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Application of Calcareous Nannofossil to Petroleum Exploration; A Case Study of Offshore Depobelt, Niger Delta

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Abstract**—** *Calcareous nannofossil biostratigraphic studies were carried out on ditch cutting samples obtained from wells X-1 and X-2, offshore deep water area, Niger Delta. The focus of these studies, using the pipette strew preparation methodology, was to establish a nanno fossilbiozonation, age, and correlation across the study intervals. Lithologically, the study sequences composed of shales, siltstones / mudstones which are grey, with intercalation of thin-bedded sandstones. Fairly diverse nannofossil assemblages were recovered. Calcareous nannofossils zones were established based on first and last occurrences of readily identifiable marker species and their relative abundances. These zones aided the age assignment of Early Pliocene through to Middle Miocene to the studied sections. Marker species and assemblage diagnostic types such as Calcidiscus leptoporous, Ceratho- lithusrugosus,Coccolithuspelagicus, Coronocylcusnitescens, Discoastervariabilis Reticulofenestrapseudoumbilica, Sphenolithusabies, Sphenolithusheteromorphus and Sphenolithusmoriformis have been used in the designation of the zonal ages ranging from NN15 through to NN5 based on the classic zonation scheme of Martini (1971). The recognition of such a disparate array of zones in the study wells, suggests that poor preservation of nannofossils or poor recoveries which could be linked to the Middle Miocene (Serravallian) Carbonate Crash as alluded to by Fadiya and Salami (2012) may be affecting zoning of intervals*.

I. Introduction

Calcareous nannofossils are fossil remains of golden-brown, single-celled algae that live in the oceans. Because they are plants, they require sunlight, so they float near the surface of the water. These algae make tiny calcite platelets inside their cells, and these platelets (the calcareous nannofossils or nannos for short) move to the surface of the cell. The platelets fall off the cell and slowly drift down to the bottom of the ocean, they are slowly covered up with remains of other plants and animals and bits of mud and sand that have washed out with the rivers of the world. At this point they are part of a mud or marl or sandy clay. Eventually, there are many sediments on the ocean bottom, and their weight is enough so that the lowest sediments are squeezed enough to become rocks. The calcite platelets that are preserved in the rocks in this manner are the fossils that paleontologists study.

Calcareous nannofossils have become increasingly a valuable tool to unravel palaeoclimatic, palaeoceanographic, palaeoenvironment and palaeoecologic conditions aside its biostratigraphic potentials. Detailed nannofossil assemblage data can provide an excellent basis to monitor changes in primary productivity in the ocean due to their sensitivity to surface water conditions, temperature, salinity, and availability of nutrients, location and other biogeographical factors.

Aim and Objectives of the Study

The aim of this study is to carried out zonation and correlation of wells using calcareous nannofossils and document their assemblages (Niger Delta Nannofossils Album) for the purpose of academic, industry research and consultancy work which hitherto was not in existence.

This objective of this study is to document the nannofossils assemblages that are characteristics of the study area, studying the lithostratigraphy, sedimentary boundaries, correlate the wells and deduce the age of the studied area.

Location of Studied Wells

The study wells are located offshore, off the Nigerian coast, at a distance of 120km southwest of the Niger Delta. The field covers approximately 60 km^2 in an average water depth of 1,000 metres (3,300 ft). The field produces both *petroleum* and *natural gas* (*See fig. 1 below).*

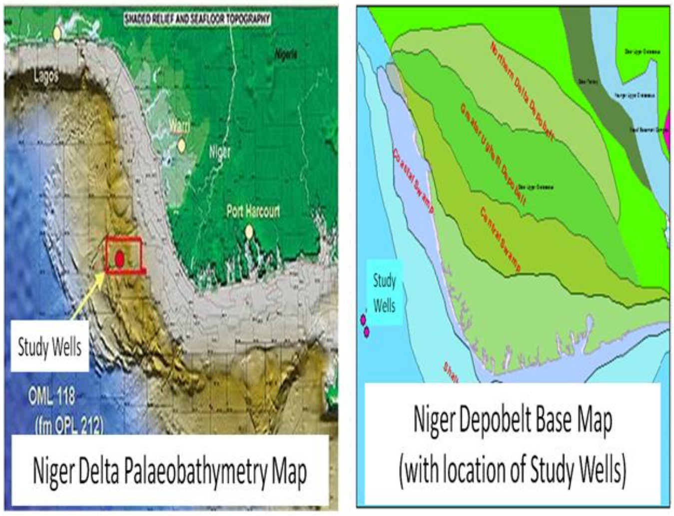

Fig. 1. Niger Delta Paleobathymetry and Depobelt base map (showing location of study wells).

II. Literature Review

Nannofossils are a group of calcareous microplanktons found in marine deposits, which are smaller than 30 microns in size. They became stratigraphically useful from the Jurassic through to Recent (Oriaifo, 1999). They were first used in the hydrocarbon industry in the early 1960's and during the 1980's the technique rapidly gained an excellent reputation as a powerful tool in biostratigraphic, dating and correlation disciplines giving rapid to reliable results (Raffi, 1999).

Osman Varol has played the leading role in recent developments in the industrial application of calcareous nannofossil analyses through his work with numerous oil companies. His research publications include: zonations schemes for Palaeogene (World-wide and North Sea Basin) and Neogene (South East Asia) in addition to numerous papers on the taxonomy of calcareous nannofossils. A number of other biozonation schemes that have been contributed by other workers for the entire Era are also available in published literature.

Many classic detailed studies of calcareous nannofossil biostratigraphy abound, however, few key papers are highlighted here (Rade, 1977; Bukry, 1978; Miller, 1981; Bukry, 1981; Gartner and Shyu, 1996; Stefano, 1998; Su *et al*., 2004; Holcova, 2005; Tremolada and Siesser, 2005; Jiang and Wise, 2007). From works investigated taxonomic schemes of Martini, (1971) and Okada and Bukry, (1980) have been the wisely used zonations. However, other schemes (Sissingh, 1977; Young, 1999; Burnett, 1999; Varol, 1999) are adopted by some workers, which have been modified to handle the challenge of setting up a local zonation. It is obviously noted that almost all age intervals from the time calcareous nannofossils became stratigraphically useful have had biostratigraphy applied in other overseas stratigraphic basins unlike our local (Nigerian) sedimentary basins.

Various workers have carried out more quantitative nannoplanktonic biostratigraphy studies. Holocova (2005) carried out studies on the Oligocene/Miocene boundary interval in the Central Paratethys region. Melinte (2005) based his study on the distribution and fluctuation pattern of calcareous nannofossils to delineate environmental changes that took place during the Oligocene in the Eastern Carpathians. He was able to recognize the cool and warm regimes associated with the nannoplankton distribution patterns.

In Nigeria generally, calcareous nannofossil studies seem to be undertaken more by the oil and gas industry though their own studies and are not normally published for confidential reasons. Therefore, published literature on calcareous nannofossil is scarce. However, a few publications can still be explored and understood in context.

In the Niger Delta, biostratigraphic studies have routinely been carried out by the usual traditional means of foraminifera and palynomorphs by researchers in the oil and gas industry (Reyment, 1959; Adegoke*et al*., 1976; Harris, 1981; Ogbe, 1982,Petters, 1984; Okoro, 1992; Ozumba, 1995; Adeniran, 1997). However, calcareous nannofossils have been used by the oil industry since the mid- 1980's but the bulk of the materials remain unpublished because such studies have been deemed as proprietary. In addition, the late application of the discipline to the Niger Delta sequences supports the premise that knowledge on nannofossil occurrences are scarce. Hence in order to bridge this gap this research work is part of an effort to study and document the Nigerian local assemblages of Calcareous Nannofossils to foster accessibility of biostratigraphical information which is driving force in oil industries exploration and exploitation programme and oil industry related academic research and consultancy work

III. METHODOLOGY

Materials and Methods

Data for this study was generated from ditch cutting samples from offshore Niger Delta . Samples were collected at 120ft interval which was obtained from two wells namely X-1, and X-2, with depth range of 5650ft-12596ft, 6830-11220ft respectively. Lithologic interpretation of the well X-1 and X-2 were made from the wire line logs of the two wells.

Field Measurement

Lithologic Interpretation of the Wells. The lithologies penetrated by the studied wells were interpreted from only the Gamma Ray logs provided. The Gamma Ray logs provide information on the sand and shale content of the wells. The dominant lithologies noted throughout the studied wells were sandstone, mudstones, and inter gradational siltstones. The results obtained after data analysis are presented well by well below

X-1 Well: The Gamma Ray wireline log data reveals a dominantly shale sequence interbedded with variably thick sandstone interbeds which attain maximum thickness in the basal part of the well. Mudstones predominate over the sandstones throughout the entire well section.

X-2 Well: The dominant lithology is a thick sequence of shales with variably thin sand interbeds, which became thickest from the middle intervals of the well. The sequence presents a succession of interbedded mudstones and sandstones with whereas the upper intervals show a thicker mudstone unit.

Laboratory Analysis

(A) Nannofossil Slides preparation: Pipette strew method was utilized in the preparation of Nannofossils slides;
The procedure is as follows;

- Ninety six ditch cuttings Samples were prepared for Nannofossils slides analysis from two wells namely X-1 and X-2. (*See fig.2 below*).
- The supplied ditch cuttings were logged and composited at interval of 120ft.
- About 3g of crush sample was gently dissolved in distilled water.

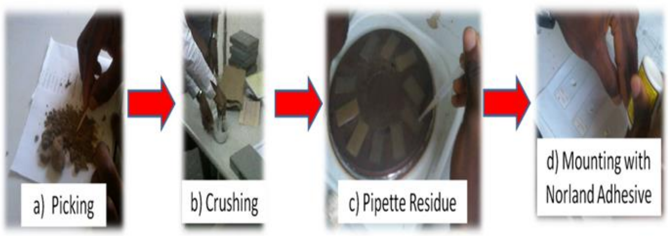

Fig. 2 (a-d). Showing steps of the methods of study.

The resulting suspension was pipetted on a microscope glass slide, place on a hot plate and gently dried. Cover slip

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was then mounted on a labeled glass slide using two drops of the Norland optical adhesive. Slides were later cured under the ultra violet light. Prepared slides were examined under transmitted light microscope at x1000 magnification. Detailed identification (to species level where possible) was made by consulting the Published monographs works on nannofossils.

(B) Observation Techniques

The prepared Nannofossils slides were examined for their calcareous nannofossil content under a high power MEIJI light microscope in cross-polarized and transmitted lights. Detailed abundance counts of the assemblages were made at x1000 magnification. Identification of species was made by consulting of the monographs published on the internet by various authors.

IV. Results and Discussion

Presentation of Results

The results of the identified calcareous nannofossils for samples from the wells are shown in calcareous nannofossils distribution Table for Wells X-1 and X-2 (see figures 1 and 2). The pictures of the different forms of nannofossils encountered during the study are also displayed. (See plate 1). Out of 96 samples slides that were analyzed, some samples were barren. The nannofossils observed were used for age determination and correlation of the two wells. The sample yielded rich moderately preserved species with moderately dissolution effect from very poor to fairly rich, occurrences in the different intervals of the wells. Most of the species observed show a rare to common occurrences within the studied intervals. The flora assemblage comprises mainly of *sphenolithus heteromorphus, Coronocylusnitescens, Helicosphaeraintermedia, Reticulofenestra Pseudoum-bilicus, Sphenolithusmoriformis, Coccolithuspelagicus, Sphenolithus abies, Ceratolithus rugosus-Calscidiscusleptoporous.* Stratigraphically important zonal markers of chronostratigraphic values recorded include are *sphenolithusheteromorphus, Reticulofenestra Pseudoumbilicus, Ceratolithus-rugosus.*

TABLE 1. Nannofossil distribution table for well X–1.

X-1 Depth interval	Calcidiscusslepto	Sphenolithusmo	Sphenolithus	Helicospaehrain	Sphenolithusabi	Coccolithuspela	Discoaterspp	shenolithusheter	Reticulofenestra
	NA	NA	NA	NA	NA	NA	NA	NA	NA
									1
5650	1	3		2	1				
5770		2				3			
5890				1				2	3
6010									
6130		3		1					
6250	3							3	
6370			4	3			1		1
6490									
6610								2	
6730									
6850									
6970					3				4
7090								2	
7210	2	4							
7330							2		
7450				6					1
7570								2	
7690									
7810	5								
7930					2				
8050	4								
8170				2				2	1
8290					5				
8410								1	
8530									
8650									2
8760								3	
8880	1		7		2				
9000					1				
9120	2		5	3					
9240						5			
9360				2					
9480									
9600			6						
9720				4					
9840	1		1			1			
9960									
10080	1			6					
10200									
10320	6					3			
10440		2	2	2					
10560									
10680									
10800	3								
10920									
11040				4					
11160	2		5			1			
11280									
11400						3			
11520									
11640									
11760									
11880				2					1
12000									
12120	3	4							
12240				1					
12360	2								
12480									
12596				1					4

TABLE 2. Nannofossil distribution table for well X-2.

X-2 Depth interval	Sphenolithusmoriformis	Coccolithuspelagicus	Cronocystus	Coccolithusmiopelagicus	Sphenolithusspp	Sphenolithusabies	Discoastervariabilis	Helcosphaeraintermedia	Ceratolithusrugosus
	NA	NA	NA	NA	NA	NA	NA	NA	
6830	1			1					
6950			1		2	7			
7070									
7190									
7310	1								
7430	3				1				

7550	4						2		
7670									
7790									
7880									
8180									
8300	1								
8420									
8540								2	3
8660		6			2				
8780									
8900									
9020		2							
9140		3			3				
9260									
9380								3	
9500									
9650									
9770					3				
9890	4								
10010									
10130									
10250					1				
10370									
10490									
10610									
10730									
10850									
10970									

V. DISCUSSION

Calcareous Nannofossil Biozonation

The stratigraphic interval studied in well-X-1 and well-X-2, has been sub-divided into biostratigraphic zones based on their calcareous content. The well was sectioned using the globally recognized calcareous zonation scheme of Martini (1971). Three major (3) zones were identified belonging to the Middle Miocene, late Miocene and early Pliocene. These are NN5, NN13 and NN15 zones. The zones are *Sphenolithus heteromorphus*, *Ceratolithusrugosus* Zone, and *Reticulofenestrapseudoumbilica* Zones.

Nannofossils Biozonation.

NN15

1. Well Name: Bonga-X-1
Nannofossils zone: Zone NN15
Stratigraphic Interval: 11880-12596 feet
Zonal Description:- *Reticulofenestra pseudoumbilica* Zone
Age: Early Pliocene

NN5

2. Well Name: Bonga-X-1
Stratigraphic Interval: 8880 to 11880 feet
Zonal Description:- *Sphenolithusheteromorphus* Zone
Age: Middle Miocene

NN13

3. Well Name: Bonga-X-2
Stratigraphic Interval: 8540 -11220 feet
Zonal Description: *Ceratolithusrugosus* Zone
Age: Early Pliocene

NN5

4. Well Name: Bonga-X-2
Stratigraphic Interval: 6830 - 8540 feet
Zonal Description:- *Sphenolithusheteromorphus* Zone
Age: Middle Miocene

The presence of *Reticulofenestra pseudoumbilica* established in Well X-1 suggests an age of not younger than NN15 (Early Pliocene). In addition, the observation of *Ceratolithus rugosus* in Well X-2, further restricts the age to not older than NN13 over the interval 8540ft - 11220ft (dc) corresponding with the Early Pliocene - Late Miocene.

Sphenolithus heteromorphus is noted in both wells supporting, in the absence of NN4 Zone marker species *Helicosphaera ampliaperta* that the age of the well has to be not younger than Middle Miocene, Serravallian, NN5 Zone, Martini (1971). The species is recorded in both wells offering the potential for correlation between the two wells. Thus young and old (NN15 and NN5) age constraints are recorded from both wells, whereas the intermediate stratigraphic framework has yet to be established due to the none or poor preservation of nannofossils over the study interval.

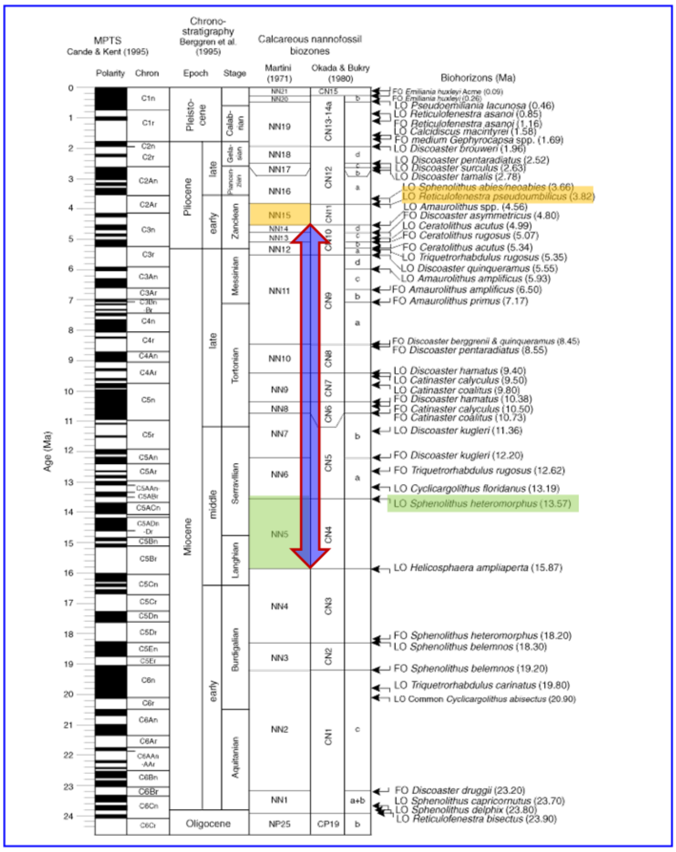

Fig. 3.Chronostratigraphic Scheme; Index taxa recorded allowed the subdivisions based upon the zones of Martini (1971) in designation of the zonal ages ranging from NN15 through to NN5.

Correlation

Sphenolithus heteromorphus NN5 Zone was established in both wells at depth interval of 8880-11880ft for well X-1 and 6830 to 8540ft for X-2 well.These zones observed were used for correlation of the two wells (See figure 4-correlation panel) The deduction from the correlation panel implies that the sequence of the two wells at that depth interval has an age range most likely of Middle Miocene (Serravallian).

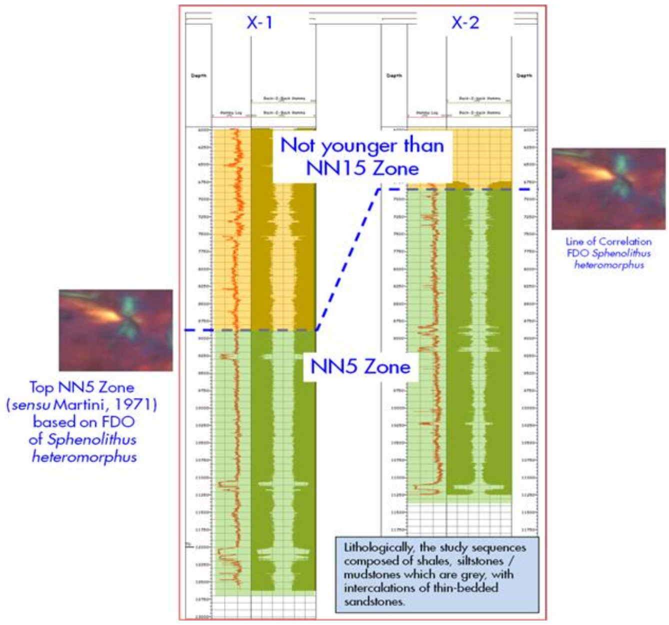

Fig. 4.Correlation panel.

VI. Conclusion

The data set obtained has demonstrated that the zonation of the study wells range from NN15 through to NN5 zones. These studied wells are thus dated from Early Pliocene through to Middle Miocene in age. The disparate array of zones highlighted in the study so far could relate to the over-riding imprint of the Middle Miocene Carbonate Crisis (MMCC) as alluded to by Fadiya and Salami (2012) which does not allow for key markers species to be present/readily recovered in all instances.

VII. Recommendation

It is recommended that more funding should be made available so that the further study of nannofossil should be done to accommodate more wells so that we can generate holistic regional data bank of nannofossils which will serve as a source of stratigraphic information for oil industry exploration and production activities, as well as erecting a Calcareous Nannofossil Chronostratigraphic Zonation Scheme for the Niger Delta which hitherto was not available.

Acknowledgement

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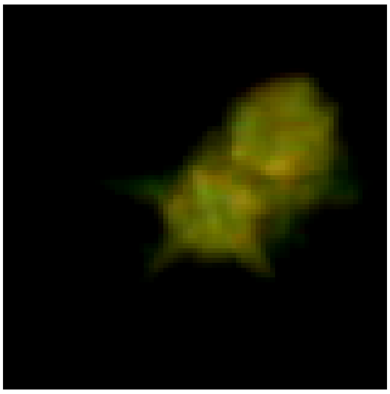
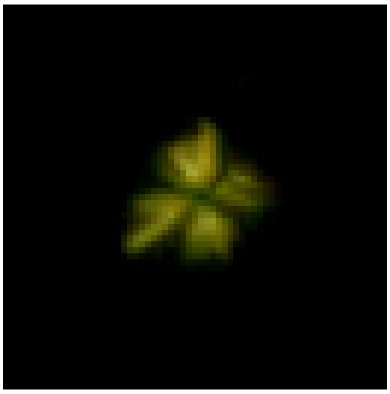
PLATE 1

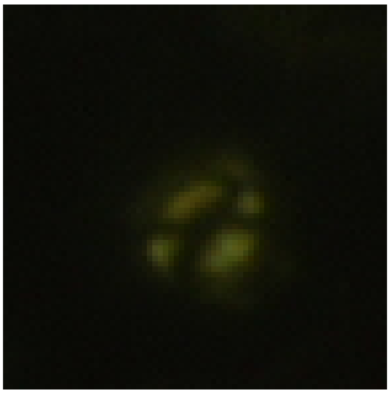


D. berggrenii

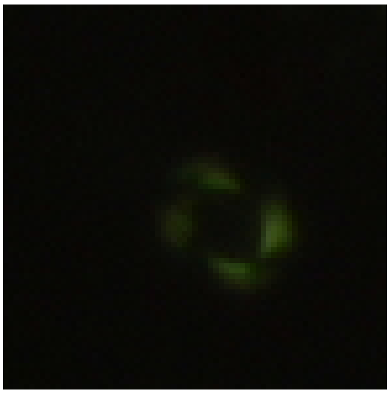


S. moriformis

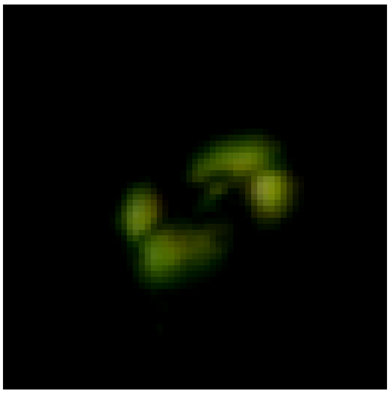
S. abies



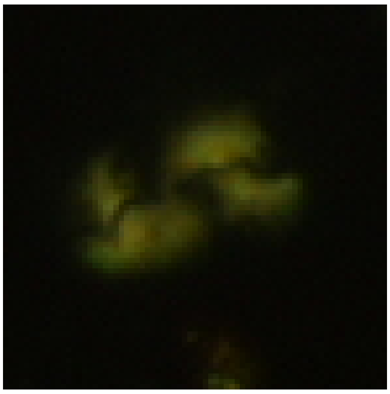
Co. pelagicus



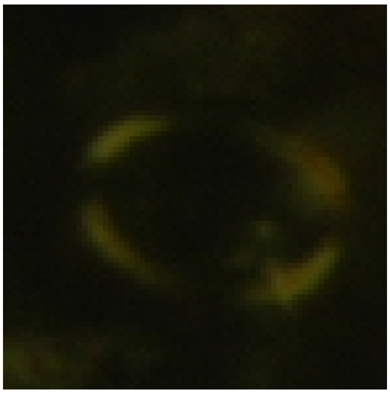
R. pseudoumbilicus



H. intermedia



H. carteri



P. discopora

R. haqii