RESEARCH ARTICLE

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Biostratigraphy and Palaeoecological Studies of the Late Cretaceous-Tertiary Sediments in the Dahomey Basin, Nigeria

Mariam B. Saadu, Ayoola Y. Jimoh, Olabisi A. Adekeye, and Taofeeq A. Issa

ABSTRACT

The Maastrichtian–Eocene sediments (mainly shales and limestones) penetrated by the Itori borehole and Ilaro boreholes in the Dahomey Basin were investigated for foraminiferal biostratigraphy and palaeoecological interpretation. These boreholes penetrated Araromi, Ewekoro, and Oshosun formations at varying depths. Selected shale sediments were subjected to foraminiferal analysis and many planktonic and benthic species of foraminifera (agglutinated and calcareous) were recovered from the Cretaceous interval of the penetrated boreholes. Twelve species of planktic foraminifera (*Globalomalina planocompressa, G. pseudomenardii, Globigerina inaequispira, Acarinina cf.coalingenis, Acarinina nitida, Chiloguembelina cretacea, chiloguembelina subtriangularis, Orthokasrstenia sp., Hedbergella holmdelensis, Globigerina sp., Globigerinelloids asperus, Morozovella formosa formosa)* and thirteen species of benthic i.e Bolivina *sp., B. Crassicostata, , E. africana, Eponides psuedoelevatus, Gavelinella cf. guineana, Gavelinella pachysuturalis, Haplophragmiodes sp., Lenticulina cyprina, L. inornata, L. olokuni, L. psuedomamilligera, L. taylorensis, Nonionella communis, N. spissa, N. panamensis, Orthokarstenia sp., Planulina oyae*) were identified. In general, benthic species of infauna deposit feeder and epifauna dominate the population. These species occupy a range of environments from dyoxic to anoxic, brackish water to marsh environment down to upper bathyal depth. Based on the abundant and stratigraphical distribution of the foraminiferal species, four biostratigraphic zones were recognized: *Afrobolivina afra* zone of late Maastrichtian, *Globigerina z*one of early Paleocene, *Globalomalina pseudomenardii z*one of late Paleocene and *Morozovella formosa formosa z*one of the early Eocene.

Keywords: Anoxic, Biostratigraphy, Dahomey, Globigerina.

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I. Introduction

The eastern part of the Dahomey basin in Nigeria has been attracting lots of geoscientific interest in the last decade. There is a lot of research work with respect to hydrocarbon potential assessment which has been well focused. However, there is limited information with respect to the biostratigraphy and paleoecology of shales in the borehole penetrating those formations.

It has been established by many authors that the stratigraphic buildup of a basin happens simultaneously with the accumulation of organic matter and bio-contents, especially in marine settings. This paper is aimed at evaluate the biostratigraphic zonation and foraminiferal paleoecology of benthic foraminifera species in shale sediments penetrated by Ilaro-24, 26, and, Itori boreholes.

The eastern Dahomey Basin falls in the Southwestern part of Nigeria (Fig. 1). It is a very extensive sedimentary Basin on the continental margin of the Gulf of Guinea. [1] suggested that it is a marginal pull-apart basin that extends from Southeastern Ghana through Togo and Benin Republic on the West side. The Okitipupa basement high/Benin hinge line separated the basin from the Niger Delta on the west side (Fig. 1) [2], [3]. According to [3] the tertiary sediments of the Dahomey basin thin out to the east and are partially cut off from the sediments of the Niger Delta basin against the Okitipupa basement ridge. There are different series of textures of sediments ranging from Cretaceous to recent [4], [5].

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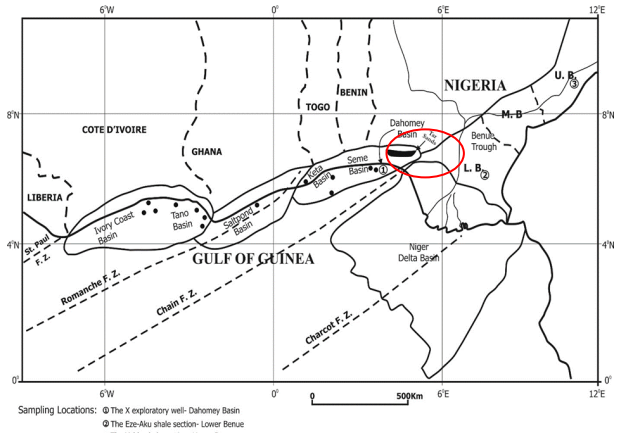


Fig. 1: Regional map of Dahomey Basin. Showing Ghana, Togo, and Benin republic (Modified from [10], [11]).
Study location:

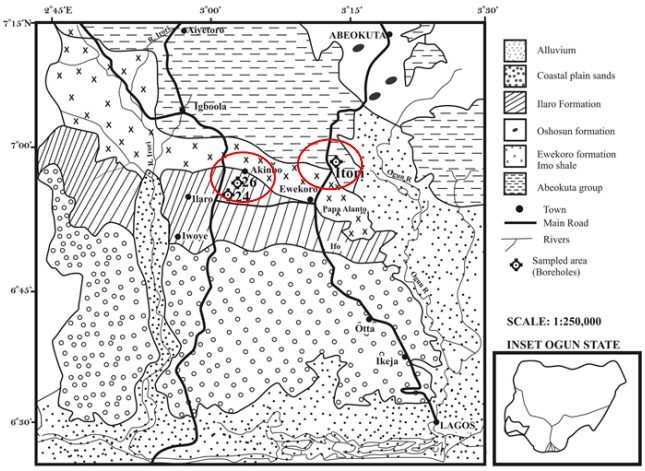


Fig. 2: Geological map of the Nigerian sector of the Dahomey basin showing the location of Itori, and Ilaro. Modified after [4].

AGE		FORMATION (Ako et al., 1980)	FORMATION (Omatsola and Adegoke, 1981)	LITHOLOGY
TERTIARY	EOCENE	ILARO FM	ILARO FM	SANDSTONE
		OSHOSUN FM	OSHOSUN FM	SHALE
		AKINBO FM	AKINBO FM	
	PALEOCENE	EWEKORO FM	EWEKORO FM	LIMESTONE
CRETACEOUS	MAASTRICHTIAN	ABEOKUTA FM	ARAROMI FM	SHALE
	TURONIAN		AFOWO FM	SANDSTONE AND SHALE
	BARREMIAN		ISE FM	SANDSTONE

Fig. 3: Generalized Stratigraphic setting of the Dahomey basin (SW, Nigeria) Adapted from [4].

Three different boreholes from this basin are being analyzed for their Biostratigraphy and palaeoecological characteristics. The boreholes are drilled in Itori and Ilaro town of Ogun state, southwestern Nigeria (Fig. 2). The origin of the basin is associated with subsidence, basement rifting, and fragmentation which led to the separation of African and South American land masses [6]. The stratigraphic setting of this basin has been discussed in detail in the earlier works of [7] – [9], [3]. Five lithostratigraphic sections were discovered from the Cretaceous to Tertiary ages, these include the Abeokuta Group, Ewekoro Formation, Oshosun Formation, and Ilaro Formation. (Fig. 3).

II. Materials and Methods

The method employed includes sample collection work and laboratory study. The sample materials for this work are drill cores sediments from shallow boreholes namely Ilaro boreholes 24, 26, and Itori borehole collected from Nigeria Geological Survey Agency (NGSA) Kaduna main office. The laboratory analysis carried out in this work involves foraminiferal analysis. The microfossil analysis was done at the Department of Geology and Mineral sciences laboratory, University of Ilorin. 30 selected shale sediments were subjected to digestion, sieve washing, and drying. About 200 g of shale samples were digested in 10 % hydrogen peroxide for 24 hours and washed over a 0.063 mm sieve, dried, and stored in a bottle. Foraminifera species were finally identified, picked, and classified under the microscope with the help of relevant literature. All these were done in the Geology laboratory of the University of Ilorin Nigeria. Photomicrographs of the identified foraminiferal species were taken by scanning electron microscope in the laboratory of the geology department at the University of Frankfurt, Germany.

III. Results And Discussion

A. Lithologic Description

The Itori Borehole reached a total depth of 165m with two lithologies, which include shale and limestone. (Fig. 6). The shale lithology is the oldest, greenish in color, indurated, and highly fossiliferous. Overlying the Shale lithology is the Ewekoro Limestone, which is calcareous, greenish in color, and highly fossiliferous. There is another occurrence of shale overlying the Limestone, it is also indurated but grayish in color. The shale samples contain both planktic and benthic foraminifera species such as lenticulina olokuni, Gavelinella pachysuturalis, and Nonionela panamensis to mention a few. Ilaro Borehole 24 has a depth of 160 m. Its section is divided into five Lithologic units. (Fig. 7). The uppermost part comprises the laterite, followed by, the upper shale lithology, mudstone, limestone, sandy clay, sandstone, and another series of mudstone then continues the lower shale. The Ilaro Borehole 26 has a total depth of 151 m. It consists of four lithologies comprising Sandstone, Shale, Mudstone, Claystone, and Laterite (Fig. 8).

B. Foraminiferal Study

Foraminifera belongs to the Kingdom Porifera and Phylum Sarcodina. It is essentially a microfauna that is very useful geologically to study biostratigraphy and paleoecology.

TABLE I: RELATIVE ABUNDANCE AND DISTRIBUTION OF FORAMINIFERA SPECIES IN ITORI WELL

Sample No	Planktic	*Globigerina sp.*	Benthic	*Afrobolivina afra*	*Eponides africana*	*Gavelinella c.f guineana*	*Gavelinella pachysuturallis*	*Lenticulina olokuni*	*Lenticulina pseudomamilliger us*	*Nonionella paramnesias*	*Nonionella spissa*	*Planulina oyae*	Total
ITB-41		–		9(9.1%)	–	–	38(38.3%)	–	20(20.2%)	16(16.2%)	–	16(16.2%)	99
ITB-44		–		12(57.1%)	–	–	–	6(28.6%)	3(14.3%)	–	–	–	21
ITB-46		–		–	–	–	–	9(40.9%)	9(40.9%)	2(9.1%)	–	2(9.1%)	22
ITB-48	–	–	–	–	–	–	–	1(33.3)	2(66.7%)	–	–	–	3
ITB-50		–		–	–	5(14.7%)	–	22(64.7%)	–	5(14.7%)	–	2.(5.9%)	34
ITB-52		12(32.4%)		–	–	–	–	–	10(27.1%)	–	3(8.1%)	12(32.4%)	37
ITB-54		–		–	12(11.3%)	10(9.4%)	–	52(49.1%)	28(26.4%)	–	–	4(3.7%)	106

Foraminifera has a wide range of other applications but for this study, its focus is to construct biostratigraphy of the Maastrichtian to Eocene sediments penetrated by boreholes under study. This is discussed in light of the various species of foraminifera recovered from the sediments.

C. Occurrence and Distribution

Benthic and Planktic foraminifera species were recovered in all the selected shale samples from the three different Boreholes (Fig. 4 and Fig. 5). The shale sediments of the Maastrichtian-Araromi Formation, penetrated by the Itori borehole are generally fossiliferous. The foraminifera tests occur as a replaced calcified shell. The species are generally well preserved. Table I shows the distribution of these species in the Itori borehole. The taxonomic classification of the foraminifera is based on external morphology and as well discussed by previous authors including [12] – [14].

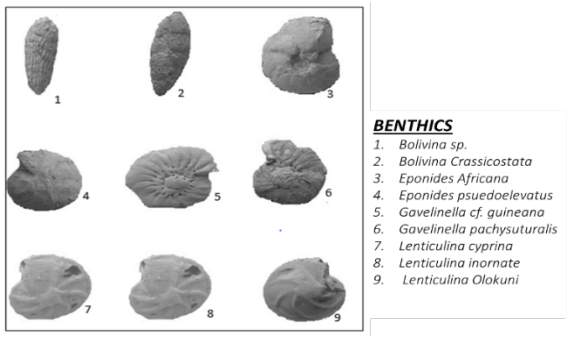


Fig. 4: Photomicrographs of Benthic foraminifera species recovered in the borehole.

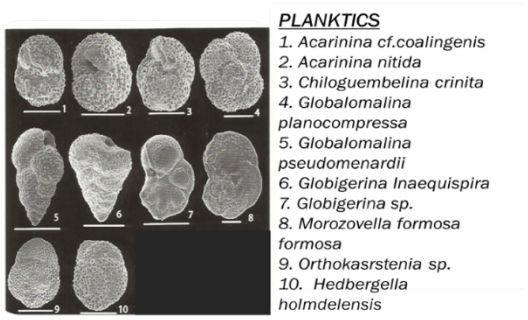


Fig. 5: Photomicrographs of Planktic foraminifera species recovered in the borehole.

The species of foraminifera include Globigerina sp., Eponides Africana, Gavelinella cf. guineana, Gavelinella pachysuturalis, Lenticulina Olokuni, Lenticulina psuedomamilligera, Nonionella communis, Nonionella Spissa, Nonionella panamensis, planulina oyae. In the Ilaro borehole 24 samples of the Oshosun Formation, both benthic and planktic foraminifera species were recovered (Table II).

The planktic foraminifera ranged from globular to ovate chambered species, although some exist as agglutinated specimens. The species recovered include: Globanomalina pseudomenardii, Globigerina sp., Globigerina Inaequispira Globgerinelloids asperus, Morozovella Formosa Formosa, Bolivina sp., Bolivina Crassicostata, Orthokarstenia sp., Lenticulina inornata, Lenticulina cyprina, Lenticulina taylorensis.

In the Ilaro borehole 26, the relative abundance of both planktic and benthic foraminifera species recovered are shown in Table III. The planktic species include Globalomalina archeocompressa, Globalomalina planocompressa, Globalomalina pseudomenardii, chiloguembelina cretacea, chiloguembelina subtriangularis, Hedbergella holmdelensis, Hedbergella monmouthensis while the benthic species are Eponides psuedoelevatus, Gavelinella pachysuturalis, Haplophragmiodes sp., Lenticulina olokuni, Lenticulina psuedomamilligerus.

D. Biostratigraphic Zonation

Several authors have published different papers on the aspect of the biostratigraphy of planktic foraminifera, this includes [15] – [22]. The foraminifera recovered from the study areas covering Maastrichtian to Early Eocene ages were compared with the works of these authors to establish biostratigraphic zones for the shale samples. Four different biostratigraphic zones were identified including Afrobolivina afra zone covering late Cretaceous, Globigerina zone also in the Late Paleocene, Globalomalina pseudomenardii zone, Late Paleocene and Morozovella Formosa Formosa zone covering the Early Eocene. A detailed description of these biozones is discussed below.

1) Afrobolivina afra Zone

The lower boundary of the Afrobolivina afra zone is marked by the first occurrence of Afrobolivina afra. (Fig. 6). It represents the oldest Maastrichtian zone recorded in the Itori well. The Afrobolivina afra is a marker species for Late Cretaceous sediment [21]. This zone occurs at a depth of about 143m in the Itori well. The species found in the Itori well are very small in size probably due to environmental conditions during their lifetime. The zone also consists of

other benthic foraminifera like; Gavelinella pachysuturalis, Lenticulina olokuni, Lenticulina psuedomamilligera, Nonionella communis, Nonionella panamensis, Planulina oyae. This zone is characterized by the mass extinction of Maastrichtian species such as Heterohelicids, Rugoglobigerinoides, Globigerinalloids, and other foraminifera associated with the Cretaceous [21].

1) Globigerina Zone

This zone is marked by the last occurrence of Globigerina sp. It occurs between the depth of 100 m – 120 m in the Ilaro borehole 24. (Fig. 7). It occurs in the upper Cretaceous. This foraminifera species is characterized by 3 or 4 chambers in the final whorl [23]. The species found include Globigerina Inaequispira and Globgerinelloids asperus.

1) Globalomalina pseudomenardii Zone

The Globalomalina pseudomenardii zone of [16], [22] is defined by the total range of Globalomalina pseudomenardii, the lower boundary is marked by the extinction of igorina pusilla pusilla and the upper boundary is defined based on the first occurrence of Morozovella velascoensis [21]. In the studied wells, the zone is marked by the last occurrence of Globalomalina pseudomenardii (Fig. 8). The first and the last occurrence occur in the late Paleocene. This zone is characterized by the abundance of Planktic foraminifera such as Globalomalina planocompressa, and Globigerina inaequispira.

2) Morozovella formosa formosa Zone

The zone is defined by the occurrence of the zonal maker Morozovella Formosa Formosa Zone [17]. This zone represents the youngest planktonic foraminifera zone in the studied wells. It can be found at the depth of about 110 m. (Fig. 7). This zone also depicts the boundary between Eocene and Paleocene. It has been assigned to the early Eocene age. The diagnostic planktonic foraminifera found in this zone includes m. Formosa Formosa [21].

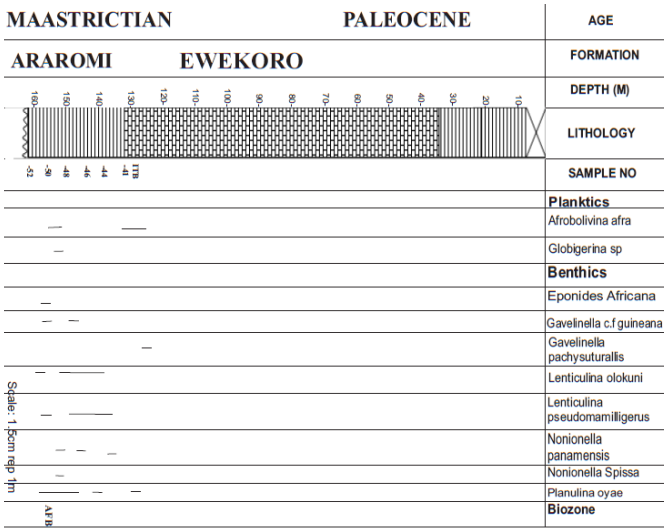


Fig. 6: Distribution of foraminifera species and biozones in the Itori borehole.

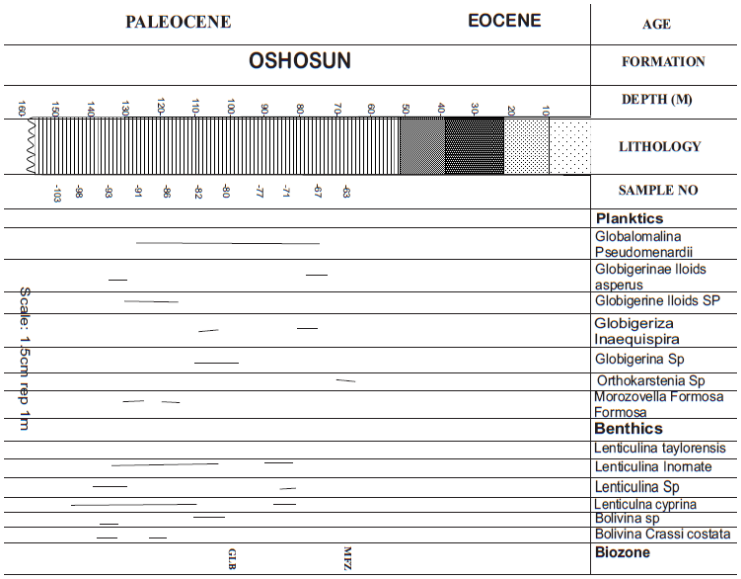


Fig. 7: Distribution of foraminifera species and biozones in the Ilaro borehole 24.

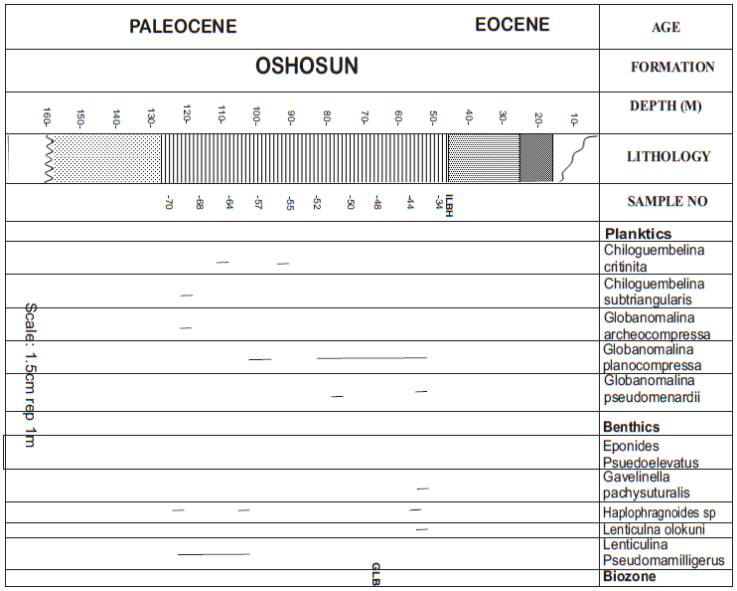


Fig. 8: Distribution of foraminifera species and biozones in the Ilaro borehole 26.

TABLE II: RELATIVE ABUNDANCE AND DISTRIBUTION OF FORAMINIFERA SPECIES IN ILARO 24 WELL

Sample No	Planktic	*Globanomalina pseudomenardii*	*Globgerinelloids asperus*	*Globgerinelloids sp.*	*Globigerina inaequispira*	*Globigerina sp.*	*Morozovella formosa formosa*	*Orthokarstenia sp.*	Benthic	*Gavelinella pachysuturalis*	*Lenticulina inornata*	*Lenticulina sp.*	*Lenticulina cyprina*	*Bolivina sp.*	*Bolivina crassicostata*	Total
ILB 24-71	–	–	–	–	–	–	–	–		44 (75.9%)	8 (13.8%)	6 (10.3%)	–	–	58	–
ILB 24-77	15 (50%)	–	–	–	–	–	–	–		5 (50.0%)	–	–	–	–	30	–
ILB 24-80	8 (5.9%)	85 (63.4%)	–	15 (11.2%)	–	26 (19.4%)	–	–		–	–	–	–	–	134	–
ILB 24-82	7 (77.8%)	–	–	–	–	–	–	–		2 (22.2%)	–	–	–	–	9	–
ILB 24-86	11 (5.1%)	–	–	41 (19.2%)	9 (4.2%)	–	–	–		45 (21.0%)	–	6 (2.8%)	102 (47.7%)	–	–	214
ILB 24-91	21 (18.9%)	–	–	–	39 (35.1%)	–	–	–		8 (34.2%)	–	13 (11.7%)	–	–	–	111
ILB 24-93	40 (16.2%)	–	9 (3.6%)	–	–	–	9(3.6%)			66 (26.7%)	24 (9.7%)	55 (22.6%)	–	44 (17.8%)	247	–
ILB 24-98	2 (5.1%)	–	2 (5.1%)	–	–	–	–	–		–	17 (43.5%)	10 (25.6%)	8 (20.5%)	–	39	–
ILB 24-103	–	–	9 (3.6%)	–	–	–	39(15.7%)			–	–	17 (69.5%)	–	28 (11.2%)	249	–
ILB 24-105	–	25 (12.8%)	–	–	–	–	79(40.5%)			–	–	85 (43.6%)	–	6 (3.1%)	195	–

TABLE III: RELATIVE ABUNDANCE AND DISTRIBUTION OF FORAMINIFERA SPECIES IN ILARO 26 WELL

Sample No	Planktic	*Chiloguembelina cretacea*	*Chiloguembelina subtriangularis*	*Globalomalina archeocompressa*	*Globalomalina planocompressa*	*Globalomalina pseudomenardii*	*Hedbergella holmdelensis*	*Hedbergella monmouthensis*	Benthic	*Eponides psuedoelevatus*	*Gavelinella pachysuturalis*	*Haplophragmiodes sp.*	*Lenticulina olokuni*	*Lenticulina psuedomamilligerus*	Total
ILB 26-34		–	–	–	–	–	–	–		6 (54.5%)	–	5 (45.5%)	–	–	11
ILB 26-44		–	–	–	1 (2.7%)	1 (2.7%)	–	–		–	19 (51.4%)	–	12 (32.4%)	14 (37.8%)	37
ILB 26-48		–	–	–	10 (76.9%)	–	–	–		–	–	–	3 (23.1%)	–	13
ILB 26-50		–	–	–	6 (4.8%)	–	–	–		–	–	–	120 (95.2%)	–	126
ILB 26-52	–	–	–	–	180 (44.4%)	–	–	23 (5.7%)	–	–	–	–	202 (49.9%)	–	405
ILB 26-55		–	–	–	89 (24.1%)	55 (14.9%)	–	–		–	–	–	225 (60.9%)	–	369
ILB 26-57		43 (24.4%)	–	–	–	–	22 (12.5%)	58 (32.7%)		–	–	–	53 (30.1%)	–	176
ILB 26-64		–	–	–	2 (100%)	–	–	–		–	–	–	–	–	2
ILB 26-68		–	–	–	82 (39.8%)	–	–			–	15 (7.3%)	–	109 (52.9%)	–	206
ILB 26-70	–	120 (74.5%)	–	–	–	–	–	6 (3.7%)	–	–	–	–	35 (21.7%)	–	161
ILB 26-72	–	–	102 (49.9%)	28 (11.5%)	–	–	–	–	–	–	60 (24.7%)	–	53 (21.8%)	–	243
ILB 26-79	–	–	–	–	–	–	16 (23.5%)	–	–	–	–	–	52 (76.5%)	–	68

3) Palaeoecological Interpretation

Benthic foraminifera has been used by several authors in the paleoecologic interpretations of past environments such as paleo-salinity, paleo-oxygenation, and paleo-bathymetry, the authors include [12], [13], [15], [20]. Interpretations have been made based on a comparison with modern environments and their faunas. The paleoecology of the genera present in the shale sediments in all the wells is discussed below:

- Ammobaculites is an infauna deposit feeder that lives in muddy sediments with brackish to normal-marine salinities from marsh to bathyal environments

[12]. They cover almost all ecological niches in modern seas [24].

- Bolivina belongs to the elongated flattened morpho group whose genera are adapted to anoxic environments. It is usually found in sediments that are muddy in an inner shelf to bathyal environments [12]. It is a detritivore organism and lives as infauna or epifaunal in marine salinities [13].
- Haplophragmoides is primarily a marine genus but has been reported from hyposaline lagoons and estuaries [13], [25]. They are infauna detritivore that is commonly found in muddy to sandy substrates in environments ranging from marsh to bathyal [12].
- Gavelinella sp. may be allocated to dyoxic environments [26]. It is an active deposit feeder that usually tolerates low oxygen levels [27]. This species follows a strong opportunistic life strategy and reacts quickly to sudden nutrients. The species recovered in the study area include Gavelinella pachysuturalis, Gavelinella guineana
- Nonionella sp. occurs in the inner shelf to upper bathyal depth with almost no tolerance against reduced salinity or oxygen deficiency [12],[13],[28]. It is an infauna, detritivore usually found in muddy marine water [12]. It is also associated with dyoxic conditions. The species recovered in the study area include Ninionella Communis, Ninionella Spissa, and Ninionella panamensis.
- Lenticulina sp. is commonly present in a non-anoxic environment. It prefers cool, marine conditions on the outer shelf to bathyal depths [13]. The species found include Lenticulina olokuni and Lenticulina Psuedomamilligerus.
- Planulina sp. is an infauna species, found in environments with increased oxygen content relating to higher water energy [19]. The only species found in the samples are in Itori, which is called Planilina Oyae.
- Eponides sp. is typical of colonizing muddy sediments of the inner shelf to bathyal environments. It is probably a detritivore and lives in infauna or epifaunal in marine salinities [13]. The species found in the sediments include Eponides Africana.

Conclusion

Three different wells covering Late Maastrichtian to Early Eocene were investigated for Paleoenvironment and Biostratigraphy. The total depth of these boreholes ranges from 151 m to 165 m. The wells consist of different lithologies such as Claystone, Mudstone, Siltstone, Sandstone, and Shale.

Microfossil analysis of the shale samples revealed both Planktic and Benthic foraminifera. In Itori well, the total of species recovered is 106, (12 Planktics and 94 Benthics). In Ilaro borehole 24, the total number of Planktics recovered was 1039, (500 Planktics and 539 Benthics) and the total number of species recovered from Ilaro borehole 26 was 1817 of which (844 planktic and 973 benthic) were recovered. The species recovered includes; *Globalomalina planocompressa, G. pseudomenardii, Globigerina Inaequispira, Acarinina cf.coalingenis, Acarinina nitida, Chiloguembelina cretacea, Chiloguembelina subtriangularis, Orthokasrstenia sp., Hedbergella holmdelensis, Globigerina sp., Globigerinelloids asperus, Morozovella formosa formosa, Bolivina sp., B. Crassicostata, E. Africana, Eponides psuedoelevatus, Gavelinella cf. guineana, Gavelinella pachysuturalis, Haplophragmiodes sp., Lenticulina cyprina, L. inornata, L. Olokuni, L. psuedomamilligera, L. taylorensis, Nonionella communis, N. Spissa, N. panamensis, Orthokarstenia sp., Planulina oyae*).

Four different biostratigraphic zones were discovered including *Afrobolivina afra* zone covering late Cretaceous, *Globigerina* Zone also covering the upper Cretaceous, *Globalomalina pseudomenardii* Zone of Late Paleocene, and *Morozovella formosa formosa Zone* of the Early Eocene. The Benthic foraminifera paleoecology reveals different organisms adapting to different environments ranging from dyoxic to anoxic environments, some are infauna deposit feeder that lives in muddy sediments with brackish to normal-marine salinities while some are epifauna in marine salinities.

Acknowledgment

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Conflict of Interest

The authors declare that there is no conflict of interest.

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