



## BIOSTRATIGRAPHY STUDIES OF MIOCENE SEDIMENTS IN THE ONSHORE/OFFSHORE AREA, NIGER DELTA BASIN, NIGERIA

Ukpabi N<sup>1</sup>, Osterloff P. L<sup>2</sup> and Oloto I.N<sup>3</sup>

<sup>1,3</sup> Department of Geology, University of Port Harcourt, Port Harcourt,

<sup>2</sup> Geological Services, Shell Petroleum Development Company Limited, Port Harcourt

### ABSTRACT

Palaeoenvironmental interpretation was carried out on 17 wells based on the biostratigraphic charts and data generated. The biostratigraphic data included population counts of pollen, *Belskipolliselegans*, microfauna and nannoflora which were distributed within the Middle Miocene sequences of the onshore/offshore Niger Delta. The wells penetrated the shale and sandstone formations of the Agbada Formation. From the biostratigraphic charts, statistical data were derived and tabulated based on sampled stratigraphic horizons from which histogram plots were generated. The result reflected changes in occurrences of *Belskipolliselegans*, microfauna and nannoflora through time, resulting from influences of climate, sea level change and/or sediment influx in the Niger Delta during the Middle Miocene. The observed trends in the distribution pattern of these fossils were compared with climatic curve derived by previous workers, in order to determine the depositional control during the Middle Miocene within the Niger Delta. Based on the palaeoenvironmental interpretation, biozonation scheme were grouped under the Middle Miocene *Pachydermitesdiederixi* (P680) Zone (17.4 Ma), *Crassoretitriletesvanraadshooveni* (P720) Zone (15.7 Ma), *Belskipolliselegans* (P740) Zone (14.2 Ma) and *Verrutricolporitesrotundiporis* (P770) Zone (12.1 Ma) palynological zones. The transgressive and regressive trends which were dependent on the changes in climate and sea level were interpreted using the distribution of *Belskipolliselegans* (continental), microfauna and nannoflora (marine). The 17 wells were correlated based on the general distribution of *Belskipolliselegans* within the palynological zones, in the Middle Miocene Agbada formation of the Niger Delta.

## INTRODUCTION

The Niger Delta complex developed as a regressive offlap sequence during Cenozoic times, i.e. from Paleocene through to Recent. A constructive high energy depositional environment appears to have prevailed only since Early Miocene times. The stratigraphy of such a constructive high energy depositional environment is complicated by the syndepositional collapse of this prograding clastic wedge into underlying overpressured mobile shales. This clastic wedge contains the 12th largest known accumulation of recoverable hydrocarbons, with reserves exceeding 34 billion barrels of oil and 93 trillion cubic feet of gas (Tuttle et al., 1999). These deposits have been divided into three large-scale lithostratigraphic units: (1) the basal Paleocene to Recent pro-delta facies of the Akata Formation, (2) Eocene to Recent, paralic facies of the Agbada Formation, and (3) Oligocene-Recent, fluvial facies of the Benin Formation (Evamy et al., 1978; Short and Stauble, 1967; Whiteman, 1982).

This study examined the distribution pattern of *Belskipolliselegans*, microfauna and nannoflora and their use in determining the influences of climate, sea level changes and/or sediment influx within the Middle Miocene.

### **(a) Aims and Objectives:**

The aim of this research was to understand what could be responsible for the succinct range appearance of *Belskipolliselegans* and how it may relate to climate driven processes, linking to changes in sedimentation rates and basin progradation in the Middle Miocene, onshore/offshore Niger Delta.

### **(b) Location and Accessibility:**

The Niger Delta is one of the World's largest Cenozoic delta systems and an extremely prolific hydrocarbon province. It occurs at the southern end of Nigeria, bordering the Atlantic Ocean (Gulf of Guinea) and extends from about longitude 3°-9°E and latitude 4°30'-5°20'N (Fig. 1). Throughout its history, the delta has been fed by the Proto-Niger, Benue and Cross rivers, which between them drain more than 10<sup>6</sup> km<sup>2</sup> of continental lowland savanna. Its present morphology is that of a wave-dominated delta, with a smoothly seaward-convex coastline traversed by distributary channels. From apex to coast the subaerial portion stretches more than 300 km, covering an area of 75 000 km<sup>2</sup>. Beneath the Gulf of Guinea, two enormous sub-sea lobes protrude a further 250 km into deeper waters, across the shelf and down the continental slope.

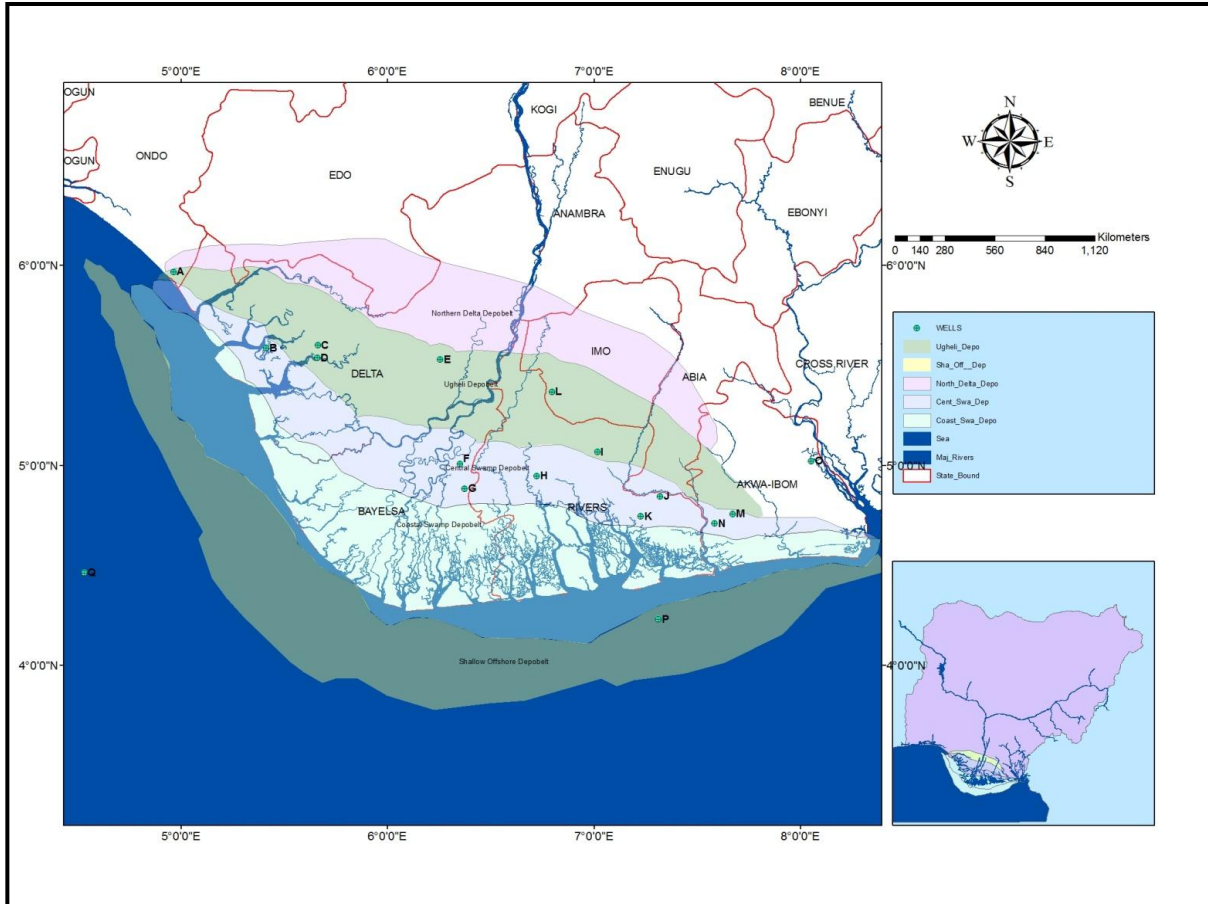


Figure 1: Location map of the Niger Delta modified from Stacher (1995).

**(c) General Geology of the Niger Delta:**

The Niger Delta stratigraphic sequence comprises an upward-coarsening regressive association of Tertiary clastics up to 12 km thick. It is informally divided into three gross lithofacies: (i) marine claystones and shales of unknown thickness, at the base, (Akata Formation); (ii) alternations of sandstones, siltstones and claystones, in which the sand percentage increases upwards, (Agbada Formation); (iii) alluvial sands, at the top, (Benin Formation) (Doust, 1990).

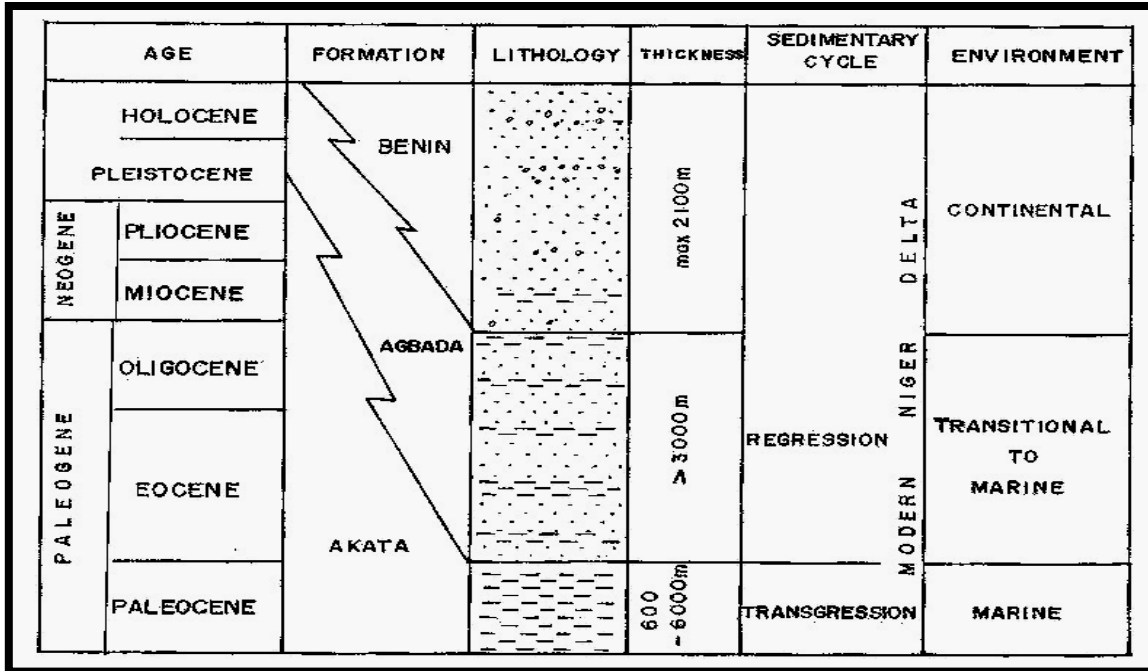


Figure 2:Stratigraphic section of the Niger Delta adopted from Doust, 1990

### METHODOLOGY

Biostratigraphic information of 17 analyzed wells was interpreted. From the log, the Gamma Ray log and the lithology sections showed that the wells comprised of a variety of lithological types, ranging from fine grain sandstones, sandy shale and shale formations of the Agbada formation. The wells are well distributed within the Niger delta. Emphasis were made only on the Middle Miocene sequences within these wells using *Belskipolliselegans* as a control specie and comparing its distributions with the distributions of microfauna and calcareous nannoplanktons.

### PRESENTATION OF RESULT

#### (A) LITHOSTRATIGRAPHIC DESCRIPTION:

The lithologic sequences of the wells were difficult to describe because samples from these wells were not made available, however, from the Gamma ray logs and the lithologic sections of the charts, it showed a wide variety of lithological types, ranging from sandstone, sandy shale and shale based on the degree of the gamma ray log response. These formations were the shale and intercalated sand of the Agbada Formation.

#### (B) BIOSTRATIGRAPHIC RESULTS:

Biostratigraphic events are important stratigraphic signatures left by fossils through which

important deductions on their past life or palaeoenvironmental reconstruction could be made, this forms the bases for regional or global correlation.

Biostatigraphic data extracted from each of the 17 wells were plotted to generate charts which showed the distribution of the different fossils at different stratigraphic horizons. Other data included are; well depth, chronostratigraphy, and biozonation, based on data availability / completeness, etc.

The biostratigraphic data for the 17 wells were interpreted based on sampled stratigraphic horizon from one well to another starting with the onshore wells to offshore wells in the Niger Delta.

Interest in the course of the analysis were on *Belskipolliselegans* occurrences of greater than 10 counts (high), faunal and nannofloral occurrences of greater than 100 counts (abundance).

Using a concentual scale, the occurrences of fossils were rated as follows:

**Belskipolliselegans occurrences:**

1 - 10 = Low

➤ 10 = High

**Faunal and Nannofloral occurrences:**

1 = Single

2 - 5 = Rare

6 - 20 = Frequent

21 - 100 = Common

➤ 100 = Abundant

**(a) WELL A:** Well A is located at the Greater Ugheli Depobelt of the Niger Delta, Nigeria. The well interval ranged from (2250.0 ft - 9705.0 ft). The sample type is Sidewall core and sample comprised of a variety of lithological units based on their log signatures, only one sampled stratigraphic horizon with *Belskipolliselegans* were encountered at 2412.00 ft which corresponded to *Belskipolliselegans* (P740) Zone. There are sporadic high occurrences of *Belskipolliselegans* at *Belskipolliselegans* (P740) Zone, and no occurrence of microfauna and nannoflora.

**(b) WELL B:** Well is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (2250.0 - 12800.0 ft). The sample type is Ditch Cuttings and comprised of a variety of lithological units

based on their log signatures, 11 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. 2 sampled stratigraphic horizons corresponded to *Pachydermitesdiederixi* (P680) Zone, no sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, 8 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone and 1 sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. At *Pachydermitesdiederixi* (P680) Zone, there were low occurrences of *Belskipolliselegans*, rare to abundance occurrences of microfauna and no occurrence of nannoflora.

At *Belskipolliselegans* (P740) Zone, there were sporadic high occurrences of *Belskipolliselegans*, absent to rare occurrence of microfauna and no occurrence of nannoflora.

At *Verrutricolporitesrotundiporis*(P770) Zone, there were low occurrences of *Belskipolliselegans*, and no occurrences of microfauna and nannoflora.

**(c) WELL D:** Well D is located at Greater Ugheli Depobelt of the Niger Delta, Nigeria. The well interval ranged from (2750.0 ft – 12285.0 ft). The sample type is Ditch Cuttings and comprised of a variety of lithological units based on their log signatures, 10 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. 3 sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, 6 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone, while only one sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone.

There are high occurrences of *Belskipolliselegans* at *Belskipolliselegans* (P740) Zone, absent to rare occurrence of microfauna and no occurrence of nannoflora. There were no occurrences of *Belskipolliselegans* in **WELL C** and **WELL E**, from where comparison could be drawn, well C interval ranged from (4250.0 ft – 13020.0 ft) while well E interval ranged from (3000.0 ft – 14025.0 ft). Well C and well E are both located at the Central Swamp Depobelt in the Niger Delta, Nigeria. (Table 2)

Zonal Epithets	Depth Range	<i>B. elegans</i> Qual Statement	Total Foraminifera	Planktic Foraminifera	Calcareous Benthic	Agglutinating Benthic	Nannofloral
P770	3040.0ft	1: Low	Absent	Absent	Absent	Absent	Absent
P740	3261.0ft	24: High	Rare	Absent	Absent	Rare	Absent
	3340.0ft	25: High	Absent	Absent	Absent	Absent	Absent
	3460.0ft	40: High	Single	Absent	Single	Absent	Absent
	3560.0ft	3: Low	Absent	Absent	Absent	Absent	Absent
	3640.0ft	2: low	Absent	Absent	Absent	Absent	Absent
	3700.0ft	10: Low	Absent	Absent	Absent	Absent	Absent
P720	3800.0ft	2: Low	Absent	Absent	Absent	Absent	Absent
	3900.0ft	1: Low	Absent	Absent	Absent	Absent	Absent
	4100.0ft	3: Low	Rare	Absent	Rare	Absent	Absent

**Table 2:** Data Synthesis Table for well D

**(d) WELL F:** Well F is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (5250.0 ft – 12500.0 ft). The sample type is Sidewall Core sample and comprised of a variety of lithological units based on their log signatures, 5 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. 2 sampled stratigraphic horizons corresponded to *Pachydermitesdiederixi* (P680) Zone, 2 sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, and 1 sampled stratigraphic horizon corresponded to *Belskipolliselegans* (P740) Zone, while no sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. At *Pachydermitesdiederixi* (P680) Zone, there were very low occurrences of *Belskipolliselegans*, frequent to abundance occurrence of microfauna and no occurrence of nannoflora. At *Crassoretitriletesvanraadshooveni* (P720) Zone, there were sporadic high occurrence of *Belskipolliselegans*, abundance occurrence of microfauna, and no occurrence of nannoflora. Abundance occurrence of microfauna was associated with abundance in Calcareous Benthic foraminifera and Common occurrence in Planktonic foraminifera.

At *Belskipolliselegans* (P740) Zone, there were high occurrences of *Belskipolliselegans*, absent to abundance occurrence of microfauna and no occurrence of nannoflora. Abundance occurrence of microfauna was associated with abundance in Calcareous Benthic foraminifera and absent to frequent occurrence in

Planktonic foraminifera.

**(e) WELL G:** Well G is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (3000.0 ft – 8332.0 ft). The sample type is Sidewall Core sample and comprised of a variety of lithological units based on their log signatures, 19 sampled stratigraphic horizons with *Belskipolliselegans* were encountered, sampled stratigraphic horizon corresponded to *Pachydermitesdiederixi* (P680) Zone, no sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, 16 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone (7 sampled stratigraphic horizons corresponded to P730 subzone P740, and 9 sampled stratigraphic horizons corresponded to P750 subzone P740), while 2 sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. At *Crassoretitriletesvanraadshooveni* (P720) Zone, there were low occurrence of *Belskipolliselegans*, absent to frequent occurrence of microfauna, and no occurrence of nannoflora.

At *Belskipolliselegans* (P740) Zone, there were high occurrences of *Belskipolliselegans*, single to abundance occurrence of microauna and no occurrence of nannoflora.

Abundance occurrence of microfauna was associated with abundance in Calcareous Benthic foraminifera and abundance in Planktonic foraminifera. At *Belskipolliselegans* (P740) Zone (P750 Subzone), there were high occurrence of *Belskipolliselegans*, single to frequent occurrence of microfauna and no occurrence of nannoflora.

At *Verrutricolporitesrotundiporis*(P770) Zone, there were low occurrences of *Belskipolliselegans*, and no occurrences of microfauna and nannoflora.

**(f) WELL H:** Well H is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (3250.0 ft – 11000.0 ft). The sample type is Sidewall Core sample and comprised of a variety of lithological units based on their log signatures, 12 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. 1 sampled stratigraphic horizon corresponded to *Pachydermitesdiederixi* (P680) Zone, 1 sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, 9 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone (4 sampled stratigraphic horizons corresponded to P730 subzone P740, and 5 sampled stratigraphic horizons corresponded to P750 subzone P740), while 1 sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. At *Pachydermitesdiederixi* (P680) Zone, there was low occurrence of *Belskipolliselegans*, rare to abundance occurrences of microfauna and no occurrence of nannoflora. At *Belskipolliselegans* (P740) Zone (P730 Subzone), there were high occurrences of *Belskipolliselegans*, rare to abundance occurrence of microfauna and no occurrence of nannoflora.

Abundance occurrence of microfauna was associated with Common in Calcareous Benthic



foraminifera and rare in Planktonic foraminifera.

At *Belskipolliselegans* (P740) Zone (P750 Subzone), there were high occurrences of *Belskipolliselegans*, absent to rare occurrence of microfauna and no occurrence of nannoflora.

At *Verrutricolporitesrotundiporis*(P770) Zone, there were low occurrences of *Belskipolliselegans*, and no occurrences of microfauna and nannoflora.

**(g) WELL I:** Well I is located at Greater Ughelidepobelt of the Niger Delta, Nigeria. The sample type is sidewall core sample and comprised of a variety of lithological units based on their log signatures. The well interval ranged from (3830.0 ft – 3472.0 ft) and the interval of interest (the Middle Miocene sequences) within well I, corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone - *Belskipolliselegans* (P740) Zone. Three sample stratigraphic horizons (3830.0ft, 3723.0ft & 3646.0ft) with *Belskipolliselegans* were encountered at *Crassoretitriletesvanraadshooveni* (P720) while two sampled stratigraphic horizons (3538.0ft & 3472.0ft) with *Belskipolliselegans* were encountered at *Belskipolliselegans* (P740) Zone.

There are sporadic high occurrences of *Belskipolliselegans* at *Crassoretitriletesvanraadshooveni* (P720) Zone, and no occurrence of microauna and nannoflora at *Belskipolliselegans* (P740) Zone, there are high occurrence of *Belskipolliselegans*, and no occurrence of microfauna and nannoflora.

**(h) WELL J:** Well J is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (4000.0 - 8285.0 ft). The sample type included Ditch Cuttings and Sidewall Core sample and comprised of a variety of lithological units based on their log signatures, 11 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. 7 sampled stratigraphic horizons corresponded to *Pachydermitesdiederixi* (P680) Zone, 4 sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, no sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone and no sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. At *Pachydermitesdiederixi* (P680) Zone, there were low occurrences of *Belskipolliselegans*, rare to abundance occurrences of microfauna and no occurrence of nannoflora.

At *Crassoretitriletesvanraadshooveni* (P720) Zone, there were low occurrences of *Belskipolliselegans*, absent to common occurrence of microfauna, and no occurrence of nannoflora.

**(i) WELL K:** Well K is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (4750.0 ft – 10022 .0 ft). The sample type is Sidewall Core sample and comprised of a variety of lithological units based on their log signatures, 20 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. No sampled stratigraphic horizons corresponded to *Pachydermitesdiederixi* (P680) Zone, 1 sampled stratigraphic horizons corresponded to

*Crassoretitriletesvanraadshooveni* (P720) Zone, 20 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone (4 sampled stratigraphic horizons corresponded to P730 subzone P740, and 12 sampled stratigraphic horizons corresponded to P750 subzone P740), and 3 sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone.

At *Crassoretitriletesvanraadshooveni* (P720) Zone, there were low occurrences of *Belskipolliselegans*, rare to abundance occurrence of microfauna, and no occurrence of nannoflora.

At *Belskipolliselegans* (P740) Zone (P730 Subzone), there were high occurrence of *Belskipolliselegans*, rare to frequent occurrence of microfauna and no occurrence of nannoflora.

At *Belskipolliselegans* (P740) Zone (P750 Subzone), there were high occurrences of *Belskipolliselegans*, absent to common occurrence of microfauna and no occurrence of nannoflora.

At *Verrutricolporitesrotundiporis*(P770) Zone, there were low occurrences of *Belskipolliselegans*, and no occurrences of microfauna and nannoflora.

**(j) WELL L:** Well Lis located at Greater Ughelidepobelt of the Niger Delta, Nigeria. The well interval ranged from (2700.0 ft, 2400.0 ft&2340.0ft). The sample type is ditch cuttings and comprised of a variety of lithological units based on their log signatures, the interval of interest (the Middle Miocene sequences) within the section corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone - *Pachydermitesdiederixi* (P680) Zone. Three sampled stratigraphic horizons with *Belskipolliselegans* occurrences (2700.0 - 2340.0 ft) were analyzed as shown below (Table 1).

Zonal Epithets	Depth Range	<i>B. elegans</i> Qual Statement	Total Foraminifera	Planktic Foraminifera	Calcareous Benthic	Agglutinating Benthic	Nannofloral
P720	2340.0ft	7: Low	Absent	Absent	Absent	Absent	Absent
	2400.0ft	5: Low	Absent	Absent	Absent	Absent	Absent
P680	2700.0ft	2: Low	Absent	Absent	Absent	Absent	Absent

**Table 1:** Data Synthesis Table for well L

There are very low occurrences of *Belskipolliselegans* in well L, while microfauna and nannoplankton are absent within the Middle Miocene sequences

**(k) WELL M:** Well M is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval

ranged from (1750.0 – 8700.0 ft). The sample types included Ditch Cuttings and Sidewall Core samples and comprised of a variety of lithological units based on their log signatures, 17 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. 5 sampled stratigraphic horizons corresponded to *Pachydermitesdiederixi* (P680) Zone, 2 sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, 5 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone and 5 sampled stratigraphic horizons corresponded to *Verrutricolporitesrotundiporis*(P770) Zone.

At *Pachydermitesdiederixi* (P680) Zone, there were sporadic high occurrence of *Belskipolliselegans*, abundance occurrence of microfauna and no occurrence of nannoflora.

Abundance occurrence of microfauna was associated with abundance in Calcareous Benthic foraminifera and frequent occurrence in Planktonic foraminifera.

At *Crassoretitriletesvanraadshooveni* (P720) Zone, there were sporadic high occurrence of *Belskipolliselegans*, abundance occurrence of microfauna and no occurrence of nannoflora.

Abundance occurrence of microfauna was associated with Common in Calcareous Benthic foraminifera and frequent occurrence in Planktonic foraminifera. At *Belskipolliselegans* (P740) Zone, there were high occurrences of *Belskipolliselegans*, absent to common occurrence of microfauna and no occurrence of nannoflora.

At *Verrutricolporitesrotundiporis*(P770) Zone, there were low occurrences of *Belskipolliselegans*, and no occurrences of microfauna and nannoflora.

At *Verrutricolporitesrotundiporis*(P770) Zone, there was low occurrence of *Belskipolliselegans*, no occurrence of microfauna and Nannoflora. There is no occurrence of *Belskipolliselegans* in **WELL P** from where comparison could be drawn, well P interval ranged from (4500.0 ft – 14580.0 ft). Well P is located at the Shallow Offshore Depobelt in the Niger Delta, Nigeria.

**(I) WELL N:** Well N is located at Central Swamp Depobelt of the Niger Delta, Nigeria. The well interval ranged from (4750.0 ft – 9387.0 ft). The sample type is Sidewall Core sample and comprised of a variety of lithological units based on their log signatures, 34 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. Sampled stratigraphic horizons corresponded to *Pachydermitesdiederixi* (P680) Zone, 8 sampled stratigraphic horizons corresponded to *Crassoretitriletesvanraadshooveni* (P720) Zone, 20 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone, while 3 sampled stratigraphic horizons corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. 6 sampled stratigraphic horizons with *Belskipolliselegans* were encountered. Sampled stratigraphic horizon corresponded to *Pachydermitesdiederixi* (P680) Zone, no sampled stratigraphic horizons corresponded to

*Crassoretitritesvanraadshooveni* (P720) Zone, and 8 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone, while 1 sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone

**(m)WELL O:**Well O is located at the Northern depobelt of the Niger Delta, Nigeria. The well interval ranged from (250.0 ft – 4490.0 ft). The sample consists of sidewall core and comprised of a variety of lithological units based on their log signatures, the interval of interest (the Middle Miocene sequences) within the section corresponded to *Pachydermitesdiederixi* (P680) Zone, and only one sampled stratigraphic horizon (1048.0 ft) with *Belskipolliselegans*was encountered.

*Belskipolliselegans*recoveries within this sequence is very low while foraminifera and nannoplankton are absent as shown below (Table 1).

There are very low occurrences of *Belskipolliselegans*in well O, while microfauna and nannoflora are absent within the Middle Miocene sequences

**(n) WELL Q:** Well Q is located at Deep Offshore Depobelt of the Niger Delta, Nigeria. The well interval ranged from (8250.0 ft – 13670.0 ft). The sample is Ditch Cuttings and comprised of a variety of lithological units based on their log signatures, 9 sampled stratigraphic horizons with *Belskipolliselegans*were encountered. 1 sampled stratigraphic horizon corresponded to *Pachydermitesdiederixi* (P680) Zone, no sampled stratigraphic horizons corresponded to *Crassoretitritesvanraadshooveni* (P720) Zone, 7 sampled stratigraphic horizons corresponded to *Belskipolliselegans* (P740) Zone and 1 sampled stratigraphic horizon corresponded to *Verrutricolporitesrotundiporis*(P770) Zone. At *Pachydermitesdiederixi* (P680) Zone, there was low occurrence of *Belskipolliselegans*, frequent occurrence of microfauna and rare occurrence of nannoflora.

At *Belskipolliselegans* (P740) Zone, there were low occurrences of *Belskipolliselegans*, rare to Abundance occurrence of microfauna, single to common occurrence of nannoflora.

Abundance occurrence of microfauna was associated with abundance in Calcareous Benthic foraminifera and Common occurrence in Planktonic foraminifera.

At *Verrutricolporitesrotundiporis*(P770) Zone, there was low occurrence of *Belskipolliselegans*, frequent to abundance occurrence of microfauna, and frequent occurrence of nannoflora.

Abundance occurrence of microfauna was associated with abundance in Agglutinating Benthic foraminifera and frequent occurrence in Planktonic foraminifera.

## DISCUSSION OF RESULT

Interpretation of the biostratigraphic data involved, age determination and biozonation using the

scheme adopted in the charts, correlation of the wells and finally, palaeoenvironmental reconstruction of the Middle Miocene Niger Delta basin using the distribution pattern in *Belskipolliselegans*, microfauna and nannoflora extracted from the biostratigraphic charts across the 17 wells.

**(A) AGE DETERMINATION:** Age determination in the Niger Delta has been carried out using combined benthonic, planktonic and palynomorph index species. However, the benthonic forms are found to be tied to the palaeoenvironmental reconstruction rather than age determination.

Seiglieet *al*, 1983 developed planktonic and benthonic foraminiferal zones for the Niger Delta. This compared favorably with Blow, 1969 & 1979 zonations. Other workers such as Germeraadet *al*, 1968, Evamyet *al*, 1978, Haqet *al*, 1978. The biozonation scheme adopted in this study was that of Evamyet *al*, 1978.

**(B) BIOZONATION:** The biozonation scheme of Evamyet *al*, (1978) and Germeraadet *al*, (1968) were adopted in discussing the Middle Miocene sequences encountered in these wells. The Middle Miocene sequences of interest comprised of biozones noted with the following markers;

***Pachydermitesdiederixi* (P680) Zone, (17.4 Ma):**

*Pachydermitesdiederixi* has taxonomic affinities with the pollen of *symphoniaglobulifera*, as far as known, this pollen type does not occur in other genera and the identification has a very high degree of probability. The zone is marked by the first appearance of *Pachydermitesdiederixi*, *Cyathidites minor* and *Magnastriatiteshowardi*.

***Crassoretitriletesvanraadshooveni* (P720) Zone, (15.7 Ma):**

*Crassoretitriletesvanraadshooveni* has taxonomic affinities with *Lygodiummicrophyllum*. It belonged to the marshes and swamps ecology and was proposed by Germeraadet *al*. 1968.

***Belskipolliselegans* (P740) Zone, (14.2 Ma):**

***Verrutricolporitesrotundiporis* (P770) Zone, (12.1 Ma):**

*Verrutricolporitesrotundiporis* has taxonomic affinities with the pollen of *Crenea maritime*, and was proposed by Van der Hammen & Wijmstra 1964. The dominance of *Verrutricolporitesrotundiporis* in coastal and marine sediments is in agreement with the present day habitat of *Crenea*, growing in swampy places along river courses and in the mangrove vegetation.

In Nigeria only the *Globorotaliafoshisifohsi* Zone is represented in the upper part of the *Verrutricolporitesrotundiporis* Zone.

Evamy et al, (1978) biozonation scheme which was used in the biostratigraphic charts was further

reviewed and compared with Germeraadet al. (1968), Lorente, M. (1986), Muller et al, (1987) and Hoom, (1993)

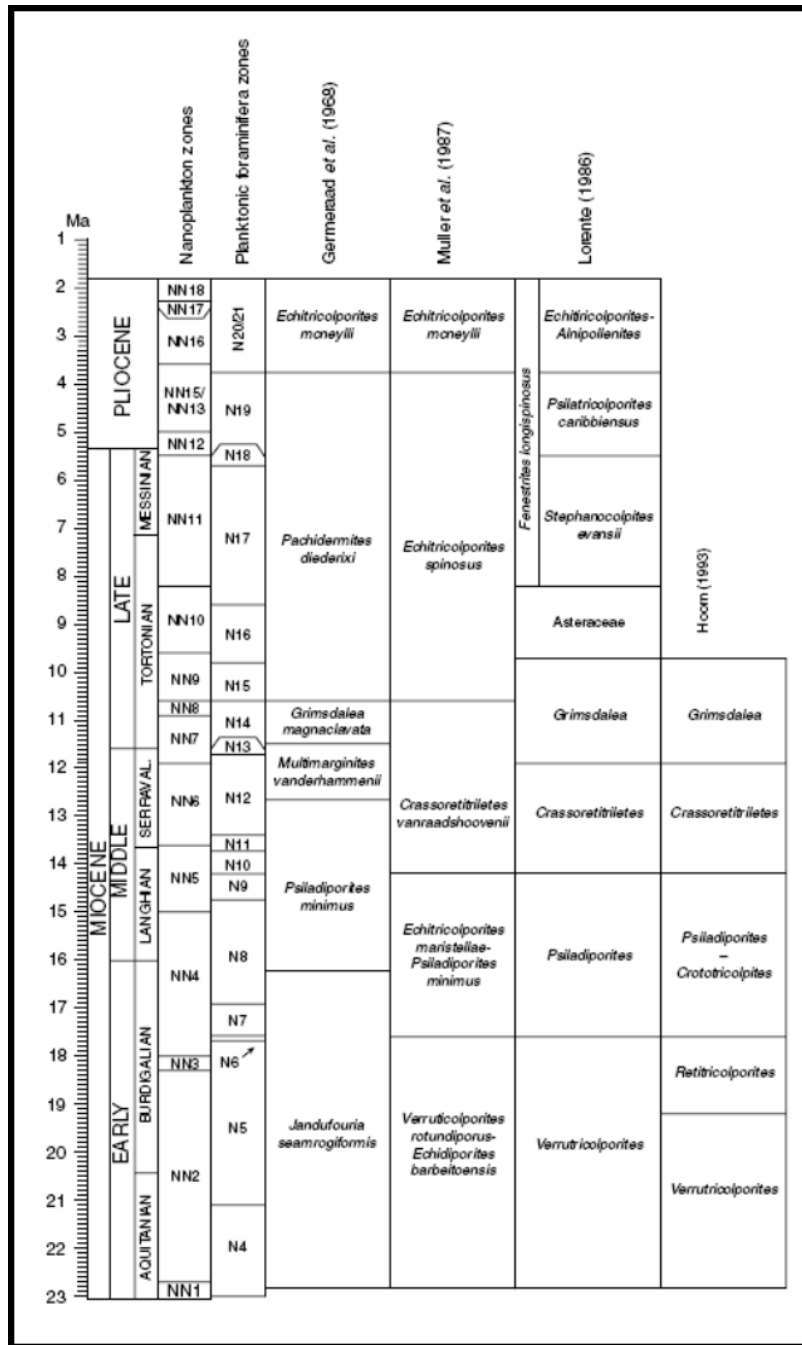


Figure 3: Biozonation scheme adopted from Germeraad et al, (1969), Muller et al, (1987), & Lorente (1986)

(C) PALAEOENVIRONMENTAL RECONSTRUCTION: It is worthy to note the concentration of foraminifera towards the South – Eastern part of the Niger Delta during the Middle Miocene; this may contribute towards

explaining the depositional systems in the Niger Delta during the Middle Miocene, this is subject to further researches going forward.

Verification on the use of *Belskipolliselegans* as a marker in the Niger Delta Middle Miocene was carried out by determining *Belskipolliselegans* First Appearance Datum (FAD), Last Appearance Datum (LAD) and wide spread and abundant (Acme) events within the Middle Miocene sequences across the 17 studied wells.

Low occurrences of *Belskipolliselegans* and high occurrences of foraminifera at *Pachydermitesdiederixi* (P680) Zone – *Crassoretitriletesvanraadshooveni* (P720) Zone which was rated 17.6 Ma – 14.5 Ma, in Haq et al, 1978 may be linked to a period of transgression caused by the Middle Miocene Climatic Optimum recorded in Zachos et al, (2001) oxygen isotope climatic curve at 17.0 Ma – 14.0 Ma. This may be as a result of melting of ice sheets in the polar region with increased temperature which in turn flooded the continental plain depositing marine fossils at the continental plain (increased productivity in foraminifera) as was seen in *Pachydermitesdiederixi* (P680) Zone – *Crassoretitriletesvanraadshooveni* (P720) Zone.

High occurrences of *Belskipolliselegans* with decreasing occurrence of foraminifera at *Belskipolliselegans* (P740) Zone (P750 – P730 subzones) which was rated 14.5 Ma – 12.0 Ma, in Haq et al, 1978 may be linked to a period of regression caused by 1.5 my of rapid cooling following after the Middle Miocene Climatic Optimum in Zachos et al, 2001 oxygen isotope climatic curve. This may be as a result of increased terrestrial activities with increased land reclamation as the sea receded back into the basin with the formation of ice caps in the polar region. Wide spread decrease in *Belskipolliselegans* occurrence at *Verrutricolporitesrotundiporis* (P770) Zone which was rated 12.0 Ma, in Haq et al, 1978 may be linked to a period of initial excessive regression which gave rise to the deposition of submarine fan (LST) seen in the deep water wells as temperature cooled gradual in Zachos et al, 2001 oxygen isotope climatic curve after the 1.5 my rapid cooling. *Belskipolliselegans* may have existed under certain temperature range. This temperature range may have been attended within a very short while as climate cooled rapidly from the maximum to minimum temperature within which *Belskipolliselegans* survived leading to a succinct range appearance of *Belskipolliselegans* during Middle Miocene.

## CONCLUSION

This research developed spatial distribution patterns of fossils in maps that reflected the climate controls on sea level changes linked to changes in sedimentation and basin progradation in the Niger Delta Middle Miocene sequences. These maps compared favorably with Zachos et al., (2001) generated models from which the following conclusions were made:

1. Orbital parameters are believed to be responsible for the grasp of the warm climates while 1.5 my



rapid cooling could be linked to high productivity of cool preference parent plants (high *Belskipolliselegans* occurrences) as more land is recovered, and low productivity of calcareous nannoplankton and foraminifera within Middle Miocene sequences in the Niger Delta as the sea level fell.

2. These changes in climate and sedimentation could be attributed to the Miocene Climate Optimum (17.0 Ma - 14.0 Ma), which ended with 1.5 my (14.0 Ma - 12.5 Ma) of rapid cooling, associated with the increased production of cold Antarctic ice sheets, after which global cooling continued more gradually.
3. Temperature decrease and high rate of sedimentation in the Niger Delta during the Middle Miocene caused a fall in sea-level which in turn could be linked to edaphic changes that affected phytoecologies across the Niger Delta.

## REFERENCES

1. Allen, J.R.L., 1965, Late Quaternary Niger Delta, and adjacent areas-sedimentary environments and lithofacies: AAPG Bulletin, v. 49, p. 547-600.
2. Blow, W. H. 1969, Late Middle Eocene of Recent Planktonic Foraminiferal Biostratigraphy. Proc. Int. Conf.: Lank. Micro; V. 1, P. 199 - 442
3. Doust, H., 1990, The Niger Delta: Hydrocarbon Potential of a Major Tertiary Delta Province, in coastal lowlands, geology and geotechnology. In:Proceedings of the Kon. Nederl. Geol. Mijnb. Genootschap, p. 203-212.
4. Doust, H. and E. Omatsola, 1990, Niger Delta. In:J. D. Edwards and P.A. Santogrossi, eds., Divergent/passive margin basins: AAPG Memoir 48, p. 239-248.
5. Evamy, B.D., J. Haremboure, R. Kammerling, W.A. Knaap, F.A. Molloy, and P.H. Rowlands,1978. Hydrocarbon habitat of tertiary Niger Delta: AAPG Bulletin,v. 62, 1 - 39.
6. Germeraad, J. H., Hopping, C. A. & Muller, J, 1968. Palynology of Tertiary Sediments from Tropical Areas.Review of Palaeobotany& Palynology. V. 6 189 - 346. P. 1 - 18
7. Haq, B.U., J. Hardenbol and P.R., Vail, 1987, Chronology of fluctuating sea-levels since the Triassic: Science, v. 235, p. 1153-1165.
8. Tuttle, M. L. W., R. R. Charpentier and M. E. Brownfield, 1999, The Niger delta petroleum system: Niger Delta province, Nigeria, Cameroon, and Equatorial Guinea, Africa: USGS Open-file report 99-50-H.
9. Van der Hammen, T., Wymstra, T.A. (1964) Apalynological study on the Tertiary and Upper Cretaceous of British Guayana. *LeidseGeologischeMededelingen*30, 183-241.
10. Whiteman, A. J., 1982, Nigeria, its petroleum, geology, resources and potential. v. I and II, Edinburgh, Graham and Trotman.