

Original Research Article

Microfossils and Paleoenvironment of the Limestone-Shale Sequences of Gboko Formation, Middle Benue Trough, Nigeria.

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

SAMPLE ABSTRACT:

Aims: To determine the allochem and biofraction modal compositions of the Limestone, ascertain the paleoenvironments as well as the microfossil contents of the Limestone-Shale Sequence of Gboko Formation, Middle Benue Trough, Nigeria.

Study design: Detailed field study, Petrographic, and Biostratigraphic analyses were carried out on representative samples collected.

Place and Duration of Study: Sample: Samples were collected in areas within Latitudes 7°00'00"N and 8°00'00"N and Longitudes 8°00'00"E and 9°30'00"E. These samples were prepared and properly packaged for petrographic and biostratigraphic analyses in Department of Geology, University of Ibadan laboratory in Nigeria, between October 2010 and May 2011.

Methodology: Petrographic study was carried out on prepared thin sections of 17 Limestone samples, under the petrological microscope. A total of 26 samples were processed for microfossils (especially foraminifera). The systematic paleontology was based on the published reports of species.

Results: The lithological assemblages show sedimentary sequences of shale and limestone, that represents transgressive-regressive cycle with many short lived environments. Petrographic studies shows that the limestone as a whole have both mud-supported and grain supported textures with micrite forming over 75% of the bulk. The microfacies recognized include mudstone, bioclastic packstone, intrapelsparite packstone-grainstone, bioclastic grainstone, bioclastic wackestone-packstone, oncolitic grainstone-packstone, intrabiomicrite wackestone-packstone, stromatolitic boundstone and bioclastic wackestone microfacies. Foraminifera, algae, ostracods, gastropods, pelecypods and skeletal grains, constitute the major bioclasts, while pellets; oncoids and lithoclasts are the major non-bioclastic components of the microfacies. The systematic biostratigraphic analysis yielded few stratigraphically significant planktonic and benthonic species of foraminifera. Some of the foraminifera species recovered from the sediments include *Ammobaculites coprolithiformis*, *Ammotium sp.*, *Gvelinella sp.*, *Anomalina*, *Miammia*, *Reophax guineana*, *Fursenkoina dibollensis*, *Lenticulina taylorensis*, *Heterohelix* and *Hedbergella species*. Ostracods, few echinods remains and gastropods are the other microfuna recorded.

Conclusion: The Integration of interpretations from the lithologic and biostatigraphic data suggests that the sedimentary sequence was deposited in a shallow marine, shelf lagoonal environment

Keywords: Gboko, Benue, Petrographic, Biostratigraphic, Paleoenvironment, Nigeria, Microfossil, Limestone

1. INTRODUCTION

The Cretaceous sediments of the Benue Trough are geographically divided into Lower, Middle and Upper Benue Trough [29], [17], [4]. The mid-Cretaceous sediments of the Benue Trough are rich in foraminiferal and ostracods assemblages, which are of paleoenvironmental and paleoecological significance. The studied area falls within the Albian Asu River Group sediments of the Middle Benue Trough (Figs.2).

Unlike the Lower Benue Trough, very few studies have been carried out in the Middle Benue Trough. Petters [31] worked on the paleontology of Albian sediments exposed at Yandev. Nair and Ramanathan [26] studied the sedimentology, stratigraphy and paleogeographic significance of the Albian limestone at Yandev. Adekeye and Akande [1] studied the depositional environment of carbonates of the Albian Asu River Group around Yandev. Adekeye [2] further carried out a quantitative analysis and paleoecological interpretation of foraminiferal fauna.

1.1 Geological Setting

The Benue Trough owe its genesis to episodes of marine transgressions and regressions during the Cretaceous and early Tertiary (Fig. 1). It developed as the failed arm of the R-R-R triple junction, located in early Cretaceous times at the site of the present day Niger Delta [9]. Reports of many authors indicated that Gboko Formation evolved during the first marine transgressive cycle in the Benue rift system. It consists of sedimentary sequences of shale and limestone.

The stratigraphic succession of the Middle Benue basin comprises of the Albian Asu River Group. These sediments are interpreted as sediments of the first marine transgressions into the Benue valley. The Albian Arufu, Uomba, Gboko Formations are generally referred to as the Asu River Group [28]. This Group is succeeded by the late Albian - early Cenomanian Awe Formation; a regressive phase which succeeded the first marine transgressive phase. Overlying this Formation is the Keana Formation, the lateral equivalent of Makurdi Formation. This was deposited in fluvial environments during the Cenomanian regression in the Middle Benue region. The late Cenomanian - early Turonian Eze-Aku Formation overlies the Keana Formation. It marks the beginning of the second depositional cycle (marine strata). Overlying this Formation in the upper section is the late Turonian-Early Santonian Agwu sediments. This represents the last shallow marine deposits of the second depositional cycle. This was followed by Mid-Santonian period of folding throughout the Benue Trough. The post-folding Campano-Maastrichtian Lafia Formation unconformably overlies Agwu Formation. It ended the sedimentation in the Middle Benue Trough. This Formation represents sediments of the third depositional cycle in the middle Benue region. The sediments were deposited in a continental (fluvial) environment

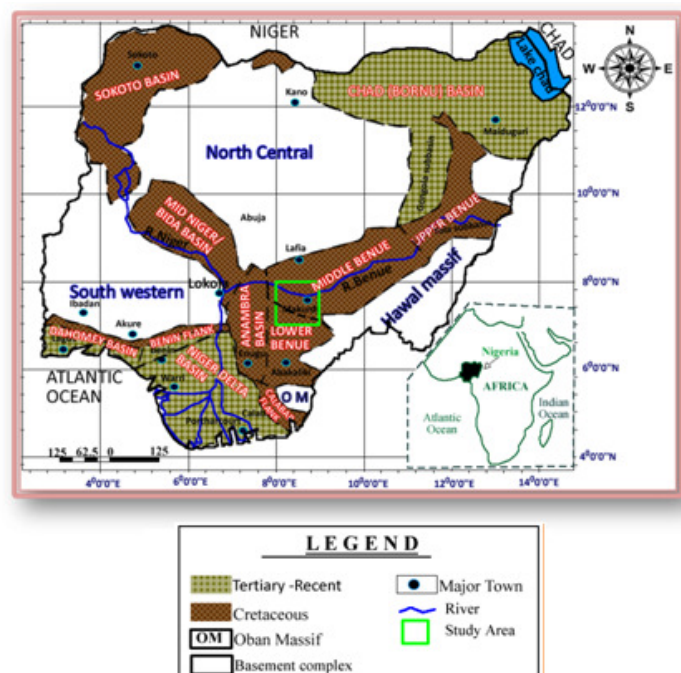


Fig. 1: Geological map of Nigeria showing the in land basins (Obaje et al., 2004)

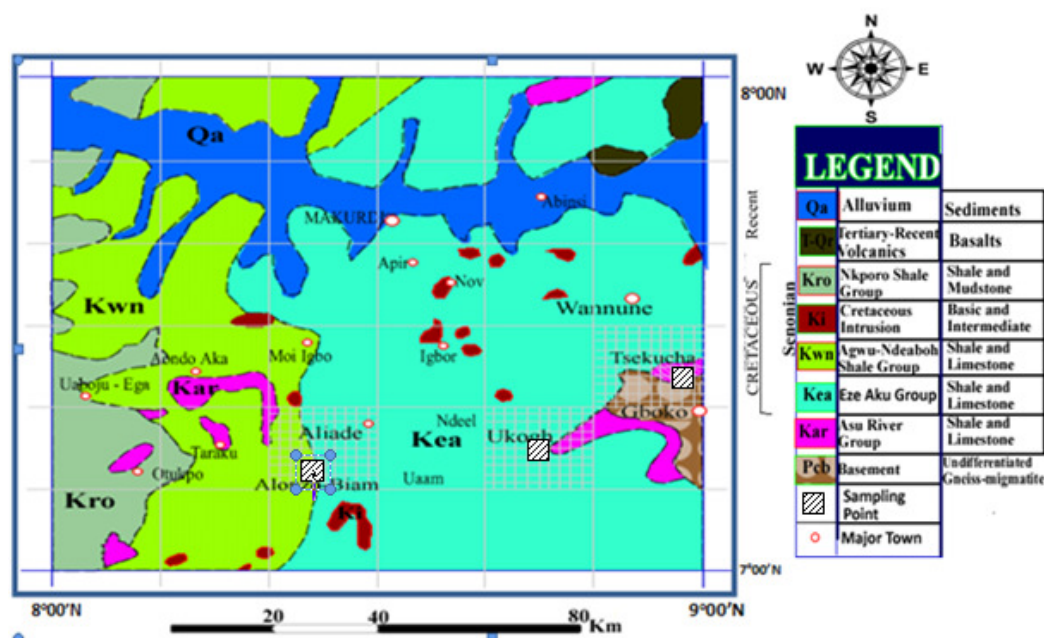


Fig. 2: Geological map of Middle Benue Trough showing the stratigraphic successions and sampling points (adapted from Nigeria Geological Survey Agency, 2010)

The purpose of this paper is to document the distribution of the foraminifers and ostracods in the outcrop sections of the limestone-shale sequences and their significance in regard to the depositional environment.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

This study involved measurements, documentation of sedimentologic features and collection of representative samples. Fresh samples of shale and limestone were selected for further studies.

2.1. Biostratigraphic Studies

Biostratigraphy is the study of rock strata using fossils. A total of 26 samples were processed for microfossils (especially foraminifera). The systematic paleontology is based on the published reports of species, which were already described in literature in the works of Reyment [36] and Petters [31], [32].

About 25g of the pre-treatment samples were placed in the sample plate with corresponding labels attached and were securely placed on the hot plate. The hot plate was put on and regulated to a temperature of about 80°C for 2-3 hours and allowed to cool. The dried samples were then weighed. Microfossils especially foraminifera and Ostracods were washed out of the samples in the laboratory using routine washing technique with hydrogen peroxide (H₂O₂) and deionised water. After drying, each sample was sieved into coarse, medium and fine fractions before picking. Each of these fractions was scattered gently and evenly in a picking tray. The identification, classification and description of the microfossils were carried out using the binocular microscope (EFMA, No 772822). Microfauna found were picked onto a labeled slide with the aid of moistened picking brush. This analysis was carried out in the laboratory of Global Energy, Lagos.

2.2. Petrographic Studies

Routine carbonate mineralogical observation, textural description and modal analysis were carried out on the rock slabs and standard thin section of seventeen (17) Limestone samples. The samples were broken into smaller chunks using hammer, before they were taken to the petrological laboratory for thin sectioning.

In the laboratory, a cutting machine was used to cut the rocks samples into a small flat polished surface chips. The mounting slides were also grinded to produce a flat polished surface, using a mechanized grinding machine. This was to prevent the slide from breaking when mounting the chip on it. The polished chips surface was mounted on the prepared glass slide (76mm x 25mm x 1.2mm) using superglue. It was then left to dry up. The mounted chips were then grinded to a thickness of 30microns.

The thin sections of the limestone were studied under a petrographic microscope. The constituent minerals were observed. The microfacies determinations were carried out using a petrographic microscope with transmitted light. Folk [16], Wilson [42] check list, and Dunham [13] charts were used for the carbonate rock classification. The analysis was carried out in the Geological department, University of Ibadan, laboratory.

3. RESULTS AND DISCUSSION

3.1. Lithostratigraphic description and Depositional Environments

Three outcrop sections within the Gboko Formation were studied. The section exposed on the quarry face is about 80m thick (Fig.3b). This was divided into two sections, a lower

122 section consisting of limestone with millimeter-thick shale partings and an upper section
 123 consisting of meter thick shale and limestone beds. The beds show alternation of shale and
 124 limestone (Fig.3b). The alternation of the shale and limestone units suggest relatively
 125 unstable carbonate shelf platform in which at intervals, clastics were supplied from adjacent
 126 highlands at low sedimentation rate [39]. The shale/limestone couplets are remarkably
 127 laterally persistent. The shale beds are thinly laminated, dark grey, carbonaceous and
 128 generally devoid of micro fauna. The limestone beds are light gray and thin to very thickly
 129 bedded (<10cm to 100cm) (Fig.5).

130
 131 In the lower half of the exposed section, shale occurs as paper-thin laminae to thin beds
 132 rhythmically alternating with the limestone beds. In the upper half, the limestone layers show
 133 a narrow thickness range, the shale range in thickness from less than one millimeter to over
 134 a meter. The shale thus exhibits a thickening upward trend which is not as clearly evident for
 135 the limestone. In the lower half of the quarry face, the very sharp boundary between the
 136 paper-thin shale and limestone beds is attributable to diagenetic overprinting. In the process,
 137 carbonate was dissolved and moved from the initially more clayey layers to the purer
 138 carbonate layers where calcite cement was precipitated. Thus the layers initially richer were
 139 further enriched. The initially more clayey members then collapsed into shale seams, or into
 140 stylolites.

141
 142 The sediments are fossiliferous, and contain numerous ammonites (Fig.4), bivalves, few
 143 gastropods, and pelecypods fossil. Pyritized worm burrows are common (Fig.4). Laminated
 144 shale with phosphatic nodules scattered all around. The presence of quartz indicates
 145 nearness to the shoreline while the pyrite suggests marine and/or reducing depositional
 146 environment. The rhythmic carbonate-shale alternation, i.e. a more or less regular
 147 alternation of chemical and clastic depositional conditions, may be due to quiet water
 148 sedimentation (resulting in mud/clay snerling) regularly alternating with slight deepening to
 149 clearer water conditions, promoting micrite precipitation. Such rhythmic alternation of shales
 150 and carbonate layers has also been attributed to diagenetic unmixing whereby secondary
 151 carbonate migration accentuated primary inhomogeneities [19], [41]. However the sharpness
 152 of the lithological boundaries, presence of carbonate-filled burrows in some of the shale
 153 beds and the perfect horizontality of the strata suggest origin by primary sedimentation. A
 154 shallow marine shelf to lagoonal environment was established, based on the earliest marine
 155 transgression into the Benue Trough in the Aptian to Albian [26], [1].

156
 157 In Ukogh village (near Akpergher), the limestone are exposed on the farmland and along
 158 stream channels. They are grayish in colour with microcrystalline texture. Tiny or juvenile
 159 bivalve impressions were observed. The topsoil is dominantly lateritic and clayey in places.
 160 Most of the grasses and plants are flourishing very well due to soil conditioning capacity of
 161 the limestone. In Alonso-Biam (off Aliade), the limestone also occurred as large boulders
 162 exposed along stream channel. They are grayish in colour. The topsoil is lateritic and
 163 brownish-black in colour (lateritic shale).

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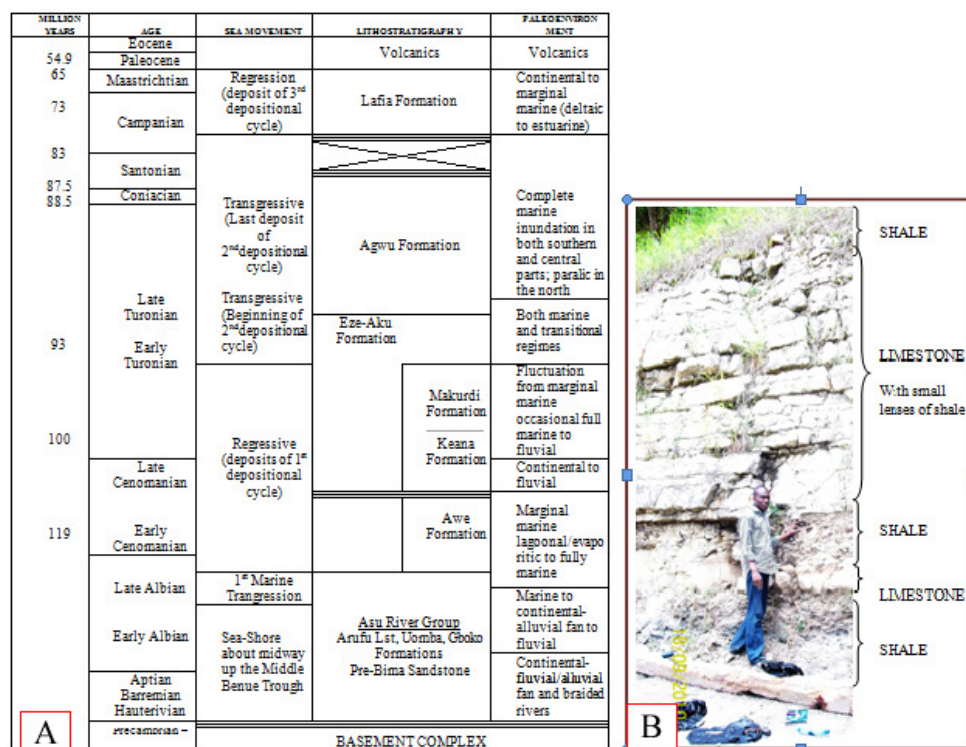


Fig. 3A: Cretaceous paleoenvironments and lithostratigraphy of the Middle Benue Trough. B: A photograph of shale beds rhythmically alternating with the Limestone beds at Benue Cement Quarry, Tse-kucha; Benue State. (Scale: Geologist=1.77m tall)



Fig. 4: Photograph of Features collected from Limestone-Shale sequence of Gboko Formation

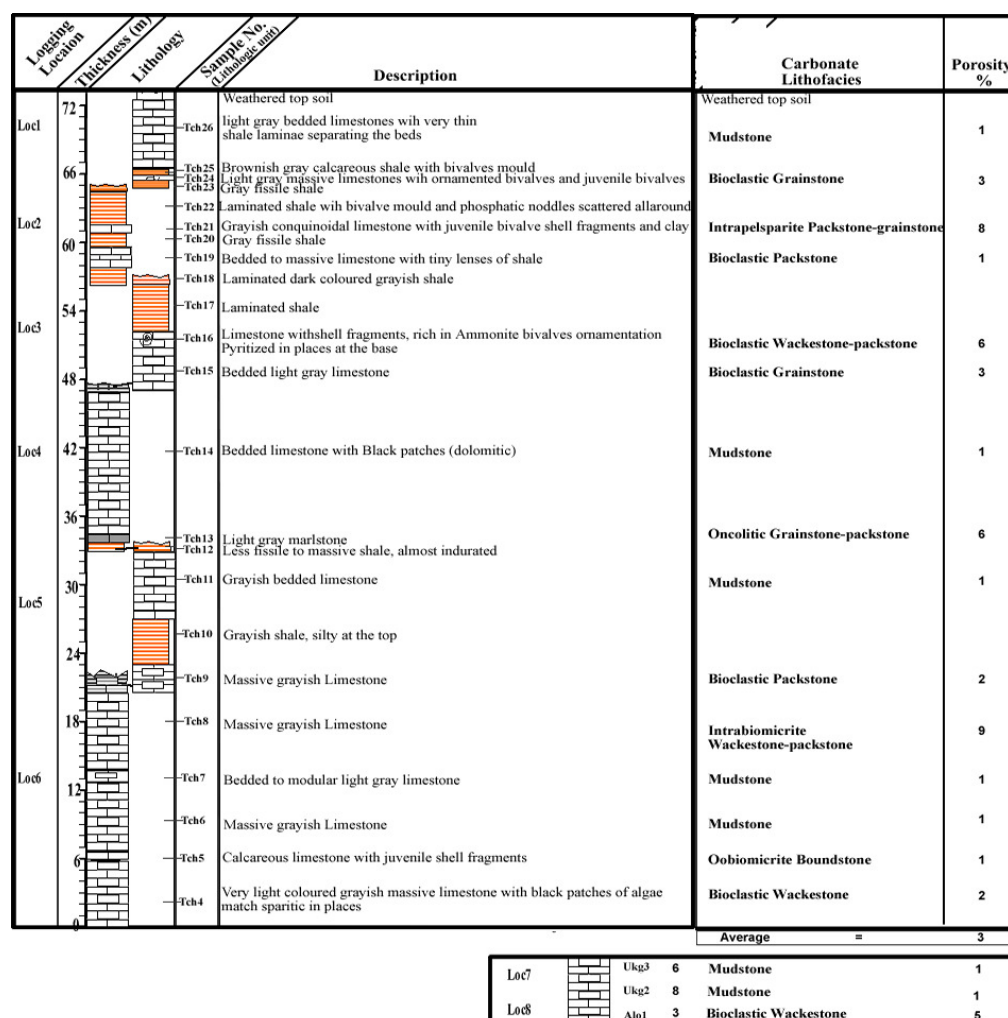


Fig. 5: The Lithostratigraphic Section of Gboko Formation logged at Benue Cement Company Quarry, Tse-kucha.

The lithostratigraphic section of Gboko Formation logged at Benue Cement Company Quarry, Tse-kucha is presented in Fig.5. The carbonates were described and grouped using Folks [16] classification table (based on composition) and Dunham [13] classification table as modified by Embry and Klovan [15] (based on depositional texture). Texturally, the limestones ranges from grainstones to mudstones and the allochems include gastropod, coralline algae, pelecypods, foraminifera, brachiopods, echinoid fragments and other skeletal debris. Such an assemblage points to a shallow marine environment [5]. The presence of oncolitic grainstones points to a moderately high-energy areas in very shallow waters [1].

The prevalence of micrite which is uniformly recrystallised to drusy cement and burrows created by worms, are common evidence of a shallow intertidal environment characterized by low energy [42]. The abundance of lime mud in the groundmass combined with a shallow marine fauna, gastropods and coated grains indicating mild protection and occasional tidal energy; suggest that these facies formed in a protected shallow marine inner shelf setting [35]. The bioclastic packstone-wackestones which show high diversity and abundance of

micro and macrofauna were probably formed in the shallow open marine environment with moderate circulation and agitation [39], [30]. The bioclastic wackestones are characteristics of shoreward deposit of subtidal restricted lagoon and shoals. The bioclastic grains are those derived from carbonate secreting organisms living in the subsurface area. The bioclastic packstone and intrapelsparite packstone-grainstone microfacies with some coated and abraded broken fragments of bioclasts resemble deposits in an area textural inversion, where dominant particles from the high energy environment have moved down local slopes to low energy setting [42], [1]. The bioclastic grainstone are common in intertidal zone of shallow marine water.

3.2. Paleoecology and Distribution of the Foraminiferal Fauna

The summary of the foraminiferal biostratigraphic studies is presented in table1. The studied sediments yielded few foraminifera species. Fossils were only recorded at particular intervals while others were completely barren of fossils. Some of the foraminifera species recovered (Fig.7) from the sediments were used based on their abundance occurrence, well preserved state in marine and brackish water, their stratigraphic relationship with the environment they live in, and similarity between biofacies of tertiary and recent.

Ammobaculites- This genus covers almost all ecological niches in modern seas [10]. They are infaunal deposit feeders. The organism lives in muddy sediments of brackish to normal marine salinity in marsh to upper bathyal environments [24], [18]. *Ammobaculites* are tolerant to low oxygen level. *A.corprolithiformis* *Ammobaculites* sp. and *Ammobaculites benuensis* were found in the studied section.

Ammotium- This is an infaunal deposit feeder, restricted to shallow brackish water of tidal marshes, brackish lagoons and estuaries and enclosed brackish shelf seas [24]. *Ammotium nwalium*, *Ammotium* sp. and *Ammotium nkalagum* were found in the studied section.

Gavelinella: - This epifaunal genus may be allocated to dysoxic environments. It is an active deposit feeder that tolerates low oxygen level. The only specie found in the sections of the Gboko Formation that was studied is *Gavelinella* sp.

Anomalina: - These species are infaunal deoposit feeders. They are decretive mud dwellers living in marine shelf seas [24]. This genus tolerates low oxygen levels. The only specie found in the studied sections of the Gboko Formation is *Anomalina plummerae*.

Miliammia: - This is an infaunal deposit feeder dwelling in muddy and silty sediments [24]. The species occurs in a very wide range of environments from brackish water to hypersaline marshes down to upper bathyal [18]. The only specie found in the studied sections of the Gboko Formation is *Miliammia pindigensis*.

Reophax: - This genus is commonly found in mud and sands of lagoons, shelves and bathyal regions [10]. It may occur in brackish lagoon and estuaries [8] and mostly in infaunal deposit feeder. The only specie found in the studied sections of the Gboko Formation was *Reophax guineana*.

Fursenkoina: - This genus is infaunal deposit feeder thriving in muddy sediments under marine conditions, in lagoons, shelf seas and upper bathyal realm [18]. The only specie found in the sections of the Gboko formation that was studied is *Fursenkoina dibollensis*.

Lenticulina: - Ramanathan and Kumaran [34] described these species from the Lower Cretaceous subsurface sediments in Calabar flank, Nigeria. Schiebnerova [37] also

described and illustrated it to be from Aptian to Albian interval of the Indian Ocean. Only a solitary specimen was recovered i.e. *Lenticulina taylorensis*.

Heterohelix: - This genus is a shallow water fauna (0-50m); epipelagic. It is Planktic specie that shows a wide variation in trochoidity. It ranges from Upper Albian to Maastrichtian. The species found in the section of the Gboko Formation that was studied are *Heterohelix moremani*: - It has been used to date rocks of Cenomanian age in the Gulf Coast of United State and Brazil. *Heterohelix reussi* recorded it first appearances in early Turonian. Biostratigraphic record from Texas, Arkasas, Mississippi, Bohemia, Mexico and Egypt shows that *Heterohelix reussi* rages from Turonian to Maastrichtian [11].

Hedbergella: - This genus is a shallow water fauna (0-50m); epipelagic. It is of late Aptian to early Albian in age. Rugosity is a preservational artifact of hedbergellids of this age, although Leckie [22] has argued against widespread poor preservation as the principal cause for the marked decline in planktonic foraminiferal diversity during latest Aptian-early Albian time. The only specie found in the studied sections of the Gboko Formation is *Hedbergella sp.*

Ostracods: - Ostracods is found from the Cambrian to recent. They have been particularly useful for the biozonation of marine strata on a local or regional scale, and they are invaluable indicators of paleo-environments because of their widespread occurrence, small size, easily-preserved generally-moulded calcified bivalve carapaces, and the valves are a commonly found microfossil.

Gastropod: - are found worldwide, in marine, freshwater, and terrestrial environments. They are numerous with low species diversity. Most gastropods are benthic, some are crawlers. The fossil history of this class goes all the way back to the Late Cambrian.

Echinoid remains: - Echinoderms are found at every ocean depth, from the intertidal zone to the abyssal zone. They are wholly marine organisms (echinoids, sea urchins, crinoids), they occupy reefs and associated environments, whereas crinoids are in deeper waters and not significant as carbonate producers. The echinoderms are important geologically, as their ossified skeletons are major contributors to many limestone formations, and can provide valuable clues as to the geological environment.

3.3. Paleoenvironment Interpretation of the Limestone-Shale Sequences of Gboko Formation

The paleoenvironment and probable age of the samples is summarized and presented in table2. The criteria considered when assigning environment include Species diversity, Planktic foraminiferal count, Foraminiferal population and Planktonic Benthonic ratio.

The recovered foraminifera include both the planktonic and benthonic forms (Table1). In term of abundance, the foraminiferal recovered could be described as rare to moderate with low species diversity. High dominance and low diversity is characteristic of nearshore-shallow water marine environments. The benthonic forms were dominant and dwarfed, while the planktonic forms were relatively scanty. The benthonic is predominantly composed of agglutinated taxa (48%) with very few calcareous taxa (1%) and planktonic taxa (3%). Ostracod, echinoid remains, scaphopod and gastropod are the other microfauna (48%) recorded (Table1). The assemblages differ from normal marine which consist predominantly of calcareous species. Funas consisting dominantly of agglutinated forms are attributed to brackish environments or to stagnant conditions [25]. The relative abundance of the Foraminiferal suborders was also considered because of low diversity of species. This was by a triangular plot of Textulariina, Milioliina, and Rotaliina abundance which show the fields

303 marine environments as reported by Murray [24]. From the triangular plot (Fig.8) it is evident
304 that the sediments were deposited on hyposaline lagoons.

305
306 Reliable paleoecological interpretations of past environment with regard to paleobathymetry,
307 paleosalinity, or paleo-oxygenation can be made with the aid of benthonic foraminifers, at
308 least as far back as the Cretaceous [38], [24]. This method was used based on successes
309 recorded by previous workers. Benthic foraminifera are generally mostly affected by
310 ecological conditions of their environment and they thus react appropriately to various
311 environmental settings [31]. The average percentages of the benthic foraminiferal
312 assemblages in the studied beds are made of two categories: the calcareous species have
313 average population density of 1% while the arenaceous benthics have average population
314 density of 48%. *Ammobaculites* (8%) and *Gavelinella* (29%) are the most frequent genera at
315 tse-kucha, while additional occurrences of *Ammotium* (5%), *Reophax* (2%) are indicative for
316 brackish conditions at tse-kucha (Table1). The planktics recovered are *Heterohelix* (2%) and
317 *Hedbergella* (2%) which indicates a shallow-water regime, probably between 0 to 50m
318 depth. The Heterohelids are age diagnostic according to Gebhardt (1997). *Heterolix*
319 *moremani* (Cushman) ranges from Albian to Turonian while *Heterohelix reussi* (Cushman)
320 ranges from Turonian to Campanian. Non-foraminiferal fossils referred as accessories were
321 identified and classified as ostracods, gastropod species and echinoid remains etc. The
322 gastropods are benthic forms which clearly reveal near shore confined shallow marine
323 environment. The distributions of the accessories are given as 32%, 13%, and 3%
324 respectively. The calculated average percentage of planktic foraminiferal assemblages in
325 the studied beds is 3%, benthonic is 50% while that of the accessories is 48% (Table1).

326
327 The predominant factor that controls the distribution of foraminifers and other marine
328 microfossils is salinity [6]. The occurrence of a predominantly agglutinated foraminiferal
329 assemblage in the studied strata suggests the existence of a low salinity environment of
330 deposition for the sediments. In low salinity condition, shallow marine foraminiferal
331 assemblages are characterised by a low population with benthonic species dominating. This
332 is because of the intolerant nature of the planktonic species to wide salinity ranges,
333 especially to low salinity [12].

334
335 The planktonic forms were relatively scanty, which suggests that the environment was
336 unfavourable for their survival. Bernhard [7] categorizes oxygen levels as anoxic
337 ($<0.1\text{ml}/1\text{O}_2$), dysoxic ($0.1\text{-}0.5\text{ml}/1\text{O}_2$) and oxic ($>0.5\text{ml}/1\text{O}_2$). Anoxic bottom conditions are
338 characterized by the absence of calcareous benthonic foraminifers but the presence of
339 planktonic foraminifers [14], [21], [20]. Agglutinated benthonic foraminifers, however can
340 survive under dysoxic to anoxic conditions [40], [20]. Low-oxygen content may also create
341 difficulties in calcium carbonate secretion [33], [7] and therefore leaves agglutinated
342 foraminifers as the only survivors under strong oxygen deficiencies. The dominance of
343 agglutinated foraminifers and abundance of infaunal forms with some planktonic species
344 indicate oxygen depletion and are therefore interpreted to represent a dysoxic to suboxic
345 environments for the study area.

346
347 The small number of planktonic foraminifers relative to the benthonic forms in the limestone-
348 shale sequences of Gboko formation indicates deposition under shallow water marine
349 condition. A low percentage of planktonic foraminifers, a relatively low diversity of species
350 and a dominance of benthonic over planktonic forms are reasons to infer a shallow water
351 environment for the Gboko formation.

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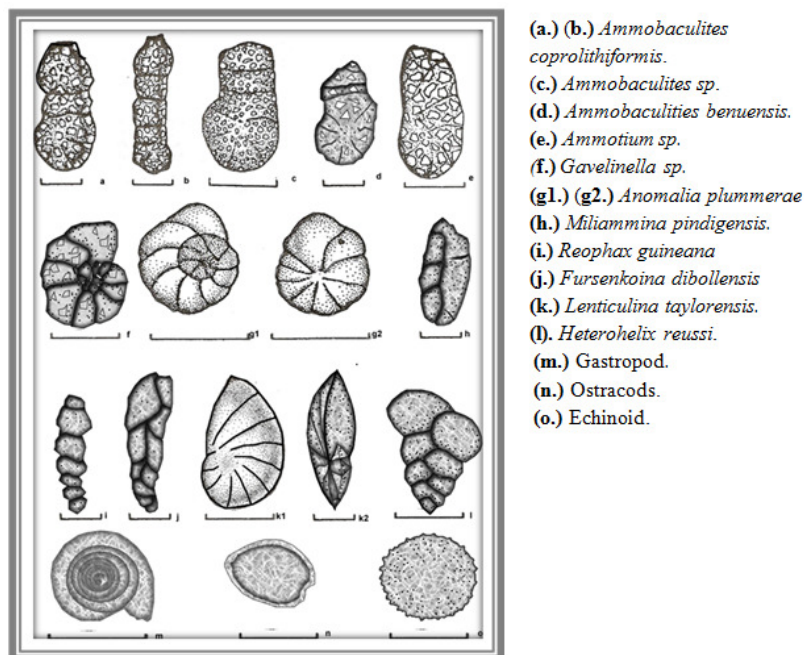


Fig. 7: Foraminifera species and other microfauna from Gboko Formation. (Bar length indicates 0.2mm). Courtesy: Global Energy Company Limited.

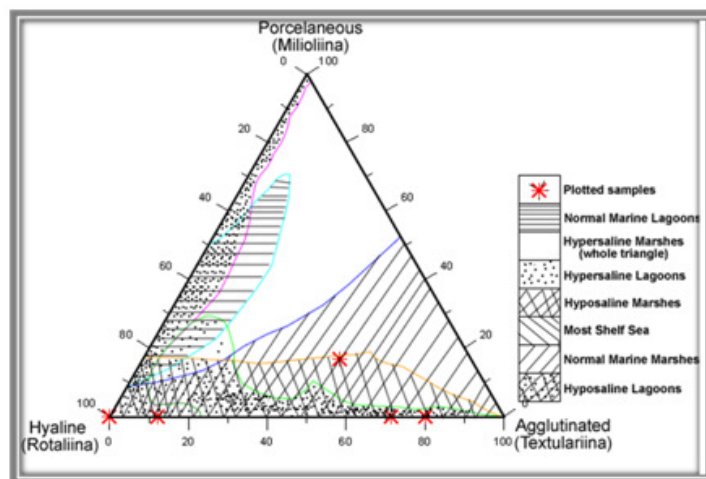


Fig. 8: Triangular diagram showing Depositional Environment (adapted from Murray, 1973)

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Table 1. A table summarizing the foraminifera recovered in Percent Genera

SAMPLE	Benthonic							Planktonic		Other		
	Arenaceous (Agglutinated)							calc		Microfauna		
	48%							1%	3%	48%		
	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>	<i>Ammonia</i>
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Tch26	-	-	-	-	-	-	-	-	-	-	-	-
Tch25	13	0	0	0	0	6	0	6	6	25	38	0
Tch24	0	0	0	0	0	0	0	0	0	100	0	0
Tch23	-	-	-	-	-	-	-	-	-	-	-	-
Tch22	0	43	0	29	14	14	0	0	0	0	0	0
Tch21	0	0	0	0	0	0	0	0	0	82	4	14
Tch20	-	-	-	-	-	-	-	-	-	-	-	-
Tch19	-	-	-	-	-	-	-	-	-	-	-	-
Tch18	50	0	0	0	0	33	0	0	17	0	0	0
Tch17	5	7	85	0	0	0	0	2	0	0	0	0
Tch16	0	0	0	0	0	0	0	0	0	36	64	0
Tch15	0	0	0	0	0	0	0	0	0	100	0	0
Tch14	-	-	-	-	-	-	-	-	-	-	-	-
Tch13	-	-	-	-	-	-	-	-	-	-	-	-
Tch12	0	0	100	0	0	0	0	0	0	0	0	0
Tch11	-	-	-	-	-	-	-	-	-	-	-	-
Tch10	43	14	14	0	0	0	0	0	0	14	14	0
Tch9	0	0	0	0	0	0	0	0	0	100	0	0
Tch8	-	-	-	-	-	-	-	-	-	-	-	-
Tch7	-	-	-	-	-	-	-	-	-	-	-	-
Tch6	-	-	-	-	-	-	-	-	-	-	-	-
Tch5	-	-	-	-	-	-	-	-	-	-	-	-
Tch4	-	-	-	-	-	-	-	-	-	-	-	-
Tch3	-	-	-	-	-	-	-	-	-	-	-	-
Tch2	0	0	0	0	0	0	0	0	0	100	0	0
Tch1	-	-	-	-	-	-	-	-	-	-	-	-
Total Percent	8	5	29	2	1	2	2	1	2	32	13	3

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Table 2. A table summarizing the Paleoenvironment and probable age of the Limestone-Shale bed

SAMPLE	PALEOENVIRONMENT OF DEPOSITION	PROBABLE AGE	COMMENT
Tch 26			
Tch 25	Marginal/Shallow marine	Upper Cretaceous	Foraminifera common
Tch 24	Fluvial/Marginal Marine	Non Diagnostic	No Foram, Ostracod present
Tch 23	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 22	Marginal/Shallow marine	Upper Cretaceous	Rare foraminifera
Tch 21			no Foram, Microfauna represented by echinoid remains, Ostracods and gastropod
Tch 20	Shallow Marine	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 19	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 18	Marginal/Shallow marine	Upper Cretaceous	Rare foraminifera
Tch 17	Shallow Marine	Upper Cretaceous	fairly abundant foraminifera
Tch 16	Fluvial/Marginal Marine	Non Diagnostic	Microfauna represented by gastropod and ostracod
Tch 15	Fluvial/Marginal Marine	Non Diagnostic	Ostracod only
Tch 14	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 13	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 12	Shallow Marine	Non Diagnostic	Rare foraminifera
Tch 11	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 10	Shallow Marine	Non Diagnostic	few foraminifera
Tch 9	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 8	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 7	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 6	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 5	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
Tch 4	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
UKG 3	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils
UKG 2	Fluvial/Marginal Marine	Non Diagnostic	Ostracod only
ALO 1	Continental	Non Diagnostic	Barren of Foraminifera and other microfossils

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4. CONCLUSION

This Gboko Formation lithounits comprises study has attempted to analyze the biostratigraphy of Limestone and Shale sequences in Gboko Formation; Middle Benue Trough, Nigeria. Shale and limestone were the major lithologies of the Formation that were critically assessed.

The limestone beds are light to dark grey, thin to massive, wavy laminated, and stylolitized. The shale beds are generally dark-grey, laminated and fossiliferous. Ammonites, pelecypods and molluscs are abundant. Carbonaceous detritus, glauconite and detrital pyrite occur in various forms both in the limestone and shale beds. However the sharpness of the lithological boundaries, presence of carbonate-filled burrows in some of the shale beds and the perfect horizontality of the strata suggest origin by primary sedimentation.

The biostratigraphy study confirmed that all the samples are Cretaceous in age and that they were derived from a mixture of terrestrial and marine biota deposited under anoxic/dyoxic condition. The studied sediments are generally low in fauna population and diversity. A good number of the samples are barren of foraminifera and other microfauna. Some of the foraminifera species recovered from the sediments include include Ammobaculites coprolithiforms, Ammotium sp, Gvulinella sp, Anomalina, Miammia, Reophax guineana, Fursenkoina dibollensis, Lenticulina taylorensis, Heterohelix and Hedbergella species. Ostracods, echinoid remains, scaphopods, and gastropods are the other microfauna recorded. The dominant arenaceous benthic foraminifera and the smooth ostracods suggest a mainly shallow marginal marine brackish water environment with an increase in water depth represented by horizons with planktonic foraminifera.

The presence of abundant lime mud supported carbonate rock types, glauconites, oncolites, corals, few monotonous species of bioclasts, limited benthic foraminifera and ostracods (population and diversity) and almost complete absence of planktonic foraminifera suggest a shallow marine shelf lagoonal depositional environment. Sea level fluctuation, probably due to intermittent subsidence was responsible for the alteration of shale and limestone in the formation.

The Integration of interpretation from the lithologic and biostratigraphic data suggests that the sedimentary sequence was deposited in a shallow marine, shelf lagoonal environment.

COMPETING INTERESTS

Declaration of competing interest should be placed here. All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding. If no such declaration has been made by the authors, SDI reserves to assume and write this sentence: "Authors have declared that no competing interests exist."

AUTHORS' CONTRIBUTIONS

Authors may use the following wordings for this section: " 'Author A' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the

manuscript. 'Author B' and 'Author C' managed the analyses of the study. 'Author C' managed the literature searches..... All authors read and approved the final manuscript."

CONSENT (WHERE EVER APPLICABLE)

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