(RESEARCH ARTICLE)

Foraminiferal study and Depositional Environment of an outcropping unit of Awgu Formation, South Eastern Nigeria

Geoffrey Chijioke Soronnadi-Ononiwu [1], Innocent Sunday Didei [2] and Fortune Ijeoma Chiazor [1, *]

[1] Department of Geology, Faculty of Science, University of Port Harcourt, Choba, Port Harcourt., Nigeria.
[2] Department of Geology, Faculty of science Niger Delta University, Wilberforce Island, Yenagoa, Nigeria.

Abstract

Foraminifera analysis were carried out for the purpose of evaluating the microfauna present in outcropping units of the Awgu Formation in South Eastern Nigeria. In the course of the research, secondary sources of data in form of past literature on the study area and its microfaunal assemblages, were reviewed. The methodology applied in the study involved microscopic assessment of the microfossil groups present in samples which were collected from the outcrops. These samples were taken on the field, and served as representative specimens of the three main outcropping units that were visited. The preparation of the samples involved procedures of maceration and mounting on microscopic slides. On analysis, it was revealed that forms such as *Textularia*, *Ammobaculites*, and *Haplophragmoides* are present in the Awgu Formation. These were utilized in the prediction of paleoenvironmental conditions and age of the formation and it was deduced that the sediments were deposited in a range of shallow marine environments, in the Early to Mid-Cretaceous Period. Through field studies, lithostratigraphic description was also derived for the outcrops, which are dominated by shaley materials and other clastic sediments.

Keywords: Microfaunal; Outcrops; Deposition; Awgu Formation; Paleoenvironment

1. Introduction

The stratigraphic nomenclature for South Eastern Nigeria was stated by Tattam (1944) to be composed of seven lithostratigraphic units namely, the Cross River and Benue Shale, the Awgu Sandstone and Shale, the Nkporo Shale, Lower Coal Measure, False-bedded Sandstone, the Upper Coal Measure, and the Imo Clay Shale. Simpson (1954) modified the Cross River and Benue Shale to the Asu River Series and the Ezeaku Shale, was renamed Ezeaku Group and dated Turonian, and the Awgu-Ndeaboh Shale became known as Awgu Group (including the Agbani Sandstone) and dated Coniacian.

The Awgu Formation constitutes one of the pre- Santonian unit in South Eastern Nigeria. It occupies a narrow strip between the Eastern flank of the cuesta between Enugu and Awgu and the gentle rolling land North of Ndeaboh (Hoque, 1977, Agumanu, 2011). It is a linear NE-SW trending sedimentary deposit composed of the Awgu Shale at the base and overlain by the Agbani Sandstone. The blue gray shale with some pyrite indicates a marine environment that occasionally attained anoxic level (Agumanu, 2011).

The post-Santonian Nkporo Group of the South Eastern Nigeria comprises the Nkporo Shale, the Owelli/Afikpo Sandstone and the Enugu Shale (Reyment, 1965, Obi *et al*, 2001, Onuigbo and Okoro 2014). The position and age of the Owelli Sandstone within the Nkporo Group has been a matter of controversy. Grove (1951), Simpson (1956) and Reyment (1956) previously referred this sand body as "Awgu Sandstone". Reyment (1956) described the Owelli sand

* Corresponding author: Chiazor FI

body as "the sedimentary rock intervening between the deformed Coniacian- Santonian Awgu Formation and the gently-dipping Campanian-Maastrichtian Enugu Shale in the Awgu area of Anambra Basin". Obi (2000) and Obi *et al* (2001) described as the Owelli Sandstone as intervening between the Nkporo Shale and the Enugu Shale. Akande *et al* 2011, Nwajide 2013, Onuigbo and Okoro 2014; described the sandstone as being laterally equivalent to the Nkporo Shale and Enugu Shale.

Reyment (1965) assigned Campanian- Maastrichtian age to the Owelli Sandstone and this was widely adopted until recently when mix-ups in the age showed up. Obi (2000), Obi *et al* (2001) and Nwajide (2013) proposed Campanian age for the sand body.

The main focus of this work is to provide a detailed geological mapping of the Obeagu Awgu and its Environs accompanied by granulometric analysis and paleocurrent analysis to interpret the depositional environment within the area

1.1. Location and Accessibility of the Study Area

The study area is located in the Southern Benue Trough, South Eastern Nigeria. It lies between longitudes 7°51' E to 7°53' E and latitudes 5°2' N to 5°22' N and readily accessible by the network of roads (Figure i).
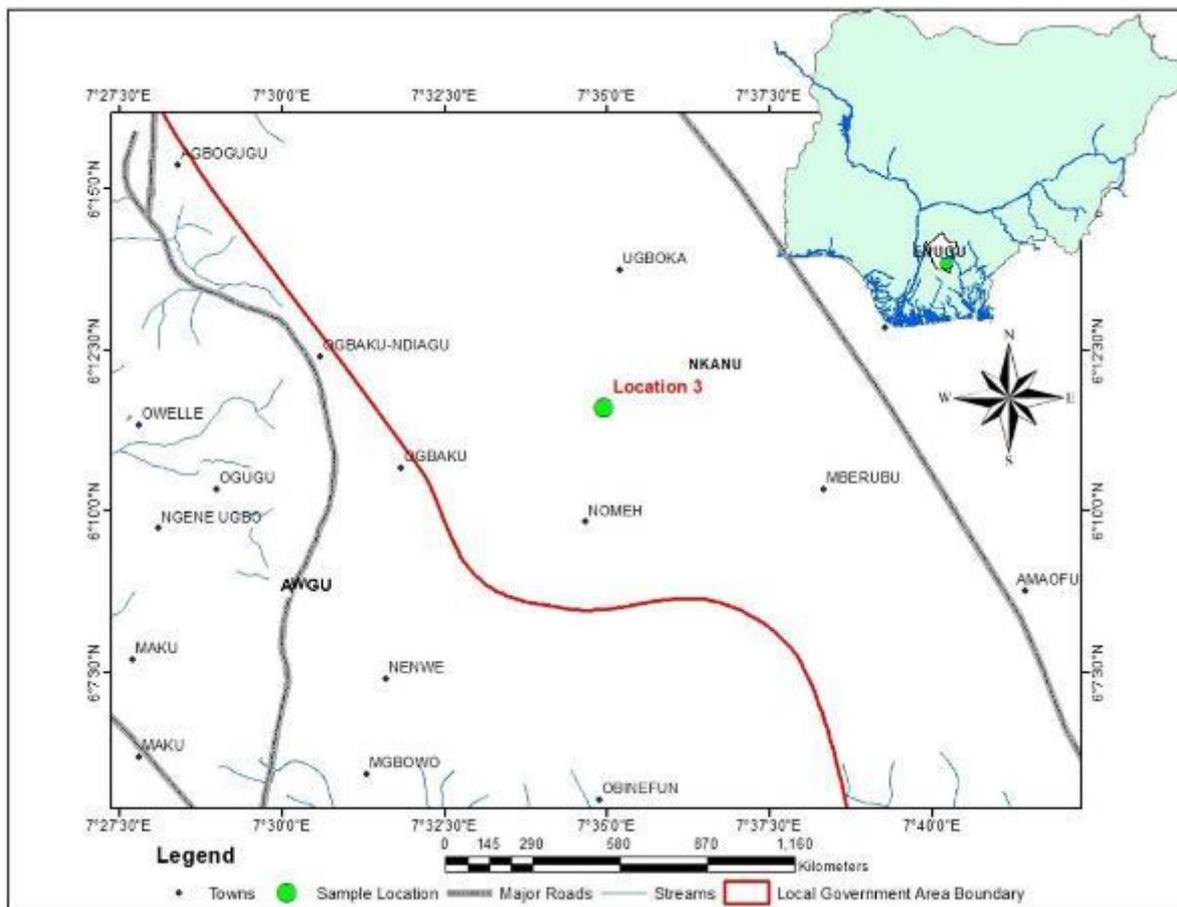
Figure 1 Map of study area showing points of sample collection and outcrop study

2. Materials and methods

2.1. Field mapping

The field mapping exercise was carried out by locating and describing exposed outcrops of the Agwu formation in the study area (Figure 1). Transverses were made along various localities in the area. Three outcrops of the Agwu formation were studied using descriptive and lithological characteristics of the rocks. The sedimentary attributes studied include lithology, texture, sedimentary structures and contact types. The lithofacies were recognized based on these attributes.

Thirteen representative samples were collected for sieve analysis. Preparation of Samples Fresh portions of each sample was taken at least log and was crushed into pieces in a mortar and was later transferred into a pan, mix and soared with water and treated with 2 gram of sodium chloride salt and was left to boil for 30 minutes on hot plate at about 250°C. All this is done in order to disintegrate the clay and, shale particles and free the fossils from the matrix.

2.2. Paleotological and Sedimentological analysis

Five sandstone samples were collected from various locations, samples were disaggregated in the laboratory with a rubber padded pestle as suggested by PettiJohn, (1975). 100g of each disaggregated sample was measured using a weighing balance as test portions for sieve analysis. The test portions were sieved with a Rotag electrical automatic shaker for 15 minutes using a set of sieves with mesh size 0.5 phi apart. Cumulative curves of the grain size distribution were plotted from the sieve result. The univariate, and bivariate parameters were computed based on Folk and Ward (1957), Miola and Weiser (1977), and Sahu (1964).

2.3. Wet Seiving/Washing

The boiled solution from each plate is discounted into a stack of sieve meshes arranged in decreasing order 250μm, 100um and 75μm. The coarsest is placed at the top while the finest is, at the bottom. The disintegrate sample are then allowed to pass through the sieves using a shower of water. The washing continues until clear water is observed on each of the sieves. Residues from each sieve size are collected in a filter paper tagged is label for each sample depth and allowed for some minutes for water to drip off before drying on the hot plate.

2.4. Drying Storage and Picking

The Filter paper containing the respective residual fractions of the sample is dried at temperature of 100°C on the hot plate. Excess heating is usually avoided to ensure that the sample does not pour out or get damaged. The three dried, fractions of the samples are then cooled and placed into an envelope marked with the necessary details. Analysis of the dried samples was done using a stereomicroscope. The dried samples from each pack; were gently spread on a picking tray that was placed under the stereomicroscope with a specific magnification. Fossils were picked using a single trimmed brush which was constantly moistened by dipping it in water. The fossils picked were placed in plastic mountain slides and sealed with cover slips so as to avoid contamination and loss of fossils. The slides were labeled according to various depths. This operation was carried out repeatedly in the same form for each sample for coarse medium and fine grains. Once the fossils are sorted or mounted, the slide are then labeled and arranged in horizontal type slide cabinet. The identified forms are sketched and the total number of each form is noted down which helps to know the ones that are abundant.

3. Results and discussions

3.1. Presentation of Data (tables, graph and figures)

The lithologic description of the relevant samples was based on the physical inspection of the sample worked on. Thirteen (13) samples was tested using hydrochloric acid, those that reacted with the acid and showed evidence of efflorescence/bubble were termed calcareous while those that did not react with the hydrochloric acid were classified as been not calcareous. All the samples used in the analysis were fine-grained as shown on Figures 2-4

3.2. Foraminifera Analysis Results

A total of thirteen (13) samples were prepared and analyzed for Foraminifera studies, and the result after picking is presented below in Figures 8-23, 5,6 and 7 in a distribution chart.
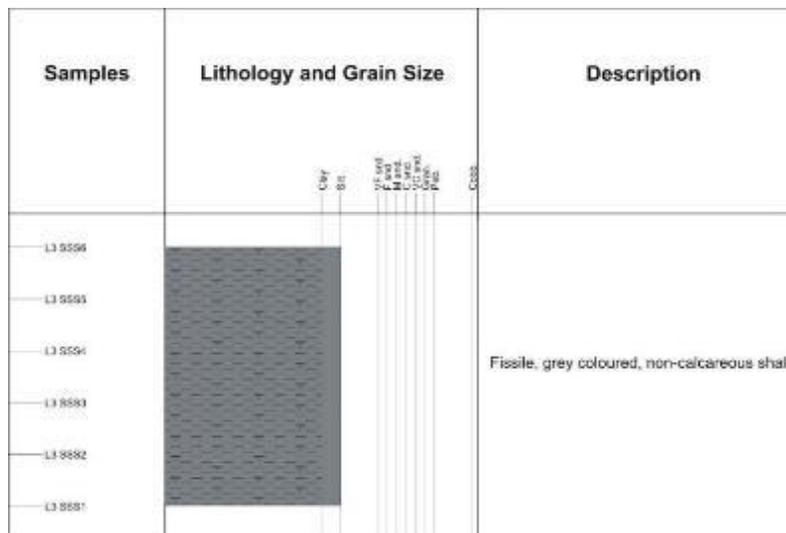
The percentage occurrence is also presented in the table below, with each table displaying the index fossil used for age dating (tables 1-7)
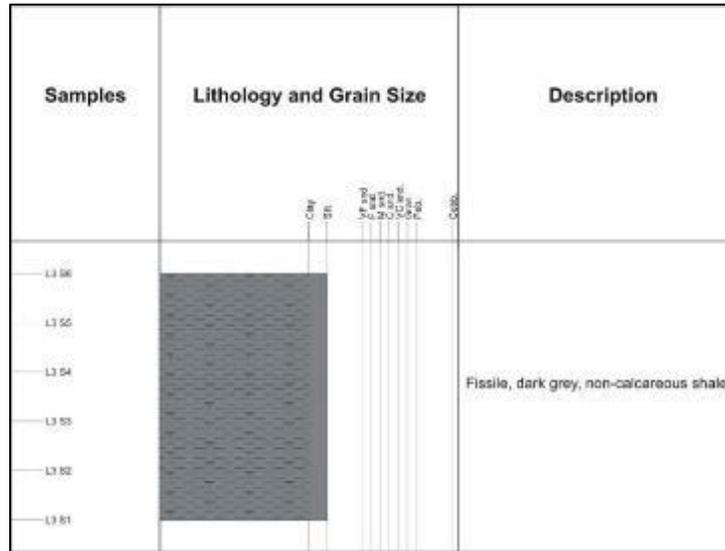
Figure 2 Graphic Log produced from the field L3S1 – L3S6, a section showing the lithology
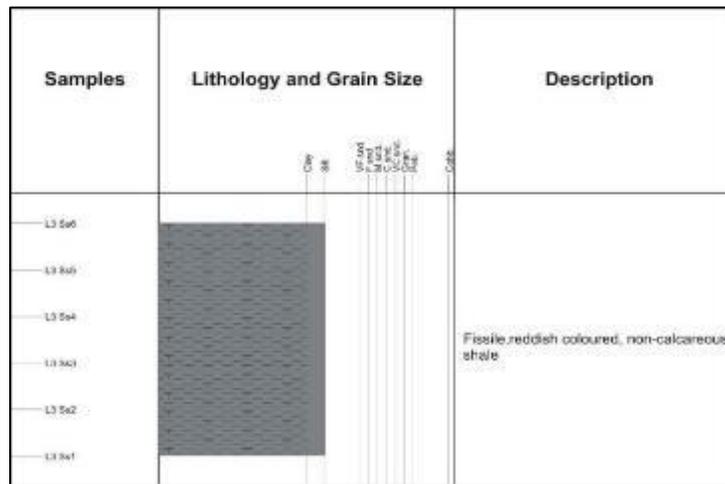
Figure 3 Graphic Log produced from the field L3SS1 – L3SS6, a section showing the lithology

Figure 4 Graphic Log produced from the field L3SSS1 – L3SSS6, a section showing the lithology
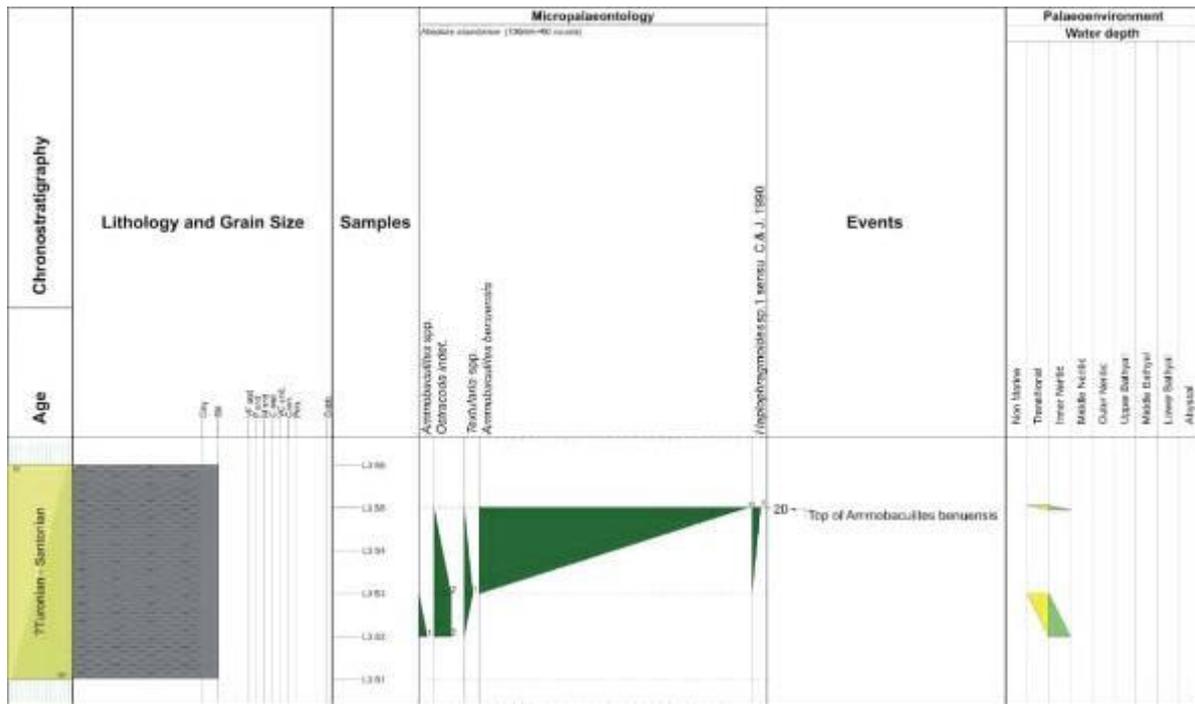
Figure 5 Distribution chat showing the foraminifera assemblages for L3S1 - L3S6
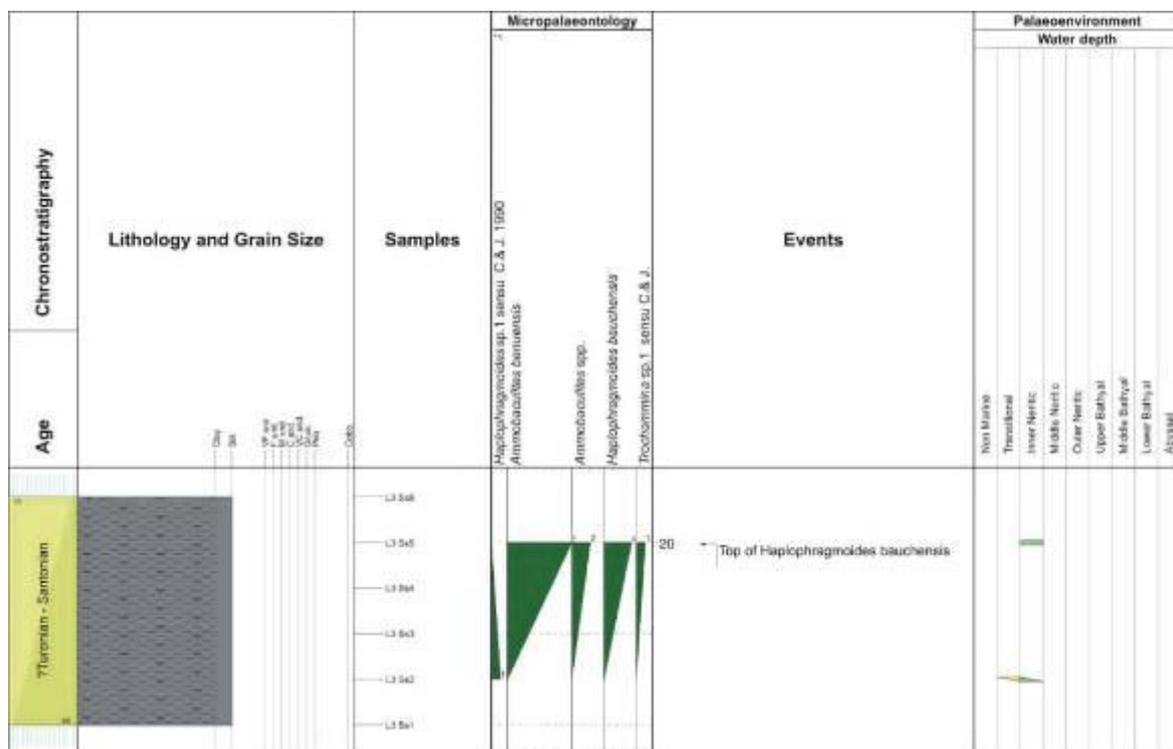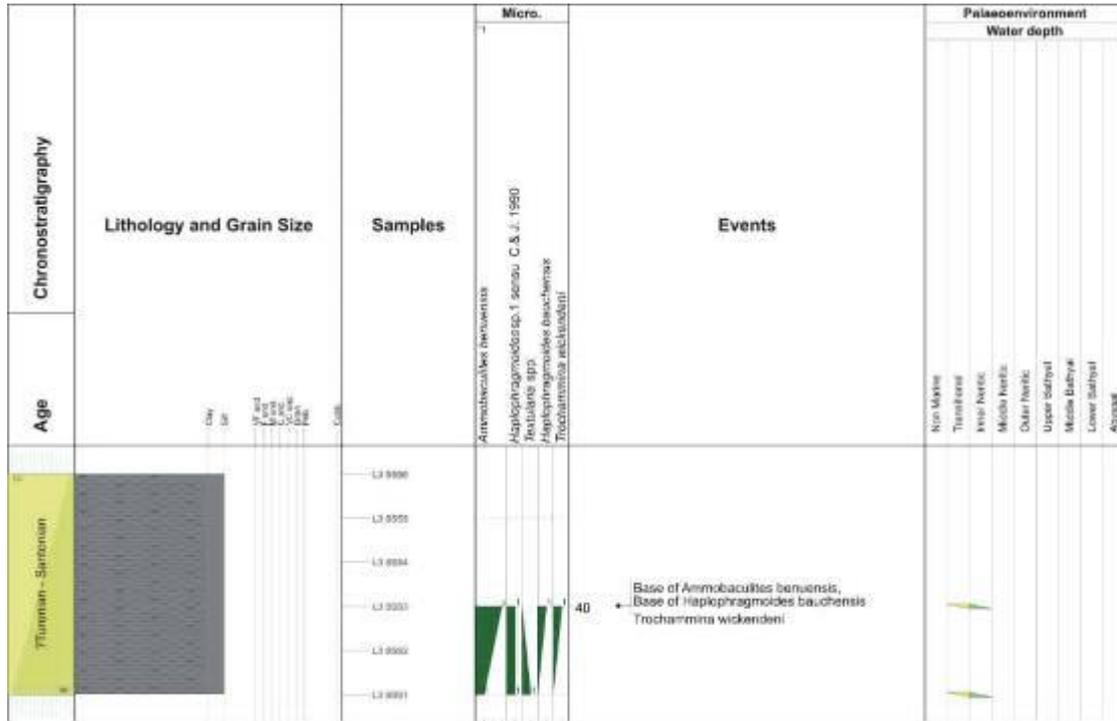

Figure 6 Distribution chat displaying the foraminifera assemblages for L3SS1 - L3SS6

Figure 7 Distribution chat showing the foraminifera assemblages for L3SSS1 - L3SSS6

Table 1 This shows the percentage occurrence displaying the index fossil in each table L3S2

S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Ammobaculites Sp*	1	33.3
2	*Ostracoda*	2	66.7

Age: Turonian- Santonian

Table 2 This shows the percentage occurrence displaying the index fossil in each table L3S3

S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Textularia* sp	1	33.3
2	*Ostracoda*	2	66.7

Age: Turonian- Santonian

Table 3 This shows the percentage occurrence displaying the index fossil in each table L3S5

S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Ammobaculites benuensis*	31	96.9
2	*Haplophragmoides sp*	1	3.1

Age: Turonian- Santonian

Table 4 This shows the percentage occurrence displaying the index fossil in each tableL3SS2

S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Haplophragmoides sp*	1	100.0

Age: Turonian- Santonian

Table 5 This shows the percentage occurrence displaying the index fossil in each table L3SS5

S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Trochammina sp*	1	7.7
2	*Ammobaculites sp*	2	15.4
3	*Ammobaculites benuensis*	7	53.8
4	*Haplophragmoides bauchensis*	3	23.1

Age: Turonian- Santonian

**Table 6** This shows the percentage occurrence displaying the index fossil in each table L3SSS1

S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Ammobaculites* benuuensis	1	33.3
2	*Haplophragmoides sp*	1	33.3
3	*Textularia sp*	1	33.3

Age: Turonian- Santonian

Table 7 This shows the percentage occurrence displaying the index fossil in each table L3SSS3

| S/No	Taxon Name	Count	Percentage of Occurrence (%)
1	*Haplophragmoides sp*	1	16.7
2	*Haplophragmoides bauchensis*	1	16.7
3	*Ammobaculites benuensis*	3	50.0
4	*Trochammina wickendeni*	1	16.7

Age: Turonian- Santonian
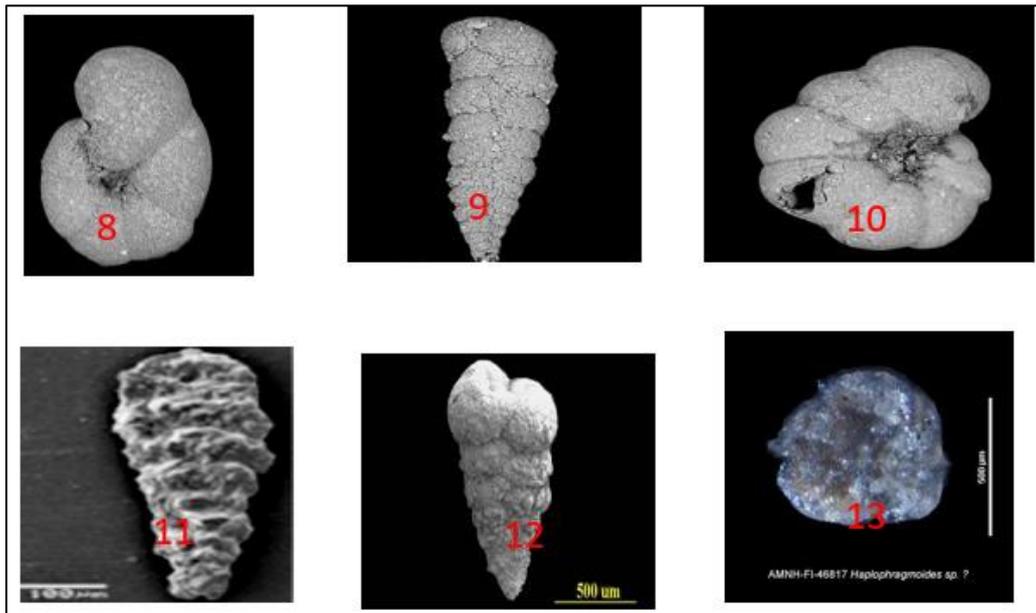
Figure 8 & 9 Foram *Trochammmmina wickendeni,* **Figure 10** Foram *Haplophragmoides bauchensis*

Figure 11 Foram *Ammobaculites benuenensis*

Figure 12 Foram Ostracods, **Figure 13** Foram Textularia sp ,
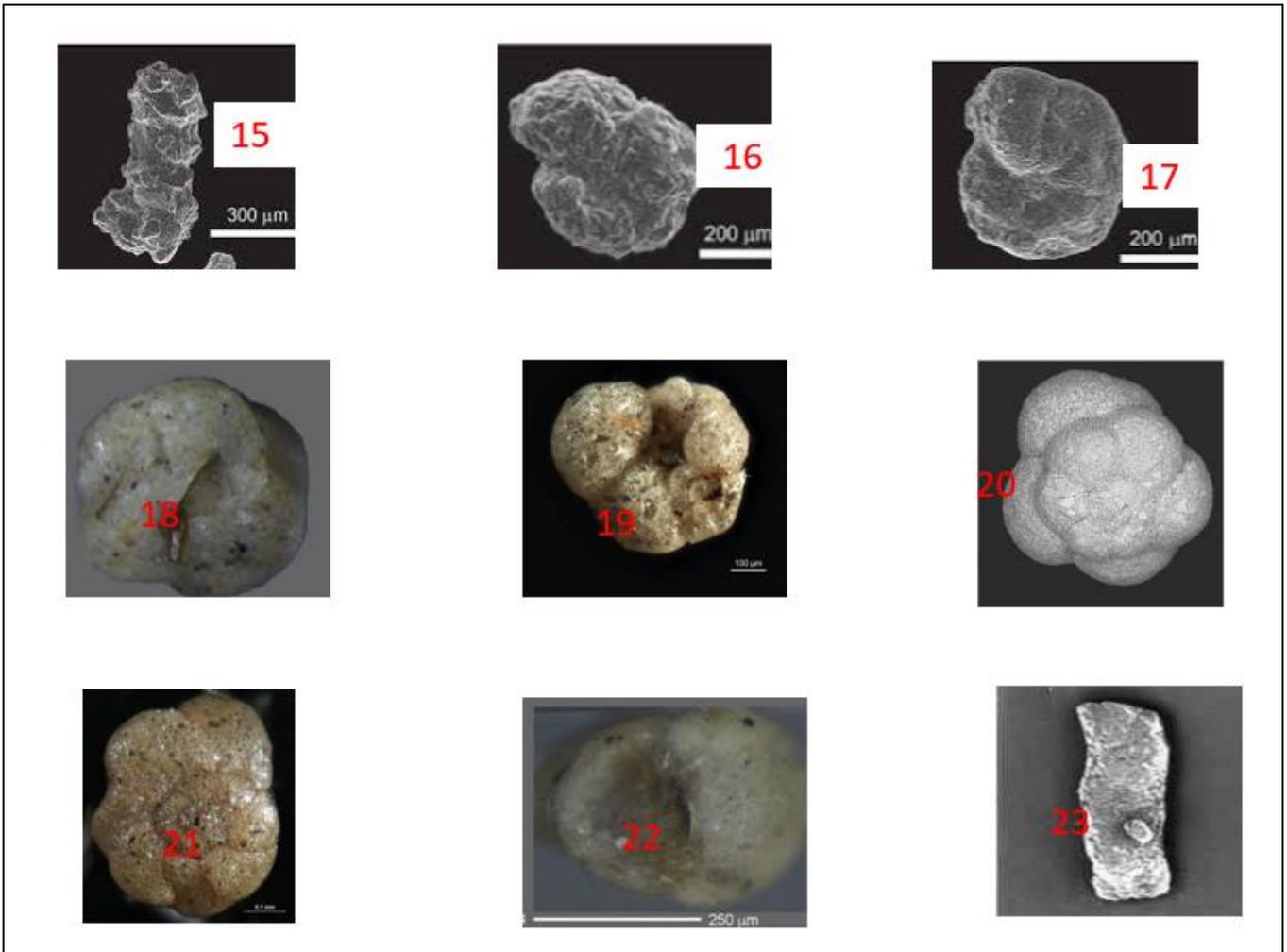
Figures 16 and 17 shows the foram *Ammobaculites sp* , **Figure 15 and 23** shows the foram *Textularia s* **Figure 18,19 ,20,21 and 22** shows the foram *Trochammina Globigeriniformis*

3.3. Paleoenvironment

Paleoenvironmental interpretations were carried out based on the fairly abundance and diversity of the microfauna encountered and the presence of environmentally significant fauna. These sediments were deposited within a Non-marine to Inner Neritic paleo-water depths. Based on these, the following deductions were made:

Table 8 This shows the percentage occurrence displaying the index fossil in each table

Sample/Range	Paleoenvironment
L3 S1	Barren
L3 S2	Shallow-Inner Neritic
L3 S3	Shallow-Inner Neritic
L3 S4	Barren
L3 S5	Shallow -Inner Neritic
L3 S6	Barren
L3 SS2	Shallow-Inner Neritic
L3 SS3	Barren

L3 SS4	Barren
L3 SS5	Inner Neritic
L3 SSS1	Shallow – Inner Neritic
L3 SSS2	Barren
L3 SSS3	Shallow inner – Inner Neritic

3.4. Age Determination

The studied outcrops of the Awgu Formation have been dated Turonian- Santonian age based on the occurrence of the predominant Arenaceous benthics; however, these samples were devoid of planktics counterparts. Age interpretation was therefore based on the arenaceous assemblage encountered within the analyzed samples. The analyzed key fauna are *Ammobaculites benuenensis, Haplophragmoides bauchensis* and *Trochammmmina wickendeni.*

The most abundant foram recovered with the highest frequency of occurrence at almost all the sample range is *Ammobaculites benuenensis.*

4. Discussion

The samples after analysis showed that L3S1 sample was barren, L3S2 has 33.3% of *Ammobaculites Sp* and 66.7% of Ostracods. Ostracods are usually indicators of shallow marine environment. Its occurrence with *Ammobaculites* which is a benthic affirms to that.

66.7% of Ostracoda again appears in L3S3, alongside 33.3% of *Textularia*, implying a similar Shallow to Inner Neritic environment for the sediments. The same inference was made for section L3S5, owing to the dominance of *Amobaculites Benunesis* with 96.9% in the section.

Sections L3SS5, L3SSS1, and L3SSS3 of outcrops 2 and 3 exhibit the same species found in L3S2, L3S3 and L3S5 of outcrop 1, asides the occurrence of *Trochammina Wickenendi* (16.7%) in section L3SSS3 (Outcrop 3). Therefore, the same prediction was given to these outcrop sections, which suggests that they were deposited in the Nertitic marine zone.

The dominance of fauna such as *Ammobaculites, Trochammina*, *Ostracoda* and *Haplophragmoides* in the outcrops indicate an age range of Turonian- Santonian, which is within the Cretaceous. This is in alignment with predictions by other authors concerning the Agwu Formation.

4.1. Summary

The Foraminieral study was carried out on 13 samples with the aim of determining the age of the formation in the study section. The samples were described in the laboratory following the standard laboratory sample description method. The lithostratigraphy of the outcrops in the study was also characterized by the dominance of shales which had calcareous, ferruginized and dark grey characteristics. These observations also helped to predict the paleoenvironment and age of the outcrops. The samples were further prepared for Foraminimeral studies following the standard foraminiferal sample preparation and analysis. This was aimed at identifying and separating from the rock mass, the forams preserved within the rocks of the study outcrops. The Foraminieral analysis produced abundant arenaceous benthics taxa and the samples were devoid of planktics counterparts. The analyzed key fauna are *Ammobaculites benuenensis, Haplophragmoides bauchensis and Trochammmmina wickendeni.* The most abundant foram recovered with the highest frequency of occurrence at almost all the sample range is *Ammobaculites benuenensis.* The age interpretation was therefore based on the arenaceous assemblage encountered within the analyzed samples and this probably points to the Turonian- Santonian age.

5. Conclusion

The results of the sieve analysis show that the sediments are predominated by moderately sorted medium grained, negatively skewed and very leptokurtic sands which are deposited under a moderately to high energy with possible turbulent conditions. The depositing medium is water in a fluvial environment controlled hydraulically and possible continue reworking of the sediments by current and waves since the structure found within the study include cross

beds, wave and current ripples The study has shown that the Awgu Formation is dominated by foraminiferal species which range across a series of marine environments, and are restricted in their age to the Cretaceous Period which has helped identify the most notable of these microfauna, including *Haplophragmoides, Textulaira, Trochammina* and Ostracoda. The species thus identified, can be used for other geologic purposes, such as prediction of the degree of maturation of the Awgu Formation, and determination of hydrocarbon prospects.

Compliance with ethical standards

Disclosure of conflict of interest

The Authors declare that there is no conflict of interest.

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