Journal of Mining and Geology Vol. 58(1) 2022. pp. 53 - 61 0022-2763
© Nigerian Mining and Geosciences Society (NMGS) - Printed in Nigeria.

Paleoecology and Paleodepositional Environment of Ostracod from Igumale Formation, Southern Benue Trough, Nigeria

Ogbahon, O.A., Opeloye, S.A. and Oluwajana, O.A.
Department of Applied Geology, Federal University of Technology, Akure, Nigeria
Corresponding E-mail: oaogbahon@futa.edu.ng

Abstract
Ostracod fauna from Igumale Formation of the Cenomanian-Turonian Eze Aku Group in the Southern Benue Trough have been studied to document the assemblage, paleoecology and depositional environment of the sediment in the stratigraphic interval. Seventeen core samples spanning a stratigraphic interval of 85.34 m were analyzed for ostracod. The lithologic composition of lithostratigraphic unit consists of siliciclastic-carbonate sequences with the carbonates more conspicuous at the upper portion of the stratigraphic section. A total number of eight species belonging to five genera and five families were recovered from the samples. The recorded ostracod taxa are *Bythocypris sp., Bairdia malzi, Bairdia illaroensis, Bairdia sp., Cytherella aegyptopuntata, Cytherella farafraensis, Xestoleberis sp.*and *Paracosta parakefensis* listed in order of decreasing abundance. Of the total population abundance of 138, *Bythocypris sp* is the dominant taxa, accounts for 69.6 % of the population. Its distribution is however cyclical, suggesting fluctuation in sea level. Based on the low species diversity, environmental preferences of the recorded taxa and distributional pattern, shallow marine depositional environment (inner to middle shelf) is deduced for the fossiliferous portion of the section with dissolved oxygen levels fluctuating between well oxygenated and disaerobia.

Keywords: *Benue Trough, Nigeria, Ostracod, Paleocology, Paleodepositional.*

Introduction

The Benue Trough is a NE-SW oriented intracratonic linear basin in Nigeria in (Fig. 1) commonly referred to as an aulacogen. It contains 3-5 km thickness of Cretaceous-Paleogene sedimentary successions of varied lithologies including limestone, shale, coal and sandstone. The Benue Trough aulacogen developed during the early cretaceous separation of Africa from America. The basin has received considerable attentions from numerous researchers especially since the discovery of oil in the terminal Tertiary Niger Delta Basin in 1956. The Cenomanian-Coniacian eustatic marine transgression is represented in the southern Benue Trough mainly by the Eze Aku Group comprising Eze Aku Shale, Amasiri Sandstone, Nkalagu Formation and Igumale Formation (Nwajide, 2013) (Fig. 2). While the biostratigraphic details of Nkalagu Formation, Eze Aku Formation are well documented in literature it is not so for the ostracod distribution of Igumole Formation as data on Igumale Formation are scarce. Reports on ostracod fauna from Eze Aku and Nkalagu Formations include those of Reyment (1960, 1966; cited by Okosun (1987) and Gebhardt (1999). Other studies on ostracod microfauna from the Cretaceous of the Benue Trough include the publications of Okosun (1992), Opeloye and Obaje (2005), Mamman and Obaje (2006). Okosun (1987) studied the ostracod fauna from the Cretaceous and Paleogene of southern Nigeria basins, including Eze -aku Shale in the Benue Trough based on samples from two boreholes while Gebhardt (1999) studied the ostracod fauna from Nkalagu Formation based outcrop samples from Nkalagu quarries. Igumale formation as one of the component lithostratigraphic units of Eze Aku Group in the southern Benue Trough has not been well studied compared to the Eze-Aku Shale and Nkalagu formation (Nwajide 2013).

Ostracods are diminutive bivalved-carapace crustacean arthropods inhabiting virtually all aquatic environments, with most of the known species adapted to marine and marginal marine environments (Horne, 2005, Börner et al., 2013). The benthic nature of ostracods allows them to be used as paleoecological indicators (Horne 2005; Piovesan et al., 2014). Studies have demonstrated that ostracods are good indicators of temperature, dissolved oxygen, circulation and water depth since most species are sensitive to hydrologic characteristics (Bergue et al., 2006) As noted by Benson (1984), Dingle and Lord (1990) and Ayress et al. (1997), different taxonomic assemblages of ostracods inhabit different depths depending on the available water masses. Ostracods are particularly sensitive to environmental changes and are therefore, very vital in paleoenvironmental interpretation Mereiles et al (2014). Although ostracods may serve as useful biostratigraphic tool, the strong provincialism exhibited by most species biozones erected on the basis of ostracods are mainly of local or limited regional applications (Gebhardt, 1999; Viviers et al 2000)

Geological Setting of the Study Area

The Benue Trough is an elongate NE-SW trending intracratonic basin in Nigeria stretching for over 1000 km along its length and varying between 120 and 250 km in width (Nwajide, 2013). The trough is part of the Cretaceous West African Rift System (WARS) which can be traced for roughly 4000 km distance from Nigeria, stretching northwards into the neighboring Niger Republic, Chad, Republic of Niger Sudan, and terminating in Libya (Oha et al 2017).

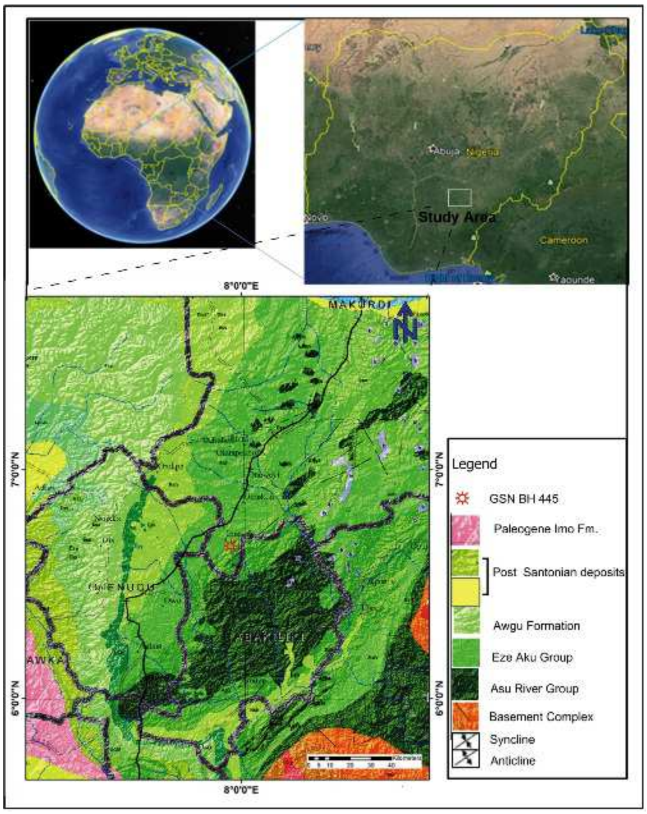

Fig. 1: Google map of the location of Igumale where GSN BH 445 is located m (modified from GNSA, 2004).

There is a consensus among many workers that the trough represents the failed arm of the rifted triple junction that initiated the separation of South America from Africa in the Early Cretaceous times (Nwachukwu, 1972; Whiteman, 1982; Reijers 1996; Nwajide, 2013). The sedimentary infill of the trough presents a record of tectonic processes, erosion, and of depositional environments (Nwajide 2013; Odigi and Amajor 2009; Gebhardt 2004; Gebhardt et al 2019). The sedimentary fills of the southern Benue Trough were deposited during four sedimentary cycles associated with the transgression and regression of the sea (Ehinola, 2010; Najime, 2011; Nwajide 2013*)*. The first phase of sedimentation in the Benue Trough occurred during Albian to Cenomanian and was considered to have been initiated by the opening of the South Atlantic Ocean and Gulf of guinea, resulting in the deposition of beds of the extensive Asu River Group in the southern and central Benue trough as well as layers of Nfamosing Formation on the Calabar flank only (Petters 1982; Ehinola 2010; Nigeme 2011). Beds of arkosic sandstones of the Asu River Group forms the core of the Abakaliki Anticlinorium where it is thought to reach thickness of about 3,000m (Awi and Mamfe Formations of Aptian – Albian age) and shallow marine shales and sandstones (Awe Formation of Early Cenomanian to Early Turonian age). The Asu River Group consists of sandstones and dark shales with ammonites, and grade northwards into platform carbonates of the Arfufu and Gboko members (Reyment, 1965; Odigi and Amajor 2009). The Asu River Group as well as the Eze-Aku Group have been folded into series of northeast trending anticlinal and synclinal folds, with the oldest stratigraphic unit, the Asu River Group constituting the core of the Abakaliki Anticlinorium (Odigi and Amajor 2009; Nwajide 2013). Sediments of the unit are unconformably overlain by those of Eze Aku Group (Fig. 2). The unconformity between the 2 stratigraphic units has been attributed to Cenomanian tectonic activity (Ezepue 1984; cited by Nwajide 2013).

The second sedimentary phase between the Late Cenomanian and Middle Turonian caused the deposition of Eze-Aku Group in the southern BT and in the southern part of the Central Benue Trough (Gebhardt, 2004; Ehinola, 2010; Nwajide 2013). Simpson (1955; cited by Nwajide 2013) described the Eze Aku Group as consisting of hard, flaggy, carcareous grey shales and siltstones commonly with the impressions of *innoceramus species*. The unit consists of Eze Aku Shale, Amasiri Sandstone, Nkalagu Formation, Igumale Formation, Konshisha River Formation as components, with Makurdi Sandstone as its lateral equivalents in the Central Benue Trough respectively, while Gongila, Jessu and Dukul Formations are its lateral equivalents in the upper Benue Trough (Gebhardt, 2004; Nwajide 2013). The thickness of the unit is roughly 1000 m. In the area around Nkalagu, on the western flank of the core of Abakaliki Anticlinorium, the Eze Aku unit consisting of sandstone, shale, siltstone and limestone lithofacies (Amajor 1984: cited by Nwajide 2013). The type locality of the main shale unit, the Eze Aku Shale is the Eze-Aku River, near Aka-Eze in the southern part of the basin where the Cenomanian section of sequence transits stratigraphically into the Turonian without any hiatus (Ojoh, 1992). The Nkalagu Formation consists of alternating pyritic, black, calcareous shales and limestones in Isinkpume, Ezillo, and Nkalagu areas, with type locality at Nkalagu quarries (Petters, 1978).

Both the Asu river and the Eze Aku Groups have been affected by igneous activity (Ezepue 1984; cited by Nwajide 2013).

The third sedimentary cycle took place from the Late Turonian to the Santonian and was associated with the deposition of the Awgu shale and Agbani sandstones, which are lateral equivalents of the Fika/Sekunle shale in the upper Benue Trough (Ehinola, 2010). The sediments of Abakaliki- Benue Trough were subjected to tectonic activity in the Santonian, leading to the folding and uplift as well as igneous activity in the area and subsequent down-warping of Anambra platform and Afikpo area to form Anambra Basin and Afikpo Syncline to west and southwest of the Abakaliki Anticlinorium. The tectonic event resulted in the westward translation of depositional axis to the newly formed Anambra basin and Afikpo Syncline which hitherto were draped by veneers of sediment. The folded strata of the Abakaliki –Benue basin were eroded variously overstepped by post Santonian sedimentary successions of the Anambra Basin, with the occurrence of angular unconformity demarcating older strata from younger ones (Reijers and Nwajide, 1996, Nwajide 2013; Odigi and Amajor 2009). The last phase of sedimentation during the Campanian to Maastrichtian marine transgressive-regressive event resulted in the deposition of Nkporo Group, Mamu, Ajali and Nsukka Formation in the Anambra Basin.

Material and Methods

The studied material consists of 17 core samples collected within a stratigraphic interval of 85.34 m of Igumale borehole (GSN BH 445) drilled by the Nigeria Geological Survey Agency. The samples were collected adopting the spot sampling method. The samples were examined for their lithologic, textural and sedimentary structural detail. Precisely 40 g of dry sample was weighed for ostracod analysis. The sample was disaggregated into small bits with hammer and then put in a tin beaker. It is then heated with few drops of kerosene. The preheated sample is then transferred into a beaker of boiling water similar to the method described by Thomas and Murney (1985). The sample is left to soak for 24 hours before washing under running water through a 63 micron sieve.

Washed sample is dried on hot plate maintained at 50 ^{0}C. Ostracods were picked from washed, dried sample strewn on picking tray with the aid of stereoscopic light-reflecting microscope. Specimens were picked and kept in cavity slides endowed with cover slip for identification, sorting and description using relevant published albums. The data presentation was done in Microsoft Excel and Surfer 12 software.

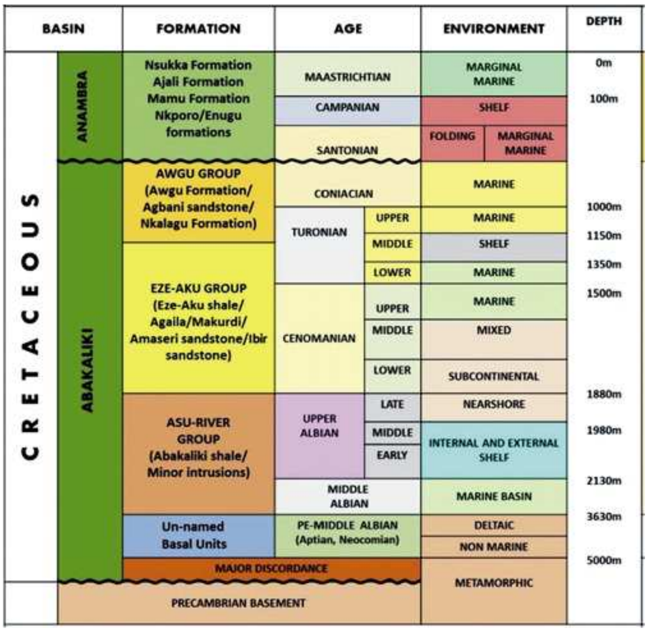

Fig. 2: Generalized stratigraphic section of the southern Benue Trough (modified after Ojoh, 1992)

Results and discussion

Sedimentology

Sediment drill cores of Igumale borehole section reveals that the stratigraphic section is composed predominantly of shale with subordinate limestone facies successively replacing the shale facies towards the top of the section. The total depth of the bore is 85.34 m. The clastic shale facies is generally grey to dark grey, fine grained, massive to laminated with sparse noddles of creamy, fine grained limestone . The limestone facies is grey to cream, medium grained, locally shelly bioclastic wackestone and oolitic packstone with shells of brachiopods and bivalves. The fossils content of the carbonate facies include brachiopods, gastropods, belemnites and echinoids. The non-skeletal gains are increasingly more important towards the upper part of the stratigraphic sections and are represented by peloids and oolites with minor constituents of fine-grained angular detrital quartz.

Ostracod Fauna

Only nine (9) out of the total of 17 analyzed samples yielded ostracods fauna, indicating poor recovery. A total number of 9 species belonging to 5 genera and 5 families were recorded in the study (Fig.3). The stratigraphic distribution of the ostracod assemblages recorded in Igumale section is shown in Table 1 and Figs. 3, 4 and 5. The recorded species are *Bathyocypris sp., Bairdia sp., Bairdia illaroensis, Bairdia malze, Cytherella aegyptopunctata, Cytherella parafraensis, Paracosta parakefensis* and *Xestolebris sp*. The platycopid family Cytherelidae is represented by the genera *Cytherella*. The podocopids are represented by the families *Bythocyprididae, Bairdiodae, Trachylerididae* and *Trachyleberididae (Tables 1&2)*. The stratigraphic distribution of the assemblages is highly variable. In the total abundance of 138 ostracods found in the study, *Bathyocypris sp*. is the dominant taxa, accounting for roughly 69.6 % of the total ostracod fauna. Species diversity is generally low and ranges from 1 to 6 with the highest diversity recorded at 64.0 m (sample IGU/B-15). The vertical distribution of ostracod fauna suggests that their occurrence is either facies controlled or that the ecological requirements of *Bathyocypris sp*. and Bairdia are different than those of *Cytherella aegyptopunctata*, *C. parafraensis, Paracosta parakefensis,* and *Xestolebris sp.* because of the inverse relationship in the vertical stratigraphic distribution of the two aforementioned groups.

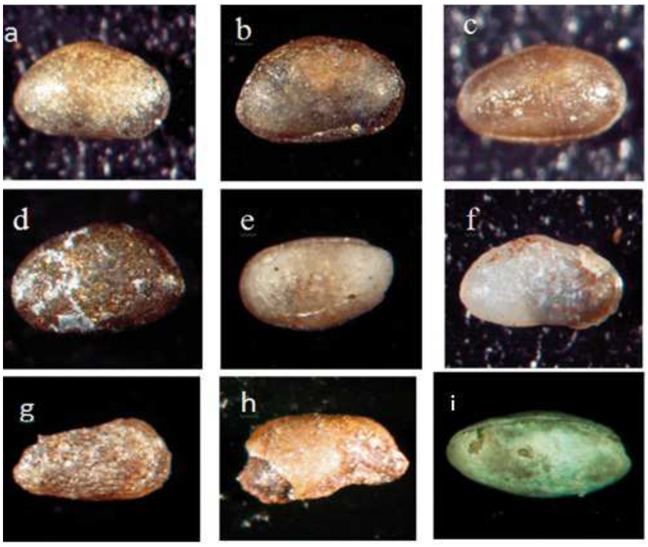

Fig. 3: Photomicrographs of some of the ostracod taxa recovered from the sediments in studied stratigraphic section. (a) *Bythocypris sp.,* (b) *Bairdia illaroensis*, (c) *Bairdia sp*., (d) *Bairdia Malzi*, (e) *Cytherella aegyptopunctata*, (f) *Cytherella farafraensis* (g) *Paracosta parakefensis(h) Xestolebreris sp., (i) Ostracod interminate.*

Biostratigraphy

The ostracod fauna recorded in the study is not suitable for biostratigraphic purpose not only because of the low abundance population but also because of they are long-

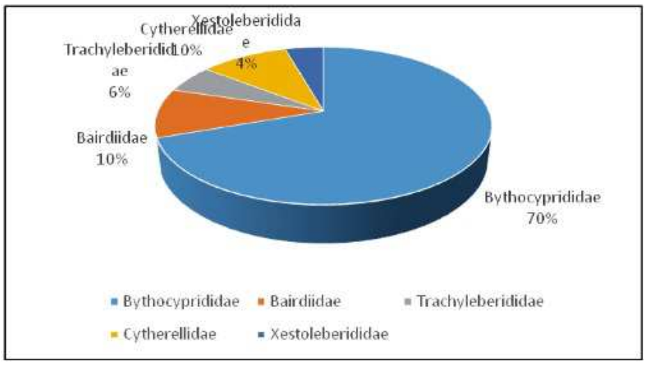

Fig. 4: Abundance distribution of ostracod genera in Igumale stratigraphic section.

ranging. According to Gebhardt (1999), many Upper Cretaceous ostracod taxa are long–ranging and have no chronobiostratigraphic significance. As pointed out by Viviers *et al.*(2000) and Santos Filos *et al.* (2016) ostracod can provide biostratigraphic data on certain environments such as in shallow seas and coastal marine settings only when they occur in high abundance. However, they are very useful for paleoecological interpretation (Opeloye and Obaje, 2005). The pattern of distribution of ostracod fauna shown in Fig 4 suggests that the vertical stratigraphic changes in the ostracod assemblage compositions is as a result of variations in the ~~in~~ environmental conditions such as water depth, temperature and salinity rather than extinction or origination events. This is evident for instance in the disappearance of *Bathyocypris sp.* within the 59.0 -18.9 m interval and then reappearing higher up in the stratigraphic section at the 15.4 m level. Furthermore, some of the taxa, including *Bairdia illaroensis* have been recorded in younger sediments in Nigeria (see Okosun and Osterloff (2014). An inverse relationship can be seen in the distribution and abundance patterns of *Bathocypris* and *Cytherella*. Gebhardt (1999) attempted a Biozonation of the Nkalagu section based on ostracod, erecting four informal zones spanning Cenomanian-Coniacian. He submitted that such zonation may be useful on regional scale. None of the index species of Gebhardt are present in the current work.

Paleoecology and Depositional Paleo-Environments

Paleoecologic and paleoenvironmental interpretation of the ostracod fauna recorded in the studied stratigraphic succession is attempted partly by comparing the ostracod fauna with known ecological data or the environmental preferences of ostracod species (Dingle and lord 1990, Shanshin 1991; Al-shareef et al 2010; Okosun and Osterloff 2014) and partly by considering the population structure as well as other associated

Table 1: Ostracod assemblage distribution table in Igumale samples and diversity indices.

Sample/Taxa	*Bythocypris sp.*	*Bairdia spp*	*Bairdia malzi*	*Bairdia ilaroensis*	*Ostracod indet*	*Cytherella aegyptopunctata*	*Cytherella cf. farafraensis*	*Paracosta parakefensis*	*Xestoleberis sp.*	Abundance	Species richness	Dominance	% Platycopids
IGU/B-2					2								
IGU/B-4	8									8	1	1.0	0.0
IGU/B-11							5			5	1	1.0	100.0
IGU/B-12						1	1	2	5	9	4	0.4	22.2
IGU/B-13						4		4	1	9	3	0.4	44.0
IGU/B-14	3	1	2			1	1	1		9	6	0.2	66.7
IGUIB- 15	65			3		1				69	3	0.9	1.5
IGU/B-16	1	4			1					6	3	0.5	0.0
IGU/B-17	19			4						23	2	0.7	0.0

Table 2: Summary of taxonomy of ostracod fauna from Igumale stratigraphic section as well as the absolute and relative abundances of the various families

Genus	Family	No. of species	Total abundance at family level	Relative abundance (%)
1. Bythocypris Brady1880	Bythocyprididae	1	96	69.6
2. Bairdia M'Coy 1844	Bairdiidae	3	14	10.1
3. Paracosta, Siddiqui, 1971	Trachyleberididae	1	8	5.8
4. Cytherella Jones 1849	Cytherellidae	2	14	10.1
5. Xestoleberis Sars, 1866	Xestoleberididae	1	6	4.4
Total		**8**	**138**	**100**

microfauna, especially foraminifera. Although many ostracod taxa exhibit a wide range of environmental occurrence, some genera are regarded as depth indicators. Data on depth ranges indicate that some ostracod species are adapted to broad ranges while others are restricted to narrow range and therefore there are specific depth intervals in which each species is more abundant (Ayres et al.,1997; Bergue et al. 2006; Al-Ashareef et al 2010). The ostracod taxa recorded in the study are known to inhabit wide depth ranges. Bairdia are regarded as shallow marine ostracods commonly associated with warm carbonates platforms (Hoomes 2005) but they have also been reported from deep marine setting (Meirele et al 2014). *Cytherella* and *Bairdia* are adapted to a wide range of depths and are present from shallow marine to bathyal and even abyssal depths (Shahin, 1991). Dingle and Lord (1990) recorded high frequencies of Bythocypris sp. alongside Buntonia and Bairdia in ostracod fauna from the Quaternary of Angola Basin and North Atlantic deep water (> 1,000 m) and interpreted the occurrences of Bythocypris sp. as indicative of either a marine or a transitional palaeoenvironment. Dingle and Lord (1990) reported that Cytherella sp., Bythocypris sp. and Bairdia sp. constituted important components of the ostracod fauna from the North Atlantic deep waters (> 1km). Similarly, Sciuto (2014) reported high diversity of Bythocypris among the ostracod fauna from the deep marine Pliocecene Pleistocene Punta Mazza succession of Sicily. Meireles et al (2014) reported the occurrences of Xestoleberididae and Bairdiidae alongside 10 other genera of benthic shallow-water ostracods from the Azores. Cytherella have been found in large range of depths from intertidal to abyssal zone (Hoome 2005; Whatley et al 2003).

Therefore, the *Cytherella- Xestoleberis- Paracosta association* in the interval 47.1 to 64.0 m in the studied section suggests deposition in shallow marine outer to middle neritic environment characterized by low oxygen levels. Provision et al (2014) posited that low Channon value and high dominance is typical of brackish water environments. It is likely that the environment of deposition fluctuated between shallow

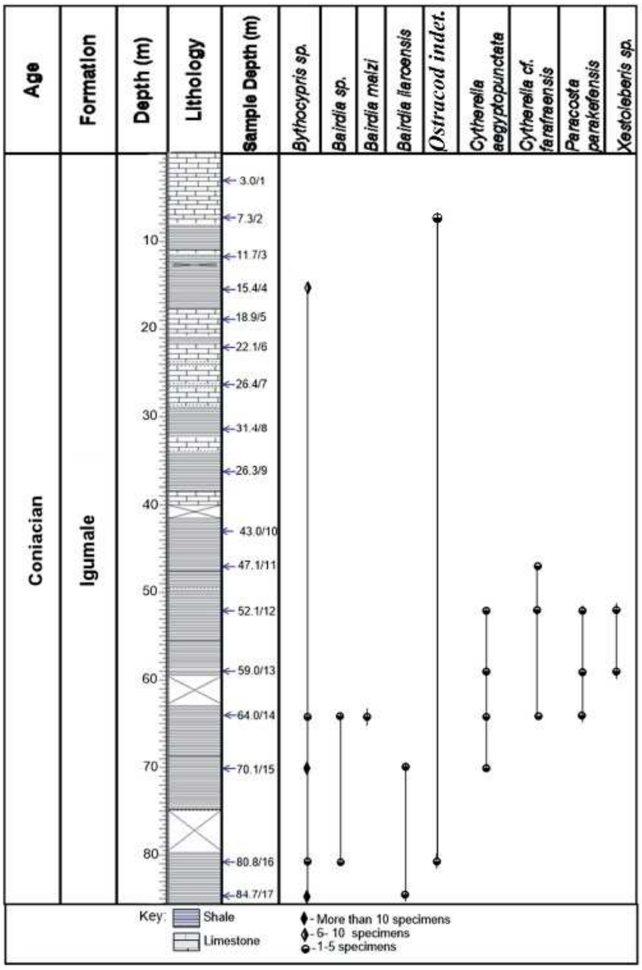

Fig. 5: Stratigraphic range chart of ostracod fauna recorded in Igumale borehole.

and littoral. This deduction is corroborated by the associated benthic foraminiferal assemblage consisting entirely of agglutinated tests. According to Meireles et al (2014) low diversity assemblages with few or single dominating species point to stressed, unstable conditions, fluctuations in bottom water oxygen level. They reported the occurrences of Xestoleberididae and Bairdiidae alongside 10 other genera of benthic shallow-water ostracods from the Azores. Yousef (2018) reported that salinity has a direct effect on the diversity and abundance of specimens in marine and marginal marine environments and considered dissolved oxygen and availability of algal substrate as some of the factors contributing to the abundance of some living ostracods taxa. Benson (1984), Dingle and Lord (1990) and Ayress et al (1997) considered temperature and salinity and dissolved oxygen level as the most important factors controlling ostracod fauna diversity and population abundance in different water masses characterized by a particular sets of physic-chemical parameters. The lower portion of the section characterized by Bythocypris-Bairdia association probably suggests more stable, more oxygenated, warmer environment of deposition. Horne (2005) reported that Bairdia are well adapted warm, oxygenated shallow water, especially in carbonated platfroms.

Oxygen Level and Sea Level Change

It has been demonstrated severally that the proportion of platycopids in any ostracod assemblage can be used as an indicator for peleo-oxygen level (Boomer and Whatley, 1992; Gebhardt 1999; Whatley et al 2003; Hoome 2005; Santos Filho et al 2017). There is consensus among these authors that high percentage of platycopids in an assemblage suggests episodes of low concentration of dissolved oxygen in an environment (dysaerobia). Also, strong dominance of platycopids has been used to suggest either environmental stress related to low dissolved oxygen (Whatley et al, 2003) or high primary productivity and restricted vertical movement of water mass (Santos et al (2017). On the other hand, high proportion of podocopids is a signal for high concentration of dissolved oxygen. Whatley et al (2003) observed that Cytherella is the dominant ostracod taxa in the oxygen minimum zone (OMZ) in modern oceans. Their adaptation to low oxygenated environment has been attributed to their possession of filter feeding apparatus that enable them to circulate more water over the respiratory surface thereby bringing more oxygen to the surface. Based on the aforementioned, the percentage cytherella in study (Table 1) range from 0 to 100 %, suggesting fluctuations in oxygen levels between well oxygenated and poorly oxygenated depositional episodes. The intervals with 0 or 1.5 % platycopids indicates very high oxygen level. The 22.2 % platycopids suggests high oxygen level The 66.7 % platycopids registered at 64.m suggests low concentration of dissolved oxygen (3-2 ml/l); the recorded 100 % at 49.3 m signifies deposition in very low oxygen environment (2 to < 1 ml/l).

The cyclical pattern in temporal distribution Bbythocypris sp. is noteworthy. Its disappearance after the 64.0 m depth and subsequent reappearance higher up in the stratigraphic section probably indicates sea level changes involving fluctuations in bottom water oxygenation level, with the development of unfavorable conditions forcing it to emigrate to a nearby refugium until the favorable conditions was restored in the area. Change in water depth may result in biological crisis related to increased stress within the adaptive framework of a species until threshold is reached (Benson, 1984).

According to Whatley et al (2003), 80 % or more than 80 % platycopids indicates very low oxygen; 60-80 % platycopids signifies low oxygen level (3-2 ml/l). The interval with high proportion of cytherella (Table 1) indicates low oxygen paleoenvironment of deposition, whereas the interval with high percentage of podocopids probably suggests well oxygenated paleoenvironment. Gebhardt (1999) used high occurrence and diversity of cytherella in ostracod fauna from Turonian-Coniacian Nkalagu Formation to infer dysaerobic paleoenvironment of deposition. Ostracods strive best in well-oxygenated marine environment, exhibiting highest species diversity in areas with highest dissolved oxygen level, especially where substrates that encourage the growth of macro-algae well known for its affinity with ostracods are present (Whatley et al 2003; Yoseph 2018). Petters (1982) deduced fluctuations in oxygen level during sedimentation of Cenomanian-Coniacian of the Benue Trough. Anoxic bottom condition may have been occasioned by restricted/poor circulation leading to stratification of water mass. This inference is reasonable since the southern Benue Trough was a semi enclosed body water that opened to the sea. Temperature and salinity variation are inevitable in such setting in view of freshwater influx from fluvial sources and dilution of oceanic saline waters.

Paleobiogeography

The ostracod fauna in this study is compared with previous studies on ostracods fauna from Cretaceous of Nigeria and elsewhere at the genera level. Most of the taxa have been reported in previous studies by various authors. Bythocypris have been reported from the Turonian Nkalagu (Okosun 1987) and Coniacian Numanha Formation in the Benue Trough of Nigeria (Opeloye and Obaje (2005). Bairdia was reported by Okosun (1987) from the Maastrichtian Abeokuka Formation and younger sediments in Dahomey Basin. Gebherdt (1999) reported the occurrence of Cytherella, Bairdia and Xestoleberis in the Turonian –Coniacian Nkalagu Formation in the southern Benue Trough. Also, Cytherella have been reported from the Upper cretaceous of Benue Trough and Paleogene of Nigeria (Okosun, 1987; Okosun, 1992; Opeloye and Obaje, 2005; Gebhardt 1999).

Some authors including Piovesan et al (2000) and Ismail and Ied (2005) have noted the similarities between ostracod assemblages from West Africa (Nigeria, Gabon) and comtemporaneous assemblages from Brazil and NE Africa (Egypt) respectively, suggesting links between these areas in the Cretaceous period. For example, Cytherella aegyptopunctata Bairdia illaroensis and and Paracosta parakefensis were report from Maastrichtian-Paleocene of Egypt by Morsi and Ied (2005). The reported high index of similarity is in agreement with the lithologic similarities (siliciclastic-carbonate sequences) in the Upper Cretaceous of Nigeria and Brazil as they both preserve important records of the development of the South Atlantic Ocean.

Conclusion

The ostracod fauna of Igumale Formation has been studied to elucidate on the paleoecology and paleoenvironment of deposition. The 17 core samples taken from 85.34 m stratigraphic interval yielded non-diverse assemblages of marine ostracods comprising eight species distributed in five genera and five families. The retrieved species are *Bathyocypris sp., Bairdia sp., Bairdia illaroensis, Bairdia malzi, Cytherella aegyptopunctata, Cytherella parafraensis, , Paracosta parakefensis* and *Xestoleberis sp*. Most of the assemblages are dominated by *Bathyocypris sp.* with marked cyclical distributional pattern. The changes in the vertical distribution of the assemblages suggest fluctuations in water level. Based on the lithologic composition, low species diversity, low population abundance and associated foraminifera, shallow marine (inner to middle neritic) depositional paleoenvironment with fluctuating dissolved oxygen level is deduced for the fossiliferous lower portion of the studied stratigraphic section.

References

Al-Shareef, I.Y., Khalaf, S.K., Eisa, M.A. (2010). Paleoecology of some Upper Cretaceous Formations from Selected Wells Northwest and Middle Iraq. raqi Journal of Earth Sciences, vol. 10, no. 2, pp. 67-96.

Ayress, M, Neil, H, Passlow, V, Swanson, K. (1997). Benthonic ostracods and deep watermasses: A qualitative comparison of Southwest Pacific, Southern and Atlantic Oceans. Palaeogeography, Palaeoclimatology, Palaeoecology, 131, 287–302.

Benson, R. H. (1984). Estimating greater paleodepths with ostracodes, especially in past thermospheri oceans. Palaeogeography, Palaeoclimatology, Palaeoecology, 48, pp. 107–141.

Bergue, C.C., Costa, K., Dwyer, G.C. and Moura, C.A. (2006). Bathyal ostacode diversity in the Santos Basin, Brazilian southeastern margin: Response to late Quarternary climate changes. Rev. Bras Paleontol., 9(2), 201–210.

Ciuto, F.S. (2014). Ostracods of the Upper Pliocene - Pleistocene Punta Mazza succession (NE Sicily) with special focus on the Family Trachyleberididae S YLVESTER -B RADLEY , 1948 , and description of a new species. Carnets de Géologie [Notebooks on Geology], 14(1), 1–13.

Dingle, R.V. and Lord, A.R. (1990). Benthic ostracods and deep water-masses in the Atlantic Ocean. Palaeogeography, Palaeoclimatology, Palaeoecolog, 80, 213–235.

Ehinola, O.A. (2010) 'Biostratigraphy and depositional environment of the oil shale deposit in the Abakaliki fold belt, Southeastern Nigeria', Oil Shale, 27(2), pp. 99–125. doi: 10.3176/oil.2010.2.02.

Gebhardt, H. (1999). Cenomanian to Coniacian ostracodes from the Nkalagu area (SE Nigeria): biostratigraphy and palaeoecology. PaRiontologische Zeitschrift, 73(1&2), 77–98.

Gebhardt, H., Akande, S.O.., Adekeye, O. A. (2019) 'Cenomanian to Coniacian sea-level changes in the Lower Benue Trough (Nkalagu area, Nigeria) and the eastern Dahomey Basin: palaeontological and sedimentological evidence for eustasy and tectonism', Geological Society, London, Special Publications.

Horne D.J. (2005). Ostracoda. In: Selley R.C., Cocks R.M. & Plimer I.R. (eds.), Encyclopedia of Geology.-Elsevier, Oxford, pp. 453-463.

Ismail, A.S, Ied, I. . M. (2005). Maastrichtian - lower eocene ostracodes from safaga area, eastern desert, Egypt. Egypt. Jour. Paleontol., Vol., 5(May), 119–159.

Mamman, Y.D., Obaje, N. G. (2006). Ostracod biostratigraphy and paleoecology of the Dukul Formation in the Yola Arm of the Upper Benue Trough, northeastern Nigeria. Global Journal of Geological Sciences, 4(1), 39–46.

Meireles, R. P, Keyser, D., Borges, P.A, silva, L, De Frias Martins, A.M, Avila, S. (2014). The shallow marine ostracod communities of the Azores (Mid- North Atlantic): taphonomy and palaeoecology. Geologica Acta, 12(1), 53–70. https://doi.org/10.1344/105.000002073

Najime, T. 2011. Depositional framework and Cretaceous stratigraphy of the Gboko Area, Lower Benue Trough, Nigeria. Journal of Mining and Geology, vol.47, no.2, pp147-163

Nigeria Geological Survey Agency, NGSA (2004). Geological map Nigeria/

Nwajide C.S., Reijers T.J.A. 1996. Geology of the southern Anambra Basin T.J.A. Reijers (Ed.), Selected Chapters on Geology, Warri, SPDC 1996, pp. 133-148.

Nwajide, C. S. (2013) 'The geology of Nigeria's sedimentary basins'. CSS Press Limited, Lagos, Nigeria, 565p.

Nwajide, C.S. (2013). The gology of Nigeria's sedimentary basins, CSS Press, Lagos, Nigeria, 565p.

Nwachukwu, SO. (1972). The tectonic evolution of the southern portion of the Benue Trough. Geol. Mag., vol. 109, 1775-1782.

Nwajide, C.S., and Reijers, T.J.A. (1996) Geology of the southern Anambra Basin. In: T.J.A. Reijers (Ed.), Selected Chapters on Geology, Warri, SPDC 1996, 133-148.

Ojoh K. A. (1992) The Southern part of the Benue Trough (Nigeria) Cretaceous stratigraphy, basin analysis, paleo-oceanography and geodynamic evolution in the equatorial domain of the south Atlantic. NAPE Bull 7:131-152

Okosun, E. A. (1992). Cretaceous ostracod biostratigraphy from Chad Basin in Nigeria. Journal of African Earth Sciences, 14(3), 327–339. https://doi.org/10.1016/0899-5362(92)90036-C

Reyment R.A. (1960) Studies on Nigerian Upper Cretaceous and Lower Tertiary Ostracods, part 1: Senonian and Maaastrichtian Ostracods- Stockh. Contr. Geol. V. 7, pp.1-238

Reyment, R.A. (1965) Aspects of the geology of Nigeria: The stratigraphy of the Cretaceous and Cenozoic deposits. Ibadan University Press, 145p

Reyment R.A. (1966) Studies on Nigerian Upper Cretaceous and Lower Tertiary Ostracods, part tratigraphical, Paleontological and biomentrical conclusions, Stockh. Contr. Geol. v. 14, pp.1-151

Odigi M.I., Amajor L.C. (2009) Geochemical characterization of Cretaceous sandstones From the Southern Benue Trough, Nigeria. Chin.J.Geochem., 28, pp. 44–54. DOI: 10.1007/s11631-009-0044

Oha, I. A., Onuoha, K. M., & Dada, S. S. (2017). EARTH SCIENCES Contrasting styles of lead-zinc-barium mineralization in the Lower Benue Trough , Southeastern Nigeria. Earth Science Research, 21(1), 7–16.

Okosun, E. A. (1987). Ostracod biostratigraphy of the Eastern Dahamey Basin, Niger Delta and the Benue trough of Nigeria. Geological Survey of Nigeria bulletin 41.

Opeloye, S. A., Obaje, N. G. (2005). Ostracods from Yola Arm, Upper Benue Trough, Nigeria. Global Journal of Geologial Sciences, 3(2), 179–185.

Simpson, A. (1955). The Nigerian coalfield: The geology of part of Onitsha, Owerri, and Benue provinces,GSN Bull. No. 24, 85p.

Shashin A. (1991). Cenomanian-Turonian ostracods from Gebel Nezzazat, southwestern Sinai, Egypt, with observations on d13C values and the Cenomanian/Turonian boundary. journal of Micropa;eontology, 10(2), pp. 133-150.

Thomas, F.C. and Murney, M.G. 1985. Techniques for extraction of foraminifers and ostracodes from sediment samples. Can. Tech.Rep. Hydrogr. Ocean Sci. 54: vi + 24 p.

Ehinola, O.A. (2010). 'Biostratigraphy and depositional environment of the oil shale deposit in the Abakaliki fold belt, Southeastern Nigeria', Oil Shale, 27(2), pp. 99–125. doi: 10.3176/oil. 2010.2.02.

Gebhardt, H., Akande, S.O.., Adekeye, O. A. (2019) 'Cenomanian to Coniacian sea-level changes in the Lower Benue Trough (Nkalagu area, Nigeria) and the eastern Dahomey Basin: palaeontological and sedimentological evidence for eustasy and tectonism', Geological Society, London, Special Publications.

Perçin-Paçal, F., Altinsaçli, S. and Balkis, H. (2015) 'An updated checklist of recent marine and coastal brackish water ostracods (Crustacea Ostracoda) in Turkey', Journal of Entomology and Zoology Studies, 3(3), pp. 20–33.

Petters, S.W. (1978) 'Mid-Cretaceous paleoenvironments and biostratigraphy of the Benue Trough, Nigeria', Bulletin of the Geological Society of America, 89(1), pp. 151–154. doi: 10.1130/0016-7606(1978)89<151: MPABOT>2.0.CO;2.

Piovesan, E.K., cabral, M.C., Colin, J.-P., Fauth, G. B. C. T. (2014) 'Ostracodes from the Upper Cretaceous deposits of the Potiguar Basin , northeastern Brazil:\taxonomy , paleoecology and paleobiogeography . Part 1: Turonian', Carnets de Géologie [Notebooks on Geology], 14(12), pp. 211–252.

Piovesan, E. K., Melo, R. M. and Fernando, M. (2017) 'Ostracoda and foraminifera from Paleocene (Olinda well), Paraíba Basin , Brazilian Northeast', 89, pp. 1443–1463.

Piovesan, E. K. and Nicolaidis, D.D., Fauth, G., Viviers, M. C. (2013) 'Ostracodes from the Aptian - Santonian of the Santos , Campos and Espírito Santo basins , Brazil', Journal of South American Earth Sciences. Elsevier Ltd, 48, pp. 240–254. doi: 10.1016/j.jsames.2013.09.012.

Santos Filho, M.A.B., Fauth, G., Piovesan, E. K. (2017) 'Journal of South American Earth Sciences Cretaceous ostracods of the Barreirinhas Basin: Taxonomy , biostratigraphic considerations and paleoenvironmental inferences', Journal of South American Earth Sciences. Elsevier Ltd, 73, pp. 130–152. doi: 10.1016/j.jsames.2016.12.011.

Whatley, R.C., Pyne, R.S. and Wilkinson, I.P. (2003) 'Ostracoda and palaeo-oxygen levels , with particular reference to the Upper Cretaceous of East Anglia', Palaeogeography, Palaeoclimatology, Palaeoecology, 194, pp. 355–386. doi: 10.1016/S0031-0182(03)00333-X.

Whiteman, A.J. (1982). Nigeria: Its petroleum geology, resources and potential. Graham and Troutman, London, 394 p.

Yousef, E.A. (2018). Distribution and Taxonomy of Shallow Marine Ostracods from the Western Coast of the Red. Open Journal of Marine Science, 8, 51–75. https://doi.org/10.4236/ojms.2018.81004.

GARNET ENERGY SERVICES NIGERIA LTD.

Geological, Petroleum and Environmental Consultants

12 Floor, Bookshop House, 50/52 Broad Street, Lagos
P.O. Box 70011, Victoria Island, Lagos, Nigeria
Tel. 01-8546699, 06035101804
E-mail mariesonuga@yahoo.com

BARACAL CONSULT LTD.

Environmental Consultants

Suite 65/66 Dolphin Plaza, Dolphin Estate, Ikoyi
P.O. Box 70885, Victoria Island, Lagos, Nigeria
Tel. 234-1-7741441, 234-1-2629251 *Fax* 234-1-2610735
E-mail baracalnig@yahoo.com, carolsoladg@yahoo.com

Jonakod

Jonakod Nigeria Limited

Energy, Environment & Safety Consultants

34 Ontario Crescent, Maitama, Abuja
Tel. 09-4133521, 08035300958, 08057467878
E-mail jonas.odocha@yahoo.com

AMJU SERVICES NIG. LTD.

Specialists in Geological & Mining Services

1B Rock Road, Off Rabah Road
P.O. Box 7216, Kaduna, Nigeria
Tel. +234-(0)8054073338
E-mail abuykarofi@gmail.com