

CAMPANO-MAASTRICHTIAN FORAMINIFERAL STRATIGRAPHY AND PALEOENVIRONMENT OF FIKA SHALE, BORNU BASIN, NORTHEASTERN NIGERIA

Fadiya¹, S. L. and Adebambo, B. A.¹

¹Department of Geology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

*Corresponding author's e-mail: slfadiya@oauife.edu.ng; fadiyalawrence@yahoo.co.uk

Telephone: (+234- 80333-20230; 234-80278-36738)

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ABSTRACT

The foraminiferal stratigraphy and paleoenvironment of the Fika Shale, Bornu Basin had been studied from the Kasade-1, Kinasa-1 and Mbeji-1 wells. Foraminifera were picked from washed samples and studied under the reflected light microscope. The well sections yielded fairly abundant but less diverse assemblage of foraminifera which consisted principally of the agglutinated family Lituolidae (*Ammobaculites*, *Haplophragmoides* and *Ammotium*) and the planktic assemblage represented by the Heterohelicids group (*Heterobelix*, *Pseudotextularia* and *Guembelitra*). The absence of calcareous benthics in the studied sections of the three wells had been attributed to high anoxia resulting from increased organic matter flux to the basin. Foraminifera distribution pattern of the well sections allowed the delineation of three informal zones - *Heterobelix globulosa*/*Pseudotextularia elegans*, *Heterobelix navaroensis* and *Ammobaculites* spp. zones based on the First Appearance Datum (FAD), Last Appearance Datum (LAD) and the relative abundances of the nominate taxa. The well section had been dated Campanian to Maastrichtian based on the presence of *Pseudotextularian elegans*, *Heterobelix globulosa* and *Heterobelix navaroensis*. The bulk of the studied sections with Heterohelicids which were the only planktic species recorded in the study were characteristic of shallow, inner neritic epiceric seas. A transitional (lagoonal and estuarine) environment had been inferred for the part of the sequences with the dominant occurrence of agglutinated benthic foraminiferal species (*Ammobaculites*, *Haplophragmoides* and *Ammotium*) which were typical of brackish water environment.

Keywords: Foraminifera, Stratigraphy, Campanian, Maastrichtian, Fika, Paleoenvironment, Heterohelicids.

INTRODUCTION

The growing quest for hydrocarbon in the Bornu Basin has continued to attract the attention of researchers to the basin in recent times. Various studies had been carried out in the area of Geophysics, Sedimentology, Geochemistry and Stratigraphy. Age, biozonation and paleoenvironmental interpretation are key in determining the crucial factors of source, seal, trap and reservoir which are required in the petroleum systems for hydrocarbon accumulation. In addition, sequence stratigraphic studies require age, paleobathymetric data, and fossil abundance and diversity patterns for the characterization of system tracts and these are adequately supplied by biostratigraphy. There is also an increasing need for biozonation scheme which can be used to compliment seismic data acquired within the basin. A local biozonation scheme is vital in the correlation of strata within a basin. Published works on the biostratigraphy of the Bornu Basin are very rare. Few publications however exist on the paleontology of some

formations in the basin (Adegoke *et al.*, 1978, 1986; Dike, 1993; Hamza, 2001; Hamza *et al.*, 2002, 2011).

Biostratigraphic data has been actively employed in oil exploration and exploitation activities in the Niger Delta which is the most prolific basin in Nigeria. There is no doubt that this geologic subdiscipline will also contribute immensely to exploration work in this frontier basin, when integrated with other geologic subdisciplines.

Geology and Stratigraphy of the Bornu Basin

The Bornu Basin (Fig. 1) is part of the Western Central African Rift System (WCAS) that formed in response to the tectonic separation of the African crustal blocks in the Cretaceous (Genik, 1992). The basin is a broad sediment-filled depression with a cumulative sediment thickness exceeding 3600 meters. The stratigraphic interpretation of the Bornu Basin has been based by earlier workers on extrapolation from adjoining Chad and Upper Benue Basins, seismic sections

and more recently, seismic and well cuttings. Many of these workers (Carter *et al.*, 1963; Avbovbo *et al.*, 1986; Okosun, 1995; Zaborski *et al.*, 1997) have shown that the stratigraphy of the basin is composed of Albian to Turonian continental Bima Sandstone, overlain by Turonian estuarine and deltaic Gongila Formation, followed by the Turonian to Maastrichtian marine Fika Shale.

Overlying the Fika Shale is the Maastrichtian Gombe Sandstone. The Gombe Sandstone is in turn overlain successively by the continental Paleocene Kerri-Kerri Formation and the Pleistocene Chad Formation. An unconformity separates the Gombe Sandstone from the Kerri-Kerri Formation and the Kerri-Kerri and Chad Formations are in turn separated from one

another by another unconformity (Carter *et al.*, 1963; Okosun, 1995; Hamza, 1995; Zaborski *et al.*, 1997). The hydrocarbon potentials of the Bornu Basin have been evaluated by workers like Petters and Ekweozor (1982), Olugbemiro (1997), Dike and Obaje (2002), Boboye and Abimbola (2009), and Johnson *et al.* (2014). Some of these authors concluded that the Fika Shale Formation within the basin is a good source rock which has not reached the “oil window”. Petters and Ekweozor (1982) however noted that surficial areas of the Fika Shale might have matured owing to the intrusion of basaltic rocks onto its horizons. The igneous intrusives could have caused a remigration or outright degradation of hydrocarbon pools to gas, carbon or graphitic residue (Goni and Zarma, 2015).

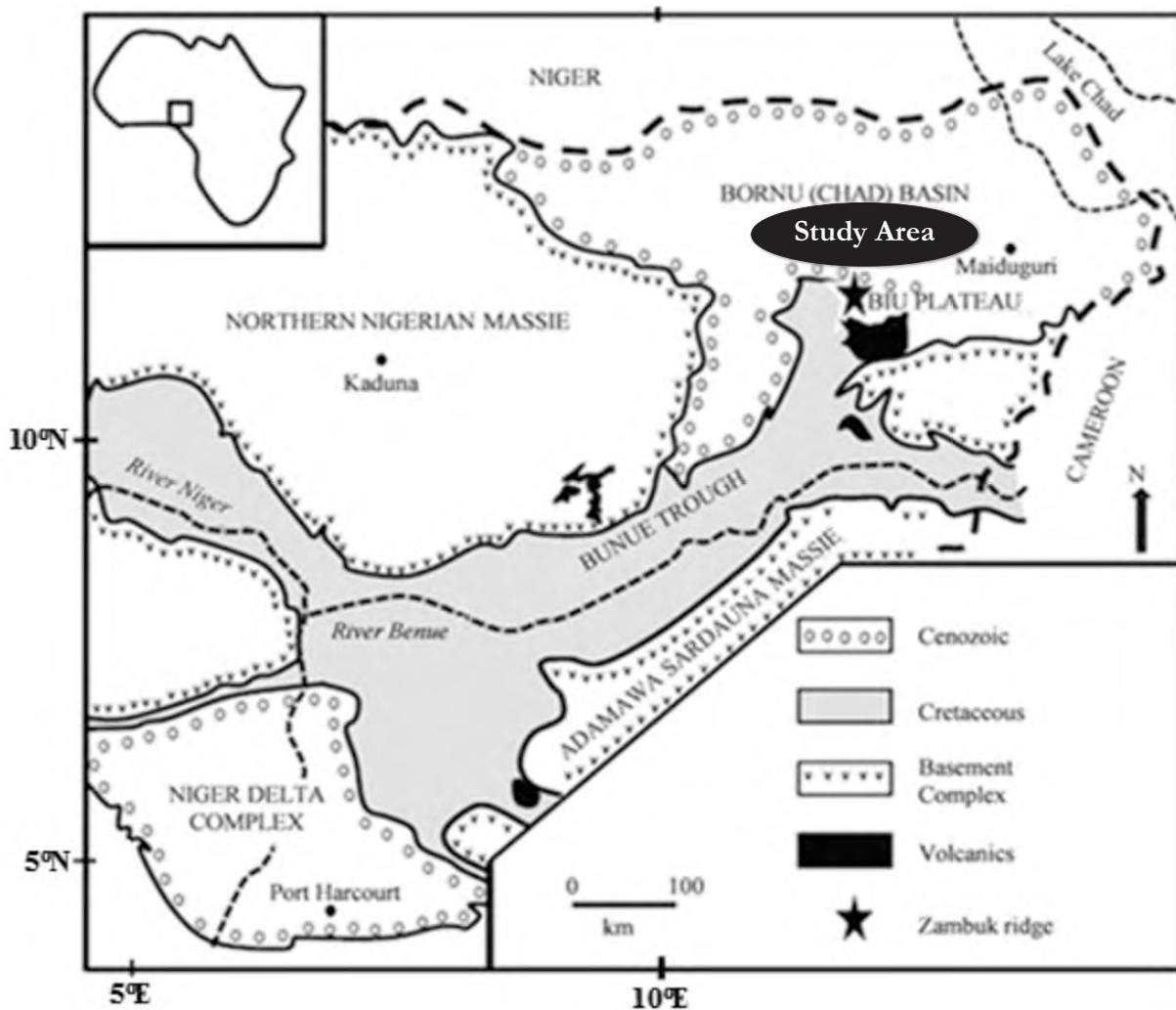


Fig. 1: Map of Nigeria Showing the Bornu Basin and the Study Area (Modified from Guiraud, 1990)

MATERIALS AND METHOD

Ditch-cutting samples obtained from three exploration wells (Kasade-1, Kinasa-1 and Mbeji-1) drilled within the Bornu Basin in the Northeastern Nigeria were made available by the Nigerian Petroleum Development Company (NPDC) for the study. Twenty-three (23) ditch cutting samples from interval 1015 – 1565 m of Kasade-1 well, thirty-five (35) from interval 920 – 1775 m of Kinasa-1 well and fifty-four (54) from interval 1690 – 3710 m of Mbeji-1 well were prepared and analysed for their foraminiferal content. The conventional foraminiferal sample processing technique was employed. Twenty grams (20 g) of each dried sample were weighed into labeled aluminum plates. Ten centiliters of kerosene were added to each sample and allowed to soak for about twenty minutes to allow water molecules to penetrate the samples, thus aiding the disaggregation of the samples. The disaggregated samples were subsequently washed through a 63 µm sieve under a jet of water until samples were freed of mud. The resultant residues were oven-dried at 50 – 70°C for about thirty minutes. The residue were then separated into coarse, medium and fine fractions using a combined set of 1 mm and 250 µm sieves coupled to a bottom pan. Foraminifera species were picked from the fractions into slides (cellules) using size-00 fine pointed brush under a stereoscopic reflected light binocular microscope. The picked specimens were glued into the cellules with the aid of Tragacanth adhesive to secure them. Foraminifera species were identified with the aid of the stereo-binocular microscope at X40 magnification using relevant published bibliographic references (Caron, 1985; Petters, 1982). Photomicrographs of identified specimens were made using the Scanning Electron Microscope. The species names and total counts were recorded in the analysis sheets while foraminifera with non distinguishable features due to either deformation or fragmentation were recorded as indeterminate species. Foraminifera taxa ranges were plotted using the Stratabug biostratigraphic software (version 1.8) in order to determine the relative abundances and distribution of species. Stratigraphic ranges of the foraminifera species were compared with established ranges which have been related to standard chronostratigraphic divisions of the geologic time scale.

RESULT AND DISCUSSION

Biostratigraphic results revealed a fairly abundant

but less diverse assemblage of foraminifera within the studied sections of the three wells. Fifteen (15) foraminifera species comprising of five (5) planktics and ten (10) agglutinated benthics were recovered from the analyzed section of the Kasade-1 well. The Kinasa-1 well section yielded eighteen (18) foraminifera species with five (5) planktics and thirteen (13) agglutinated forms. Similarly, sixteen (16) foraminifera species were recovered from the studied section of the Mbeji-1 well; seven (7) of which were planktics while the remaining nine (9) were agglutinated forms. The uppermost interval 1690 – 2765 m of Mbeji-1 well was devoid of planktic species despite the common occurrence of the agglutinated counterparts. The three wells lacked calcareous benthic species altogether.

The foraminiferal assemblage recovered in the three (3) well sections was dominated by the agglutinated family - Lituolidae and the planktic - Heterohelicidae with *Ammobaculites* and *Heterohelix* being the most abundant. Agglutinated species recovered from the wells included, *Ammobaculites coprolithiformis* (Plate 1, Fig. 9), *Ammobaculites benuensis* (Petters), *Ammobaculites bauchensis* (Petters) (Plate 1, Fig. 10), *Ammobaculites jessensis* (Petters) (Plate 1, Fig. 11), *Ammobaculites* spp., *Haplophragmoides bauchensis* (Petters) (Plate 1, Fig. 10), *Haplophragmoides talokaensis* (Petters), *Haplophragmoides* spp., *Ammotium nkalagun* (Petters) (Plate 1, Fig. 1), *Ammotium* spp., *Milliammina* sp., *Trochammina* sp., and *Spiroplectammina hausorium* (Petters).

Planktic foraminifera species recorded from the studied section of the wells consisted of *Heterohelix globulosa* (Ehrenberg) (Plate 1, Fig. 12), *Heterohelix navaroensis* (Loeblich) (Plate 1, Fig. 13), *Heterohelix* spp., *Guembelitra cretacea* (Cushman) and *Pseudotextularia elegans* (Rzehak) (Plate 1, Fig. 14). Figures 2, 3 and 4 shows the distribution of the foraminifera species recorded in the study while Plate 1 shows the scanning electron microphotographs of index foraminifera species employed in zonation and paleoenvironmental deductions.

Age of the Fika Shale

The studied section of the Kasade-1, Kinasa-1 and Mbeji-1 wells have been dated Campanian to Maastrichtian age (Upper Cretaceous) based on the occurrence of characteristic age diagnostic planktic foraminifera species. These include *Heterohelix globulosa*, *Heterohelix navaroensis*, *Pseudotextularia elegans* and *Guembelitra cretacea*. Supporting this age is the

occurrence of agglutinated foraminifera which has been found to characterize the Campano-Maastrichtian age in some Nigerian sedimentary basins: *Ammobaculites coprolithiformis*, *Ammobaculites*

bennensis, *Ammobaculites bauchensis*, *Ammobaculites jessensis*, *Haplophragmoides bauchensis*, *Haplophragmoides talokaensis*, and *Ammotium nkalagun* (Petters, 1979, 1982).

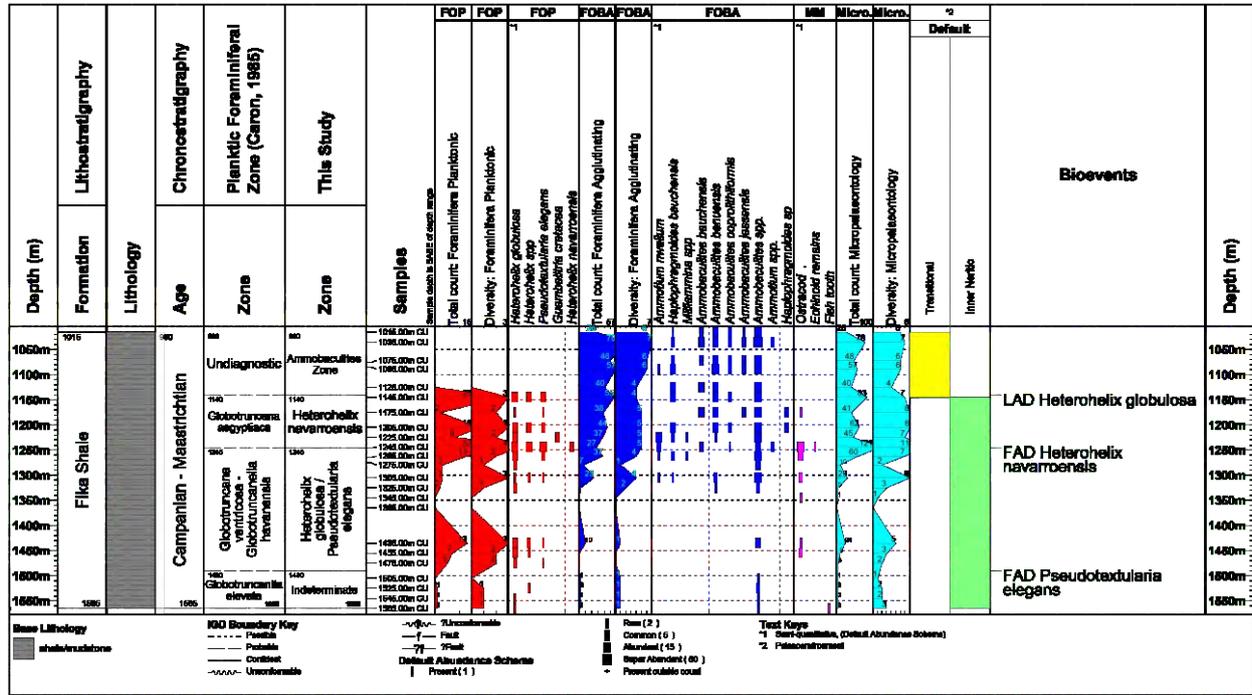


Figure 2: Stratigraphic Distribution of Foraminifera Species Recovered from Kasade-1 Well

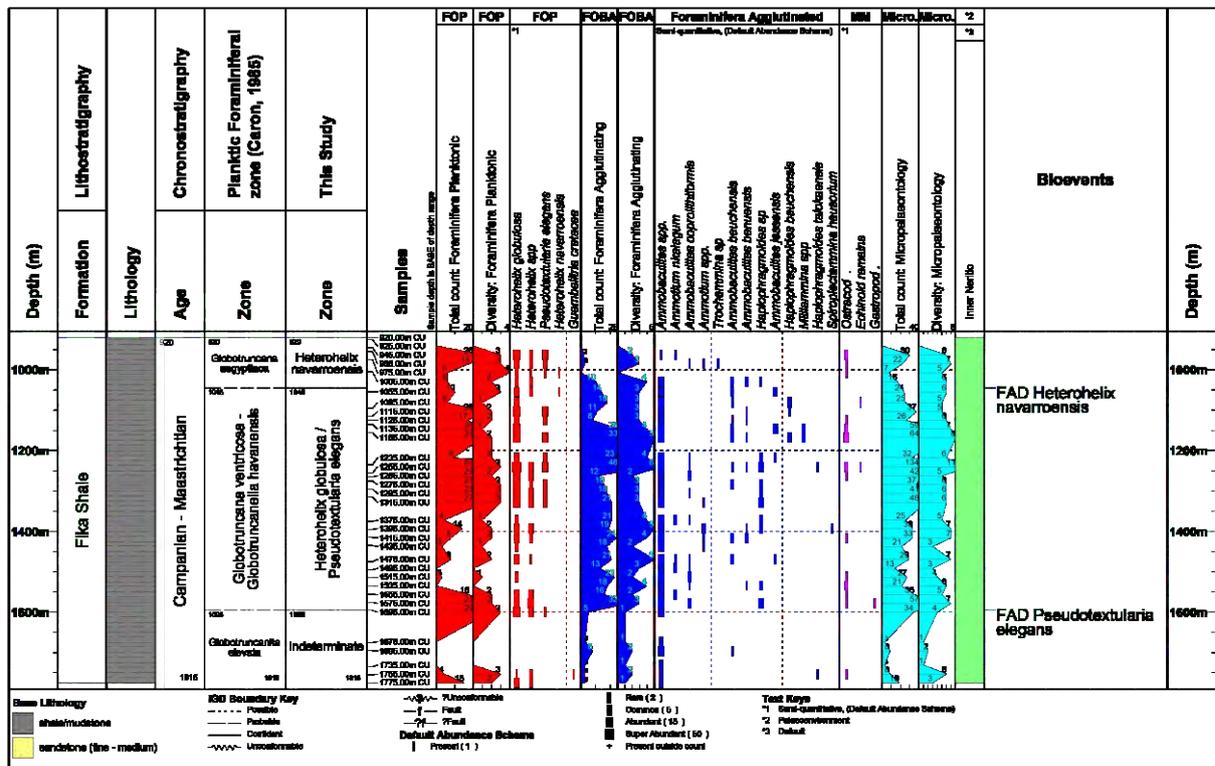


Figure 3: Stratigraphic Distribution of Foraminifera Species Recovered from Kinasa-1 Well

which was also used in this study. On the contrary eighteen (18) foraminifera species with five (5) planktics and thirteen (13) agglutinated forms were recovered from the Kinasa-1 well in this study. The recovery of characteristic planktic foraminifera (*Heterohelix globulosa*, *Heterohelix navarroensis*, *Pseudotextularia elegans* and *Guembelitra cretacea*) of the Campanian to Maastrichtian age has helped to refine the age from the Turonian - Maastrichtian earlier assigned from the long ranging, facie constrained benthic foraminiferal species. In addition, the established correlation of the planktic assemblages in this work to the Campanian – Maastrichtian *Globotruncana aegyptica*, *Globotruncana ventricosa*, *Globotruncanita calcarata*, *Globotruncanella havanensis* and *Globotruncanita elevata* zones of Caron (1985) confirmed that the Fika Shale is not older than the Campanian age.

Foraminifera Zonation

Three informal zones have been delineated within the studied section of the Fika shales in Kasade-1, Kinasa-1 and Mbeji-1 wells on the basis of the observed assemblages as well as the occurrence of some diagnostic species. The three delineated zones are the *Heterohelix globulosa*/*Pseudotextularia elegans*, *Heterohelix navarroensis* and *Ammobaculites* zones. The relatively low diversity of foraminifera in the studied section of the three wells precludes a refined zonal subdivision of the wells sections. A correlation of the delineated zones was made to the Caron (1985) Cretaceous planktic foraminiferal zones. The delineated zones are also shown in Figures 2, 3, and 4 and discussed as follows:

***Heterohelix globulosa* /*Pseudotextularia elegans* Zone**

This zone has been recognized within intervals 1245 – 1490 m in Kasade-1 well, 1045 – 1595 m in the Kinasa-1 well, and 3315 – 3710 m in the Mbeji-1 well. The base of the zone is marked by the First Appearance Datum (FAD) of *Pseudotextularia elegans* at depths 1490 m and 1595 m in the Kasade-1 and Kinasa-1 wells respectively. The base of the zone is believed to be deeper than the last analysed sample at 3710 m in the Mbeji-1 well. The FAD of *Heterohelix navarroensis* marks the top of the zone and this is found at depths 1245 m in Kasade-1, 1045 m in Kinasa-1 and 3315 m in the Mbeji-1 wells. This zone correlates with the

Globotruncana ventricosa, *Globotruncanita calcarata* and *Globotruncanella havanensis* zones of Caron (1985). These zones have been identified within the Middle Campanian – Early Maastrichtian age. The bioevents used by Caron (1985) were not recorded in the Bornu Basin probably due to harsh environmental conditions prevalent in the basin during the Campano-Maastrichtian times. However, the First Appearance Datum (FAD) of *Pseudotextularia elegans* and the FAD of *Heterohelix navarroensis* coincide with the base of *Globotruncana ventricosa* and the top of the *Globotruncanella havanensis* zones of Caron (1985) respectively. Some other authors (e.g. Nederbragt, 1991; Keller *et al.*, 1995) placed the FAD of *Pseudotextularia elegans* at the base of *Globotruncanella havanensis* zone. The nominate taxa - *Pseudotextularia elegans* and *Heterohelix globulosa* show common occurrences within this zone.

***Heterohelix navarroensis* Zone**

This zone has been recognized within interval 1140 – 1245 m in Kasade-1, 920 – 1045 m in Kinasa-1 and 2805 – 3315 m in the Mbeji-1 well. The base of the zone is delineated by the First Appearance Datum of *Heterohelix navarroensis* at depths 1245 m in Kasade-1, 1045 m in Kinasa-1 and 3315 m in Mbeji-1 wells respectively. Likewise, the zonal top is marked by the Last Appearance Datum (LAD) of *Heterohelix globulosa* at depths 1140 m in Kasade-1, 920 m in Kinasa-1 and 2805 m in the Mbeji-1 wells. However, the top of the zone may be shallower than the first analysed sample at 920 m depth in the Kinasa-1 well. The First Appearance Datum of *Heterohelix navarroensis* and the Last Appearance Datum (LAD) of *Heterohelix globulosa* coincide respectively with the base and top of *Globotruncana aegyptiaca* zone of Caron (1985), Premoli Silva and Verga (2004). However, Keller *et al.* (1995) subdivided the *Globotruncana aegyptiaca* zone of the previous authors into *Rugoglobigerina hexacamerata* and *Globotruncana aegyptiaca* zones. Nederbragt (1991) combined the *Globotruncana aegyptiaca* and *Globotruncanella havanensis* zones of Caron (1985) and designated it *Globotruncanella havanensis* zone. Again, the bioevents which these authors used in marking this zone were not recovered in the wells studied due to the suggested unfavourable condition believed to exist within the Borno Basin in the Campano-Maastrichtian times. The

Heterobelix navarroensis zone is characterized by relatively abundant heterohelicids; *Heterobelix globulosa*, *Heterobelix navarroensis*, *Heterobelix* spp., *Guembelitra cretacea* and *Pseudotextularia elegans*.

Ammobaculites spp. Zone

This Late Maastrichtian zone represents the interval between the upper limit of planktic foraminifera occurrence and the first analysed sample in the Kasade-1 and Mbeji-1 wells. The zone is believed to be present in the shallower section of the Kinasa-1 well which was not analysed in this work.

The interval is devoid of planktic species but characterized by relatively abundant agglutinated taxa including *Ammotium nvalium*, *Haplophragmoides bauchensis*, *Ammobaculites bauchensis*, *A. benuensis*, *A. coprolithiformis*, *A. jessensis* and some species of *Ammobaculites*, *Ammotium* and *Haplophragmoides*. These species have been recorded by Petters (1979) in the Upper Cretaceous of Benue Trough and Bornu Basin. Therefore, a probable Late Maastrichtian age is assigned to this interval based on its microfauna assemblage and stratigraphic position above the positively identified Early Maastrichtian *Heterobelix navarroensis* zone.

Paleoenvironmental Deductions

A relatively high abundance of the family Lituolidae represented by the genera *Haplophragmoides*, *Ammobaculites* and *Ammotium* was recorded in this study. Murray (1991) noted that high percentages of these genera indicate brackish water. Low diversities in foraminiferal assemblages (as recorded in the studied wells) are also characteristic of modern lagoons and estuaries (Murray, 1991). Whightman, (1990) noted that the foraminifera of the Cretaceous sediments of the Lusitanian Basin, Portugal which consist dominantly of *Ammobaculites*, *Haplophragmoides* and *Trochammina* indicates estuarine and marsh depositional environments.

The occurrence of *Ammobaculites* in certain Cretaceous sediments shows its tolerance to low oxygen levels (Koutsoukos *et al.* 1990). *Ammotium* - an infaunal deposit feeder is today restricted to shallow, brackish waters of tidal marshes, brackish lagoons and estuaries, and enclosed brackish shelf seas (Murray, 1991; Bronnimann *et al.* 1992) and

this is represented in the studied sections by *Ammotium nkalagum* and *A. nvalium*. This scenario played out at the uppermost interval 1015 – 1125 m of the Kasade-1 well and interval 1690 – 2765 m of Mbeji-1 well. The absence of planktic foraminiferal species within these intervals confirms a transitional, brackish water, marsh – lagoonal environment for the interval.

The genus *Haplophragmoides* is commonly found in muddy to sandy substrates in environments ranging from marsh hyposaline lagoons and estuaries to bathyal (Murray, 1991; Bronnimann *et al.* 1992). The planktic foraminiferal population of the studied wells belongs to the non-keeled morphogroup of predominantly globigeriniform heterohelicids. Non-keeled planktic foraminifera are believed to be shallow water dwellers (Jarvis *et al.* 1988). Heterohelicids are among the few foraminiferal genera to first colonise new seaways and the last survivors, being able to withstand harsh conditions such as shallow and/or dysoxic waters (Eicher and Worstell, 1970). The relatively low planktic abundance and diversity led credence to the inferred shallow water environment of deposition for the Fika Shale. Supporting evidence of this interpretation is the presence of shallow marine ammonites (Reyment, 1965) and fish bones by Carter *et al.* (1963).

The complete absence of calcareous benthics in the entire section is indicative of anoxia as oxygen is required in the reaction leading to formation of the calcium carbonate tests. This scenario was earlier observed in the ostracod distribution within the formation by Okosun (1992).

CONCLUSIONS

The studied sections of Kasade-1, Kinasa-1, and Mbeji-1 wells yielded relatively abundant but less diverse assemblages of foraminiferal species. Three informal zones: *Heterobelix globulosa* / *Pseudotextularia elegans* and *Heterobelix navarroensis* and *Ammobaculites* zones were erected for the studied section of the three wells based on the observed foraminifera assemblages. The zones erected in this work correlate to the Campanian – Maastrichtian section of the Cretaceous Planktic Foraminifera zonation scheme of Caron (1985). The *Heterobelix globulosa* / *Pseudotextularia elegans* zone correlates to the *Globotruncana ventricosa*,

Globotruncanita calcarata and *Globotruncanella havanensis* zone, while the *Heterobelix navarroensis* correlates to the *Globotruncana aegyptiaca* zone. The *Ammobaculites* zone (being a benthic foraminiferal zone) could not be directly correlated to established planktic foraminifera schemes. A strong correlation exists in the established zones across the three studied except the *Ammobaculites*

spp. zone which was not encountered in Kinasa-1 due to non availability of samples in the upper part of the well. The faunal of the wells indicate that the Campano-Maastrichtian rocks of the study area were deposited in environments ranging from transitional; marsh, lagoonal, estuarine to open marine, inner neritic settings.

PLATE 1

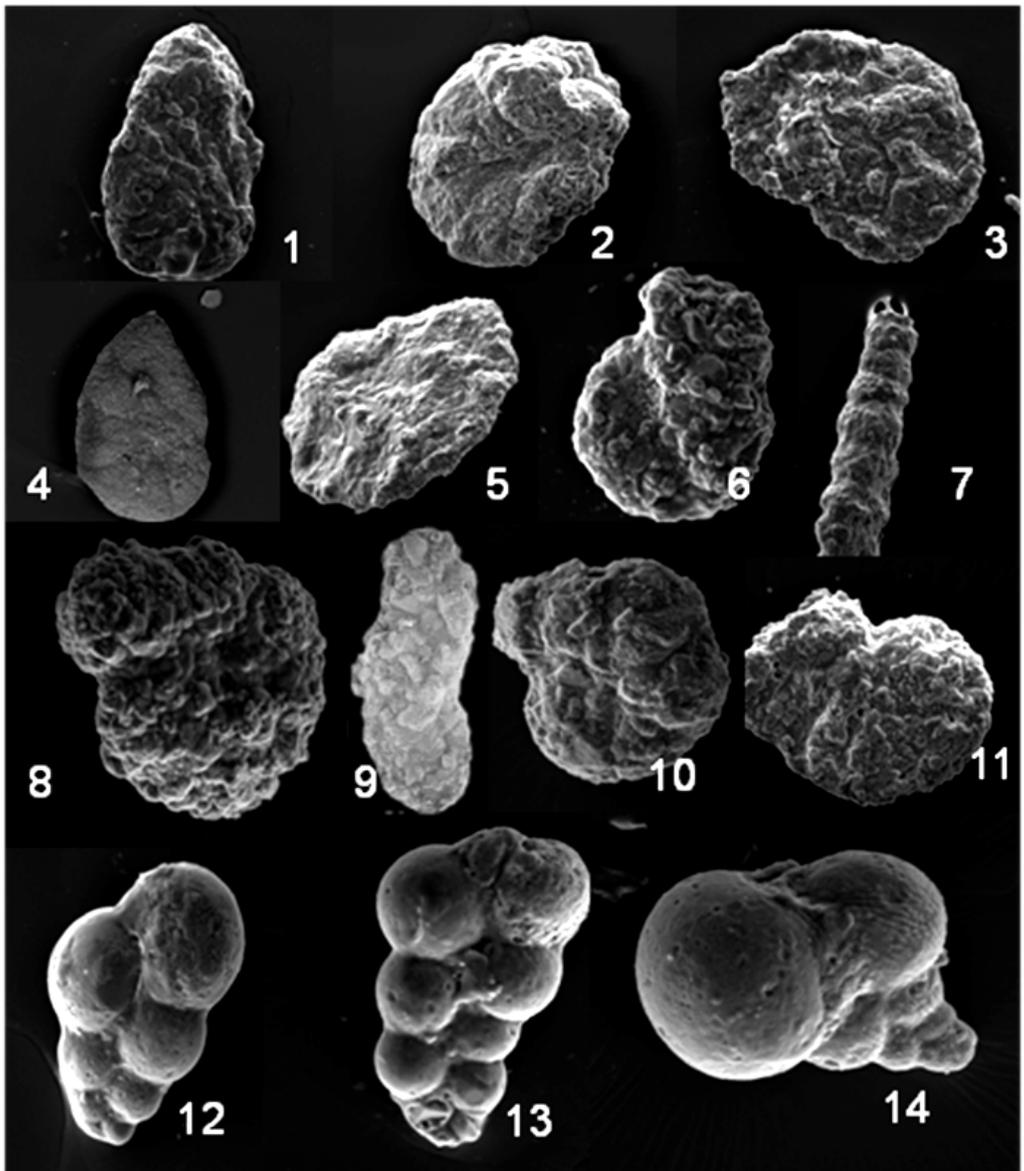


Plate 1. 1 *Ammotium nkalagum* (Petters), 2 *Haplobragmoides bauchensis* (Petters), 3 *Ammobaculites* sp., 4 *Ammotium nvalium* (Petters), 5 *Ammobaculites* sp., 6 *Ammobaculites benuensis* (Petters), 7 *Spiroplectammina baursorium* (Petters), 8 *Haplobragmoides* sp., 9 *Ammobaculites coprolithiformis*, 10 *Ammobaculites bauchensis* (Petters), 11 *Ammobaculites jessensis* (Petters), 12 *Heterobelix globulosa* (Ehrenberg), 13 *Heterobelix navarroensis* (Loeblich), 14 *Pseudotextularia elegans* (Rzehak).

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