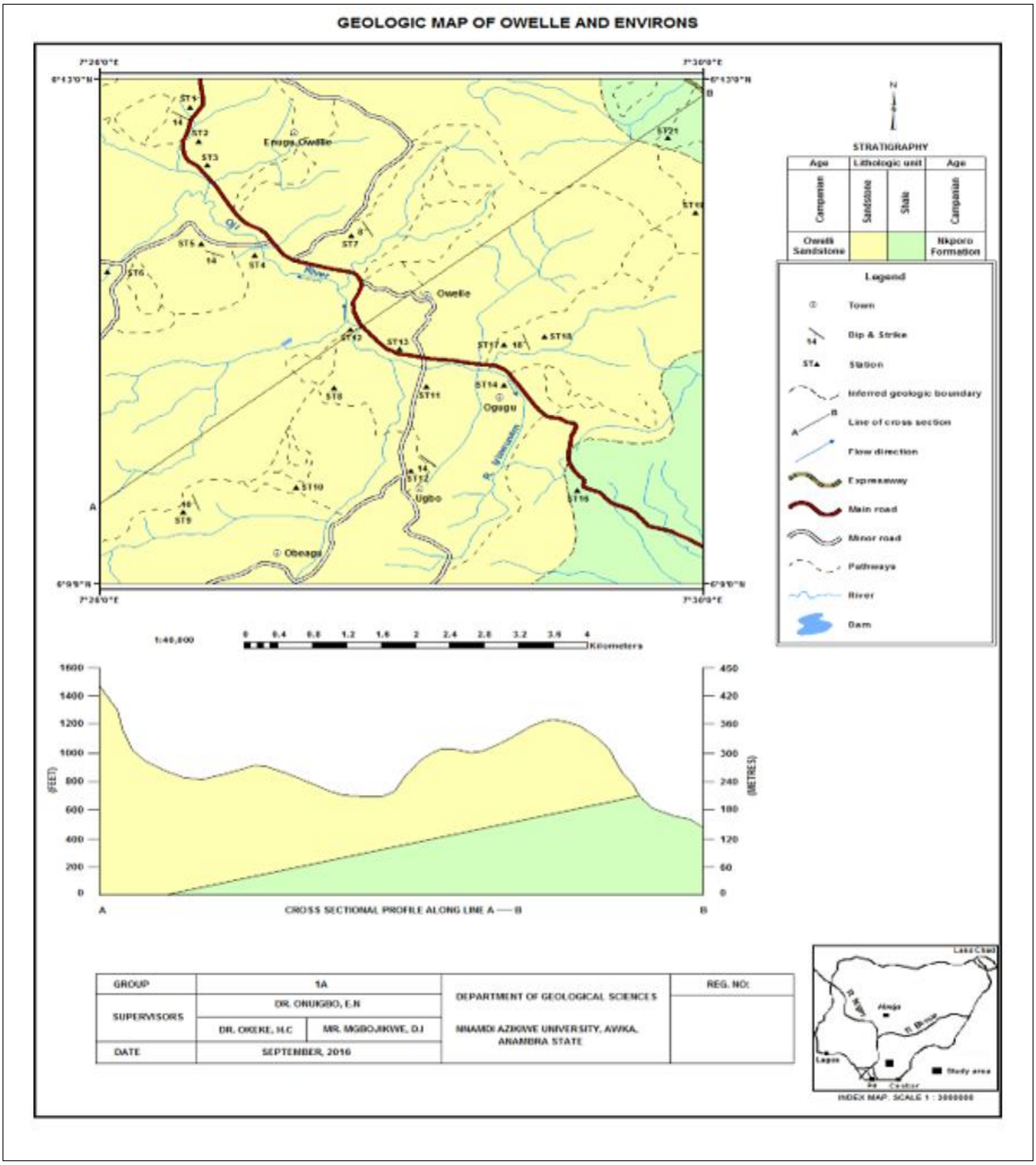


Fig 1.1: Geologic map of study area

2. Materials and Methods

2.1 Fieldwork

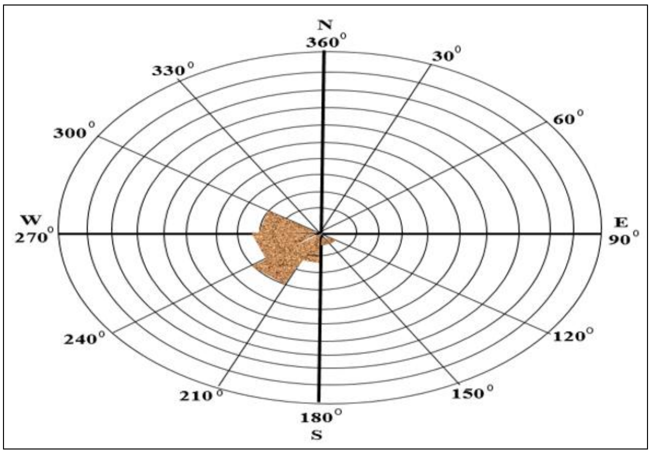
Field mapping was conducted with the aid of topographic maps, GPS, compass clinometer, geological hammer, and measuring tape. Outcrops were logged, lithologies described, and rock, soil, and water samples collected. Structural features such as dip, strike, joints, and sedimentary structures were measured.

2.2 Laboratory Analyses

- **Sedimentological analysis:** Sieve analysis was performed to determine grain-size distribution. Parameters such as mean, median, sorting, skewness, and kurtosis were calculated using Folk and Ward (1957).
- **Soil plasticity:** Atterberg limits (liquid limit, plastic limit, and plasticity index) were determined to assess engineering suitability.
- **Water quality:** Borehole and river samples were analyzed for pH, chloride, phosphate, nitrate, heavy metals, hardness, and other key parameters, following APHA (1998) standards.

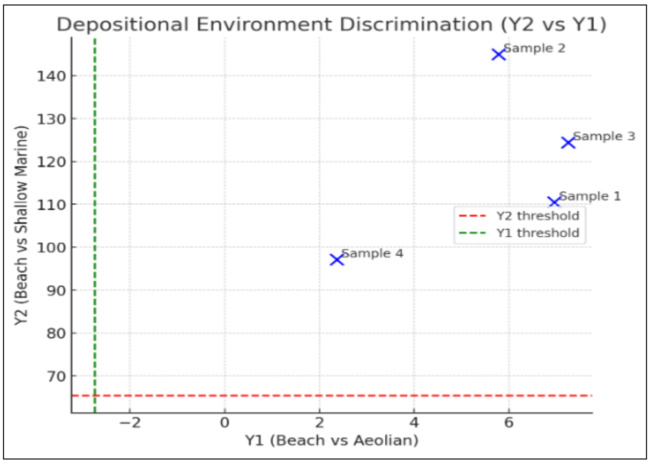
2.3 Statistical and Environmental Interpretation

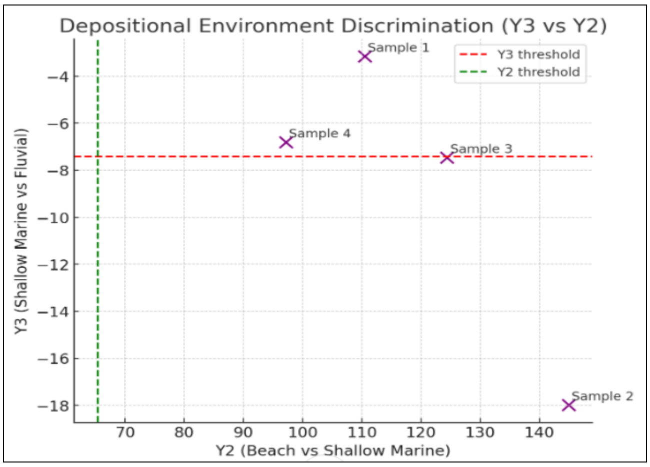
Depositional environments were inferred using multivariate discriminant functions (Sahu, 1964) [13] and paleocurrent analyses based on cross-bedding orientations. Rose diagrams were constructed to determine paleoflow trends.



Rose diagram showing the Paleocurrent of the Study Area

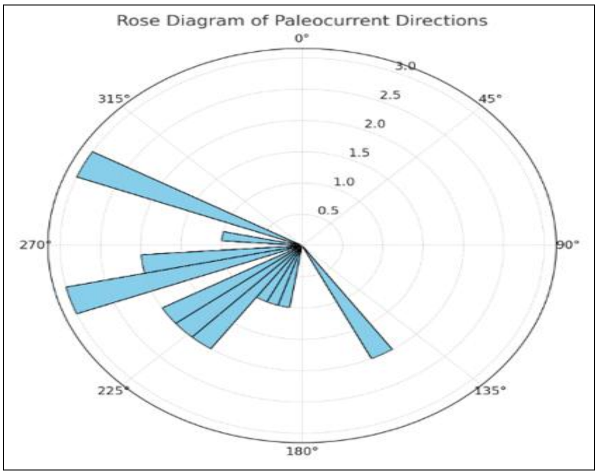
From the rose diagram above, it shows that sediments are sourcing from the northeast direction, which is the provenance, and the paleocurrent flow is towards the southwest direction. This means that the sediments could have been gotten from the nearby Oban and Cameroun Massifs, which were under a humid setting during the Turonian times.





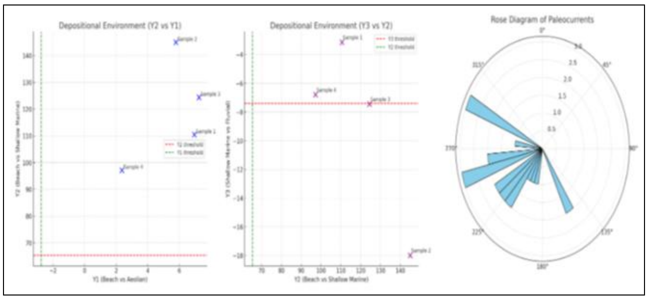
The **statistical discrimination charts** for the depositional environment

- **Y2 vs Y1 plot:** All samples fall in the **beach to shallow agitated marine field**.
- **Y3 vs Y2 plot:** The samples show a mix of **fluvial/deltaic and shallow marine influence**, confirming a **fluvio-deltaic to shallow marine depositional environment**.



Rose diagram of paleocurrents from your cross-bedding data.

It shows a dominant **southwest-directed paleoflow**, indicating that sediments were likely sourced from the **northeast (Oban and Cameroon Massifs)** and deposited towards the Anambra Basin.



3. Results

3.1 Lithographically and Outcrop Description

Two major formations were identified:
the Owelli Sandstone and Nkporo Shale. The Owelli Sandstone is medium- to coarse-grained, ferruginized quartz arenite with cross-bedding, pebbly layers, and bioturbation (Ophiomorpha, Skolithos, Arenicolites).
Nkporo Shale consists of dark grey, fissile shales with interbedded sandstones. Outcrops displayed coarsening- and fining-upward sequences, ironstone capping, and evidence of high-energy depositional processes.

Result of Multivariate and Bivariate Calculations

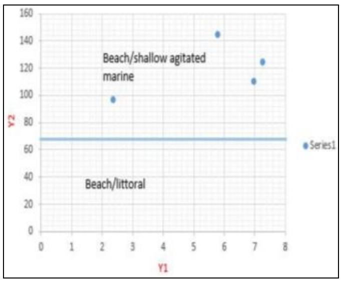
Table 3.2: Results of Y1, Y2, Y3 for samples 1 – 4

Sample	Y_1	Y_2	Y_3
1	6.9564	110.5093	-3.1524
2	5.7830	144.9717	-17.9806
3	7.2542	124.4147	-7.4489
4	2.361	97.1653	-6.7999

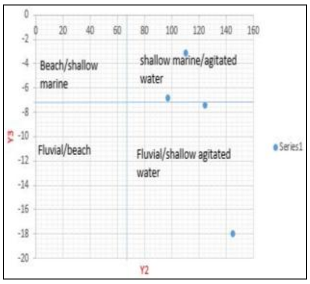
Table 3.3: Depositional environments of samples 1 – 4

S. No	Y_1	Environment of deposition	Y_2	Environment of deposition	Y_3	Environment of deposition
1	6.9654	Beach	110.5093	Shallow agitated marine	-3.1524	Fluvial deposit
2	5.7830	Beach	144.9717	Shallow agitated marine	-17.9806	Shallow marine
3	7.2542	Beach	124.4147	Shallow agitated marine	-7.4489	Shallow marine
4	2.3610	Beach	97.1653	Shallow agitated marine	-6.7999	Fluvial deposit

Bivariate Scatter Plots of Discriminate Functions



Bivariate plot of Y2 against Y1



Bivariate plot of Y3 against Y2

To further validate the results in tables 3.2 and 3.3, bivariate scatter plots of Y2 against Y1 and Y3 against Y2 was made.

It was observed that most of these plots fell within the shallow agitated marine environment which proves the validity of the calculation above (Table 3.2) that the environment is a fluvial influenced shallow marine environment.

3.2 Sedimentological Analysis

Grain-size statistics indicate medium to coarse sands, moderately to poorly sorted, with skewness ranging from negatively to positively skewed. Kurtosis values range from platykurtic to leptokurtic. Discriminant function results suggest deposition in beach, shallow marine, and fluvial-influenced environments. Paleocurrent analysis shows southwestward transport, likely sourced from the Oban and Cameroon Massifs.

Table 3.1: Grain-size parameters and discriminant function results for Owelle samples

Sample	Mean (ϕ)	Sorting (σϕ)	Skewness (Skϕ)	Kurtosis (Kϕ)	Y1	Y2	Y3	Inferred Environment
Sample 1	1.84	0.95	-0.12	0.88	6.9564	110.5093	-3.1524	Beach / Fluvial
Sample 2	1.69	0.87	0.08	1.11	5.7830	144.9717	-17.9806	Beach / Shallow Marine
Sample 3	1.64	0.94	0.05	0.95	7.2542	124.4147	-7.4489	Beach / Shallow Marine
Sample 4	1.83	1.12	-0.22	0.79	2.3610	97.1653	-6.7999	Beach / Fluvial

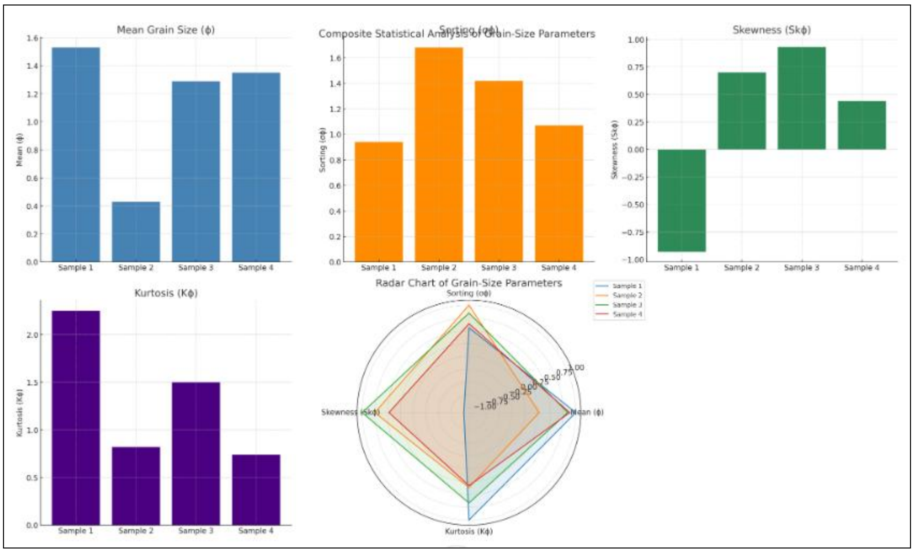
3.3 Hydrogeology and Water Quality

The Owelli Sandstone is porous and permeable, forming an important aquifer. Water samples revealed slightly acidic pH (5.2–6.2) and elevated iron content exceeding WHO standards in some cases, although most other chemical parameters were within acceptable limits.

Table 3.2: Statistical parameters calculated from sieve analysis

Sample No	Mean	Remarks	Sorting	Remarks	Skewness	Remarks	Kurtosis	Remarks
1	1.53	Medium sand	0.94	Moderately sorted	-0.93	Negatively skewed	2.25	Leptokurtic
2	0.43	Coarse sand	1.68	Poorlys orted	0.70	Very positively skewed	0.82	Platykurtic
3	1.29	Medium sand	1.42	Poorly sorted	0.93	Very positively skewed	1.50	Mesokurtic
4	1.35	Medium sand	1.07	Poorly sorted	0.44	Very positively skewed	0.74	Platykurtic

Skewness, kurtosis, standard deviation, mean were calculated to ascertain the physical characteristics of sediments, provenance studies and their environment of deposition. The result of the calculation suggests that the sediments are moderately to poorly sorted, medium to coarse grained, platykurtic to very leptokurtic, negatively to very positively skewed.



Composite figure: Top row: **Mean Grain Size, Sorting, Skewness**
Bottom row: **Kurtosis** and **Radar Chart (integrating all parameters)**

This figure clearly highlights textural differences across the four samples and supports interpretation of a fluvial-deltaic **to shallow marine environment with variable energy conditions**.

3.4 Engineering Geology

Atterberg limit results show variability in soil plasticity. Some samples were non-plastic and suitable for foundation works, while others showed medium plasticity, making them less suitable for engineering construction due to shrink-swell potential.

3.5 Economic Geology

Economically valuable deposits include:
Sandstone: Suitable for construction and as raw material for glass and aggregates**.**
Clay and shale: Suitable for bricks, ceramics, and kaolin for paint production.
Ironstone: Pisolitic and oolitic ironstones, potential raw materials for iron.
Laterite: Abundant, suitable for road construction and aggregates.

3.6 Environmental Concerns

Environmental hazards include erosion, gully development, deforestation, and pollution. These are exacerbated by heavy rainfall, anthropogenic activities such as quarrying, bush burning, poor farming practices, and deforestation.

4. Discussion

Results demonstrate that Owelle and its environs record a complex depositional history reflecting transitions from fluvial-deltaic to shallow marine conditions during the Late Cretaceous. Sedimentological parameters confirm high-energy depositional settings consistent with regional interpretations of the Anambra Basin. Hydrogeological findings show the Owelli Sandstone provides reliable groundwater resources but requires treatment due to acidity and iron enrichment. Geotechnical results reveal variable soil properties with implications for construction. Economically, the abundance of sandstone, clay, laterite, and ironstone offers significant industrial potential. However, uncontrolled exploitation and environmental degradation threaten sustainability.

5. Conclusion

The geology of Owelle and its environs is dominated by the Owelli Sandstone and Nkporo Shale, deposited in environments ranging from fluvial-deltaic to shallow marine. The area hosts valuable resources including sandstone, clay, laterite, and ironstone, and the Owelli Sandstone serves as an important aquifer. Nonetheless, water quality issues, soil plasticity limitations, and environmental hazards present challenges for sustainable development. The study underscores the importance of integrated geological, hydrogeological, and environmental assessments in resource management within the Anambra Basin.

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