

1  
2  
3  
4  
5  
6  
7  
8  
9  
10

## Original Research Article

# Calcareous Nannofossil Biostratigraphic Analysis of Well 'K-2', Deep Offshore Niger Delta, Nigeria

### ABSTRACT

A study on the calcareous nannofossil biostratigraphy has been carried out on sequences within the interval 1640 m -1980 m of well 'K-2' which is located in the deep offshore of the Niger Delta, Nigeria.

Lithologic description of the samples was done using a stereo-binocular microscope. Thirty-four slides of the samples were prepared in the laboratory. The prepared slides were studied for their calcareous nannofossil contents using Olympus Light Microscope in both plane-polarized and cross-polarized light.

The litho-stratigraphic descriptions on the samples showed the abundance of shale and mudstone/siltstone with minor amount of thin intercalated units of sand bed. Seventeen calcareous nannofossil species were identified and used to predict the biostratigraphic deductions such as zonation, dating and a tentative sequence stratigraphic framework. With the aid of a standard zonation schemes, two major nannofossil zones (NN 19 and NN 18) were identified. These zones belongs to Pleistocene and Pliocene age respectively. Two major zones of *Gephyrocapsa caribbeanica* and *Gephyrocapsa parallela* were identified for the studied well on the basis of the index taxa and fossil assemblage recorded. The insufficient amount of nannofossils in the lower part of the well precluded a definite zonation made the zone to be indeterminable. One Condensed Section believed to be associated with 2.0 Ma Maximum Flooding Surfaces was recognized.

11  
12  
13

**Keywords:** *Biostratigraphy*, *Gephyrocapsa caribbeanica*, *Gephyrocapsa parallela*, *Condensed Section*, *Maximum Flooding Surfaces*

## 1. INTRODUCTION

The focus on the Tertiary Niger Delta basin by various workers gained prominence following its discovery as a petroleum laden basin in the 1950's by Shell BP. Since then, Nigeria has been rated as the sixth largest oil producing country in the world with a proven ultimate reserve of about thirty four billion barrels of oil and two hundred and sixty trillion cubic feet of gas [1].

However, about 90% of the twenty six billion barrels recoverable oil reserve earlier estimated for the Niger Delta by [2] is said to be from the onshore areas of Niger Delta. This could have been due to the extensive exploration activities, which concentrates on the onshore areas of the Niger Delta compared to offshore regions.

Presently, attention has been directed to the offshore regions and so far prospects have been encouraging. The advancement in deep-water drilling technology and various exploration techniques have aided this development.

More recently, the integration of biostratigraphy with other methods like geophysics, well log reserve, sequence stratigraphy, have contributed immensely to hydrocarbon exploration in the offshore Niger Delta.

However, based on the biostratigraphy, three major fossil groups are focused on. These are foraminifera, pollen and spores and nannofossils. These three have proven very useful and complementary to each other but the use of nannofossils is becoming increasingly important because of the following:

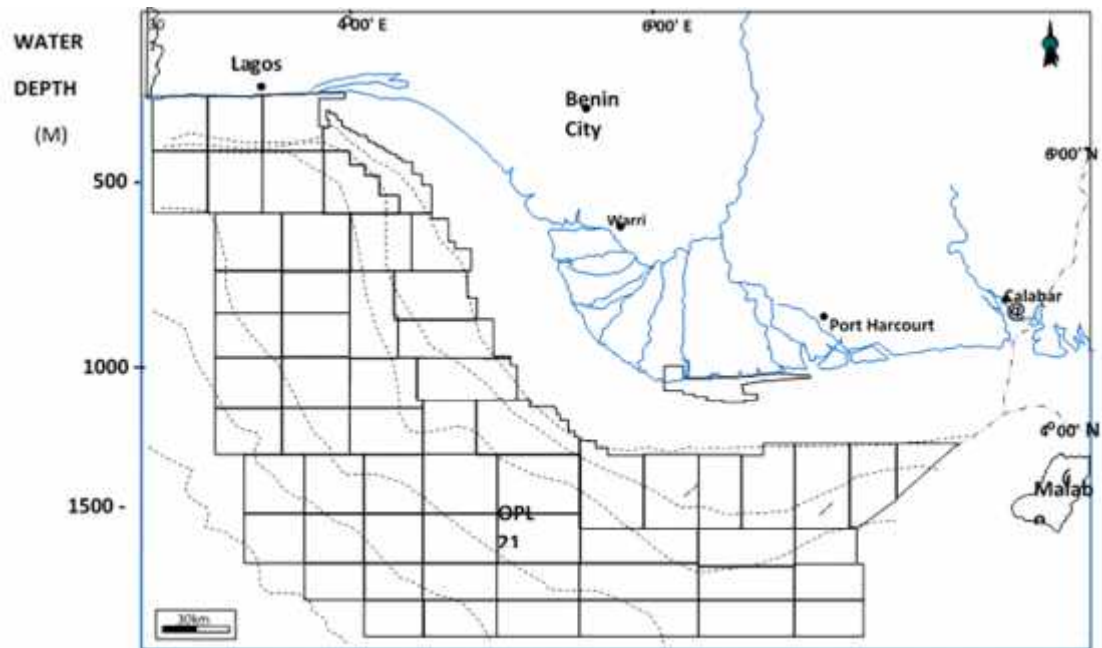
- (a) They are planktonic, abundant, evolve rapidly and largely cosmopolitan.
  - (b) They can be studied from minute rock chips because of their small size.
- This found application in hydrocarbon exploration and development, and scientific drilling.

Calcareous nannofossil therefore is defined as all calcareous fossils that are smaller than 30 microns ( $\mu\text{m}$ ). They are exclusively marine fossils of great importance in deep water exploration and they have been used in various ways to assist in operational situation in the well site during drilling which include achieving a straight-forward age monitoring of wells where stratigraphy is uncertain and also in confirmation of terminal depth where there is commitment to drill to deposit of specific age and in coring point selection to mention a few. This means that a pragmatic approach to nannofossil biostratigraphy is required. Many researchers have worked on the calcareous nannofossils ([3]; [4]; [5]).

### 1.1 Location of the Study Area

50 Ditch cutting samples were obtained from well 'K-2' in the offshore deep-water  
51 Nigeria. The samples were given out by one of the deep water operators. The name and  
52 the exact location of the well were not made available for proprietary reasons.

53 However, the Nigeria deep-water region is believed to be roughly between water  
54 depth of 600 m on the inboard side and 200 m in the outboard side for an area of  
55 approximately 48,500 Km<sup>2</sup> (Figure 1) [6].



56  
57 Figure 1: Map showing the acreage of study area

58 The samples were obtained at 10 m interval. This study covers an interval of 1640 m to  
59 1980 m comprising thirty-four samples in all.

## 60 1.2 Objectives of the Study

- 61 • To establish the lithostratigraphic sequence of the section.
- 62 • To identify the calcareous nannofossil species in the strata penetrated by  
63 the well.
- 64 • To identify new nannofossil species in the analyzed sequence (if any).
- 65 • To determine the age of the strata penetrated by the well.
- 66 • To determine a tentative sequence stratigraphic framework for the section.

## 67 1.3 Geology of the Niger Delta

68 The Niger Delta is one of the basins in West Africa formed as a result of basement  
69 tectonics related to crustal divergence and translation during the Late Mesozoic to  
70 Cretaceous continental rifting of Gondwanaland. The Niger Delta is a thick prism of clastic  
71 sediments which has prograded down the Benue Trough into the Gulf of Guinea since Early

72 Tertiary. These sediments began to reach the continental slope by Late Eocene time and  
73 subsequent progradation has progressively enlarged the continental margin to its present  
74 position [2].

75 The results of numerous studies of Tertiary Niger Delta indicate that the Delta  
76 consists of a thick sedimentary prism of about 12 km. The overall succession in ascending  
77 order consists of over pressure continuous marine shales (Akata Formation) with  
78 interbedded thin bed of siltstone interpreted as slope channel fills. These are overlain by a  
79 paralic sequence of shales and sands (Agbada Formation) and thick continental sands and  
80 gravels at the top (Benin Formation).

81

## 82 **2. MATERIAL AND METHODS**

83

84 The materials used for this study were ditch cutting samples. The well is code-  
85 named as well 'K-2' for confidential reasons. These samples were supplied by one of the  
86 major Niger Delta deep-water operators.

87 The samples were obtained at depth within the intervals of 1640-1980 m. Thirty-four  
88 samples were analyzed and the samples were packed in small polythene bags which bear  
89 the name of the well and sampling depth. The bags were arranged serially in a tray in the  
90 laboratory for lithologic description and sample processing for calcareous nannofossil  
91 analyses.

92

### 93 **2.1 Lithologic Description**

94

95 The lithologic description of the samples was done using a stereo-binocular microscope. A  
96 lithostratigraphic column for the well was then constructed based on the lithologic description  
97 of the samples and lithostratigraphic units penetrated by the well were delineated.

### 98 **2.2 Preparation**

99 Thirty four samples were processed for their calcareous nannofossil content. The  
100 technique employed for this study is the standard preparation technique of [7]. The  
101 technique involves:

- 102 (i) Taking a fresh inner portion of the sample provided and spreading over a  
103 cover slip (22 mm x 40 mm) of a glass slide (25.4 mm x 76 mm).
- 104 (ii) Adding a few drop of distilled water and making a thick sediment suspension  
105 with the help of a flat – sided toothpick.
- 106 (iii) Smearing the suspension thinly across the surface of the cover-slip using a  
107 toothpick, and drying rapidly on a hot-plate at a temperature of about 60-70  
108 °C for few minutes.

- 109 (iv) Labeling a glass microscope slide, and affixing the coverslip (smear-side  
110 down) using a few drops of Norland optical adhesive mounting medium.  
111 (v) Placing this under an ultraviolet light for about forty five minutes.

## 112 2.2 Identification of Calcareous Nannofossil

113 The prepared slides were studied for their calcareous nannofossil content under a  
114 high power Olympus Light Microscope in plane-polarized and cross-polarized light.  
115 The abundance and diversity of the assemblages were made by consulting the work  
116 of [8] and [9].

## 117 3. RESULTS AND DISCUSSION

### 118 3.1 Lithostratigraphy of Well 'K-2'

121 The samples analyzed in this well from intervals 1640 m to 1980 m have been found  
122 to have similar lithology. The sequences in the well correspond to the lower units of the  
123 Agbada paralic facies described by [10]. Most of the lithofacies are composed of shale and  
124 siltstone mudstone with thin intercalated units of sand beds. This is revealed in the lithologic  
125 description of ditch cutting samples. A summary of the lithologic log is given in Table 1.  
126 The shales and mudstones are mostly grey to dark grey and black in colour. The sands  
127 range from coarsed to fine grained, angular to rounded and poor to well sorted. Accessory  
128 minerals occurring in high abundances include ferruginous materials and pyrites. Common  
129 to few occurrences of glauconite, mica flakes and carbonates are found within certain  
130 intervals of the studied sections.

131

132 Table 1: Summary of Lithologic Log of Well 'K-2'

DEPTH [m]	LITHOLOGY	AGE	FORMATION
1640-1650	SHALE	Pleistocene	Agbada
1650-1660	SHALE	Pleistocene	Agbada
1660-1670	SHALE	Pleistocene	Agbada
1670-1680	SHALE	Pleistocene	Agbada
1680-1690	SHALE	Pleistocene	Agbada
1700-1710	SHALE	Pleistocene	Agbada
1710-1720	SHALE	Pleistocene	Agbada
1720-1730	SHALE	Pleistocene	Agbada
1730-1740	SHALE	Pleistocene	Agbada
1740-1750	SHALE	Pleistocene	Agbada
1750-1760	SHALY SAND	Pleistocene	Agbada
1760-1770	SAND	Pleistocene	Agbada
1770-1780	SHALE	Pleistocene	Agbada
1780-1790	SHALE	Pleistocene	Agbada
1790-1800	SHALE	Pliocene	Agbada

1800-1810	SANDY SHALE	Pliocene	Agbada
1810-1820	SHALY SAND	Pliocene	Agbada
1820-1830	SHALY SAND	Pliocene	Agbada
1830-1840	SHALY SAND	Pliocene	Agbada
1840-1850	SHALY SAND	Pliocene	Agbada
1850-1860	SHALY SAND	Pliocene	Agbada
1860-1870	SHALY SAND	Pliocene	Agbada
1870-1880	SHALY SAND	Pliocene	Agbada
1880-1890	SANDY SHALE	Pliocene	Agbada
1890-1900	SHALY SAND	Pliocene	Agbada
1900-1910	ARGILLACEOUS SANDSTONE	Pliocene	Agbada
1910-1920	ARGILLACEOUS SANDSTONE	Pliocene	Agbada
1920-1930	ARGILLACEOUS SANDSTONE	Pliocene	Agbada
1930-1940	ARGILLACEOUS SANDSTONE	Pliocene	Agbada
1940-1950	ARGILLACEOUS SANDSTONE	Pliocene	Agbada
1950-1960	SANDY MUDSTONE	Pliocene	Agbada
1960-1970	SHALY SAND	Pliocene	Agbada
1970-1980	SANDY MUDSTONE	Pliocene	Agbada

133

### 134 3.2 Calcareous Nannofossils Identification

135 The result shows highly abundant and diverse calcareous nannofossils. A total of seventeen  
136 nannofossils species comprising mainly of *coliths*, *pliths* and *nannoliths* were  
137 identified in the analysed section of well 'K-2'. Of these, *Gephyrocapsa caribbeanica* is the  
138 most abundant. *Helicosphaera carteri* occur almost throughout the entire analyzed section.  
139 Influxes of *Gephyrocapsa caribbeanica* were noticed within interval 1660-1680 m and at  
140 depth 1720 m and 1790 m. *Gephyrocapsa oceanica* also occur in high abundance within  
141 the upper part of the studied section.

142 The family *Noelaerhabdacea* are represented by the genus *Reticulofenestra* and genus  
143 *Gephyrocapsa*. *Reticulofenestra productella* represents the most abundant of the genus  
144 *Reticulofenestra* and are more abundant at depth 1670m. *Gephyrocapsa* has three of its  
145 species well represented within the studied interval of well 'K-2'. The three species are  
146 *Gephyrocapsa caribbeanica*, *Gephyrocapsa oceanica* and *Gephyrocapsa parallela* and are  
147 all in abundance within the studied section. These *Gephyrocapsa* species are important  
148 stratigraphically and are commonly employed as zonal markers. They are also of  
149 chronostratigraphic value in the Neogene. The two major zones proposed for the studied  
150 section of well 'K-2' were delineated using *Gephyrocapsa* species.

151 The family *Helicosphaeraceae* has two of its species well represented in the studied section.  
152 These two species are *Helicosphaera carteri* and *Helicosphaera selli*. Of these two species,

153 *Helicosphaera carteri* are very abundant and are diverse within the studied section.  
154 *Helicosphaera selli* showed a rare occurrence in the studied section.  
155 The *Calcidiscaceae* family is also represented by two of its species which are *Calcidiscus*  
156 *leptoporus* and *calcidiscus macintyreii*. *Calcidiscus macintyreii* revealed a rare occurrence,  
157 occurring only at depth 1660m. *Calcidiscus leptoporus* showed high abundance and  
158 diversity occurring within the interval 1680 m-1760 m and also at depths 1780 m, 1810 m  
159 and 1840 m within the studied section.  
160 Other nannofossil assemblage of high abundance and diversity are *Pseudoemiliana*  
161 *lacunosa* and *Thoracosphaera spp.* Other nannofossils with rare occurrence in the studied  
162 section include *Ceratolithus cristatus*, *Coccolithus pelagicus*, *Sphaerocyphosphaera globulata*,  
163 *Cyphosphaera apsteinii* and *Pontosphaera multipora*.  
164 The observed nannofossils are well preserved with minimum effect of dissolution.  
165 A nannofossil distribution chart was plotted with depth on the vertical axis and recorded taxa  
166 on the horizontal axis. The chart also includes the interpretations made from this work  
167 (Figure 3)

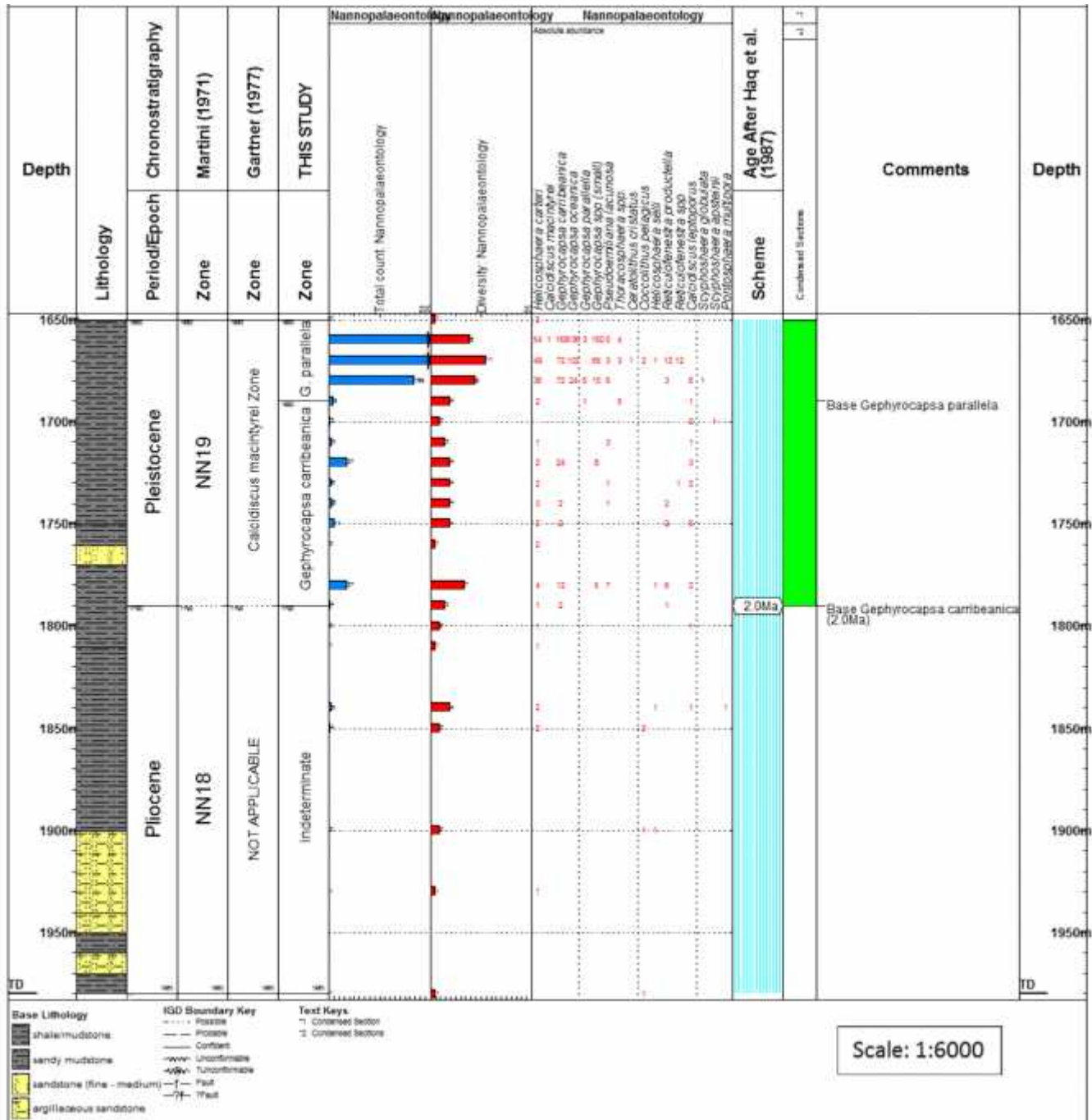


Figure 3: Calcareous nannofossil distribution chart of well 'K-2'





1950							
1960							
1970							
1980							
1990							

Figure 4: Calcareous nannofossil zones recognized in well 'K-2'.

### 3.3 Calcareous Nannofossil Zonation

The stratigraphic interval studied in well 'K-2' has been sub-divided into biostratigraphic zones on the basis of their calcareous nannofossil. The well section was zoned using the globally recognized calcareous nannofossil zonation scheme of [11] and [12]. [11] zones were tagged NN zones (Neogene Nannofossils). [12] established his zones based on the index taxa.

Two major zones belonging to Pleistocene and Pliocene ages were established in the studied section of well 'K-2' as shown in the table above. These are the NN19 and NN18 zones of [11].

### 3.4 Zone Description

#### Zone NN 19

**Stratigraphic interval:** 1640 – 1790 m

**Age** : Pleistocene

**Nannofossil zone** : NN19

**Top:** The top of this zone is believed to be shallower than the first sample analysed.

**Base:** The base of this zone is marked by the base of *Gephyrocapsa caribbeanica* at depth 1790 m.

**Description:** Zone NN 19 is otherwise known as *Pseudoemiliana lacunosa* zone according to Martini (1971) and it is divided into four sub-zones which are *Pseudoemiliana lacunosa* zone, small *Gephyrocapsa* zone, *Helicosphaera selli* zone and *Calcidiscus macintyre* zone by Gartner (1977). The sub-zone that fall within the studied well is *Calcidiscus macintyre* zone. This zone is characterized by abundant and diverse nannofossil assemblage at the upper half. The lower half is characterized by a slight reduction in fossil diversity and abundance. Index taxa recognized in the section which are in abundance include *Gephyrocapsa caribbeanica*, *Gephyrocapsa oceanica*, *Gephyrocapsa parallela*, *Calcidiscus macintyre* and *Pseudoemiliana lacunosa*. Other nannofossils in the zone include *Helicosphaera carteri*, *Thoracosphaera spp.*, *Calcidiscus leptoporus*, *Reticulofenestra*, *Coccolithus pelagicus* and *Ceratholithus cristatus*.

## 205 **Zone NN18**

206 **Stratigraphic Interval:** 1790 – 1980 m

207 **Age** : Pliocene

208 **Nannofossil zone** 18

209 **Description:** This interval is marked by rare occurrences of nannofossils. This precludes a  
210 definite zonation of the interval. However the interval has been assigned to the NN18 based  
211 on the stratigraphic position below the positively recognized zone NN 19 above. Some of  
212 the nannofossil species in this zone are *Helicosphaera carteri*, *Coccolithus pelagicus*,  
213 *Helicosphaera selli*, *Calcidiscus leptoporus* and *Pontosphaera multipora*. These  
214 assemblages comprises mainly of long range, non-age diagnostic species. However, [12]  
215 zonation scheme is not applicable to this age.

### 216 **3.5 Zonation Based on this Study**

217 Two major zones were erected for the studied section of well 'K-2'. No subzones were  
218 delineated. The erection of these zones is based on the following criteria:

- 219 • First and last occurrence of marker species.
- 220 • Assemblage characteristics

221 The erected zones are:

- 222 (i) *Gephyrocapsa caribbeanica* zone
- 223 (ii) *Gephyrocapsa parallela* zone
- 224 (iii) Intervals 1790-1990 m has been designated indeterminate zone based on  
225 lack of index taxa.

#### 226 **3.5.1 Zonal Description**

##### 227 ***Gephyrocapsa parallela* zone**

228 **Stratigraphic interval:** 1640 – 1690 m

229 **Age:** Pleistocene

230 **Nannofossil zone:** *Gephyrocapsa parallela*

231 **Top:** The top of the zone is probably shallower than the first analyzed sample.

232 **Base:** The base of this zone is marked by the base of *Gephyrocapsa parallela* at depth  
233 1690m.

234 **Description:** This zone is marked by abundant and diverse occurrence of nannofossil  
235 assemblages. The top is probably shallower than the first analyzed sample in the studied  
236 section of well 'K-2'. It has been observed that *Gephyrocapsa parallela* occurs shallower in  
237 this study than observed by earlier authors who placed the base of *Gephyrocapsa parallela*  
238 at a relatively younger age. The base of *Gephyrocapsa parallela* was used by [12] to  
239 delineate his younger subzone (*Pseudoemiliana lacunosa*) of the NN19 zone earlier  
240 subdivided by [11]. Other index taxa found in this zone include *Gephyrocapsa caribbeanica*,

241 *Gephyrocapsa oceanica* and *Pseudoemiliana lacunosa*. Other nannofossil species in this  
242 zone include *Helicosphaera carteri*, *Calcidiscus macintyreii*, *Pseudoemiliana lacunosa*,  
243 *Coccolithus pelagicus*, *Helicosphaera selli* and *Reticulofenestra productella*.

244

#### 245 ***Gephyrocapsa caribbeanica* zone**

246 **Stratigraphic interval:** 1690 – 1790 m

247 **Age:** Pleistocene

248 **Nannofossil zone:** *Gephyrocapsa caribbeanica*

249 **Top:** The top of the zone is marked by the base of *Gephyrocapsa parallela* at depth 1690  
250 m.

251 **Base:** The base of the zone is marked by the base of *Gephyrocapsa caribbeanica*

252 **Description:** This zone is characterized by fairly abundant and diverse nannofossil  
253 assemblage. This interval is delineated based on the continuous occurrence of  
254 *Gephyrocapsa caribbeanica* within the section. Other index taxa occurring in high abundance  
255 within the zone include *Gephyrocapsa oceanica*, *Gephyrocapsa parallela* and  
256 *Pseudoemiliana lacunosa*. Other nannofossils in common but few abundance within this  
257 zone include *Helicosphaera carteri*, *Calcidiscus macintyreii*, *Thoracosphaera spp.*,  
258 *Ceratolithus cristatus*, *Coccolithus pelagicus*, *Helicosphaera selli*, *Reticulofenestra*  
259 *productella*, *Calcidiscus leptoporus*, *Scyphosphaera globulata* and *Scyphosphaera apsteinii*.

260 The base of *Gephyrocapsa caribbeanica* at depth 1790 m is dated 2.0 Ma, hence,  
261 the observed condensed interval 1650-1790 m is believed to be associated with 2.0 Ma  
262 Maximum Flooding Surface.

### 263 **3.6 Sequence Stratigraphy**

264 The basic procedure of sequence stratigraphic interpretation according to [13]  
265 involves the following steps:

- 266 (i) Lithology to be interpreted from log character (gamma ray and sonic ray and  
267 ditch cuttings).
- 268 (ii) Deduction of depositional environment from foraminifera data and  
269 characters.
- 270 (iii) Interpretation of condensed section from faunal abundance and diversity  
271 peaks.
- 272 (iv) Determination of sequence boundaries and system tracts from log  
273 character.
- 274 (v) Age dating of well sequence from biostratigraphic data.

275 Due to the absence of steps (ii) and (iv), an attempt was made of a tentative sequence  
276 stratigraphic interpretation for the well section based on the available information. The

277 absence of e-logs and palaeobathymetric data from foraminifera studies prevent a detailed  
278 sequence stratigraphic interpretation of the well sequence.

279 The tentative interpretation therefore led to the identification of dated Condensed  
280 Section.

### 281 3.7 Condensed Section and Maximum Flooding Surfaces

282 Based on nannofossil abundance and diversity patterns, calibrated with chrono-  
283 stratigraphically important bio-events, one condensed section has been identified and  
284 correlated with the Global Cycle Chart of [14] as shown in Table 3. This is believed to be  
285 associated with the 2.0 Ma Maximum Flooding Surface.

286 Table 3: Condensed section recognized in well 'K-2'

Condensed Section	Interval (metres)	Age (Ma) After [14]	Dating Criteria
1	1650 – 1790	2.0	<ul style="list-style-type: none"><li>· Base <i>Gephyrocapsa caribbeanica</i> at depth 1790 m (2.0 Ma).</li><li>· Base <i>Gephyrocapsa parallela</i> at depth 1690m</li></ul>

287

## 288 4. CONCLUSIONS

289  
290 A calcareous nannofossil biostratigraphy has been done on sequences having  
291 intervals 1640 – 1980 m of well 'K-2' in the deep offshore area of the Niger Delta, Nigeria.

292 A lithostratigraphic description made on the ditch cuttings revealed sandy mudstone  
293 and hemipelagic shale and the accessory minerals in them. This was done with the aid of  
294 stereobinocular microscope.

295 The results of the analysis revealed moderately abundant and diverse nannofossil  
296 assemblages. Seventeen calcareous nannofossil species identified were used to make  
297 biostratigraphic deduction including zonation, dating and a tentative sequence stratigraphic  
298 framework for the sequences studied.

299 Two major nannofossil zones (NN19 and NN18) belonging to Pleistocene and  
300 Pliocene respectively were recognized based on the standard zonation schemes of Martini  
301 (1971) and Gartner (1977) respectively. Two major zones were identified for the studied well.  
302 The two zones are *Gephyrocapsa caribbeanica* and *Gephyrocapsa parallela* zones. The  
303 Pleistocene portion of the well section based on this study was characterized by abundant  
304 and diverse occurrence of nannofossils. The Pliocene portion of the studied interval was

characterized by rare and scattered occurrences of nannofossils which precludes a definite zonal and age assignment to the interval.

Nannofossil abundance and diversity patterns calibrated with chrono-stratigraphically important bio-events enhanced the identification of only one condensed section correlated to the Global Cycle Chart of Haq et al., (1987). This is thought to be associated with the 2.0Ma Maximum Flooding Surface.

It is recommended that a local nannofossil zonation scheme be erected for the Niger Delta Pleistocene age.

## ACKNOWLEDGEMENTS

The author wish to thank Dr. S. L. Fadiya of Crystal Age Limited, Ikorodu, Lagos for his technical assistance in the preparation and analysis of samples.

## COMPETING INTERESTS

All authors have declared that no competing interests exist

## AUTHORS' CONTRIBUTIONS

The author designed the study, performed the analysis and interpretation of the samples. The author also prepared the manuscript.








## REFERENCES

1. Reijers, TJA., Petters SW, Nwajide CS. The Niger Delta basin. In: Reijers, T.J.A. (ed.); Selected chapters in Geology-Sedimentary Geology and Sequence Stratigraphy in Nigeria and three case studies and a field guide. Shell Petroleum Development and Company, Warri, Nigeria. 1996: 105-114.
2. Doust H, Omatsola E. Niger Delta. In: Edwards, J. D. and Santogrossi, P.A. (eds.), *Divergent/Passive Margin Basins, AAPG Memoir*, U.S.A.. 1989: 48, 201-238.
3. Erba E. Nannofossils and Mesozoic oceanic anoxic events. *Marine Micropaleontology*. 2004: 52, 85–106.
4. Raffi I, Backman J, Pälike H. Changes in calcareous nannofossil assemblages across the Paleocene/Eocene transition from the paleo-equatorial Pacific Ocean. *Palaeogeography, Palaeoclimatology, Palaeoecology* 2005:226, (1–2), 93-126.
5. Zachos JC, Kroon D, Blum P. Proceedings ODP, Initial Reports 208, College Station, TX (Ocean Drilling Program); 2004
6. Sawyer RK, Connolly DL, Fontenot R, Ogilvie F, Pichon AG.. Deepwater Nigeria OPL-213: Prospect generation using integrated technologies. *Nigerian Association of Petroleum Explorationists Bulletin*, Nigeria. 2002:16(1):1-21.
7. Hay WW, Mohler HP, Roth PH, Schmidt RR, Boudreaux JE. Calcareous nannofossils from Nal'chik (northwest Caucasus). *Eclogae Geologicae Helvetiae*. 1967:59: 379-399.
8. Perch-Nielsen K. Cenozoic Calcareous nannofossil. In: Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K. (eds.), *Plankton Stratigraphy, Cambridge Earth Sciences Series*, Cambridge University Press. 1985:427-554.
9. Fadiya SL. Foraminifera and Calcareous Nannofossil biostratigraphy and well log sequence stratigraphic analysis of Opolo-5 and Opolo-9 wells, Niger Delta. Unpub.

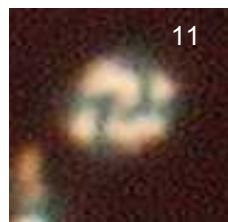
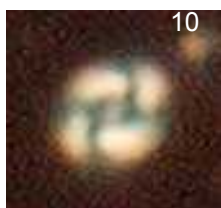
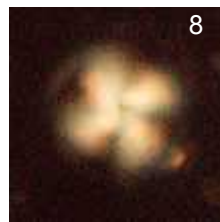
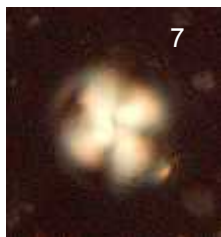
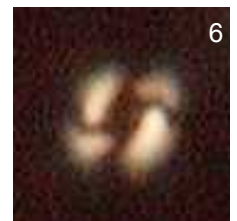
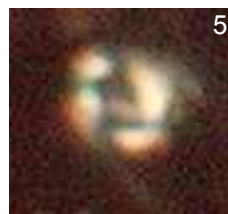
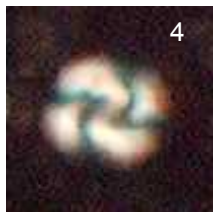
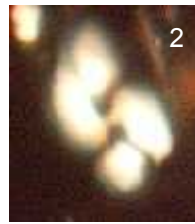
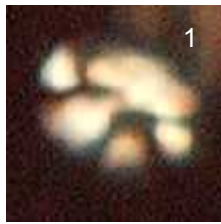
- 354 M.Sc. Thesis, Department of Geology, Obafemi Awolowo University, Ile-Ife, 149p.  
 355 Abstract Published – *American Association of Petroleum Geologists Bulletin*,  
 356 1999:82(11):2162.
- 357 10. Short KC, Stauble AJ. Outline of the Geology of Niger Delta. *American Association*  
 358 *of Petroleum Geologists Bulletin*. 1967: 51: 761-779.
  - 359 11. Martini E. Standard Tertiary and Quaternary Calcareous Nannoplankton Zonation.  
 360 In: Farinacci (eds.), *Proceedings II Planktonic Conference, Roma*, 1971: 2:739-785.
  - 361 12. Gartner S. Correlation of Neogene Planktonic foraminifera and Calcareous  
 362 nannofossil zones. *Transactions of the Gulf Coast Association of Geological*  
 363 *Societies*. 1977:19: 585-599.
  - 364 13. Vail PR, Mitchum RM, Todd RG, Widmier JM, Thompson S, Sangree JB, Bubbs JN,  
 365 Hakleid WG. Seismic Stratigraphy and global changes in sea level. Part 2. In:  
 366 Seismic Stratigraphy-Application to Hydrocarbon exploration (ed. By C. E.  
 367 Payton). American Association of Petroleum Geologists, Tulsa, Memoir, 1977:26:  
 368 49-62.
  - 369 14. Haq BU, Hardenbol J, Vail PR. Chronology of fluctuating sea levels since the  
 370 Triassic. *Science*. 1987:235: 1156-1157.
  - 371 15. Kamptner E. Untersuchungen uber den Feinbau der Coccolithen. *Archiv fur*  
 372 *Protistenkunde*. 1954:100: 1-90
  - 373 16. Boudreaux JE, Hay WW. Calcareous Nannoplankton and biostratigraphy of the  
 374 Late Pliocene-Pleistocene-Recent sediments in the Submarex Cores. *Revista*  
 375 *Espanola de Micropalaeontologia*. 1967:1:249-292.
  - 376 17. Hay WW, Beaudry FM. Calcareous Nannofossils: Leg 15, Deep Sea Drilling Project.  
 377 In: Edgar, NT., Saunders. JB et al.;(eds.). Initial Reports of the Deep Sea Drilling  
 378 Project; 15, Washington DC, 1973: 625-685
  - 379 18. Bukry D, Bramlette MN. Some new and Stratigraphically useful Calcareous  
 380 nannofossils of the Cenozoic. *Tulane studies in Geology and Palaeontology*.  
 381 1969a:7:131-142.
  - 382 19. Bukry D, Percival SF. New Tertiary Calcareous Nannofossils. *Tulane Studies in*  
 383 *Geology and Palaeontology*. 1971:8: 123-146.
  - 384 20. Gallagher LT, 1989. Calcareous Nannofossil Biozonation of the Tertiary of the North  
 385 Sea Basin. *Newsletters on Stratigraphy*, 1989: 22: 21-44.

## 387 APPENDIX

### 388 PLATE 1

- 390  *Helicosphaera carteri* (fig. 1-2)  
- 391 *Gephyrocapsa caribbea* (fig. 3-6) 
- 392 *Calcidiscus leptoporus* (fig.   [15].
- 393 *Gephyrocapsa oceanica* (fig. 10-12)  [15]

# PLATE 1

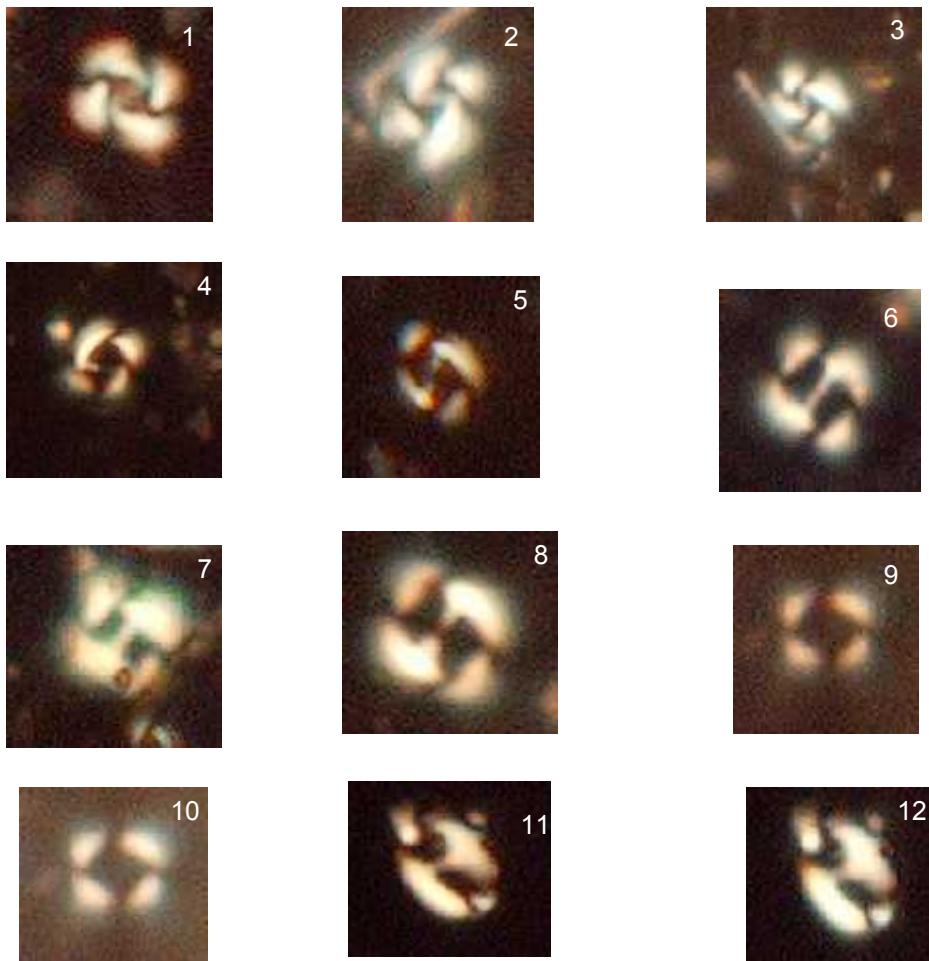




395 **PLATE 2**  
 396 *Gephyrocapsa oceanica* (fig. 1-4)  
 397 *Gephyrocapsa parallela* (fig. 5-8)  
 398 *Pseudoemiliana lacunosa* (fig. 9-10)  
 399 *Helicosphaera selli* (11-12)  
 400

[15]  
[18]

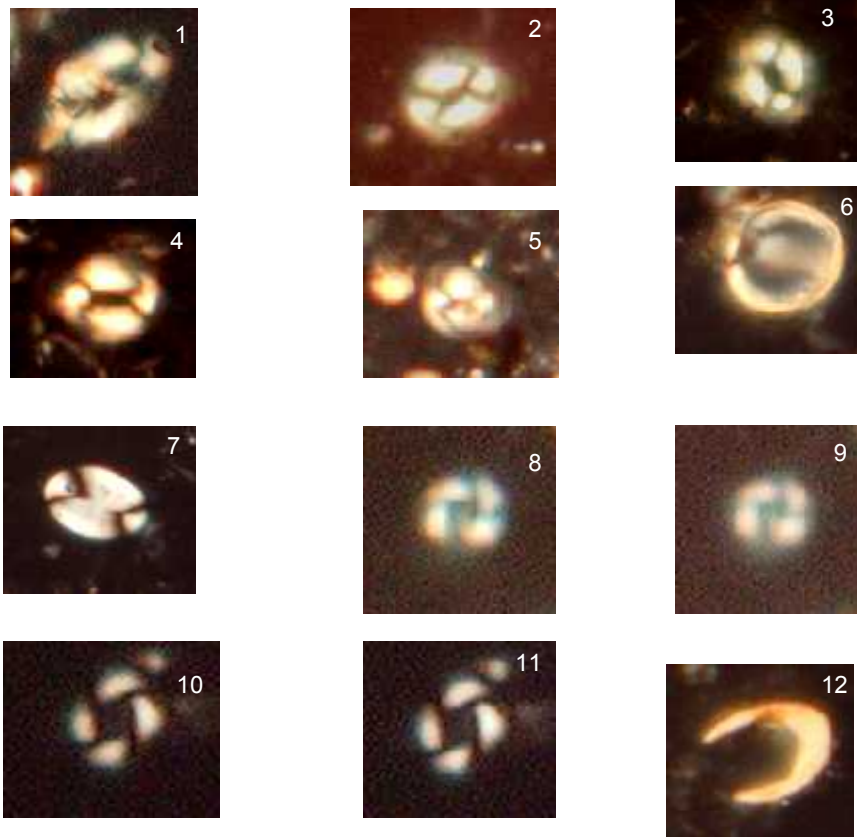
## PLATE 2



401

402	PL 3		
403		<i>Helicosphaera selli</i> (fig. 1)	[18]
404		<i>Coccolithus pelagicus</i> (fig. 2-5)	[15]
405		<i>Scyphosphaera globulosa</i> (fig. 6)	[19]
406		<i>Pontosphaera multipora</i> (fig. 7)	[15]
407		<i>Reticulofenestra productella</i> (fig. 8-11)	[20]
408		<i>Ceratolithus cristatus</i> (fig. 12)	[15]
409			
410			

### PLATE 3

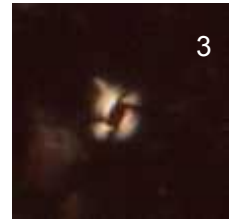
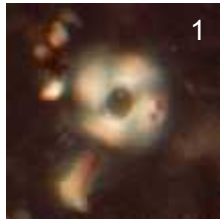


412 PLATE 4

413 *Calcidiscus macintyre* (fig. 1) [18].

414 *Reticulofenestra* spp. (fig. 2-3) [18]

## PLATE 4



415  
416