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Occurrence and Environmental Implications of Calcareous Nannofossils in Surface Sediments of the Western Gulf of Guinea: off Lagos Coast, South-western Nigeria

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Abstract
The application of calcareous nannofossils in oil exploration, and environmental studies is playing an increasingly important role all over the world. Most recent researches on this subject area in Nigeria are confined/restricted to the oil producing Niger Delta leaving most other areas untouched. This however limits nannofossils' application in biostratigraphic and paleoenvironmental interpretation of non oil producing areas within the country. Before now, nannofossils occurrence and application have not been documented in the surface sediments of Nigeria.
Consequently, calcareous nannofossils have been investigated in thirteen (13) surface sediments samples of the littoral area from the continental shelf of western Gulf of Guinea, off Lagos coast. Primarily, this research was aimed at determining the occurrence (and or non occurrence), and relative abundance of nannofossils in surface sediments of the area with which the age of the sediments, paleoenvironment and paleoecological condition(s) could be determined.The samples were collected with the aid of grab sampler, allowed to dry and subjected to detailed lithologic description. Furthermore, the samples were subjected to nannofossils analysis by standard method of preparation. Both qualitative and quantitative analysis was done using the high power Olympus Transmitted Light Microscope (TLM). The occurrence of nannofossils has been established in the study area (littoral area of the western Gulf of Guinea). Most of the sediments are poorly consolidated, fine to coarse grained sand with little amount of clay ant silt fractions that yielded Pliocene to Recent nannofossils (mainly Pleistocene). A total population of 1132 belonging to five different genera (*Calcidiscus, Ceratolithus, Gephyrocapsa, Helicosphera and Reticulofenestra*) and seven species were found in the studied samples with *Gephyrocapsa caribbeanica* being the most abundant (followed by *Gephyrocapsa oceanica* of a little lower abundance). The species indicate a truly shallow marine environment within recent sediment accumulation.
Keywords: Surface sediments, littoral, calcareous nannofossils, Gulf of Guinea, Lagos, Nigeria, biostratigraphy, paleoenvironment, paleoecology, lithologic.

1.1. Introduction

The study area falls within the Nigerian section of the Gulf of Guinea that covers approximately 900 km of coastline of West Africa (Emery *et al.,* 1975 and Salami, 1982). It lies between latitudes 3° 50' and 6° 50' North and longitudes 3° 25' and 8° 50' East (Fig. 1). As indicated by Attenbach *et al*. (2003), Gulf of Guinea is particularly interesting because of local confluence of fluvial waters with both coastal and equatorial upwelling system. Surface sediments are those sediments that lie immediately above the sea floor in a sedimentary environment. Continental shelf is a gently sloping, shallow water platform extending from the coast to a point where there begins a comparatively sharp descent to the sea floor. Shallow marine environment, on the other hand is the flooded edge of the continent and are relatively flat (slope < 0.1°), shallow (less than 200m or 600ft deep), and may be up to hundreds of kilometres wide. It is made up of the inner and the outer continental shelves. The flooding of the continent occurs when the glaciers melted at the conclusion of the Ice Age, about 10,000 years ago. Calcareous nannofossils are tiny (1 - 25µm) remains of golden brown calcareous algae. They are subdivided into coccoliths and nannoliths (Perch-Nielsen, 1985). Coccoliths are the minute calcite plates produced by unicellular marine algae, the coccolithophorids. Fossil coccoliths, together with small calcite bodies called nannoliths by some writers, constitute the calcareous nannofossils group. Nannofossils are certainly organic but are of uncertain origin. Calcareous nannofossils and related biostratigraphic studies in Nigeria has for long found its application in the oil producing Niger Delta region and few other inland basins. This left some other parts untouched, creating a gap in the application of the subject in paleoenvironmental interpretation.

Understanding the temporal and spatial distribution of fossil organisms under the field of biostratigraphy remains important aspect of geosciences not to mention the relevance of this field to oil exploration and production. More often than not, the focus is on three major fossil groups; Foraminifera, Pollen & Spores, and Nannofossils. The three have proved very useful and are complementary to each other. However, the relevance of nannofossils is becoming increasingly important not only because of the advantage of its small size, the limited stratigraphic range of many of its species, with high resolution to some thousands of years, but also its speedy processing technique that yields more rapid result especially where age determination is required.
Calcareous nannofossils proved to be extremely useful for the biostratigraphy of Jurassic through Pleistocene marine sediments. Their small size (1 - 25µm) allows for age determinations of even very small samples such as

from ditch, cuttings, sidewall samples, cores, and surface sediments which have proved useful in this work. Nannofossils are largely restricted to normal marine environments and have little tolerance for either turbidity or freshwater diluted environments (Hay *et al*., 1967).

Most recent researches on this subject area in Nigeria are confined/restricted to the oil producing Niger Delta leaving most other areas untouched. This however limits nannofossils' application in biostratigraphic and paleoenvironmental interpretation of non oil producing areas within the country. Before now, nannofossils occurrence and application have not been documented in the surface sediments of Nigeria.

This paper presents a report of nannofossils occurrence in surface sediments from the continental shelf of the western Gulf of Guinea (off Lagos coast).

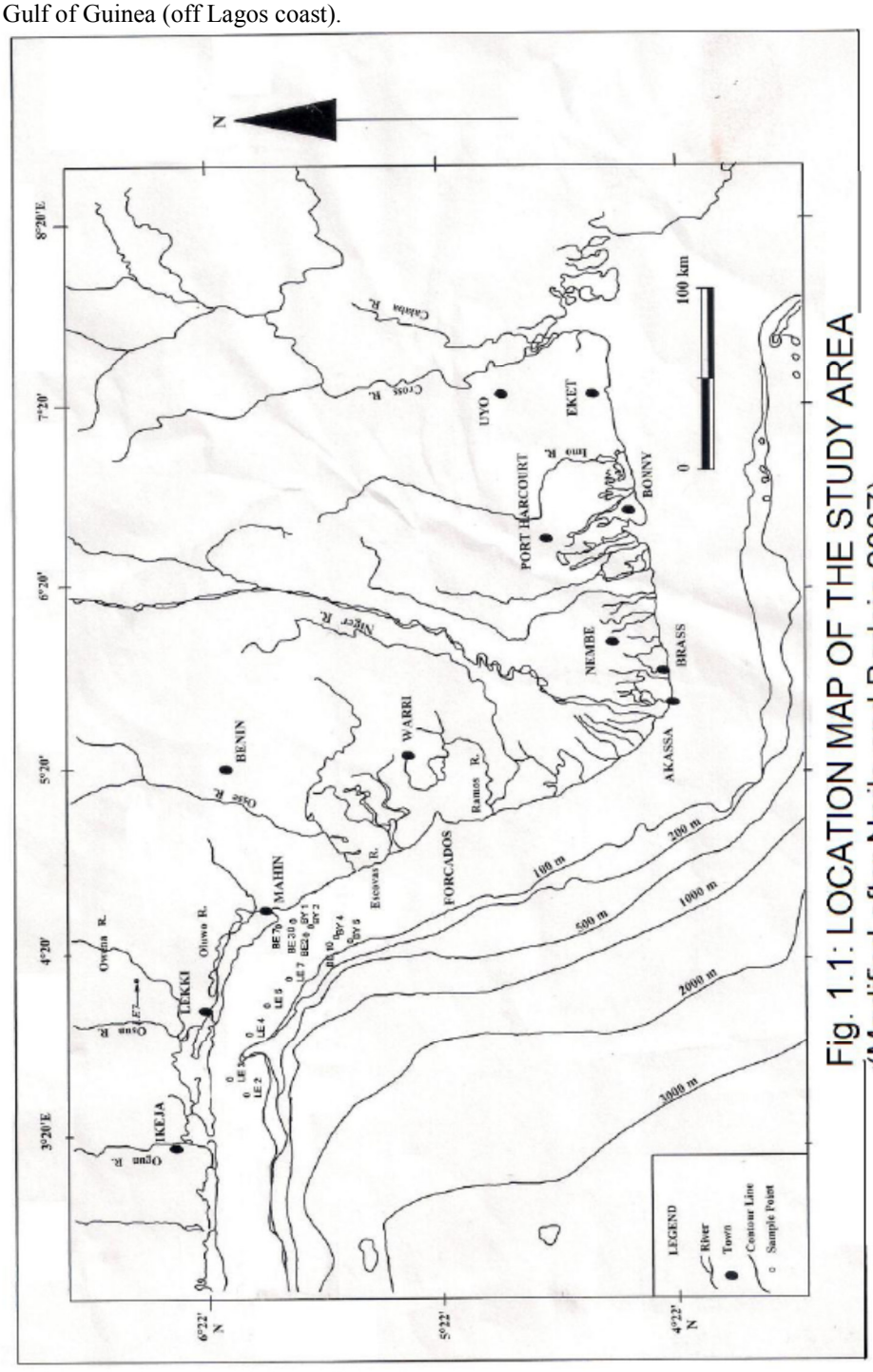


Fig. 1.1: LOCATION MAP OF THE STUDY AREA
(Modified after Nwilo and Badejo,2007)

1.2. Geologic and stratigraphic settings

The study area is situated within the inner continental shelf of the western Gulf of Guinea, off the Lagos coast, south-western Nigeria and on the western flank of the oil producing Niger Delta (Fig. 2). It is bounded in the north

by marginal shelf, which descends to a gently graded continental slope. It is underlain by low lying, nearly flat (less than 1°) and unconsolidated sediments. The width of the shelf is narrow in the study area and the depth of shelf break is about 100 m (Allen, 1965). The beach sediments, bordering the study area, are sand and further offshore, the sediments are fine grained mostly silt and clays. Narrow linear coral banks occur in the study area and beyond. They are dominated, according to Allen and Wells (1962), by *Madracis asperula* and *Dentrophylla ramen*.

From stratigraphic point of view, two suites of sediments floored the Nigerian continental shelf. These are "Older sand" and "Younger deposits". The "Older sands" are Late Pleistocene and Earlier Holocene in age (Allen and Wells, 1962). This suite outcrops extensively around the shelf edge in the study area and is composed of well sorted and well bedded, coarse quartz sand. It is enriched with Mollusc shells and Foraminifera debris, "Glauconite", fecal pellets and silt or clay.

The "Younger suite" is Later Holocene in age and has a maximum thickness of 45.27m (150ft). It comprises sands, silts, and clays. It covers some part of the study area, extending as an apron down the continental slope.

Avon submarine canyon is situated between the study area and Niger Delta. This geomorphic feature traps sediment transported eastward by the long shore drift. The sediments are periodically released down canyon by mudslide and turbidity currents (Dietz and Knebel, 1971; Martini, 1971).

2.0. Materials and Methodology

2.1. Materials

Thirteen (13) surface sediment samples collected from the continental shelf of the Western Gulf of Guinea (off Lagos Coast) with the aid of locally fabricated grab sampler were used for the analyses. The samples were code-named BE1, BE2, BE3, BE7, BY1, BY2, BY4, BY5, LE2, LE3, LE4, LE5, and LE7 for confidential reasons. The samples were provided by the Nigerian Institute for Oceanography and Marine Research [NIOMR].

2.2 Analytical methods

2.2.1. Lithologic description

The samples were dried, prepared and examined with the aid of a stereobinocular microscope for their lithologic characteristics and descriptions. Lithologic description was done on each sample with emphases on the dominant and secondary rock types, colour and texture of the constituent materials, visible fossil content and other nature of the sediment.

2.2.2. Calcareous nannofossils analysis

Samples were prepared for nannofossils analyses by mixing a small quantity (about 5g) of the sediment with distilled water inside a test tube to obtain the clay-sized nannofossils entrapped in the suspended clay-sized fraction that is used for slide preparation. A "wet" cover slip of a glass slide is placed on a hot plate, and after a continuous stirring (for effective mixture) of the prepared sample, a rubber pipette was used to draw out the clay-sized suspended fraction from the test tube. The obtained fraction inside the test tube was then gradually released on the cover slip until it covers its entire surface. The cover slip was allowed to properly dry on the hot plate for some minutes and then mounted on a glass slide using a few drops of Norland optical adhesive as a mounting medium. This was then placed under an ultraviolet light (from sunlight) for some minutes (about 10 – 15 minutes).

Calcareous nannofossils were analyzed semi-quantitatively using a high power Olympus Transmitted Light Microscope (TLM). The abundance of nannofossils in each sample as represented in the slide was noted with no special observation on preservation categories as many species are poorly preserved or are too small/tinny. Most of the nannofossils analyses follow the work of Perch – Nielsen (1985) which was used in identification, description and age determination of all the species.

3.0. Results and discussions

3.1. Lithologic decription

The samples are mostly sand (Figure 3) with little percentage of silt, clay sized particles and other materials. Their colours grade in the shades of grey, to light yellowish. The sediment particle sizes range from coarse to fine-grained, angular to sub-rounded and poorly to moderately sorted in texture. Quartz is the dominant mineral in the samples while feldspar and mica (muscovite) constitute a lesser percentage. Other constituents of the samples include ferruginous materials and Shell fragments (Mollusc, Pelecypods and other shell fragments).

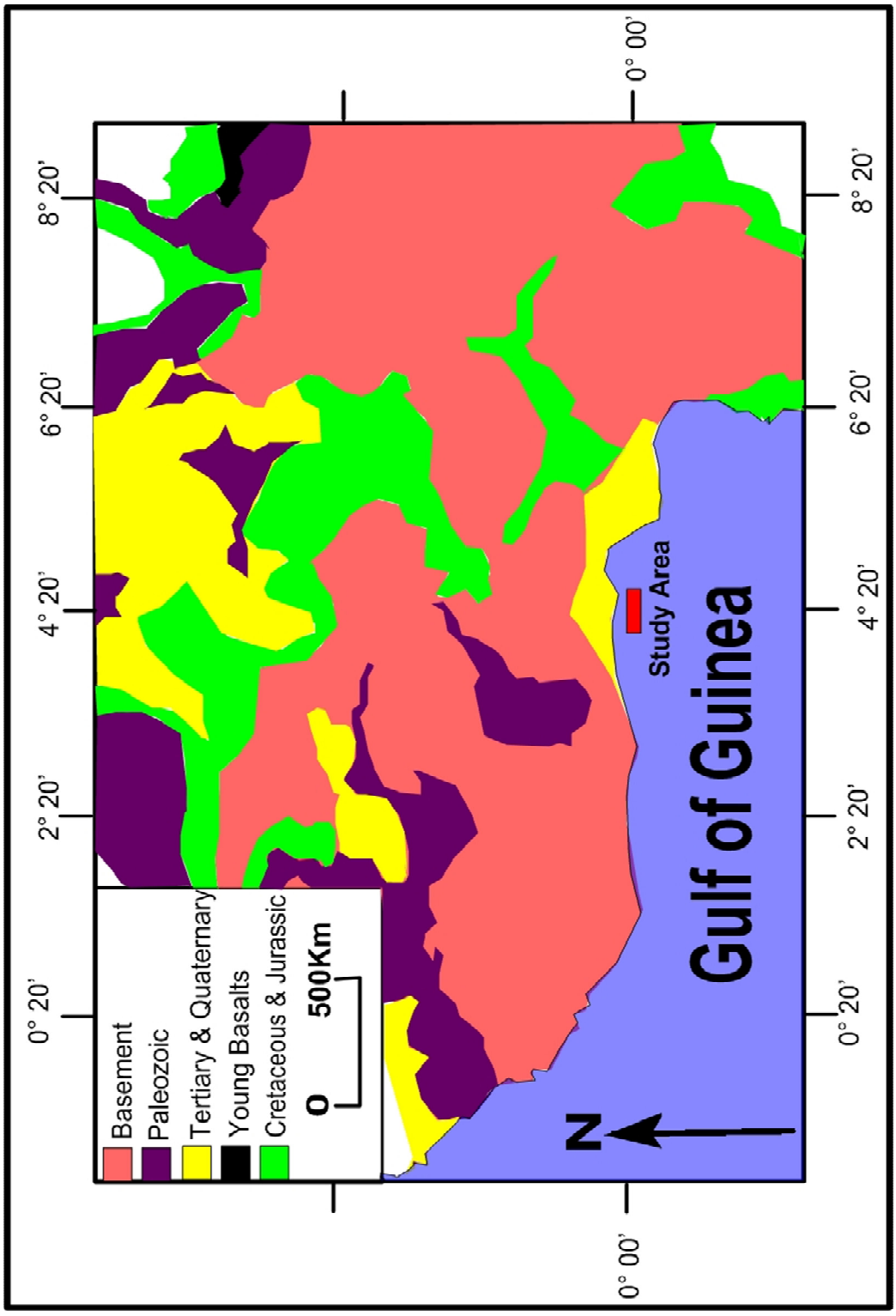


Fig. 2: Generalized Geological Map of the study area (Modified After Allen, 1965)

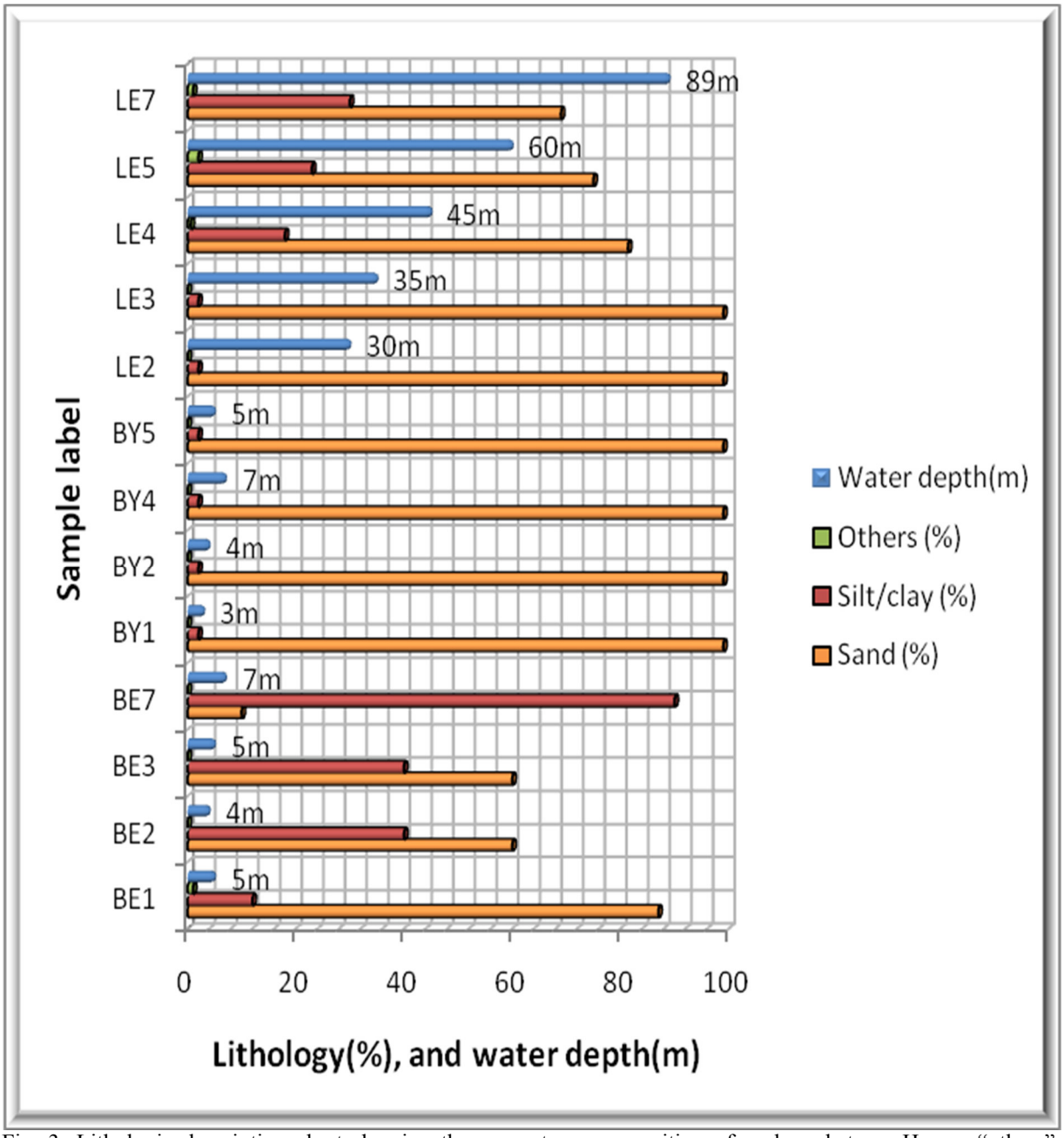


Fig. 3: Lithologic description chart showing the percentage composition of each rock type. Hence, "others" constitutes the mollusc, pelecypods and other shell fragments

3.2. Calcareous nannofossils analysis results

A total of thirteen (13) surface sediment samples collected at different water depth (Table 1.0) have been analyzed for their calcareous nannofossils content. The result shows a poor occurrence of nannofossils in the study area. Eight (8) samples (BE2, BE3, BE7, BY1, BY2, BY4, BY5, & LE3) showed total bareness and only one (1) species of *Calcidiscus leptoporus* was present in sample LE2 (Table 2.0). However, four (4) of the samples (BE1, LE4, LE5, & LE7) were found to be moderately/fairly rich with limited diversity of species (Table 2.0). Thus, the description herein will then be restricted to the four (4) rich samples and the LE2 (which have only one species) as indicated above. Only references could be made to those barren samples.

The species recovered from the studied samples include; *Calcidiscus leptoporus, Calcidiscus macintyrei, Ceratolithus cristatus, Gephyrocapsa caribbeanica, G. oceanica, G. parallela, G. species, G. spp (small), Helocosphera carteri* and *Reticulofenestra spp.* (Plate 1).

Table 1.0: Total population of nannofossils species

Sample/Location NO.	Positions		Water Depth (m)	Total Population
	Longitudes	Latitudes		
BE 1	4^0 3' E	$5^0$58' N	05.0	232
BE 2	4^0 32' E	5^0 59' N	04.0	Barren
BE 3	4^0 33' E	5^0 58' N	05.0	Barren
BE 7	4^0 34' E	$5^0$58' N	07.0	Barren
BY 1	4^0 26' E	5^0 58' N	03.0	Barren
BY 2	4^0 27' E	5^0 59' N	04.0	Barren
BY 4	4^0 29' E	$6^0$02' N	07.0	Barren
BY 5	4^0 31' E	6^0 01' N	05.0	Barren
LE 2	3^0 32' E	6^0 13' N	30.0	01
LE 3	3^0 38' E	6^0 13' N	35.0	Barren
LE 4	3^0 50' E	6^0 10' N	45.0	335
LE 5	4^0 08' E	6^0 04' N	60.0	297
LE 7	4^0 14' E	5^0 58' N	89.0	267
				1,132

Table 2.0: Individual population of species

Sample/Location No·	Gephyrocapsa spp	Gephyrocapsa oceanica	Gephyrocapsa carebbeanica	Gepyrocapsa parallela	Gephyrocapsa spp(small)	Helicosphera carteri	Calcidiscus leptoporus	Calcidiscus macintyrei	Reticulofenesra spp	Ceratolithus cristatus	
BE1	13	62	41	06	44	14	8	—	43	1	
BE2	—	—	—	—	—	—	—	—	—	—	
BE3	—	—	—	—	—	—	—	—	—	—	
BE7	—	—	—	—	—	—	—	—	—	—	
BY1	—	—	—	—	—	—	—	—	—	—	
BY2	—	—	—	—	—	—	—	—	—	—	
BY4	—	—	—	—	—	—	—	—	—	—	
BY5	—	—	—	—	—	—	—	—	—	—	
LE 2	—	—	—	—	—	—	1	—	—	—	
LE 3	—	—	—	—	—	—	—	—	—	—	
LE 4	62	44	52	16	72	43	8	5	33	—	
LE 5	48	53	61	12	43	39	9	4	28	—	
LE 7	42	13	23	4	66	41	17	—	61	—	
Total	165	172	177	38	225	137	43	9	165	1	1,132

Table 3.0: Percentage composition of species

Sample/Location No·	Gephyrocapsa spp	Gephyrocapsa oceanica	Gephyrocapsa carebbeanica	Gepyrocapsa parallela	Gephyrocapsa spp(small)	Helicosphera carteri	Calcidiscus leptoporus	Calcidiscus macintyrei	Reticulofenesra spp	Ceratolithus cristatus	Total
BE 1	5.6	26.7	17.7	2.6	19.0	6.0	3.4	—	18.5	0.4	99.9
BE 2	—	—	—	—	—	—	—	—	—	—	—
BE 3	—	—	—	—	—	—	—	—	—	—	—
BE 7	—	—	—	—	—	—	—	—	—	—	—
BY 1	—	—	—	—	—	—	—	—	—	—	—
BY 2	—	—	—	—	—	—	—	—	—	—	—
BY 4	—	—	—	—	—	—	—	—	—	—	—
BY 5	—	—	—	—	—	—	—	—	—	—	—
LE 2	—	—	—	—	—	—	100	—	—	—	100
LE 3	—	—	—	—	—	—	—	—	—	—	—
LE 4	18.5	13.1	15.5	4.8	21.5	12.8	2.4	1.5	9.9	—	100
LE 5	16.2	17.8	20.5	4.0	14.5	13.1	3.0	1.3	9.4	—	99.8
LE 7	15.7	4.9	08.6	1.5	24.7	15.4	6.4	—	22.8	—	100

Seven (7) identifiable species of five (5) different genera were recovered from the samples (Table 3.0). *Gephyrocapsa spp*.(small) dominates the assemblage. *Gephyrocapsa caribbeanica* is the most abundant identifiable species occurring in all the four rich samples. *Gephyrocapsa oceanica* also occur in high abundance within the rich samples (Fig. 4.0 & 5.0). Some species of *Reticulofenstra* and *Gephyrocapsa* could not be identified beyond the genus level due to their small sizes and poor preservation which might be as a result of unfavourable environmental condition that prevails during the time of deposition. Generally, all the samples containing nannofossils are predominantly sand containing between 12 to 30% silty/clayey materials in which the nannofossils are believed to been preserved.

The family *Coccolithaceae*, represented by the genus *Calcidiscus* has two of its species *Calcidiscus leptoporus* and *Calcidiscus macintyrei* (Table 2.0&3.0) present in the samples. The *Ceratolithaceae* represented

by *Ceratolithus cristatus* occur only once in one of the samples. Another genus of the *Coccolithaceae* family represented by the *Gephyrocapsa* with high to common occurrence of *G. caribbeanica*, *G. oceanic, G. parallela*, and other unidentifiable *Gephyrocapsa* species were found in the four rich samples. The *Helicosphaerid coccoliths,* represented by *Helicosphera carteri* shows common occurrence in most nanno-rich samples. The family *Prinsiaceae,* represented by the genus *Reticulofenestra* which are too small and poorly preserved that they cannot be identified beyond the genus level were also commonly encountered in the rich samples.

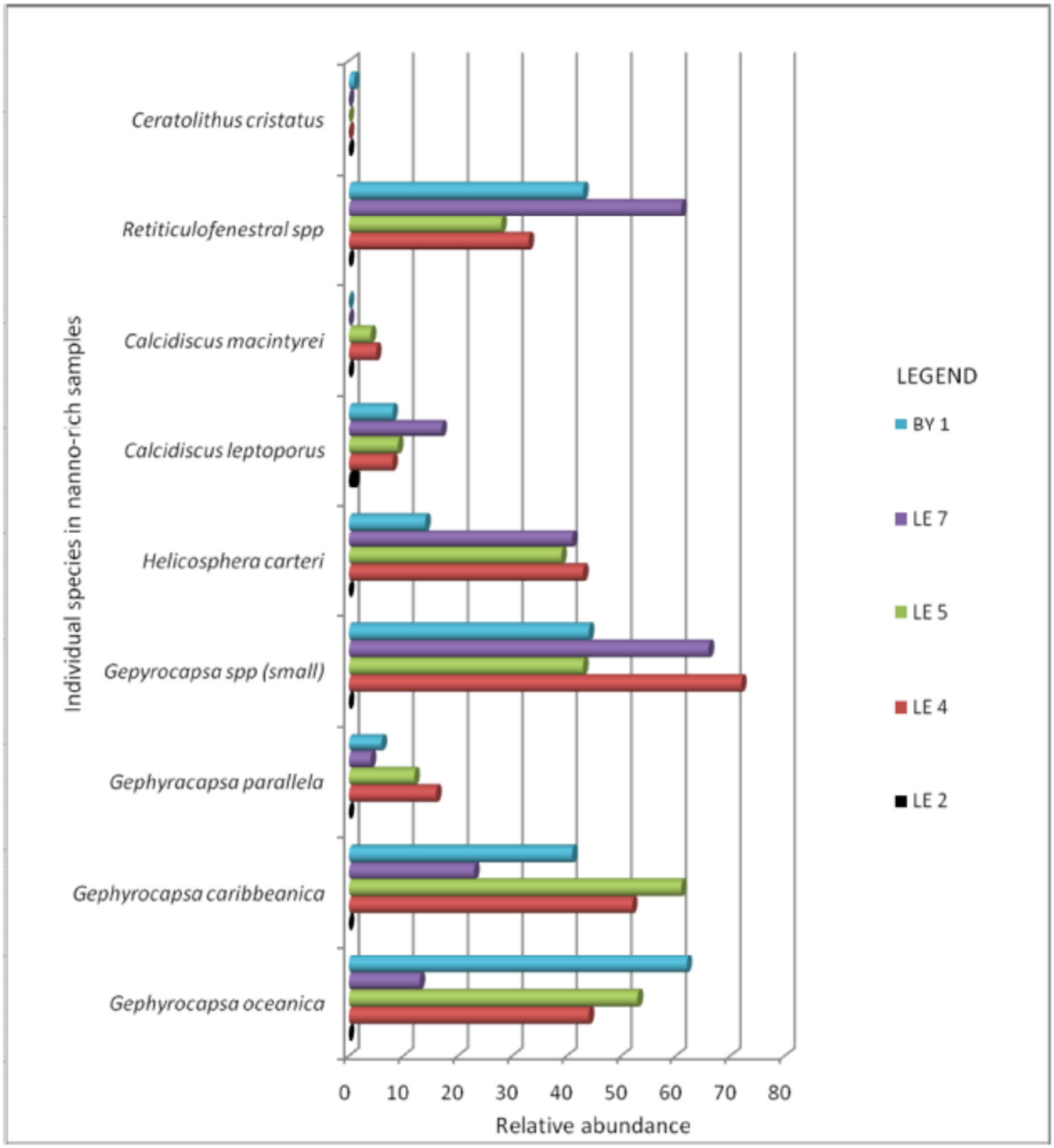
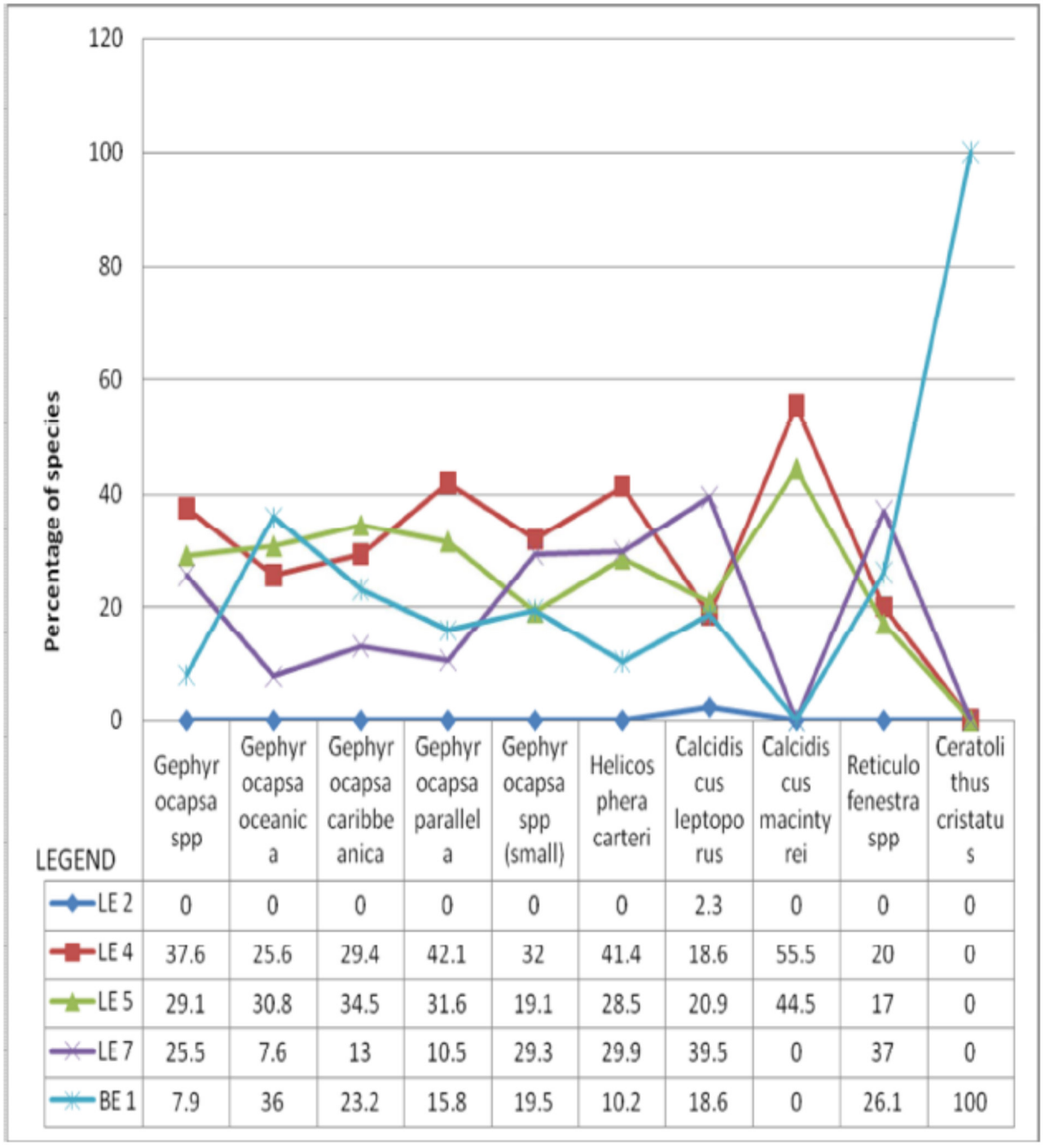


Fig. 4.0: Nannofossils distribution chart for rich samples



LEGEND	Gephyrocapsa spp	Gephyrocapsa oceanica	Gephyrocapsa caribbeanica	Gephyrocapsa parallela	Gephyrocapsa spp (small)	Helicosphera carteri	Calcidiscus leptoporus	Calcidiscus macintyrei	Reticulofenestra spp	Ceratolithus cristatus
LE 2	0	0	0	0	0	0	2.3	0	0	0
LE 4	37.6	25.6	29.4	42.1	32	41.4	18.6	55.5	20	0
LE 5	29.1	30.8	34.5	31.6	19.1	28.5	20.9	44.5	17	0
LE 7	25.5	7.6	13	10.5	29.3	29.9	39.5	0	37	0
BE 1	7.9	36	23.2	15.8	19.5	10.2	18.6	0	26.1	100

Fig. 5.0: Relative abundance plot for nannofossils species encountered

3.2. Age determination

The nannofossils species encountered in this study suggest an age ranging from Pliocene to Recent (mainly Pleistocene). Pleistocene age is found to be most appropriate because, the Pleistocene is primarily divided by small representatives of the family *Prinsiaceae* and secondarily by *Clcidiscus macintryei*, *Helicosphaera selli* and *Pontosphaera indooceanica*. This, when linked with the subdivision of *Pseudoemiliania* lacunose zone (NN19) subdivision of Martini (1971) with reference to the first occurrence (FO) of *Gephyrocapsa carribeanica*, FO of *Gephyrocapsa oceanica,* and last occurrence (LO) of *Clcidiscus macintyrei*, the samples can be said to be Middle – Upper Pleistocene (<1.77ma) in age since most of the species that marks the NN19 subdivisions are found in the studied sample without any contradiction. Also, the Pleistocene is characterized by *Gephyrocapsa caribbeanica and Gephyrocapsa oceanica* flood. These, occurring together with *Calcidiscus macintyrei* is a confirmation of the Pleistocene age. However, since the samples does not show sequential depth ranges (they are virtually from the same horizon), it is rather the best to give an age range that reflects most of the species encountered as it has been

done by other authors such as Cachao, 1993; Jijun and William, 1986; among others. This justifies the reason for giving a range from Pliocene to Recent which best reflects of the age of the studied samples.

3.3. Paleoecology

Depositional environments of surface sediments of interest are interpreted mainly from the occurrences of species and assemblages of fossil form present. The saying of "the present being the key to the past" forms the basis for paleoecological interpretation. Criteria for interpretation begin with the studies of recent species obtained from similar environment. This method permits correlation of species to environment of deposition, and information on water depths, salinities, temperatures and other significant factors may be obtained.

Interpretation of depositional environment from paleoecology and related stratigraphy was attempted for the studied samples based on primary data obtained from the analysis and inferences drawn from some previous authors. Oriafo (1991) observed that *Gephyrocapsa oceanica* is generally considered to reflect warm water conditions. Okada (1983) referred *Gephyrocapsa oceanica* as a species that may dominate surface sediment assemblages from very shallow to semi-confined seas. He recognized *Gephyrocapsa species* as having neritic affinity along western Pacific Ocean, but they can also be found in other regions.

Cachao (1993) however explained that there is a gradual decrease towards shore on relative abundance of *Calcidiscus leptoporus* over the continental shelf when compared to other species such as *Helicosphera carteri* and *Coccolithus pelagicus*. Hence, "Shore" is defined as the area where nannoplankton abundance drops to zero due to high hydrodynamic near shore conditions. *Gephyrocapsa oceanica* according to Ferriera and Cachao (2005) are found to thrive well in neritic environmental conditions.

From other observation, Jijun and William (1986) identified that calcareous nannoplankton specimens are less common in inner-shelf sediments, but increase progressively in abundance with increasing water depth.

Distribution and abundance of calcareous nannoplankton on the continental shelf are related to water temperature, salinity and clastic-sediment influx. Jijun and William (1986) stressed out that, although "Water depth" is sometimes used as a "catch-all" control when discussing distribution and abundance of nannofossils but is not, strictly speaking, a limiting factor for planktonic organisms. Rather, the changes in temperature, salinity and sediment influx are the dominant controlling features as one move progressively seaward (into deeper waters).

However, calcareous nannofossils in the western Gulf of Guinea (off Lagos coast) are found to be more abundant in areas with higher water depth (45 – 89m) when compared with those of relatively shallower depth (below 40m) from more or less the same horizon with the only exception at location BE1 (which is 5m water depth). Calcareous nannofossils recovered from the surface sediments of the western Gulf of Guinea are *Calcidiscus macintyrei, Calcidiscus leptoporus, Ceratolithus cristatus, Gephyrocapsa oceanica, G. parallela, G. spp., G. caribbeanica, small Gephyrocapsa, Helicosphera carteri* and *Reticulofenestra spp.* These species generally reflect a shallow and warm water conditions. Similar to the work of Okada (1983) in the western Pacific Ocean, *Gephyrocapsa spp*. are found to be having neritic affinity in the western Gulf of Guinea.

3.4. Environmental implication of nannofossils encountered

Several species have been shown to be more common in marginal than in open seas (Perch- Nielsen, 1985). Okada and Honjo (1975) showed clearly the different community structures of calcareous nannoplankton between the marginal sea along the western Pacific and the pelagic counterpart. Okada (1984) suggests *Florisphaera profunda* as a tool to recognize paleodepth. He found no *F. profunda* in shallow seas and an increase to over 50% of the assemblages in 200m. He found *Gephyrocapsa* dominating the flora in shallow marginal seas and inland seas. *Discoaster* was not found in the shallow Lower Pliocene of the Capricorn Basin whereas the small *Prinsiaceae, Gephyrocapsa* and *Emilianian* also dominate the calcareous nannoplankton assemblage in the Gulf of Elat.

However, the small *Prinsiaceae* and *Gephyrocapsa* are found to dominate the calcareous nannofossil assemblage in the Western Gulf of Guinea [off Lagos Coast] as showed in this present work. It is obvious and thus conclusive that the species encountered in this study are truly marine assemblages found at water depth mostly between 42 - 100m. This correlate with the work of Okada (1984) which shows absence of *Dicoaster* in the shallow Lower Pliocene of Capricon Basin and the dominance of *Prinsiaceae, Gephyrocapsa* and *Emilianian* in the Gulf of Elat.

4.0. Conclusion and Recommendation

The occurrence of calcareous nannofossils in the surface sediments of Nigeria has been established using the thirteen (13) samples collected from the western Gulf of Guinea (off Lagos coast) at different water depths and locations. Detailed lithologic description of the samples has revealed the sandy nature of the sediments. The samples also contain little percentage of clay, silt and shell fragments of mollusc and pelecypods.

The calcareous nannofossils analysis yielded low and or limited nannofossils assemblages in the study area. Several unidentifiable species of the family *Prinsiaceae* have shown to be more common in the continental shelf of Nigeria at the western Gulf of Guinea (off Lagos coast). Small *Gephyrocapsa* species are found dominating

the flora in the area. The nannofossils species occur mostly in the areas with a water depth above 40m.

Based on the relative abundance of nannofossils assemblages in the study area and the comparison made with some previous work done on nannofossils at different parts of the world, *Gephyrocapsa* species and small *Prinsiaceae* (*Reticulofenestra spp*.) were found dominating the marginal continental shelf of Nigeria at the western Gulf of Guinea (off Lagos coast). The species recovered in this study include; *Calcidiscus leptoporus, Calcidiscus macintyrei, Ceratolithus cristatus, Gephyrocapsa caribbeanica, G. oceanica, G. parallela, G. species, G. spp (small), Helocosphera carteri and Reticulofenestra spp*. which reflect a truly marine condition, with the age ranging from Pliocene to Resent (Mainly Pleistocene).

All the sediment samples are virtually from the same horizon within the recent accumulations on the sea floor ("surface sediments"). Therefore biostratigraphic deductions such as zonation, and sequence stratigraphic framework for the studied samples could not be accomplished since there is no sequential depth ranges or variation.

This present work being the first report on the occurrence of Calcareous Nannofossils in surface sediment of Nigeria is expected to provide a template for similar works in Nigeria.

Also, more effort should also be channelled in this aspect rather than diverting the whole effort and knowledge of nannofossils biostratigraphy into the oil-rich areas leaving other areas with little or no information as research in this area (surface sediments) can help to explain the prevailing environmental condition(s) of a given region better. Therefore, more research should be carried out on the surface sediments of Nigeria in order to be able to make some geologic and biostratigraphic deductions on the subject readily available.

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PLATE 1

Fig. 1: Gephyrocapsa parallela

Fig. 2: Calcidiscus leptoporus

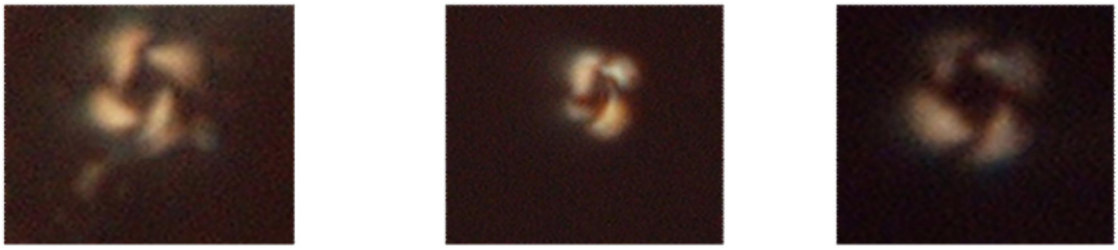

Fig. 3: Reticulofenestra spp.

Fig. 4: Gephyrocapsa caribbeanica

Fig. 5: Helicosphaera carteri

Fig. 6: Gephyrocapsa oceanica

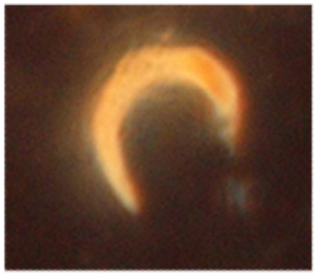

Fig. 7: Ceratolithus cristatus

[Mg: X 60]

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