Earth Science Research; Vol. 3, No. 1; 2014
ISSN 1927-0542 E-ISSN 1927-0550
Published by Canadian Center of Science and Education

Ostracod, Diatom and Radiolarian Biostratigraphy of the Niger Delta, Nigeria

Edward A. Okosun[1] & Peter Osterloff[2]

[1] Department of Geology, Federal University of Technology, Minna, Nigeria

[2] UIG/T/DGX, Geological Services, SPDC, Warri, Nigeria

Correspondence: Edward A. Okosun, Department of Geology, Federal University of Technology, Minna, Niger State, 234, Nigeria. Tel: 234-803-254-4745. E-mail: eaokosun@yahoo.com

Received: November 6, 2013 Accepted: December 2, 2013 Online Published: December 31, 2013

doi:10.5539/esr.v3n1p72 URL: http://dx.doi.org/10.5539/esr.v3n1p72

Abstract

Ditch cuttings from seven wells and foraminiferal slides of three wells have been analyzed for diatoms, ostracods and radiolaria. The wells penetrated Eocene to Miocene strata in the Niger delta. A taxonomic study of the ostracod assemblages has been undertaken. The paleobiogeography of the ostracods indicates their affinity to the coeval assemblages from Sierra Leone, Benin Republic and Gabon. Paleoecological interpretations of the ostracod assemblages suggest inner to middle neritic depositional environments. Diatoms and radiolarians were identified, with the majority of them being placed in open nomenclature. This was a pilot study to determine the stratigraphical and paleoenvironmental potential of the three fossil groups in the Niger delta.

Keywords: microfossils, Niger Delta, biostratigraphy, paleobiogeography, paleoecology, paleoenvironment

1. Introduction

1.1 The Microfosils Group in This Study

Diatoms, ostracods and radiolaria (Figure 1) are microfossils which are usually recovered from the preparation of rock samples for the analysis of foraminifera. They are usually grouped as miscellaneous microfossils (MM) in the Shell Petroleum Development Company (SPDC) data-bases. Radiolarians and diatoms have siliceous skeletons and are of the size ranges of 30–200 μm and 0.5 μm –2 mm respectively. Ostracods on the other hand are small crustaceans composed of calcareous bivalve shells. Both diatoms and ostracods inhabit all aquatic environments while radiolarians are restricted to the marine realm.

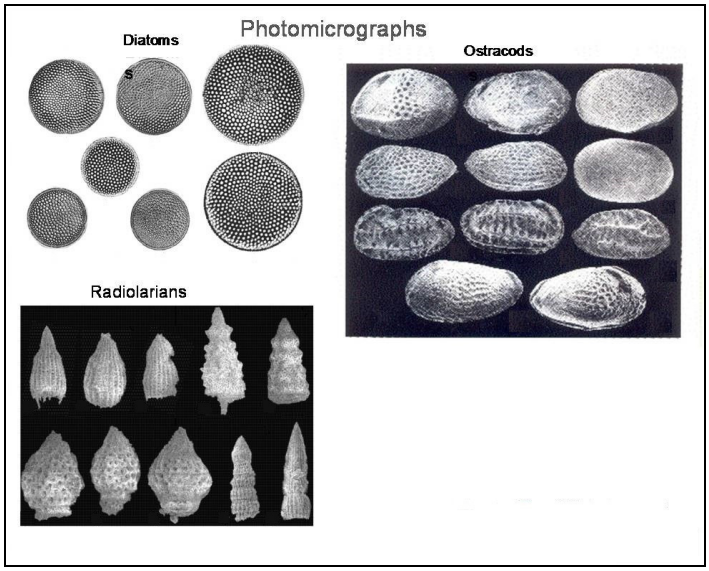

Figure 1. Photomicrographs of Diatoms, Ostracods and Radiolaria

1.2 Previous Work

Very limited published information is available on the three microfossil groups from the Niger Delta. Omatsola (1969) described three ostracod species from the basin while Jan du Chene et al. (1978) investigated the palynomorphs and ostracods of the Nsukwa-1 well. Okosun (1987, 2000) studied the ostracods of the Akata-1 well. Okosun and Petters (unpublished report) described some ostracods from both the Meren-1 and Opukeba-1 wells. Reyment (1963) carried out a taxonomic study of ostracods from the northern fringe of the Niger Delta. Ostracods, diatoms and radiolarians though occasionally recovered in microfossil sample preparations were usually grouped under miscellaneous without any detailed study and interpretations.

1.3 Aims and Objectives

The aims and objectives of this study were to document the biostratigraphy of the diatoms, ostracods and radiolaria from selected wells across the depobelts of the Niger Delta. It also includes biozonations and paleobiogeographic distribution of the fossils. The study was in essence a pilot study to determine the stratigraphic and palaeoenvironmental potential of the three microfossil groups.

2. Materials and Methods

The present study was based on the diatom, ostracod and radiolarian content of SPDC foraminiferal slides and ditch cuttings. The selection of the wells was guided by the recorded occurrences of the three microfossil groups in the SPDC StrataBugs database. Some of the microfossils were identified to the species level while others were only identified to the generic level (*Coscinodiscus* sp) and the rest of them as indeterminate in the database. The selected wells covered all the depobelts of the Niger Delta (Figure 2). Ostracod specimens from the Awaizombe-1, Akata-1, Imo River-8 and radiolaria from Ikono-1 wells were studied from the foraminiferal slides of these wells. Ditch cuttings were collected from Ihuo-1(59), Awoba-1(40), Alo-1(15), Bosi-6(20), KK-1(11) and Zarama-11(10) wells. The sampling intervals were not uniform because some well intervals were not available.

About 25 grammes of the samples were heated on a hot plate, allowed to cool and soaked in kerosene overnight. The kerosene was used to aid disaggregation of clays and shales. The samples were washed over a 45 µm sieve. An initial use of 63 micron sieve in the washing of samples did not yield diatom and radiolarians. The residues were dried and stored in well-labeled packets. The diatoms, ostracods and radiolarians were picked from the residues with the aid of a Wild Heerbrugg binocular microscope which has a maximum magnification of x 500. The taxonomy of the three microfossil groups was undertaken with references to several specialist publications. Details of these publications are listed under Taxonomic Remarks section.

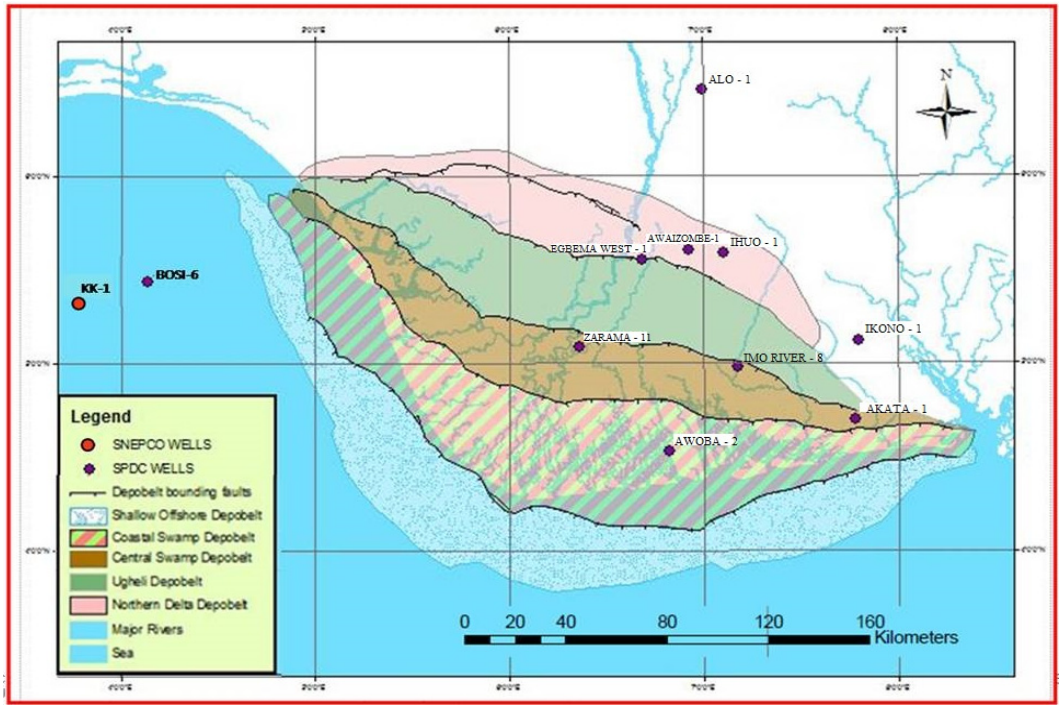

Figure 2. Map of Niger Delta showing the locations of the study wells

3. Results

3.1 Ostracod Biostratigraphy

Four of the studied wells namely Awaizombe-1, Imo River-8 and Akata-1 were fossiliferous in ostracods.

3.1.1 Awaizombe-1 Well

Forty-six (46) species belonging to twenty (20) genera were recorded from this well (Figure 3). The following species are dominant in the assemblages: *Cytherella* aff. *sylvesterbradleyi, Loxoconcha* aff. *kafountinensis, L. kafountinensis, Casamanacrai* cf. *lougaensis*, *Loxoconcha* aff. *lagosensis* and *Aglaiocypris schweyeri*.

Aglaiocypris schweyeri occurs in the well from 4240 ft to 7600 ft and the species displays morphological variations. The material presently referred to *Aglaiocypris* cf. *schweyeri* and *Aglaiocypris* aff. *schweyeri* may actually be conspecific with *Aglaiocypris schweyeri.* The morphological variation is probably a polymorphic trait in the species, it is anticipated that further detailed study of these species with the Scanning Electron Microscope (SEM) will clarify the taxonomy. The genus *Benisymmetricythere* which was first described from the Oligocene of the Benin Republic (Carbonnel et al., 1996) has its first reported occurrence in the Niger Delta from this study. The species has not been reported from pre-Oligocene strata.

The age of the studied interval is Eocene-Oligocene. The Eocene/Oligocene boundary is tentatively placed at 6750 ft in the well. This is the point of origination of the genus *Benisyymmetricythere* in the Awaizombe-1 well, thus the upper part of the well with *Benisyymmetricythere* species is of Oligocene age while the lower part is Eocene in age. This agrees with the F7200-F5700 age (Late Eocene-Early Miocene) obtained for the well based on benthic foraminifera.

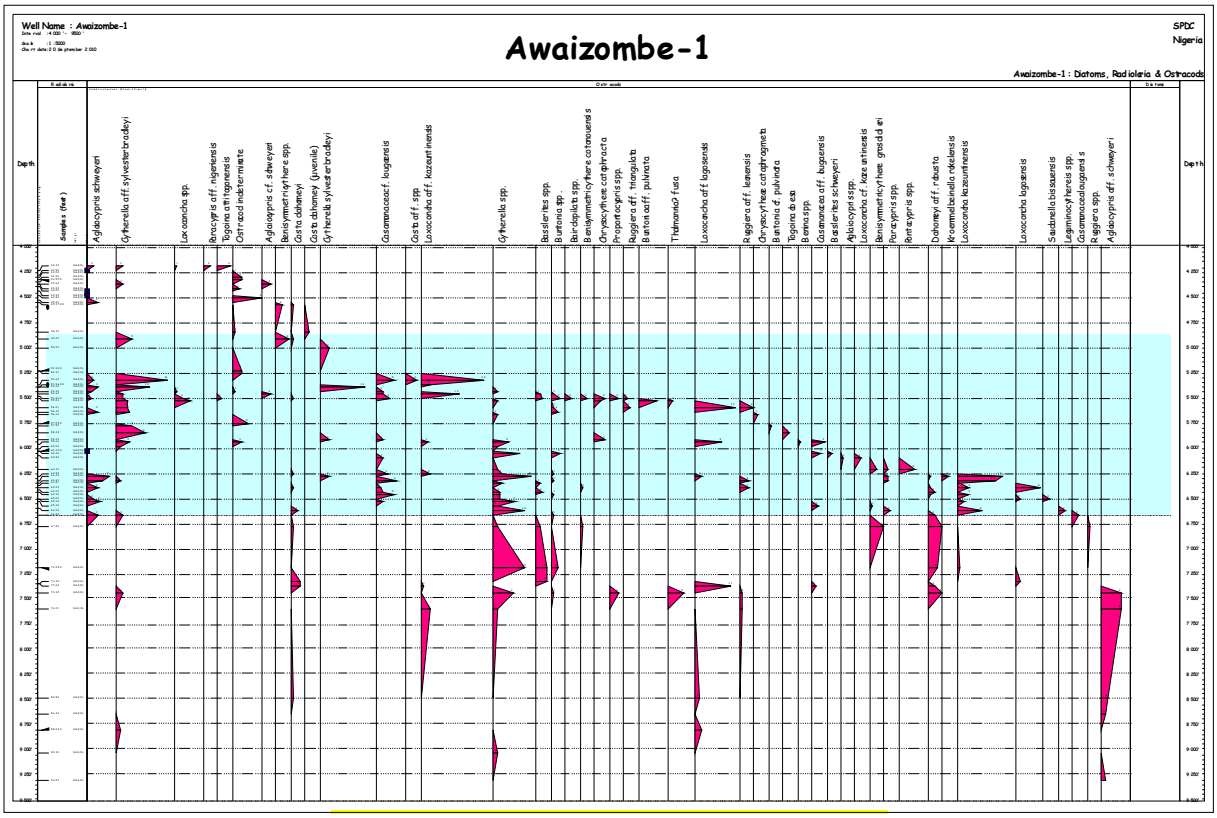

Figure 3. Distribution of ostracods in Awaizombe-1 well

3.1.2 Akata-1 Well

This well contains eleven (11) ostracod species which belong to eight (8) genera (Figure 4). The assemblages overall are of low diversity. *Soudanella fusa* Van den Bold, *Cytherella sylvesterbradleyi* Reyment and *Loxoconcha lagosensis* Reyment are dominant in the ostracod assemblages of this well. They are also well represented in the well. The ostracod assemblages are long ranging, no age-diagnostic species were found in this

well. However the age from foraminiferal analysis suggests F9500-F7800. This is equivalent to Late Oligocene–Middle Miocene.

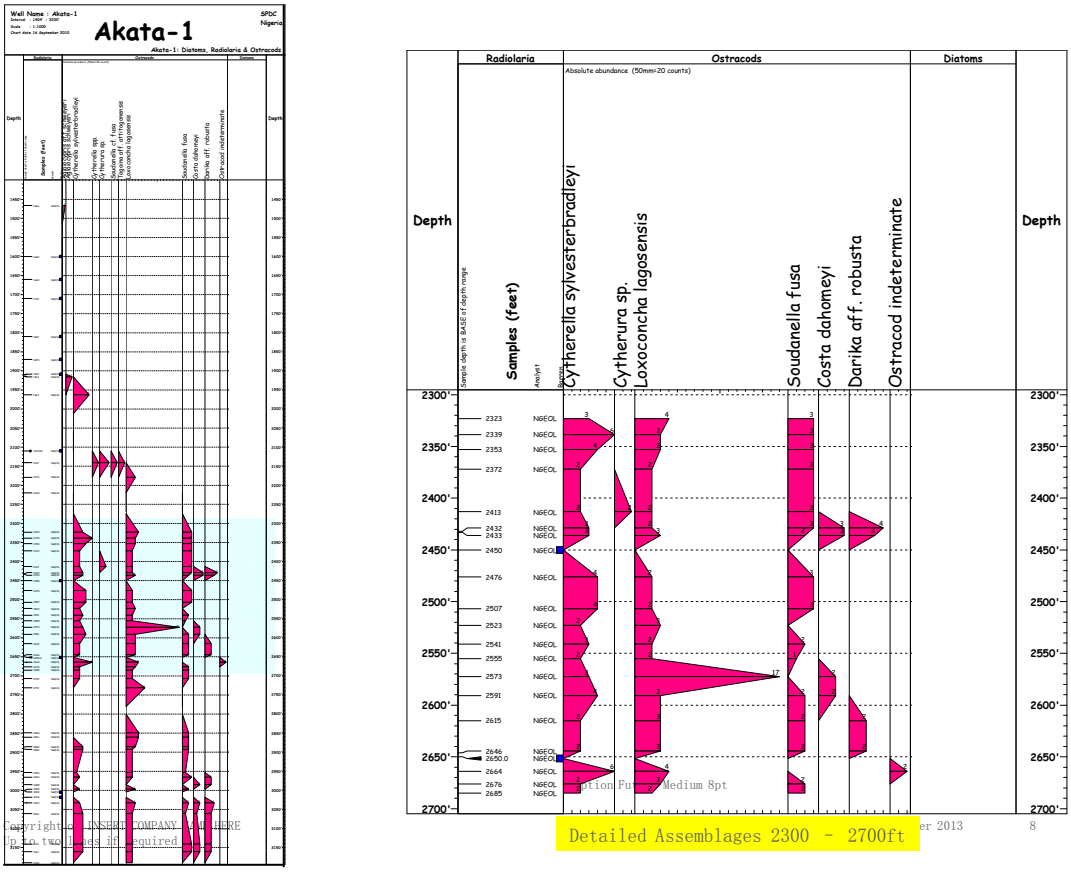

Figure 4. Ostracod distribution chart for the Akata-1 well

3.1.3 Ihuo-1 Well

Only 13 out of the 59 samples were fossiliferous in ostracods. The 13 samples contained poorly diversified assemblages (Figure 5). *Loxoconcha lagosensis, L.* aff. *kofountinensis, Benisymmetricythere cotonouensis* and *Buntonia* spp. dominate the assemblages. The genus *Benina* which was first described from the Oligocene strata of Benin Republic (Carbonnel et al., 1996) has its first reported occurrence in Nigeria from this well. It is represented by *Benina* aff. *postsehouensis*. The presence in this well of *Benisymmetricythere cotonouensis* is significant; the upper and lower parts of the well are of Oligocene and Eocene ages respectively.

3.1.4 Imo River-8 Well

Sparse ostracod assemblages were recovered from this well. A total of eleven species with dominance by *Dahomeya acuta, Togoina obesa* and *Cytherella* aff. *sylvesterbradleyi* was recorded. Other species are *Dahomeya alata* and *Paracypris* sp. No age diagnostic species were recorded for the well. The foraminiferal age is F9500-F9300 which is equivalent to Early–Middle Miocene.

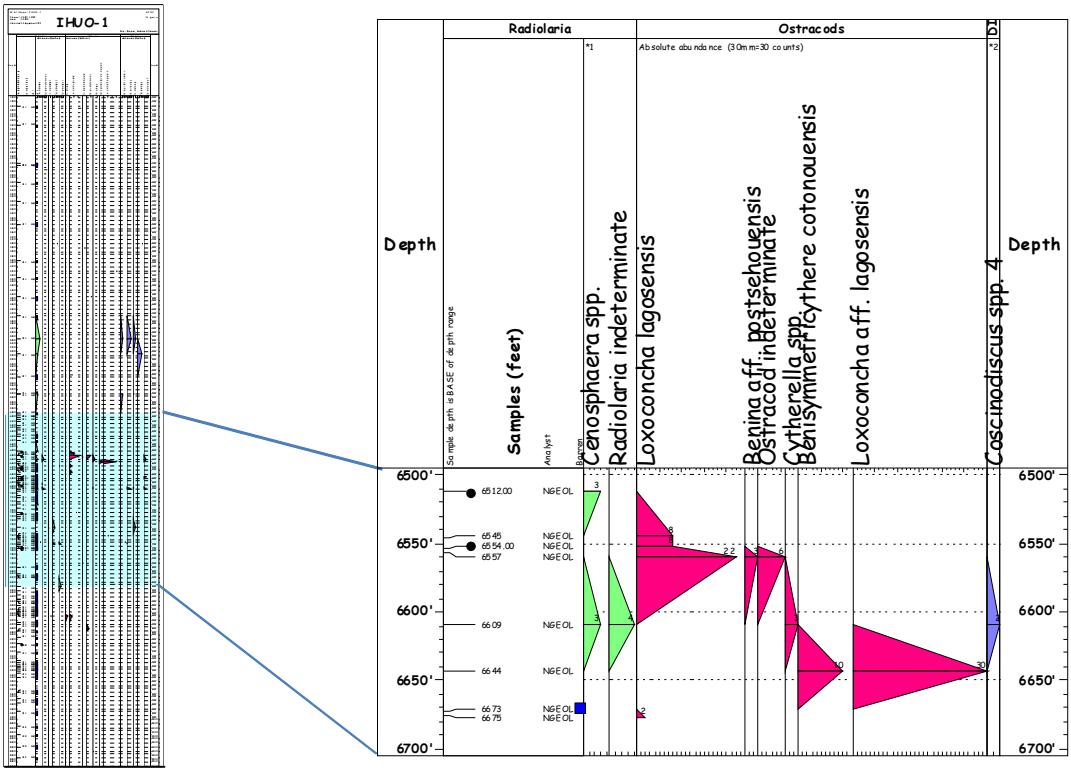

Figure 5. Ostracod, diatom and radiolarian distribution chart for the Ihuo-1 well

3.2 Diatom and Radiolaria Biostratigraphy

Diatoms and raidolarians were recovered from some of the samples from Zarama-11, Ikono-1 and Bosi-6 wells. All the samples from KK-1 well yielded diatoms and some radiolaria. Due to the low magnification microscope (x 500 maximum) that was used for the study, only two (2) species could be given full identification, others were left in open nomenclature, which means they were identified only to the genus level.

3.2.1 Ihuo-1 Well

The presence of the diatom *Actinocyclus* cf. *cuavatulus* was noted in this well. *Coscinodiscus* spp. which could belong to 2 or 3 species, *Cenosphaera* spp. and indeterminate radiolaria were accorded for this well. The diatoms and radiolaria occurrences in this well were very sparse consisting of 2–3 specimens in the majority of samples (Figure 5).

3.2.2 Zarama-11 Well

The diatom occurrences of this well include *Coscinodiscus* spp., *Actinocyclus* sp., *Hemidiscus* sp. and *Coscinodiscus lineatus.* The radiolarians include *Cenosphaera* spp. and indeterminate radiolaria. Five samples (10,950 ft, 11,130 ft, 12,390 ft, 12,480 ft and 12,540 ft) out of the 12 samples were fossiliferous in diatoms and radiolaria. However, the assemblages were very sparse (Figure 6).

3.2.3 Ikono-1 Well

Radiolaria were found in this well from 2560 to 2960 ft. One species *Dictyomitra* ex gr. *multicostata* dominates the assemblages. *Dictyomitra* sp. 1 and *Dictyomitra* sp. 2 and indeterminate radiolaria were also recorded for this well. Diatoms were not found in the slides (Figure 7).

3.2.4 Bosi- 6 Well

The diatom assemblages for this well include *Coscinodiscus* aff. *lineatus, Coscinodiscus* spp. and *Coscinodiscus* sp. The radiolarians include *Gongylothorax* aff. *verbeeki* and indeterminate radiolarian types (Figure 8).

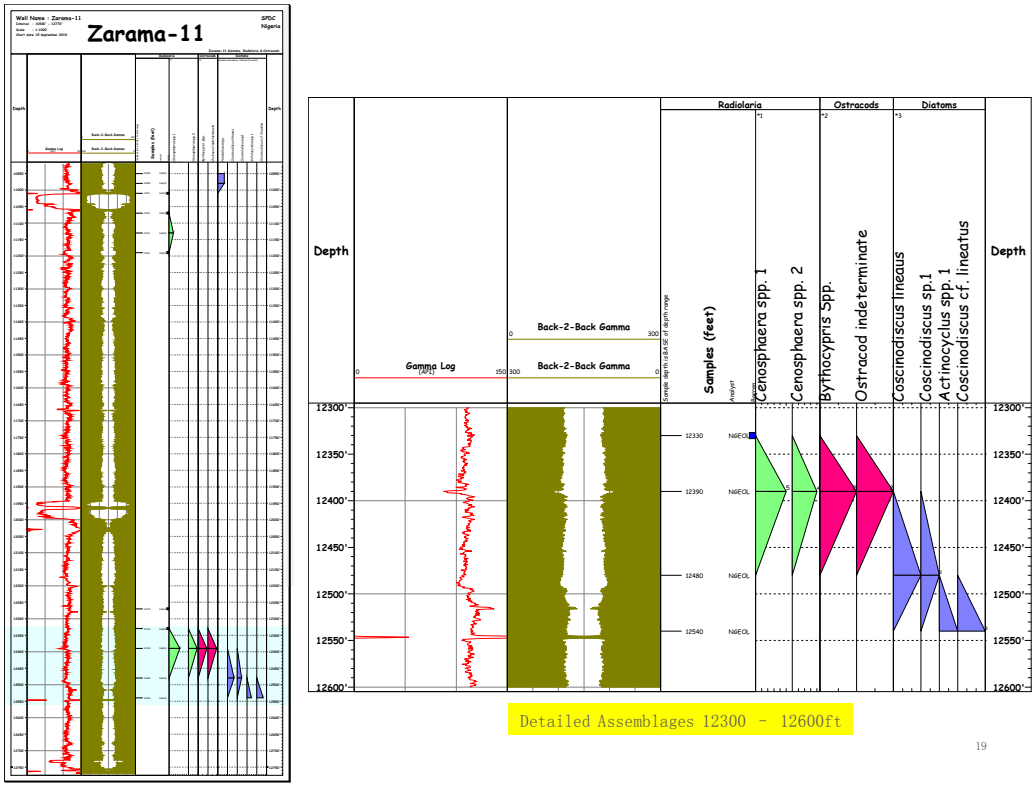

Figure 6. Ostracod, diatom and radiolarian distribution chart for the Zarama-11 well

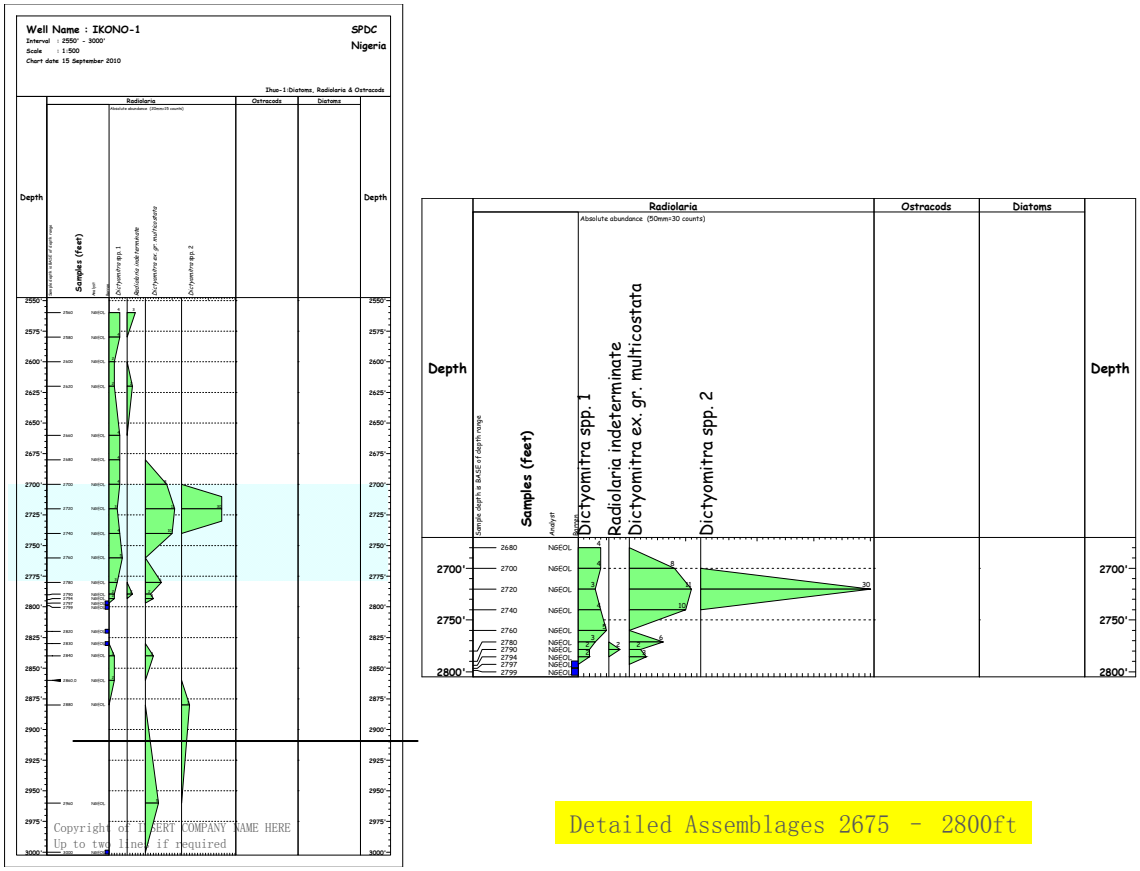

Figure 7. Radiolarian distribution chart for the Ikono-1 well

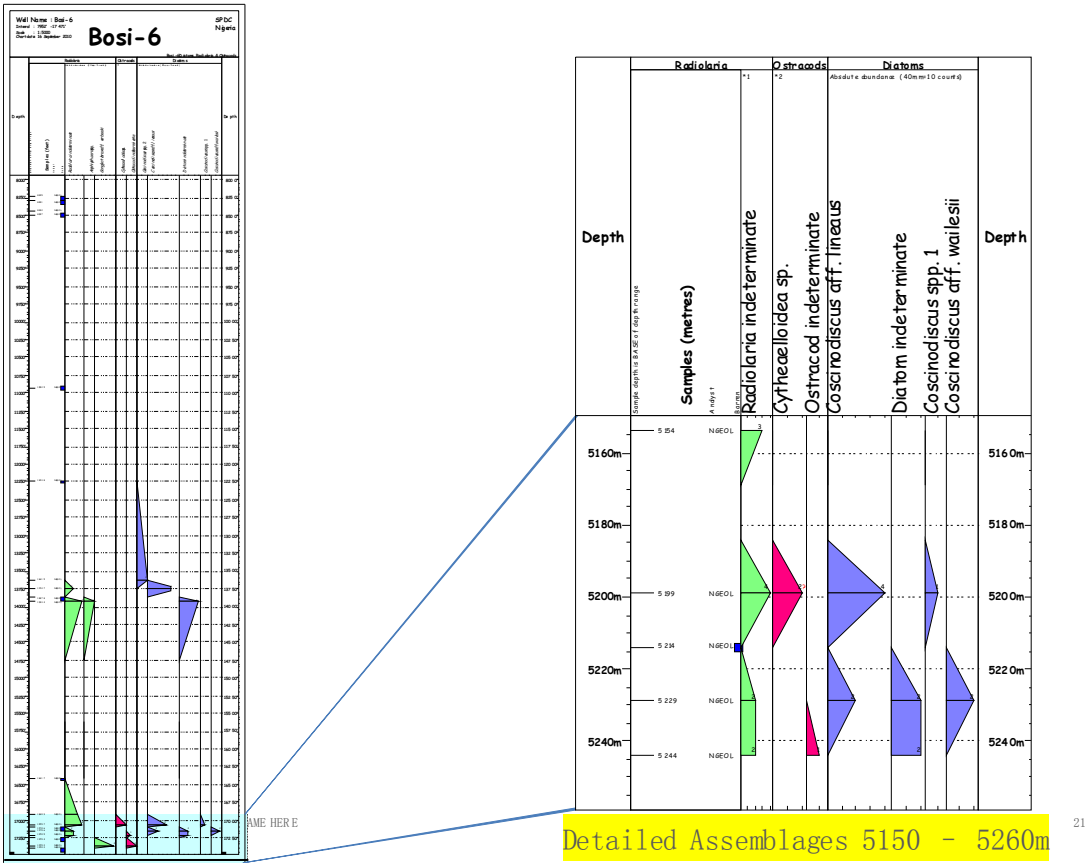

Figure 8. Ostracod, diatom and radiolariandistribution chart for the Bosi-6 well

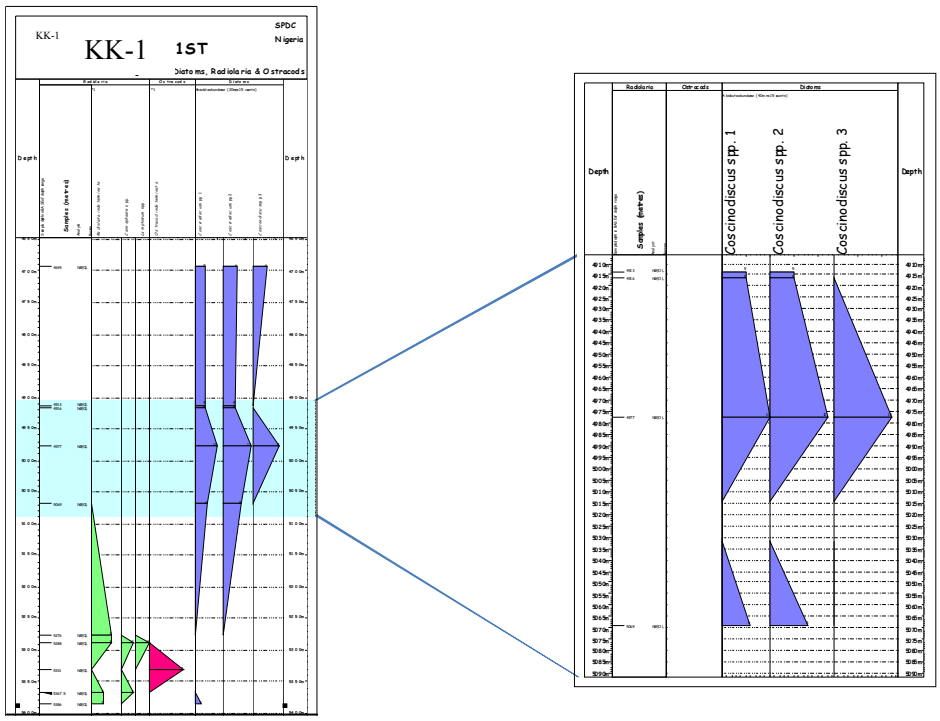

Figure 9. Ostracod, diatom and radiolarian distribution chart for the KK-1 well

3.2.5 KK-1 Well

All the samples from this well were fossiliferous. The diatoms include *Coscinodiscus* sp. 1, sp. 2, sp. 3, *Cenosphaera* sp., while the radiolarian include *Lamptonium* sp and radiolarian indeterminate (Figure 9).

3.2.6 Alo-1 Well

Seven ostracod species and 1 species of diatom were recovered from this well. *Asymmetricythere* aff. *monciardinii,* which was first described from the Eocene by Carbonnel (1978) was recorded from this well.

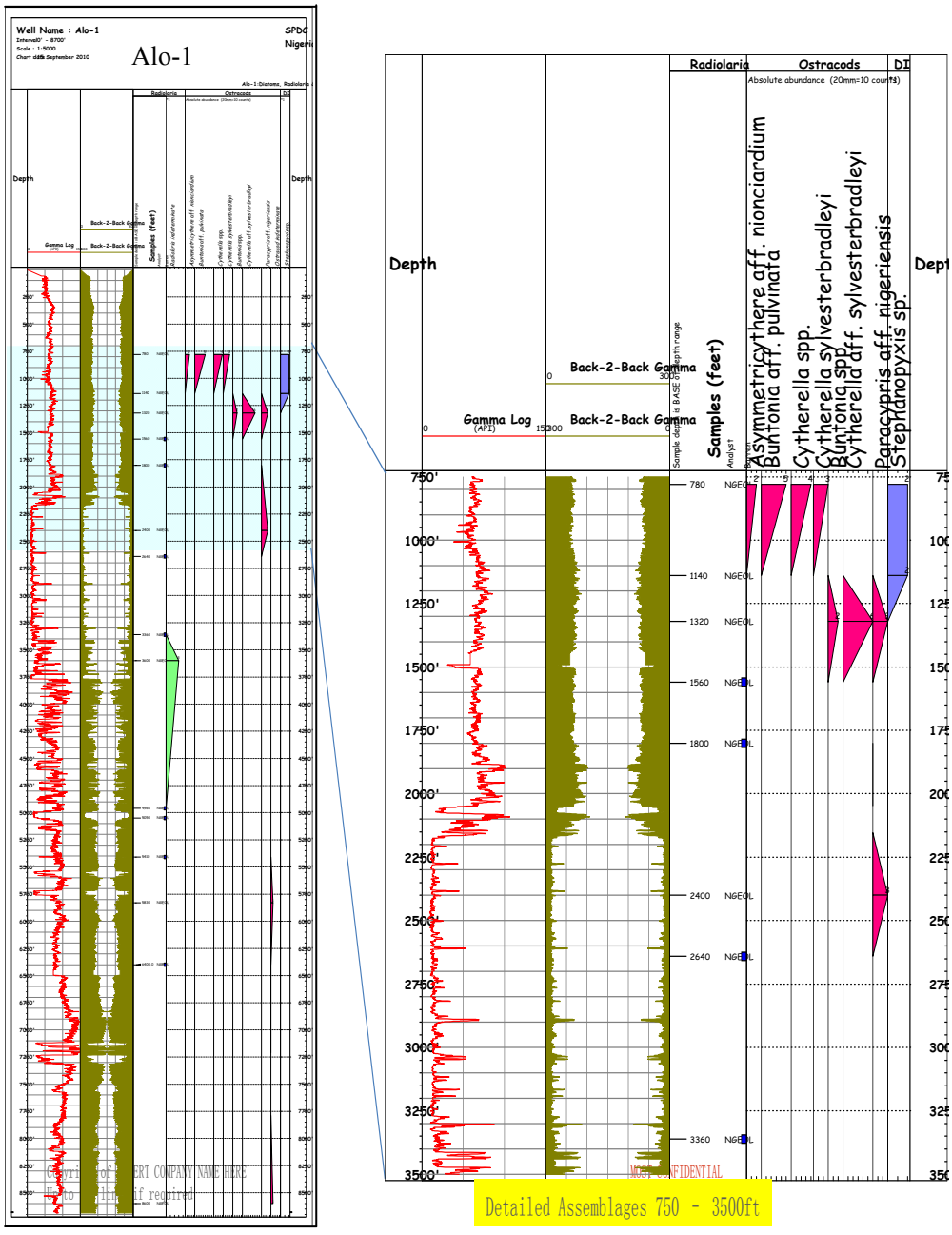

Figure 10. Ostracod, diatom and radiolaria distribution chart for the Alo-1 well

3.3 Taxonomic Notes

The systematics employed in this study follows that used by previous workers in the coastal basins of West Africa (Van den Bold, 1966; Omatsola, 1969, 1972; Carbonnel, 1988; Carbonnel et al., 1996; Keen, 1996; Okosun, 1987, 2000; Petters & Okosun, 1995). The taxonomy also benefited from Moore (1961). A total of 47

species which belonged to 21 general was recorded. Majority of them were identified to the species and subspecies levels. Some of the species were compared to, or referred to existing species (cf. and aff.). Few species were grouped as indeterminate (indet.) because of poor preservation. Some species were left in open nomenclature due to insufficient material. The species have been described by previous workers. Remarks with taxonomic comments are provided for the species to aid their identification. The well preserved species were studied using the scanning electron microscope (SEM). The figured materials have been deposited at the Paleontological Museum of the Department of Geology, Federal University of Technology, Minna, Nigeria.

Subclass: Ostracoda Latreille, 1806

Order: Podocopida Muller, 1894

Suborder: Platycopina Sars, 1866

Family: Cytherellidae Sars, 1866

Cytherella sylvesterbradleyi Reyment

Pl.2, Figure 6

Occurrence: Awaizombe-1, Akata-1, Utorogu-1 and Alo-1 wells.

Remarks: The oblique narrow depression in the anterior half of the species is well expressed in many of the specimens.

Cytherella aff. *sylvesterbradleyi* Reyment, 1960

Pl.1, Figure 3

Occurrence: Imo River-8, Alo-1and Awaizombe-1 wells.

Remarks: The oblique narrow depression in the anterior half of the carapace characteristic of the species is not very well expressed.

Cytherella sp.

Pl.1, Figure 13

Occurrence: Awaizombe-1 and Akata-1Wells.

Remarks: The carapace is oval with faint reticulations.

Genus: *Bairdopilata* Coryell, Sample & Jennings, 1935

Bairdopillata sp.

Pl.1, Figure 20

Occurrence: Awaizombe-1 well.

Remarks: Carapace with roughly triangular shape.

Family: Paracyprididae Sars, 1923

Genus: *Paracypris* Sars, 1866

Paracypris aff. *nigeriensis* Reyment, 1960

Pl.1, Figure 15

Occurrence: Awaizombe-1 well.

Remarks: Specimens have a more drawn out posterior.

Genus *Aglaiocypris* Sylvester–Bradley, 1946

Aglaiocypris schweyeri (Van den Bold), 1966

Occurrence: Awaizombe-1 and Akata-1 wells.

Remarks: Species are elongate ovoid, anterior margin bluntly rounded while posterior margin is narrowly but broadly rounded with a broad marginal zone. Maximum height is in the posterior one third. Broad inner lamella which is narrow ventrally and posteriorly.

Aglaiocypris cf. *schweyeri* (Van den Bold), 1966

Occurrence: Awaizombe-1 well.

Remarks: Specimens with faintly bluntly rounded anterior margins.

Aglaiocypris aff. *schweyeri* (Van den Bold) 1966

Occurrence: Awaizombe-1 and Akata-1 wells.

Remarks: Specimens have less broadly rounded posterior margin.

Aglaiocypris sp.

Occurrence: Awaizombe-1well.

Remarks: Specimens more convex at the middle, carapace is elongate with bluntly rounded posterior and broadly rounded anterior margins.

Family Pontocyprididae Mueller, 1894

Genus *Propontocypris* Mueller, 1894

Propontocypris sp. Carbonnel, 1986

Occurrence: Awaizombe-1 well.

Remarks: Dorsal margin sharply pointed and drawn down to meet the ventral margin. Anterior margin is narrowly rounded.

Genus Bythocypris Brady, 1880

Bythocypris olaredodui Reyment

Pl. 1, Figures 1, 7, 11, 12

Occurrence : Zarama-11 and Awaizombe-1 wells.

Remarks: Carapace is elongate ovoid. It has a more drawn out marginal zone in the anterior end. This species was reported from Nsukwa-1 well in the Niger delta (Jan du Chene & Salami, 1978) and also from the Ameki Formation in the Niger delta (Petters & Okosun, 1995).

Family *Leguminocythereididae* Howe, 1961

Genus *Leguminocythereis*, 1936

Leguminocythereis sp.

Pl.1, Figure 22

Occurrence: Awaizombe-1 well.

Remarks: Carapace is roughly bean-shaped with convex ventral margin and straight dorsal margin that slopes to the posterior of the carapace. The posterior and anterior margins are bluntly rounded. The right valve is overlapped by the larger left valve. Lateral ribs and reticulations ornament the valve surface. An ocular depression occurs beneath an eye tubercle.

Family: Loxoconchidae Sars, 1925

Genus: *Loxoconcha* Sars, 1866

Loxoconcha lagosensis Reyment, 1963

Pl.1. Figure 17, Pl.2, Figure 3

Occurrence: Awaizombe-1, Akata-1 and Ihuo-1 wells.

Remarks: Prominent ornament of pits adorn the valves surface

Loxoconcha aff. *lagosensis* Reyment, 1963

Pl.1, Figure 27

Occurrence: Awaizombe-1 well.

Remarks: Specimens belonging to this species have pits with smaller sizes on the valve surface.

Loxoconcha sp.

Occurrence: Awaizombe-1 well.

Remarks: Carapace is ovate to oblong in lateral view, the anterior and posterior margins are bluntly rounded and drawn into a caudal process respectively. The dorsal and ventral margins are sub-parallel. The right valve is overlapped by the left valve along the dorsal and ventral margins. The valve ornament consists of very weakly developed reticulations.

Loxoconcha cf. *kazeuntinensis* Carbonnel, 1986

Pl.2, Figure 12

Occurrence: Awaizombe-1 Well.

Remarks: Carapace elongate-ovate. Anterior margin obliquely rounded. Ornament is composed of coarse and prominent reticulations on the valve surface.

Loxoconcha aff. *kazeuntinensis* Carbonnel, 1986

Occurrence: Awaizombe-1 Well.

Remarks: Carapace elongate-ovate with nearly parallel dorsal and ventral margins. The anterior margin is obliquely rounded; the posterior is drawn up towards the dorsal margin into a caudal process. Very distinct ornament of reticulations adorns the valve surface.

Loxoconcha sp

Pl.1, Figure 21

Occurrence: Awaizombe-1 well.

Remarks: Carapace is smallish with very strong ornament of reticulations at the mediolateral area of the carapace. The walls of the reticulations have been thickened to form ribs. Other areas of the carapace do not have prominent ribbing.

Family: Trachyleberididae Sylvester-Bradley, 1948

Genus: *Ruggieria* Keij, 1957

Ruggieria sp.

Pl.1, Figure 24

Occurrence: Awaizombe-1 well.

Remarks: Carapace is elongated ovoid to sub-triangular, anterior and posterior margins are broadly and bluntly rounded respectively. The ventral margin is slightly convex while the dorsal margin is straight; the right valve is overlapped by the left valve along the posterodorsal, ventral and anterodorsal margins. The carapace is weakly inflated with the maximum inflation in the posterior half. Six lateral ridges make up the carapace ornamentation. Three of the ridges are sinuous in the dorsolateral region of the carapace. The remaining three run across the carapace. All ridges terminating at a short distance from the posterior margin. Smooth intercostals areas occur on the valve surface, an eye tubercle is present on each valve with post ocular depression. The anterior and posterior margins are denticulate.

Ruggieria aff. *leonensis* Keen, 1973

Pl.2, Figure 13

Occurrence: Awaizombe-1 well.

Remarks: Carapace has broadly rounded anterior and pointed posterior margins respectively. Stout and short spines may be present at both margins. About 5 to 6 lateral ribs run across the lower half of the valve surface. Weak reticulations are present in the intercostal areas and in the upper half of the valve surface. The dorsal margin is straight and slopes to the posterior. The ventral margin is weakly convex. An eye spot is present on each valve.

Ruggieria aff. *triangulata* Omatsola, 1972.

Occurrence: Awaizombe-1 well.

Remarks: Carapace is elongate with a straight dorsal margin that slopes to the posterior. The ventral margin is nearly straight to weakly convex. Elongate eye spot is present on each valve. The valve surface is adorned by 5 to 6 lateral ridges that terminate before the posterior and anterior margins, short stout spines may be present at both margins. The posterior margin is strongly compressed.

Genus: *Asymmetricythere* Bassiouni, 1971

Asymmetricythere aff. *monciardinii* Carbonnel, 1988

Pl.1, Figure 10

Occurrence: Alo-1 well.

Remarks: The carapace is elongate ovoid with straight dorsal and convex ventral margins. The anterior and posterior margins are broadly and narrowly rounded respectively. The right valve is overlapped by the larger left valve at the ventral, anterodorsal and posterodorsal margins. Short spines/denticles may be present at the posterior and ventral margins. Carapace is usually smooth.

Asymmetricythere aff. sp Carbonnel 1986

Pl.1, Figure 10

Occurrence: Alo-1 well

The carapace is ovoid with straight dorsal and weakly convex ventral margins. A weak burge is noticeable at the ventrolateral area; three lateral ribs take their origin from it. The ribs terminate before the posterior-ventral corner.The centrolateral area of the valve bears four short ribs. An eye tubercle may be on each valve.

Genus *Benina* Carbonnel et al., 1996

Benina aff. *postsehouensis* Carbonnel

Pl.1, Figure 5, Pl.2, Figure 14

Occurrence: Awaizombe-1 well.

Remarks: Carapace is elongate and subrectangular with a strongly reticulate ornament, anterior and posterior margins are thickened. The species shows some faint resemblance to *Benina postsehouensis* Carbonnel et al. (1996).

Genus *Chrysocythere* Ruggieri, 1962

Chrysocythere sp

Occurrence: Awaizombe-1 well.

Remarks: Carapace has curved and slightly straight ventral and dorsal margins. One dorsal rib which joins the median rib also joins the anterior marginal rib. A ventral rib runs near the ventral margin and is joined to the anterior marginal rib. Intercostal areas have faint reticulations.

Chrysocythere cataphracta Ruggieri, 1962

Pl.1, Figure 4

Occurrence: Awaizombe-1 well.

Remarks: Carapace is roughly rectangular with straight dorsal and ventral margins. The anterior margin is more broadly rounded than the posterior margin. Three lateral ridges run across the dorsal, median and ventral areas of the carapace. Rows of reticulations occur in the intercostals areas. There is a prominent anterior marginal rib. The anterior marginal surface of the carapace is smooth. The median rib joins the anterior marginal rib.

Genus *Benisymmetricythere* Carbonnel et al., 1996

Benisymmetricythere grosdidieri Carbonnel et al., 1996

Pl.2, Figure 11

Occurrence: Awaizombe-1 well.

Remarks: Smooth, robust carapace with fairly straight dorsal and much curved ventral margins. Few short spines may be present at the posterior end of carapace. There may be irregular depressions at the anterior and posterior sides. There seems to be a slight resemblance between the species and *Togoina* (a possible evolutionary relationship).

Benisymmetricythere cotonouensis Carbonnel et al., 1996

Occurrence: Awaizombe-1 and Ihuo-1 wells.

Remarks: Carapace is robust with slight depression at the anterior area. Traces of weakly developed ribs may be present at the medioposterior part of the carapace. One or two short spines are present at the posterior margin.

Genus S*oudanella* Apostolescu, 1961

Soudanella fusa (Van den Bold), 1966

Pl.2, Figures 4, 5

Occurrence: Akata-1 well.

Remarks: Carapace is pear shaped with straight dorsal and curved ventral margins. The posterior part of the dorsal margin is curved upwards towards the posterior margin, the midpoint of which is in the upper half of the carapace. There is a prominent eye spot on each valve. The carapace is ornamented with prominent reticulations. A medioposterior inflation occurs in the carapace.

Soudanella cf. *fusa* (Van den bold), 1966

Pl.2, Figure 10

Occurrence: Akata-1 well.

Remarks: Carapace is pear shaped with straight and weakly curved dorsal and ventral margins. The ornament is weakly reticulating. Carapace inflation is very mild. Eye spots may be prominent.

Soudanella bissauensis Carbonnel, 1986

Occurrence: Awaizombie-1 well.

Remarks: This species is very similar to *S. fusa* (Van den Bold), 1966. It differs from it by the prominent rib from the eye spot that runs towards the anterior ventral corner, the lateral ribs are more strongly developed and closely spaced. The close spacing submerges the reticulations

Genus C*asamancea*

Casamancea cf. *lougaensis* Carbonnel, 1986

Pl.1, Figure 8

Occurrence: Awaizombe-1 well.

Remarks: Carapace has broadly rounded anterior and pointed posterior margins respectively. Five lateral ribs which are more strongly developed in the medioposterior area adorn the valve surface. The intercostal areas are strongly reticulate. The lateral ribs do not extend to the anterior and posterior margins. An eye spot is present on a rib that runs downwards towards the ventral margin. The anterior and posterior margins are weakly and narrowly indented. About two rows of reticulations may be present in the intercostal areas.

Casamancea lougaensis Carbonnel, 1986

Occurrence: Awaizombe-1 well.

Remarks: More than five lateral ribs are present on the surface of the valve of this species.

Genus *Costa* Neviani, 1938

Costa dahomeyi (Apostolescu), 1961

Pl.2, Figures 7, 8, 9

Occurrence: Awaizombe-1 well.

Remarks: Carapace has an antereomarginal rib. The anterior marginal area is weakly compressed. An eye spot occurs on each valve.

Costa sp.

Occurrence: Awaizombe-1 well.

Remarks: carapace similar in shape to *Costa dahomeyi* but the ribs are not well developed.

Genus *Thalmannia*

Thalmannia fusa Van den Bold, 1966

Occurrence: Awaizombe-1 well.

Remarks: The species differs from *Soudanella fusa* by not having strongly cured ribs at the anterior and posteriordorsal areas of the carapace.

Family Brachycytheridae Puri, 1954

Genus *Darika* Omatsola, 1972

Darika cf. *robusta* (Omatsola, 1972)

Pl.1, Figures 6, 17; Pl.2, Figures 1, 2

Occurrence: Awaizombe-1 well.

Remarks: Carapace pear shaped with a ventrolateral rib that may be prominently or weakly developed. There is also a mediolateral inflation of the carapace. The ornament consists of pits which may be strongly expressed mediolaterally. The right valve is overlapped by the left. There may be depression at the anterior and posterior margins.

Dahomeya acuta Apostolescu, 1961

Occurrence: Awaizombe-1 well.

Remarks: Carapace suboval to subrectangular is lateral view. Left valve overlaps the right along the dorsal, ventral and posterior margins. There is a ventrolateral burge on each valve. Faint punctae adorns the valve surface. Weakly rimmed anterior margin. The anterior and posterior margins bear short, blunt denticles. Eye tubercles are broad and flat

Family Cytherideidae Sars, 1925

Genus *Kroemmelbeinella* Mostafawi, 1984

Kroemmelbeinella rokelensis Keen, 1996

Occurrence: Awaizombe-1 well.

Remarks: Carapace smallish with the posterior margin drawn into a caudal process. The ornament may consist of weakly expressed reticulations and ribs.

Genus *Togiona* Apostolescu, 1961

Togoina obesa Apostolescu, 1961

Occurrence: Awaizombe-1 well.

Remarks: Carapace is large or robust. About 3 to 4 short ribs occur at the mediolated area of the carapace with reticulate intercostals. There is a prominent post-ocular depression on each valve. Other areas of the carapace are smooth. There is a slight ventrolateral bulrge on each valve.

Togoina sp 1, 2, 3, 4

Occurrence: Meren-1 well.

Remarks: Carapace is large, similar to *T*. *obesa* but with faint to strong reticulations. No short ribs were observed at the mediolateral area of the carapace. This material was also reported from the Eocene- Pliocene strata in the Niger delta (Petters & Okosun, 1995). They probably represent new species of *Togoina*.

Genus *Buntonia* Howe, 1935

Buntonia aff. *pulvinata* Apostolescu, 1961

Pl.1, Figure 18

Occurrence: Awaizombe-1 well.

Remarks: Carapace has a broadly rounded anterior margin and a pointed posterior margin.

Buntonia cf. *pulvinata* Apostolescu, 1961

Pl.1, Figure 19

Occurrence: Awaizombe-1 well.

Remarks: Carapace is large with broadly and rounded narrowly pointed anterior and posterior margins respectively. The mediolateral region of the carapace has pitted ornamentation.

4. Paleobiogeography of Niger Delta Ostracods

Twenty-two (22) ostracod species which have been reported from the Niger Delta from this study show some affinity to the coeval assemblages from Sierra Leone, Benin Republic and Gabon. Seventeen (17) species are common to the Benin Republic while ten (10) and two (2) are common to Sierra Leone and Gabon respectively (Table 2). The Gabonese fauna shows the least affinity with only two (2) species common to Benin Republic and Niger Delta. It is significant to observe that *Soudanella fusa* and *Aglaiocypris schweyeri* are common to all three basins. The presence of these two species was used to infer an inner to middle neritic paleoenvironment for the Gabonese assemblages (Van den Bold, 1966). It can be suggested that the ostracod assemblages in the three basins were all deposited in an inner to middle neritic environment.

Table 1. Paleogeographic distribution of Niger Delta ostracods in the coastal basins of West Africa

Ostracod species	Benin Republic (Carbonnel et al., 1996)	Gabon (Van den Bold,1966)	Sierra Leone (Keen,1996)	Niger Delta (This Study)
Aglaiocypris schweyeri	X	X	X	X
Loxoconcha cf. *kazeuntinensis*	X		X	X
Soudanella bissauensis			X	X
Soudanella fusa	X	X	X	X
Casamancea cf. *lougaensis*			X	X
Cytherella sp. J	X		X	X
Darika cf. *robusta*			X	X
Benisymmetricythere grosdidieri	X			X
Benisymmetricythere cotonouensis	X			X
	X		X	X
Chrisocythere cataphracta	X			X
Dahomeya aff. *robusta*	X			X
Loxoconcha aff. *kafountinesis*	X			X
Loxoconcha aff. *lagosensis*	X			X
Loxoconcha lagosensis	X			X
Propontocypris sp.	X			X
Ruggieria aff. *leonensis*	X			X
Ruggieria aff. *triangulata*	X			X
Thalmania? *fusa*			X	X
Krommelbeinella rokelensis	X			X
Loxoconcha lagosensis (REPEAT?			X	X
Loxoconcha kazeuntinesis	X			X
Bassleaites sp.				

5. Paleoenvironmental Analysis

Ostracods have proved to be highly valuable in paleoenvironmental studies when they occur in good populations. Two major techniques are usually available to ostracodologists. The first technique is the plotting of ostracod population data on a Cytheracea–Cytherellidae–Bairdiacea + Cypridacea triangular diagram (CCBC plot; Dingle, 1980, 1981). This diagram indicates trends which are potentially valuable as paleoecological indicators (Figure 11). The CCBC triangular diagram has a similar function to the triangular diagram of suborders that is commonly used in foraminifera to interpret depositional environments. The caveat for the use of the CCBC triangular plot is the need for the ostracod populations to be diverse and more than 20 specimens (Dingle, 1985). Small numbers of specimens and low diversities may invalidate the palaeoenvironmental interpretations.

Majority of the ostracod assemblages from this study have small numbers of specimens and this technique was not applicable (Table 2).

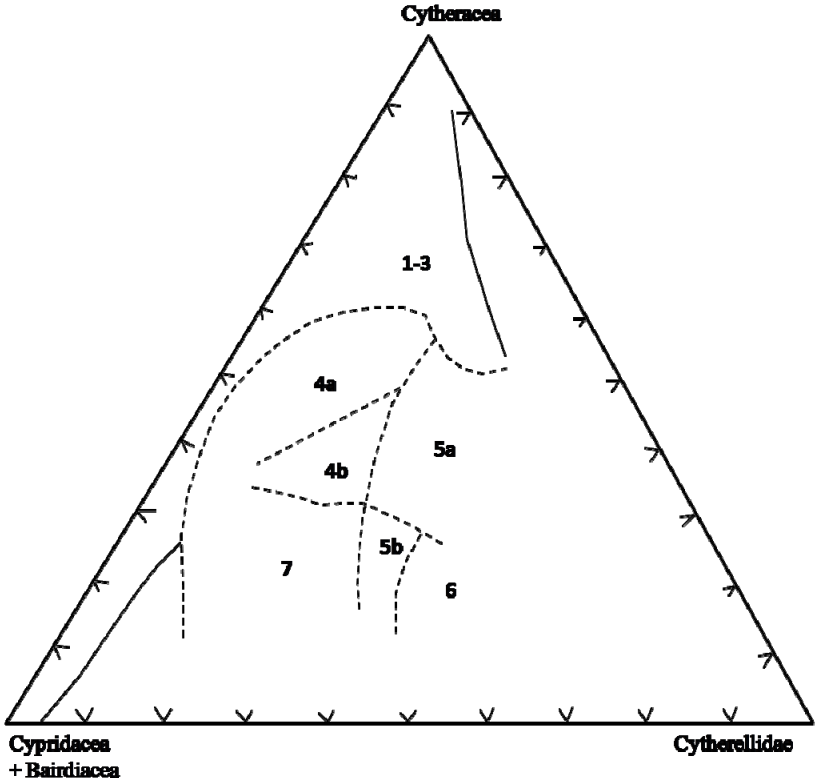

Figure 11. Triangle diagram for palaeobathymetric reconstruction (modified after Dingle, 1981) where the points are Cytheracea, Cypridacea + Baidiacea and Cytherellidae. The assemblage fields used to depict palaeodepth are as follows: 1-3: depth < 100 m; 4a: 100–200 m depth; 4b: -200 m depth; 5a: 200–300 m depth; 5b: 300–500 m depth; 6 and 7: > 500 m depth

Table 2. Percentage of ostracod species from the Awaizombe-1 well

Sample No. (ft)	*Cytheracea*		*Cypridacea and Bairdiacea*		*Cytherellidae*	
	No	%	No.	%	No	%
4240	5	45.5	4	36.4	2	18.1
4360			3	60	2	40
4520			3	100		
4557	3	100				
4840	2	100				
4920	5	50			5	50
5000	5	50			3	
5360	25	61			16	39
5400			3	11	24	89
5440	3	60	1	20	1	20
5460	19	79	3	12	2	8
5480	20	69	9	31		
5500	15	79			4	21
5601	19	89			3	14
5640	2	22	3	33	4	44
5660	1	50			1	50

5780	1	17			5	83
5840	2	18			9	82
5860	10	100				
5920	8	73			3	27
5960	15	63			9	37
6000					2	
6040	8	50			8	50
6080	4	67	1	16	1	16
6220	2	22	7	78		
6280	8	73			3	27
6320	12	36	3	9	18	56
6360	24	56	18	42	1	2
6381	2	40			3	60
6400	19	90	3	10		
6440	10	83			2	17
6500	4	50	2	25	2	25
6520	4	26	4	26	7	47
6540	3	37			5	63
6600	12	50	2	8	10	42
6680	5	42	3	25	4	33
6780	6	50			6	50
7200	9	47			10	53
7340	5	62			3	38
7360	18	100				
7440	11	39	9	32	8	29
7601	4	36	6	55	1	9
8480	2	50	2	50		
8640	2	67			1	33
9040					1	100
9300			1	100		

The second technique involves the use of species with known ecological data or environmental preferences. The ostracod assemblages from Awaizombe-1 well are dominated by *Aglaiocypris schweyeri*, *Aglaiocypris* cf. *schweyeri*, *Aglaiocypris* aff. *schweyeri, Loxoconcha kazeuntinensis*, *L*. aff. *kazeuntinensis*, *L. lagosensis* and *L*. aff. *lagosensis* (Figure 3). *Loxoconcha* is a shallow water ostracod genus (Vann et al., 2001). They are usually found inhabiting bays and other coastal environments. Van den Bold (1966) encountered five (5) species of *Loxoconcha* in the Colon Harbour of Panama. Some of these species were dominant in the assemblages. An ecological study of the ostracods in the Southern Gulf of Mexico by Machain-Castillo et al. (1990) identified three depth assemblages. The upper assemblage from 17–60 m was dominated by *Loxoconcha* species. This further confirms the shallow water index value of *Loxoconcha* species. The Akata-1 well ostracod assemblages also show dominance by *Loxoconcha* species (Figure 4). The studied intervals of these two wells were deposited in shallow water from the inner neritic to middle neritic.

Aglaiocypris schweyeri and *Soudanella fusa* from the Miocene of Gabon were used to infer an inner to middle neritic (20-80 m) paleo-water depths for the Gabonese assemblages (Van den Bold, 1966). These two species occur alongside *Loxoconcha* species in the Awaizombe-1 and Akata-1 wells. This is a further confirmation of the

inner to middle neritic paleoenvironments indicated for the two wells in this study (Figure 12).

Our knowledge of the deep sea ostracods shows that species of the following genera: *Heryhowella*, *Bradleya*, *Krithe* and *Poseidonamicus* have pandemic distribution trends (Bergue et al., 2006; Yosuharo et al., 2009). This has been supported by the work of Guernet (1998) on the Neogene and Pleistocene ostracods of Sites 959 and 960 in the Gulf of Guinea. The two sites are located in the Ivorian deep water acreage. Species of the genera mentioned above were recorded by Guernet (1998) with *Krithe* spp. dominating the assemblages. None of the Niger Delta assemblages from this study are comparable to the deep sea assemblages of the Gulf of Guinea. This further confirms the shallow water paleoenvironment of the Niger Delta ostracods.

The ostracod assemblages contain species which are indicative of normal marine salinity (Neal, 1988). Cytherellids (Platycopids) which are filter feeders and thus better adapted to reduced oxygen conditions (Whatley, 1995; Boomer & Whatley, 1992) were poorly represented in the assemblages. This indicates that the strata were deposited in oxic to suboxic conditions. The presence of large arenaceous foraminiferal species and macroinvertebrates support this interpretation.

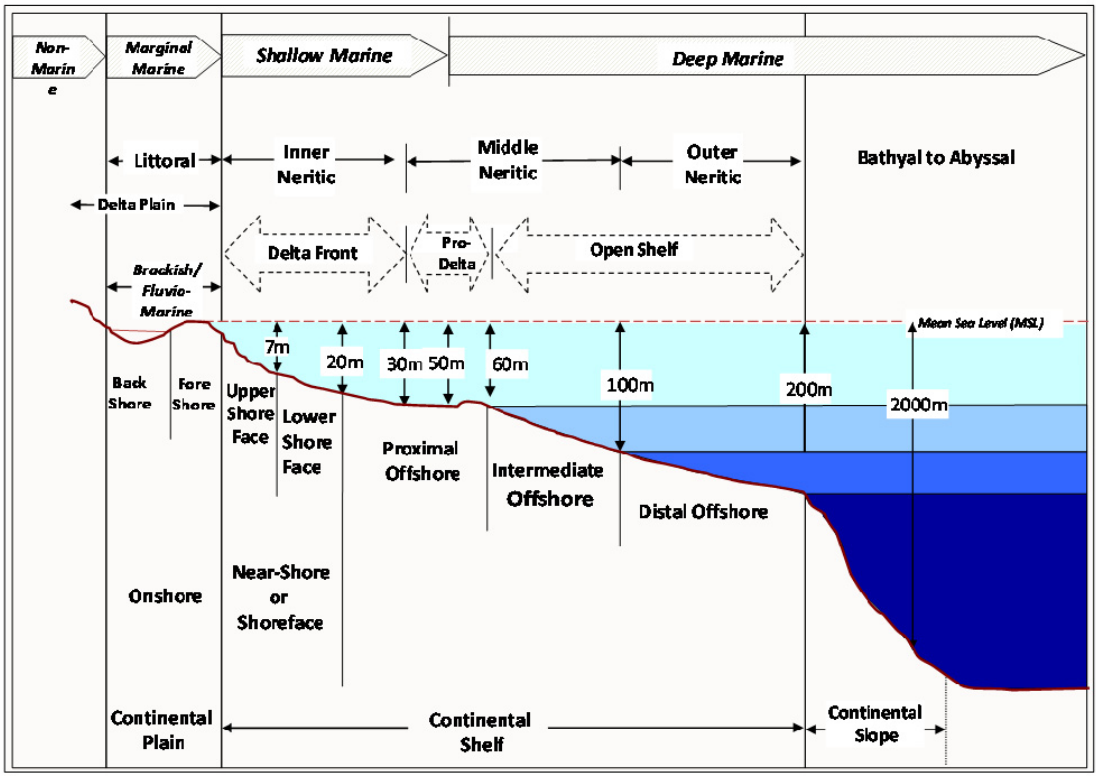

Figure 12. Depositional environments and bathymetric ranges used in paleoenvironmental interpretations (modified after Allen, 1965, 1970)

6. Conclusions

Ostracod assemblages were found from wells in the northeastern and southeastern parts of the Niger Delta. Some of the species have close affinity to coeval ostracod species from Gabon, Sierra Leone and Benin Republic. Species of *Loxoconcha*, *Aglaiocypris* and *Soudanella* encountered in this study are good indicators of the inner to middle neritic environments of deposition. These taxa could serve as environmental indicators for these depths in exploration work. Many of the species have their first recorded occurrence in the Niger Delta from this study. Diatoms show improved distribution in the deep water sector of the delta.

7. Recommendations

A high magnification binocular microscope (up to x 1000) should be provided for taxonomic work on diatoms and smaller radiolarians. The use of 38 µm sieve is more adequate in the washing of samples for diatom analysis. Further efforts on diatom studies should be directed to the Niger Delta deep water.

Acknowledgments

The sabbatical appointment offered to the first author by SPDC is greatly appreciated. My thanks go all the staff of the Geological Services Team, (UIG-T/DGX), SPDC, Warri for their support and co-operation. I also wish to thank Mrs. Georgina Ndulue and Mrs. Pat Ukeri for the preparation of samples and distribution charts respectively. Special thanks go to Dr. Peter Osterloff for his advice and assistance.

References

Bergue, C. T., Costa, K. B., Dwyer, C., & Moura, C. A. (2006). Bathyal ostracod diversity in the Santos Basin, Brazilian southeast margin: Response to Late Quaternary climatic changes. *Revista Brasilian Paleontology, 9*(2), 201-210. http://dx.doi.org/10.4072/rbp.2006.2.04

Bold, W. A. van den. (1966). Les Ostracodes du Neogene du Gabon. *Rev. Inst. Franc. Petrole., 21*(2), 155-189.

Bold, W. A. van den. (1966). Ostracoda from Colon Harbour, Panama. *Carib. J. Sci., 6*, 43-64.

Boomer, I., & Whatley, R. (1992). Ostracoda and dysaerobia in the Lower Jurassic of Wales: the reconstruction of past oxygen levels. *Paleogeography, Paleoclimatology, Paleoecology, 99*, 373-379. http://dx.doi.org/10.1016/0031-0182(92)90024-Y

Carbonnel, G. (1986). Ostracodes Pateogenes et Neogenes du Sondage offshore de Cape Tinuris: Mauritanie. *Revue de Micropaleontologie, 31*(3), 147-155.

Carbonnel, G. (1986). Ostracodes Tertiaires (Paleogene a Neogene) du basin Senegal–Guineen. *Mem. Bur. Rech. Gad. Min., 101*, 35-245.

Carbonnel, G. (1988). L'apparition du genera *Asymmetricythere* Basiouni, 1971 reflect des modifications paleoecologique sur le genre *Togoina* Apostollescu, 1961 (Ostracoda, Eocene du Togo) *Rev. Espan. Micropaleont, 20*(3), 401-417.

Carbonnel, G., Klasz, I., Klasz, S., Horvath, M., Lang, J., & Oyede, M. (1996). Microfaunes et Milieus de depot des niveaux Oligocenes Surmontant la "discordance Oligocene" sur la partie terrestre du basin sedimentaire cotier du *Annals of South African Museum* Benin (Afrique Occidentale). In Jardine de Klasz & Debenay (Eds.), *Geologie de l' Afrique et de l' Atlantique sud. 12e Collque Africain de Micropaleontologie.* Angers, 1994, 235-273.

Dingle, R. V. (1980). Marine Santonian and Campanian ostracods from a borehole at Richards Bay, Zululand. *Annals of South African Museum, 82*, 1-70.

Dingle, R. V. (1981). The Campanian and Maastrichtian Ostracoda of south-east Africa. *Annals of South African Museum, 85*, 1-181.

Dingle, R. V. (1985). Turonian, Coniacian and Santonian Ostracoda from south-east Africa. *Annals of South African Museum, 96*(5), 124-239.

Jan du Chene, R., & Salami, M. B. (1978). Palynology and Micropaleontology of the upper Eocene of the well Nsuka-1, Niger Delta, Nigeria. *Archs, Sci., Geneve*, 5-10.

Keen, M. C. (1996). Ostracods from the Miocene Bullom Group of Sierra Leone. In Jardine, Klasz, & Debenay (Eds.), *Geologie de L'Afrique et de L'Atlantique sud. 12e Collque Africain de Micropaleontologie,* Angers, 1994, 305-315.

Machain-Castillo, M. L., Perez-Guzman, A. N., & Maddocks, R. F. (1990). Ostracoda of the terrigenous continental platform of the Southern Gulf of Mexico. In R. S. Whatley & C. Maybury (Eds.), *Ostracoda and Global Events*. London: Chapman & Hall. http://dx.doi.org/10.1007/978-94-009-1838-2_26

Moore, R. C. (Ed.). (1961). *Treatise on Invertebrate Paleontology Q, Part, Arthropoda* (p. 442). University of Kansas Press.

Neal, J. W. (1988). Ostracods and paleosalinity recnstruction. In P. de Deckker, J. P. Colin, & J. P. Peypouquet (Eds.), *Ostracods in the earth sciences*, 125-155.

Okosun, E. A. (1987). Ostracod biostratigraphy of the Eastern Dahomey Basin, Niger Delta and the Benue Trough of Nigeria. *Bull. Geol. Surv. of Nigeria, 41*, 157.

Okosun, E. A. (2000). New stratigraphic ranges for some Tertiary ostracodes from southern Nigeria. *N. Jb. Geol. Palaont. Mh., 6*, 378-384.

Omatsola, M. E. (1969). Notes on the three new species of Ostracoda from the Niger Delta, Nigeria. *Bull. Geol.*

Univ. Uppsala, (N.S), 2(11), 97-102.

Omatsola, M. E. (1970). Podocopid Ostracoda from the Lagos Lagoon, Nigeria. *Micropaleontology, 16*(4), 407-445. http://dx.doi.org/10.2307/1485071

Omatsola, M. E. (1972). Recent and Sub-recent Trachyleberididae and Hemicytheridae (Ostracods, Crustaceans) from western Niger Delta, Nigeria. *Bull. Geol. Inst., Univ.of Uppsala, (N.S), 3*, 37-120.

Petters, S. W., & Okosun, E. A. (1995). *Eocene- Pliocene ostracod biostratigraphy of the Niger Delta, Nigeria* (Unpublished Report).

Reyment, R. A. (1963). Studies on Nigerian Upper Cretaceous and Lower Tertiary Ostracoda, Pt 2: Danian, Paleocene and Eocene Ostracoda. *Stockholm Contribution to Geology, 10*, 1-286.

Vann, C. D., Cronin, T. M., & Dwyer, G. S. (2001). Ecology of the Ostracode Loxoconcha in ChesapeakBay: Application to shell chemistry calibration (pp. 32B-0527). *American Geophysical Union,* fall meeting.

Yasuhara, M., Cronin, T. M., Hunt, G., & Hodell, D. A. (2009). Deep-sea ostracods from the South Atlantic sector of the Southern Ocean during the last 370,000 years. *Journal Information, 83*(6).

PLATE 1

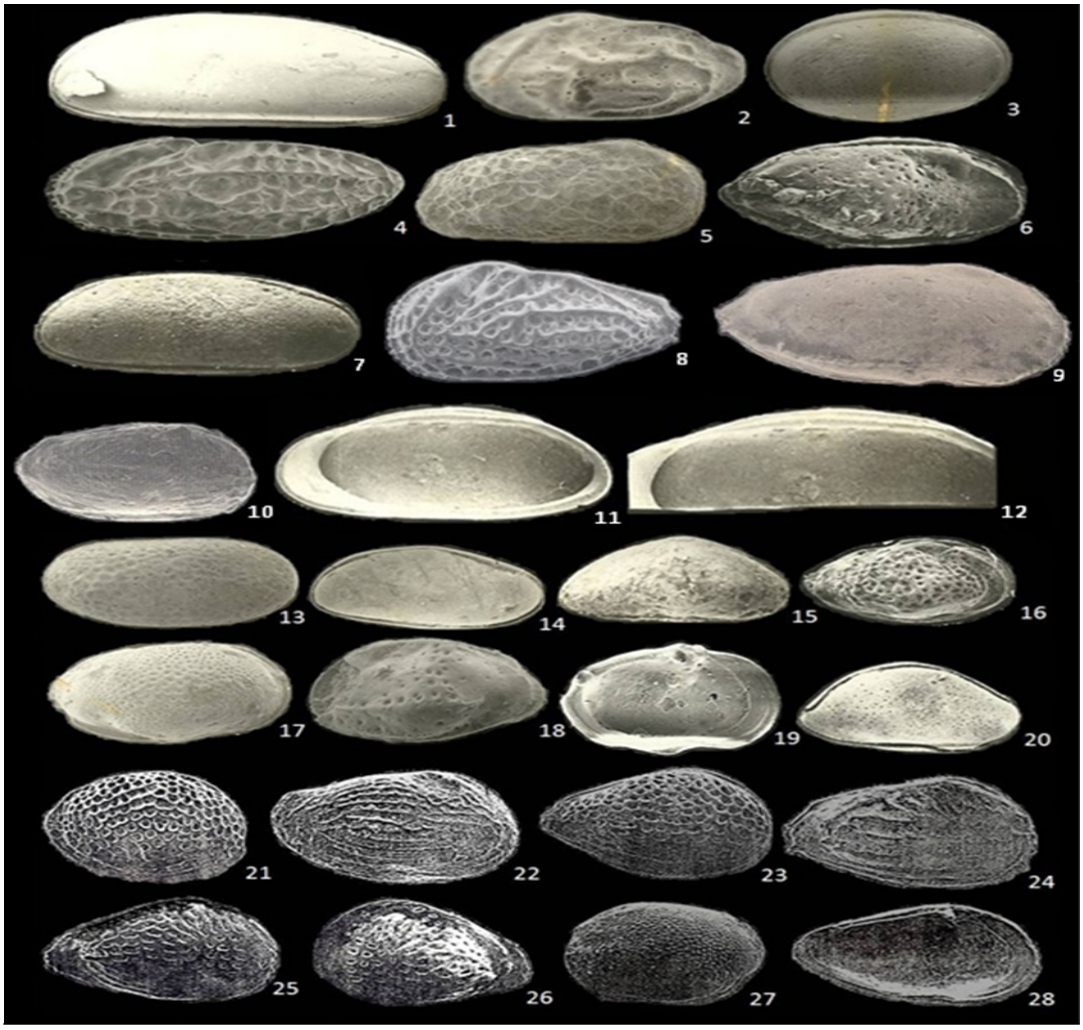

PLATE I

Figure

1. *Bythrocypris olaredoui* Reyment. Right side of carapace, Zarama-11, 12390 ft, x65

2. *Riggieria* sp Left side of carapace female, Awaizombe-1, 6750 m, x60
3. *Cytherella* aff. s*ylvesterbradleyi* Reyment. Right side of carapace, Awaizombe-1, 5840 ft, x60
4. *Chrysocythere cataphracta* Ruggieri. Left side of carapace, male, Awaizombe 1, 5550 ft, x60
5. *Benina* aff. *postsehouensis* Right side of carapace, male, Ihuo-1, 6557 ft, x45
6. *Darika* cf. *robusta* Omatsola. Left side of carapace, male, Akata-1, 2432 ft, x60
7. *Bythocypris olaredadui* Reyment. Right side of carapace, male, Nsukwa-1, x60
8. *Casmancea* cf. *lougaensis* Carbonnel. Left of carapace, female, Awaizombe-1, 5960 ft, x55
9. *Asymmetricythere* aff. *monciardinii* Carbonnel. Right side of carapace, male, Alo-1, 800 ft, x60
10. *Asymmetriccythere* aff. sp 1 Carbonnel. Right side of carapace, Ameki Formatiom, x60
11. *Bythoocypris olaredodui* Reyment. Right valve internal view, Ameki Formation , x60
12 *Bythoocypris olaredodui* Reyment. Hinge and muscle scar pattern, Ameki Formation, x60
13. *Cytherella* sp Right side of carapace, Alo-1, 800 ft, x60
14. *Bythocypris olaredodui* Reyment. Right side of carapace, Nsukwa-1, x60
15. *Paracypris* aff. *nigeriensis* Reyment. Right side of carapace, Alo-1, 1320 ft, x60
16. *Buntonia* aff. *pulvinata* Apostolescu. Right side of carapace, Alo-1,800 ft, x60
17. *Loxoconcha lagosensis* Reyment. Right side of carapace, male, Ihuo-1, 6557 ft, x60
18. *Darika* cf. *robusta* Omatsola. Left side of carapace, Akata-1, 2591 ft, x60
19. *Buntonia* cf. *pulvinata* Apostolescu. Left side of carapace, Akata-1, 5780 ft, x60
20. *Bairdopilata* sp Right side of carapace, Awaizombe-1, 5500 ft, x75
21. *Loxoconcha* sp Right side of carapace, Awaizombe-1, 5500 ft x60
22. *Leguminocythereis* sp. Right side of carapace, female, Awaizombe-1, 6540 ft, x60
23. T*ogoina* sp 1. Right side of carapace, female, Awaizombe-1, 4280 ft, x62
24. *Ruggeria* sp. Right side of carapace, male, Awaizombe-1, 4280 ft, x50
25. *Togoina* sp 2. Right valve, juvenile, male, Awaizombe-1, 4280 ft, x50
26. *Togoina* sp 3. Left valve, juvenile, female, Awaizombe-1, 4280 ft, x50
27. *Loxoconcha* aff. *lagosensis* Reyment. Left side of carapace, Ihuo-1, 6644 ft, x55
28. *Togoina* sp 4. Left valve internal view, Awaizombe-1, 4280 ft, x60

PLATE 2

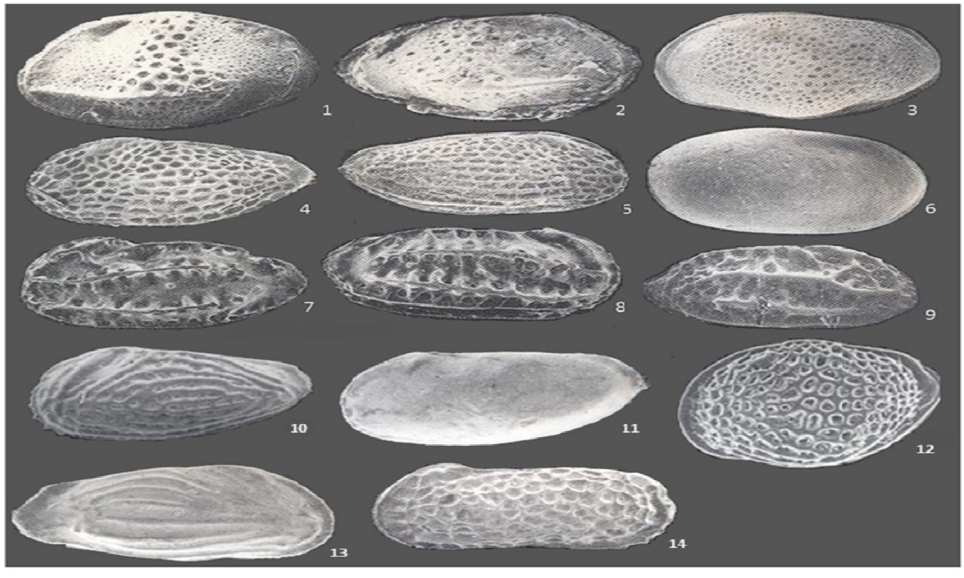

PLATE Ⅱ

Figure

1. *Darika* cf. *robusta* Omatsola. Left side of carapace, female, Akata-1, 2432 ft, x65

2. *Darika* cf. *robusta* Omatsola. Right side of carapace, female, Akata-1, 2432 ft, x65

3. *Loxoconcha lagosensis* Reyment. Left side of carapace, male, Akata-1, 2339 ft, x65

4. *Saudanella fusa* Van den Bold. Left side carapace, female, Akata-1, 2323 ft, X60

5. *Saudanella fusa* Van den Bold. Right side carapace, female, Akata-1, 2323 ft, x55

6. *Cytherella sylvesterbradleyi* Reyment. Right side of carapace, male, Akata-1, 2339 ft, x115

7. *Costa dahomeyi* (Apostolescu). Left valve external view, female juvenile, Akata-1, 2432 ft, x55

8. *Costa dahomeyi* (Apostolescu). Right side of valve external view, female, Akata-1, 2432 ft, x54

9. *Costa dahomeyi* (Apostolescu). Right side of valve external view, female, Araromi-1, Benin basin, 241-243 ft, x50

10. *Saudanella* cf. *fusa* Carbonnel. Left side of carapace, female, Akata-1, 2676 ft, x65

11. *Benisymmetricythere grosdidieri* Carbonnel et al. Left side of carapace, male, Akata-1, 6780 ft, x70

12. *Loxoconcha* cf. *kazeuntinensis* Carbonnel. Left side of carapace, Akata-1, 6320 m, 6400 ft, x60

13. *Ruggieria* aff. *leonensis* Keen. Right side of carapace, male, Awaizombe-1, 5601 ft, x60

14. *Benina* aff. *postsehhouensis* Carbonnel et al. Left side of carapace, male, Ihuo-1, 6557 ft, x48