

PRELIMINARY REPORTS ON MIDDLE MIOCENE – EARLY PLEISTOCENE DINOFLAGELLATE CYSTS FROM THE WESTERN NIGER DELTA, NIGERIA

ERNEST UZODIMMA DURUGBO*, OLUWATOYIN TEMITAYO OGUNDIPE** and OGBONNAYA KALU ULU***

*Department of Biological Sciences, Redeemer's University, Nigeria

**Department of Botany, University of Lagos, Nigeria.

***Earth Sciences and Reservoir Services Division, Chevron Nigeria Limited, Lagos, Nigeria.

*E-mail address for correspondence: ernestduru@yahoo.com

Abstract: Few published records of dinoflagellate cysts from the Middle Miocene – Early Pleistocene of the Niger Delta exist. Dinoflagellate cysts events could contribute to a wider use of palynological schemes. Their use in combination with pollen and spores will produce meaningful biostratigraphical schemes which will be useful where the other microfossils are scarce. Appreciable numbers of well preserved organic walled dinoflagellate cysts comprising 53 genera and 93 species were recovered from the analysis of 104, 100, 96 and 89 ditch cuttings of wells BA, BB, BC and BD from part of the Western Niger Delta. The ages ranged from Middle Miocene to Early Pleistocene (c.a 15.0Ma – 1.3Ma) based on the behaviour of pollen and spore marker species and confirmed with foraminiferal data. The samples were characterized by common records of peridiniaceans, especially in the Middle –Late Miocene. These occurred in association with common gonyaulaceans such as *Nematosphaeropsis labyrinthus*, *N. lemniscata*, *Sumatradinium* spp., *Lingulodinium machaerophorum*, *Operculodinium centrocarpum*, *Spiniferites ramosus*, *Spiniferites mirabilis*, *Hystrichokolpoma rigaudiae*, *Polysphaeridium zoharyi*, *Achomosphaera ramulifera*, *Achomosphaera andalousiensis*, *Tuberculodinium vancampoeae*, *Impagidinium* spp., *Homotryblum* spp., and spot occurrences of the older forms *Dinogymnium eucalense*, *Muderongia* spp., *Odontochitina cf. costata*, *Wallodinium* spp., *Paleocystodinium golzowense*, *Glaphyrocysta* spp., and the acritarch *Ascotomocystis potane* indicating reworking. The occurrence of *Achomosphaera andalousiensis* is documented for the first time in the Niger Delta and its LDO close to the 11.6Ma promises to be notable event.

Key words: Miocene-Pleistocene, Peridiniaceans, Gonyaulacealens, Western Niger Delta, Nigeria.

INTRODUCTION

The studied area is located within part of the Western Niger Delta (Fig. 1). The Tertiary Niger Delta covers an area of about 7500 square kilometers and is composed of an overall regressive clastic sequence, which reaches a maximum thickness of 9,000 – 12,000m (30,000- 40,000ft). Its development has been dependent on the balance between the rate of sedimentary and the rate of subsidence. This balance and resulting sedimentary patterns appear to have been influenced by the structural configuration and tectonics of the basement. (Evamy *et al.* 1978). Three lithographic units are recognized, namely the Akata Formation, Agbada Formation, and the Benin Formation (Short and Stauble, 1967; Doust and Omatsola, 1990).

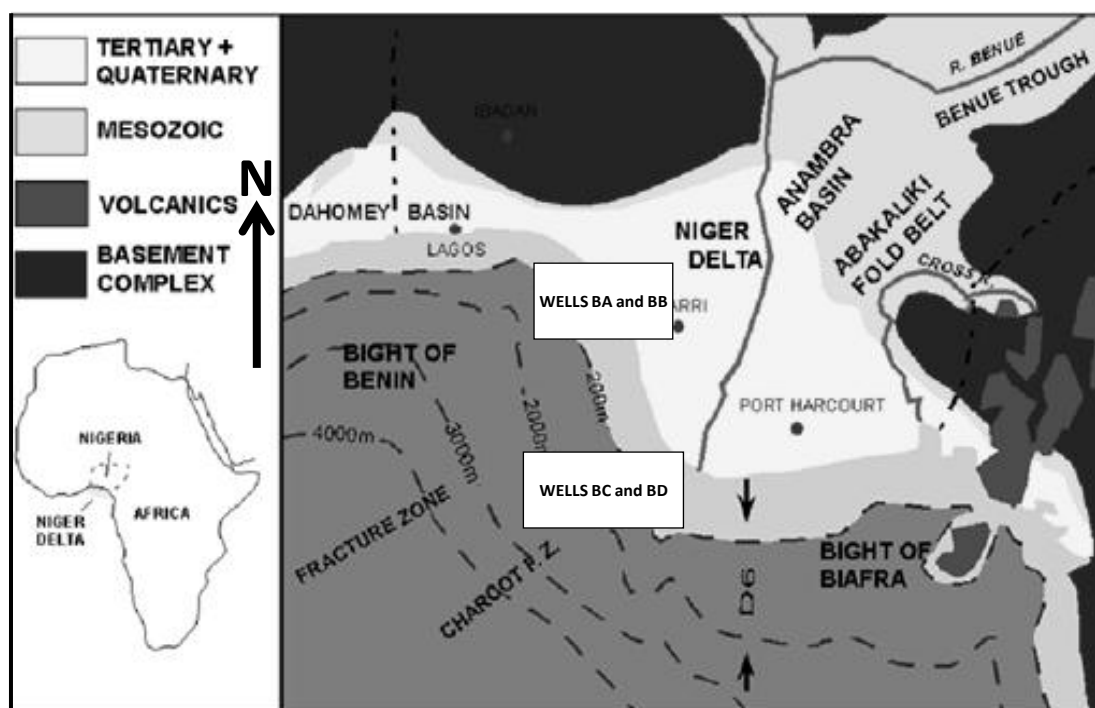


Figure 1: Map of the Niger Delta showing the studied wells (After Doust & Omatsola, 1990).

Figure 1: Map of the Niger Delta showing the location of studied wells.

According to Doust and Omatsola (1990), the Akata shales contain a few streaks of sand, possibly of turbiditic origin which were deposited in holomarine (delta front to deeper marine) environments. These marine shales range from Paleocene to Holocene in age. On the other hand, the Agbada formation is overlain by a paralic sequence of inter-bedded sand and shales, 300 – 4500m (984 – 14766ft) thick. It consists of alternating sandstones and shales of deltaic front, distributary's channel and deltaic plain origins. The alternating sequence of sandstones and shales of the Agbada formation has been shown by Weber (1971) to be a cyclic sequence of marine and fluvial deposits, determined from electric-log patterns, well, cores and dipmeter data. Furthermore, the topmost unit (the Benin Formation) consists of fluvial gravels and sand occurring from the contemporary delta surface to depths of about 2134m (7,000ft). It consists predominantly of massive, highly porous, fresh water bearing sandstones, with local thin shale inter-beds, which are considered to be of braided stream origin. The lithofacies analysis and the well log responses suggest that only one of the formally recognized lithostratigraphic units in the Niger Delta Basin viz: the Agbada Formation (Short and Stauble, 1967; Whiteman, 1982) was penetrated in all the four wells. This is a paralic sequence consisting of alternations of sands/silts and shales/mudstones, with shales predominating at the lower section and sands predominating up-section.

Earlier dinoflagellate cysts investigations from the Gulf of Guinea

Generally, in the Southern Hemisphere which encompasses the Niger Delta/Gulf of Guinea among others, dinoflagellate studies are very scanty when compared to the numerous research that have been done in the Northern Hemisphere (Antholinez, 1999, Antholinez *et al.*, 2004, Biffi and Grignani, 1983, Brinkhuis *et al.*, 2003, Jan du Chêne, 1987, Marret and So-Young, 2009, McMinn, 1992, 1994, Morzadec-Kerfourn, 1992, Oboh-Ikuenobe *et al.*, 1999, Sluijs *et al.*, 2003). It is for this reason that this study was undertaken. These recovered dinoflagellates will contribute to the global records of which only few have been documented from the Niger

Delta, Gulf of Guinea and the Southern Hemisphere and ultimately a dinoflagellate zonation would be erected for the Middle Miocene-Early Pleistocene of the Niger Delta. Marine events are generally more global as revealed by the use of nannofossils and foraminiferal zonation schemes (Hardenbol *et al.*, 1998, Bergreen *et al.*, 1995, Blow 1969,1979, Martini, 1971, among others). Again, Haq *et al.*, (1987), Grandstein *et al.*, (2004) had both incorporated dinoflagellate events in their Global cycle charts thereby highlighting their potentials. Dinoflagellate cysts could contribute to a wider use of the existing palynological schemes which are solely based on pollen and spore marker species. The incorporation of dinocyst events in combination with pollen and spores will produce meaningful biostratigraphical schemes which will be useful where the other microfossils are scarce. The study of Niger Delta dinocysts will help refine correlations between deep sequences, condensed sections and shelfally deposited strata. This will provide for meaningful correlations with the Mesozoic-Cenozoic depositional sequences of Haq *et al.*, (1988) as modified by Hardenbol *et al.*, (1998) and updated by Grandstein *et al.*, (2004).

The few records of dinoflagellate studies in the Gulf of Guinea include those of Biffi and Grignani (1983) who studied Oligocene sediments from fifteen boreholes of subsurface Tertiary sediments in the Niger Delta which yielded rich dinoflagellate cyst assemblages characterized by abundant Peridinoids particularly *Lejeunacysta*, *Phelodinium* and *Selenopemphix* species. They described seven new species of *Lejeunacysta* (*L. brassiensis*, *L. communis*, *L. pulchra*, *L. beninensis*, *L. globosa*, *L. lata*, *L. granosa*); two new species of *Phelodinium* (*P. nigericum* and *P. africanum*) and one of *Selenopemphix* (*S. warriensis*). They further emended some species of *Lejeunacysta*.

Jan du Chêne, (1987), having studied Danian sediments from Senegal reported the occurrences of such dinoflagellate species as *Fibrocysta axialis*, *Muratodinium fimbriatum*, *Danea californica*, *Xenicodinium lubricum*, *Spinidinium densispinatum*, *Kallosphaeridium yorubaense*, *Diphyes colligerum*, *Senegalinium* spp., *Phelodinium* spp., *Ifecysta* spp., *Senegalinium* (*S. orei*), *Hafniasphaera* (*H. septata*), *Spiniferites mirabilis* and *Florentinia* spp.

Oloto (1989) did a comprehensive study of dinoflagellate cysts from the Maastrichtian section of the Nkporo shale of the Gbekebo-1 well from the coastal Benin Flank of the Niger Delta. He recovered 16 genera and 37 species of dinocysts together with 6 genera and 6 species of pollen and spores from which he recognized six dinoflagellate zones and four pollen/spore zones which he used for palaeoenvironmental and palaeoclimatic interpretations. Oloto (1990) further studied some core samples from the Danian section of the Gbekebo-1 well. He recorded dinoflagellate cysts, pollen, spores and associated elements such as algae, fungal spores and chitinous microforaminiferal test linings. He used the relative diversity and abundance of the dinocysts, pollen and spores for the age determination of the sediments. Again, the dinocyst zones he recognized were based on the use of first occurrences of two or more species.

Morzadec – Kerfourn (1992) had studied the presence of estuarine dinoflagellate cysts among Oceanic assemblages of Pleistocene deep – sea sediments from the West African margin (Guinea, Ivory Coast). She opined that the importance of these estuarine cysts in oceanic assemblages depended on the configuration of the continental shelf and currents. Again, the evolution of the littoral environment she inferred to be a function of climatic changes and variations in sea level. She reported a considerable assemblage of dinoflagellate cyst species diversity in which many estuarine cysts and terrigenous supplies were brought into the oceanic domain together. Cysts characteristic of the Oceanic and Oceano – Neritic environment, as defined by Wall *et al.* (1977), revealed information about the surface water temperature. She suggested that estuarine cysts dispersed in the oceanic domain furnish information about environmental changes in the coastal zone and that *Polysphaeridium zoharyi* a species adapted to very saline waters had indicated an arid phase. On the other hand, she noted that *Tuberculodinium vancampoe* was tolerant of freshwater supplies and therefore an indicator of a more humid phase.

Oboh (1992) in her study of Middle Miocene paleoenvironments from the Niger Delta had ascribed prodelta environments to the core of her well 27 which yielded 8-11% microforaminiferal test linings and five specimens of dinoflagellate cysts with low diversity of benthic foraminifera and an assemblage composed of nearly 99% agglutinated species.

Oboh-Ikuenobe *et al.* (1999) working with Upper Oligocene-Early Miocene strata dated by the presence of the pollen types *Retibrevitricolporites obodoensis* and *Magnoliapollenites* spp., from the Côte D'Ivoire – Ghana Transform Margin observed a cyclic alternation of the dominant dinoflagellate cysts between gonyaulacaleans and peridinialeans with *Spiniferites mirabilis* and *Hystrichokolpoma* spp. (*H. cinctum*) as the commonest gonyaulacoids. *Nematosphaeropsis labyrinthus* was dominant in one sample, while the other gonyaulacoids were *Cordosphaeridium cantharellum*, *Homotryblium tenuispinosum*, and *Achillodinium biformoides*. Large numbers of Proteridinoids characterized the Peridinialean dominated sections. They found the abundances of these dinocysts, together with calcareous and siliceous microfossils to be controlled by organic matter

distribution which they opined were indicative of changes in the water mass and paleoproductivity. The pollen and spores were scarce with many showing evidence of reworking. Apart from those mentioned earlier, other recovered pollen and spores were *Peregrinipollis nigericus*, *Spirosyncolpites bruni*, and *Grimsdalea* sp. in association with long ranging dinocysts which were unsuitable for age designation.

Antolinez (1999) having analyzed forty four samples from the early Paleogene interval of Alo-1 well in Anambra State, Nigeria and ODP Hole 959D (Leg 159) in the Côte d'Ivoire-Ghana Transform Margin for dinocysts, recovered good to moderate, and well preserved specimens. He compared the stratigraphic and quantitative data with detailed and well calibrated dinocyst distributions from north-western Europe and the southern Hemisphere, Tasmania and New Zealand. He erected five informal zones (A to E). Zone A was the stratigraphically oldest which was characterized by the consistent occurrences of *Areoligera senonensis*, *Areoligera coronata*, *Palaeocystodinium bulliforme*, and *Hafniasphaera septata*. In Zone B were *Damassadinium* cf. *D. heterospinosum* in combination with abundant *Fibrocysta/Lanternosphaeridium* spp., and *Cordosphaeridium* spp. The dinocyst assemblages in zone C was characterized by the co-occurrence of abundant *Apectodinium* spp., and *Adnatosphaeridium* spp. Zone D consisted of common *Glaphyrocysta ordinata*, *Glaphyrocysta divaricata*, *Polysphaeridium subtile*, *Spiniferites microceras*, and *Adnatosphaeridium* spp. The youngest Zone E was characterized by the occurrences of *Homotryblum abbreviatum*, *Homotryblum* cf. *H. oceanicum*, and *H. pallidum*. These results, he reasoned, could have great impacts on hydrocarbon exploration in tropical areas such as southeastern Nigeria and the Equatorial Atlantic where important hydrocarbon reservoirs occur in Paleocene and Eocene continental and marginal marine rocks. Again, subsidence curves, thermal maturation histories and timing of oil migration rely heavily on ages directly derived from palynological zones in these areas.

Sluijs *et al.* (2003) had also studied the dinoflagellate cysts from the Eocene-Oligocene Transition in the Southern Ocean (ODP Leg 189). Though the transition was barren of calcareous microfossils, they recovered abundant marine organic walled dinoflagellate cysts and diatom assemblages. These, they opined, were suitable for detailed biostratigraphic and paleoenvironmental analysis. They listed twenty species among which were *Aireiana verrucosa*, *Alterbidinium distinctum*, *Brigantidium?* spp., *Deflandrea* spp. (*D. antarctica*, *D. phosphoritica*), *Enneadocysta*, *Gelatia inflata*, *Octodinium askinae*, *Paucisphaeridium* spp. *Schematophora speciosa*, *Spinidinium colemanii*, *Spinidinium luciae*, *Spinidinium macmurdoense*, *Stoveracysta kakanuiensis*, *Turbiosphaera filosa* and *Vozzhennikovia* spp.

Furthermore, Demchuk and Morley (2004) reported the occurrence of dinoflagellate cysts which they encountered in their study of some Nigerian deep offshore strata. These occurred in association with diverse assemblages of tropical pollen, spores, and sporadic abundances of freshwater algae. They had used quantitative palynological events in their chronostratigraphic deductions and indicated their use in delineating and confirming sequence stratigraphic systems tracts together with cumulative dinoflagellate cysts. The chronostratigraphically useful taxa whose First Appearances/or Extinctions they utilized were *Retibrevitricolporites obodoensis/protrudens*, *Psialtricolporites crassus*, *Racemonocolpites hians*, *Belskipollis elegans*, *Verrutricolporites rotundiporus* and *Cyperaceae* spp. They further found the quantitative occurrences of *Monoporites annulatus*, *Zonocostites ramonae*, *Magnastriatites howardi*, *Praedapollis flexibilis*, *Multiareolites formosus* (*Acanthaceae* spp.), *Celtis* spp., and cumulative freshwater algae (*Botryococcus braunii* and *Pediastrum*) also useful.

Moreover, Durugbo (2010) had also documented peridiniaceans from the Middle Miocene of the western Niger Delta which he opined resembled those recovered from the Gulf of Mexico by Wrenn and Kokinos (1986). The commonest species he recorded were *Lejeunacysta communis*, *L. lata*, *L. diversiforma*, *Apteodinium* spp. *Multispinula quanta*, *M. minuta*, *Xandarodinium* cf. *xanthum*, *Selenopemphix nephroides*, *S. warriensis*, *S. coronata*, *S. armata*, *Selenopemphix* sp. E similar to (Plate 1 # 11) of Duffield and Stein (1986), and *Spiniferites mirabilis* similar to *S. mirabilis* (Plate 6 # 4) of Wrenn and Kokinos (1986).

However, there have been several dinoflagellate studies in other parts of Nigeria such as the Cretaceous Upper Benue Trough (Lawal and Moullade, 1986), the Nkporo shale on the Calabar Flank of South eastern Nigeria (Edet and Nyong, 1994), the Maastrichtian-Lutetian succession of the Benin-1 well from the Western Anambra Basin flank of Southern Nigeria (Asadu and Lucas, 2006), the Paleocene - ?lowermost Eocene successions in the Alo-1 well from the Anambra Basin, Southeast Nigeria (Antolinez and Oboh-Ikuenobe, 2007), the Oshosun Formation in the Sagamu quarry, Dahomey Basin, South-Western Nigeria (Bankole *et al.*, 2006), and the Upper Cretaceous Patti Formation, Southeastern Bida Basin Nigeria (Ojo and Akande, 2006).

From the foregoing, the paucity of dinoflagellate studies in the Niger Delta becomes very glaring thereby revealing the need for research such as this to add to the global records, and also refine existing palynological schemes through the erection of dinoflagellate zonation schemes which would promote better use of

palynological events in age dating and correlation of wells, as well as paleoenvironmental inferences in combination with pollen and spore species.

MATERIAL AND METHODS

For this research, 104,100, 96 and 89 ditch cuttings of the wells BA, BB, BC and BD from the offshore Western Niger Delta spanning the intervals (1800-11790 feet), (1000-10570 feet), (1980- 10570 feet) and (1920-9860 feet) were donated for the investigation by Chevron Nigeria Ltd in January 2005. Standard palynological techniques involving treatments with HCL and HF were applied. Full details of the laboratory procedure are given in Durugbo *et al.* (2010). One microscope slide stained with Safranin O was studied and all the palynomorphs present were enumerated. The well, sample depth and associated England Finder localities of each dinoflagellates are given (Plates 1-6), and transmitted light photomicrographs were taken at magnifications of 400 and 1000 on a Leitz Dialux 20 EB microscope with an attached Motic 2.0 camera at the Paleobotanical laboratory of the University of Lagos. The identification of the dinoflagellates and other marine elements were based on the monographs of Brinkhuis *et al.* (2003), Bujak *et al.* (1980), Fensome *et al.*, (1993), Head and Wrenn (1992), Lentin and Williams (1989), Marret and Zonneveld (2003), Powell (1992), Rochon, *et al.* (1999), Sluijs *et al.* (2003), and Wrenn *et al.*, (1986). Generally, species nomenclature for dinoflagellate cysts followed Fensome and Williams (2004).

The slides, residues, unprocessed samples, CD copies and duplicate prints are in the palynological collections of the Biological Sciences Department, Redeemer's University, Mowe, Ogun State, Nigeria.

Chronostratigraphic Ages

The chronostratigraphic ages were provided by age diagnostic foraminifera together with pollen and spore markers species according to the zonation schemes of Evamy *et al.*, (1978) and Legoux (1978). The ages ranged from 15.0 Ma to 5.0 Ma for wells BA and BB (Blow 1969,1979; Hardenbol *et al.*, 1998; Bergreen *et al.*, 1995) which coincided with the P720-P860 Niger Delta palynological Zones of Evamy *et al.* (1978). In wells BA and BB, the upper sections were dated 5.0Ma based on the Base occurrence of the Niger Delta palynological Miocene/Pliocene boundary marker species *Retistephanocolpites gracilis* (aff. *Borreria verticillata*) at 2160 feet and 1800 feet which were close to the FDO: *Eggerella scabra*/ FDO: *Cyclammina minima* recorded at 1150 feet and 1990 feet respectively. Furthermore, the basal sections were of Early Middle Miocene age due to the FDO: *Eponides eshira* / LDO: *Orbulina universa* at 11070 feet and 10060 feet. Within these sections were common records of *Crassoretitrites vanraadshooveni* and *Magnastriatites howardi* recorded below the base occurrence of *Belskipollis elegans* (Evamy *et al.*, 1978, SHELL, 1998) confirming the age assignments. Furthermore, the ages of the wells BC and BD sediments ranged from 1.3 Ma to 5.8 Ma which aligned with the P900-P860 Niger Delta palynological Zones of Evamy *et al.* (1978). The upper sections were dated 1.3Ma based on the FDO: *Globorotalia tosaensis* picked at 2070 feet in both wells, while the 5.0Ma were marked at 8570 and 8880 feet respectively defined by the FDO: *Cyclammina minima*.

RESULTS

The Well BA Dinoflagellate cysts record

Moderate records of dinoflagellate cysts characterized the well BA (Table 1). Well BA yielded 483 dinoflagellate cysts made up of 34 genera and 55 species with 64 indeterminable dinocysts. These occurred in association with 58 marine accessories (microforaminiferal wall linings, *Leiosphaeridia*, other acritarchs and *Tasmanites* spp.) These dinoflagellate cysts peaked at some horizons (3690-4500; 4770-5220; 8010-8460; and 10980-11160 feet) suggesting possible candidates for condensed sections and their associated maximum

flooding surfaces (Monteil, 1993, Vail and Wornardt, 1990). The dominant species were *Lingulodinium machaerophorum*, *Nematosphaeropsis labyrinthus*, *Polysphaeridium zoharyi*, *Operculodinium centrocarpum*, *Sumatradinium* spp., *Selenopemphix nephroides*, *Selenopemphix* spp., and *Spiniferites ramosus*. Also recorded were *Tuberculodinium vancampoeae*, *Achomosphaera ramulifera*, *Achomosphaera andalousiensis*, *Hystrichokolpoma rigaudiae*, *Lejeunecysta communis*, *L. hyalina*, *L. diversiforma*, *Batiacasphaera* spp., *Invertocysta* spp., *Thalassiphora* spp., spot records of *Homotryblum floripes*, *Homotryblum pallidum*, *Spiniferites pseudofurcatus*, *Systematophora* spp., *?Surculosphaeridium* spp., *Paleocystodinium golzowense*, *Cordosphaeridium cantherellum*, and *?Glaphyrocysta* spp., which co-occurred with common records of the acritarch *Leiosphaeridia* spp.

The Well BB Dinoflagellate cysts record

Well BB yielded a 411 dinoflagellate cysts composed of 27 genera and 52 species together with 107 marine accessories and 87 unidentifiable dinocysts. The commonest species encountered were *Nematosphaeropsis labyrinthus*, *Sumatradinium* spp., *Operculodinium centrocarpum*, *Spiniferites ramosus*, *Lingulodinium machaerophorum*, *Selenopemphix nephroides*, *Selenopemphix warriensis*, *Selenopemphix quanta*, *Hystrichokolpoma rigaudiae*, *Polysphaeridium zoharyi*, *Spiniferites membranaceus*, *S. mirabilis*, *S. pseudofurcatus*, *Homotryblum floripes*, *H. pallidum*, *H. vallum*, *Achomosphaera andalousiensis*, *Achomosphaera ramulifera*, *Achomosphaera* spp., *Impagidinium* spp., *Lejeunecysta communis*, *Brigantedinium* spp., and common records of the acritarch *Leiosphaeridia* spp., with spot records of *Ascotomocystis potane* (Table 2).

The Well BC Dinoflagellate cysts record

The recovered dinoflagellate cysts and accessories in well BC revealed a total of 1101 dinoflagellate cysts from 36 genera and 64 species with 136 marine elements (Table 3). The peaks are possible candidates for maximum flooding surfaces (Monteil, 1993, Vail and Wornardt, 1990). The dominant species were *Operculodinium centrocarpum* and *Polysphaeridium zoharyi* accounting for 11.15% and 10.14% respectively. Other common species include *Spiniferites ramosus*, *Achomosphaera ramulifera*, *Achomosphaera andalousiensis*, *Hystrichokolpoma rigaudiae*, *Spiniferites* spp. (*delicatus*, *bulloideus*, *elongatus* etc), *Achomosphaera* spp., *Selenopemphix nephroides*, *Selenopemphix* spp., and the acritarch *Leiosphaeridia* spp. Some other remarkable dinocysts events in the well BC, were the records of *Spiniferites elongatus*, *S. frigidus*, and *S. hyperacanthus*. Also noteworthy was the abundance of *Achomosphaera ramulifera* at 9500 feet (Late Miocene). The oceanic forms, *Impagidinium* spp., *Nematosphaeropsis labyrinthus*, and *N. lemniscata* all occurred in spots. Reworking is indicated by the records of *Dinogymnium euclaense*, *Odontichitina* cf. *costata*, *Muderongia* spp., and *Paleocystodinium golzowense*. The clusters of high dinocyst counts, with corresponding high diversities at 1980-2670; 4470-5190; 5550-6450; 6540-7260 and 9500-9950 feet are suggestive of condensed sections. These intervals suggest well defined periods of marine transgressions. The highest dinocysts count of 99 was recorded at 9500 feet.

The Well BD Dinoflagellate cysts record

A total of 420 dinocysts of which 41 could not be placed in genera/ species levels in addition to 71 marine elements were recorded in well BD (Table 4). The dinocysts comprise 15 genera and 32 species. The few peaks were at (2700, 3240, 3690, 4590, 5490, 5760, and 7650 feet). These are also possible candidates for maximum flooding surfaces (Monteil, 1993, Vail and Wornardt, 1990). The commonest species include *Protoperidinium* spp., *Operculodinium centrocarpum*, *Polysphaeridium zoharyi*, *Spiniferites ramosus*, and *Invertocysta* spp. Other common forms were *Selenopemphix nephroides*, *Hystrichokolpoma rigaudiae*, *Spiniferites delicatus*, *S. bulloideus*, *S. hyperacanthus*, *S. bentori*, *S. elongatus*, *Achomosphaera ramulifera*, *Achomosphaera* spp., *Selenopemphix* spp., *Brigantedinium* spp. The common records of *Leiosphaeridia* spp., is attributed to a dominantly shallow environment. The Oceanic forms, *Impagidinium* spp., *Nematosphaeropsis labyrinthus*, and *N. lemniscata* again occurred in spots here again. There were few clusters of high dinocyst counts with corresponding high diversities suggesting brief periods of marine transgressions. The major peaks were recorded at 3600, 3690 4590, 5760 and 7650 feet. The most unique condensed section occurred between 3240-3690 feet.

DISCUSSION

These results have increased the dinoflagellate records from the Gulf of Guinea and broadened our knowledge of Middle Miocene – Early Pleistocene dinoflagellate cysts biostratigraphy. Again, it highlighted the oceanic productivity within the Middle Miocene to Early Pleistocene paleoenvironments in the western Niger Delta. Comparing the Middle –Late Miocene and Early Pliocene to Early Pleistocene revealed a more saline Early Pliocene to Early Pleistocene and a colder and more humid Middle –Late Miocene. The dinoflagellate cysts abundance was higher in the younger wells especially BC, yielding 1099 dinoflagellate cysts which was almost twice the records of either well BA or BB. Though the *Selenopemphix* sp. B which Wrenn and Kokinos (1986) had earlier reported were recovered by Stein and Duffield from offshore West Africa, the species was not encountered in this present investigation, an assessment of the total assemblage revealed a close similarity between the Western Niger Delta sediments and those from the Gulf of Mexico. The record of *Selenopemphix* sp. E of Wrenn and Kokinos (1986) in well BB and *Lejeunecysta diversiforma* in well BA (Durugbo 2010), coupled with *Sumatradinium* spp., *Spiniferites mirabilis* with thick membrane similar to plate 6 # 4 of Wrenn and Kokinos (1986), and *Melitasphaeridium choanaphorum* (Plate 4 # 8) in this study suggests that the same conditions must have prevailed during sedimentation in both areas. Moreover, the records of *Lejeunecysta lata*, *L. communis*, *L. hyalina*, *Homotryblum plectilum*, *H. floripes*, *H. pallidum* in the present study are in contrast to the Gulf of Mexico samples that yielded *Homotryblum vallum*, *H. oceanicum*, *H. tenuispinosum*, *Cordosphaeridium gracile*, *C. fibrospinosum*, *Phelodinium* spp., and numerous reworked older dinoflagellate cysts such as *Oligosphaeridium pulcherrimum*, *O. complex*, *Florentinia deanei*, *F. ferox*, *Odontochitina costata*, *O. operculata*, *O. porifera*, *Chatangiella* spp., *Ceratiopsis* spp. etc. The reworked dinocysts from the western Niger delta wells BA and BB were *Walloodinium* spp., *Areoligera* spp., *Surculosphaeridium* spp., *Glaphyrocysta* spp., while spot records of *Dinogymnium euclaense*, *Muderongia* sp. and *Odontochitina* cf. *costata* were recorded in wells BC and BD. Wrenn and Kokinos (1986) had opined that glacial/interglacial cycles had controlled these pre-Miocene reworked dinocysts which were derived from terrestrial deposits transported seawards in suspension with clay and silt-sized clasts during periods of sea level low stands.

Furthermore, Oboh-Ikuenobe *et al.*, (1999) had studied Upper Oligocene-Early Miocene strata from the Côte D'Ivoire–Ghana Transform Margin. She noted the presence of such species as *Spiniferites mirabilis*, *Hystriochokolpoma* spp. (*H. cinctum*), *Nematosphaeropsis labyrinthus* and *Cordosphaeridium cantharellum*, together with common Peridiniaceans. The recovery of these species in the present study suggests similar environmental conditions which probably prevailed into the Middle Miocene around the Gulf of Guinea. They had attributed the abundances of these dinocysts together with calcareous and siliceous microfossils to organic matter distribution which, they opined, were indicative of changes in the water mass and paleoproductivity. The pollen and spores records in wells BA and BB were moderate as compared to their scanty records indicating more terrigenous input brought about by high temperatures.

The recovery of *Apteodinium* spp. in the Miocene sections of wells BA and BB (Durugbo 2010, plate 1, fig. 9) appears to concur with the reports of Mudie (1987) who documented *A. spiridoides* and *A. tectatum* from the lower Miocene of the Norwegian Sea. Going by these results from the Niger Delta, this genus possibly ranges up to the Middle Miocene.

The oceanic genus *Impagidinium* species poorly represented in the four wells from the western Niger Delta were more common in the Gulf of Mexico samples possibly because of the inferred cold climate for these sediments brought about by high rainfall (Morley 1995). This is further supported by the abundant records of the mangrove pollen species *Zonocostites ramonae* co-occurring with abundant freshwater swamp, brackish water swamp and palm species with common freshwater algae (Durugbo *et al.*, 2010). This concurs with the report of Morzadec-Kerfourn (1992) who had worked on estuarine dinoflagellate cysts in the West African Margin about this species which she opined preferred warm waters. However, the common records of *Nematosphaeropsis labyrinthus* the cold water indicators especially in wells BA and BB agrees with the inferred wet and cold climate suggested by (Durugbo *et al.*, 2010). On the other hand, *Spiniferites elongatus* were low in occurrence or absent in the wells (Wall *et al.*, 1977, Vesteegh, 1994).

The documentation of *Homotryblum floripes* (Deflandre and Cookson) Stover in these Middle –Late Miocene western Niger Delta sediments agrees with its reported occurrence in other parts of the world. Again, Haq *et al.*, (1987) had included the FADs of species such as *Homotryblum plectilum*, *Systematophora placacantha*, *Unipontidinium aquaeductum*, *Cordosphaeridium cantharellum* within the Late Early – Late Miocene some of which were recovered in the present study. Furthermore, Powell (1992) had also incorporated *Achomosphaera andalousiensis*, *Unipontidinium aquaeductum* among others in his Miocene zonation schemes. Generally, except for *Achomosphaera andalousiensis*, the other dinocysts were long ranging and unsuitable for age designation. The assemblages of wells BA and BB appear similar to dinoflagellate suites from Miocene epochs in Japan, Denmark, Germany, northwestern Europe, Canada and the Atlantic coast of North America (Lenoir and Hart, 1986).

Peridiniaceans dominated the wells BA and BB assemblages (Durugbo, 2010), while gonyaulaceans dominated the organic walled microfossils in wells BC and BD. The assemblages were dominated by *Polysphaeridium zoharyi* and *Operculodinium centrocarpum* which were concentrated at some intervals. Durugbo *et al.* (2010) had associated this dominance of the two species to lowered sea levels resulting from glacial maxima. This concurs with the reports of Schepper (2009) who having worked with Pliocene-Pleistocene sediments from DSDP Hole 610A Eastern North Atlantic reported the dominance of gonyaulacoids, while the abundance of peridinoids was low. Possibly the same conditions prevailed from the North down to the South Atlantic during the Early Pliocene to Early Pleistocene. The paucity of peridiniaceans in the wells BC and BD could have arisen from the high salinity levels associated with lowered sea levels (Udeze and Oboh-Ikuenobe, 2005). This lowered sea level was further corroborated by the common records of the acritarch *Leiosphaeridia* spp. which Dorning, (1980) and Guerra, (1996) had associated with shallow waters.

This study highlights the first documented occurrence of *Achomosphaera andalousiensis* in the Niger Delta. The LDO of this species in the palynological zone P780 in the wells BA and BB close to the 11.6Ma, is noteworthy. Wrenn and Kokinos (1986) had also reported its presence in the Gulf of Mexico Neogene. Head and Wrenn (1992) had attributed a preference for warmer waters to *A. andalousiensis* based on these reports of Wrenn and Kokinos (1986) and its rarity within this period in the Labrador sea (Head *et al.*, 1989). The common records of *Achomosphaera andalousiensis* appears to concur with the earlier suggestions of Head *et al.* (1989a) that it prefers relatively warm waters based on the reports of de Vernal and Mudie (1989a) who associated it with warm interglacial isotopic intervals in the Labrador Sea though Harland (1988) had linked it to cold glacial stages in the offshore. It was more common in the wells BC and BD and had spot records in the Middle-Late Miocene sections of wells BA and BB. Mudie (1987) had reported its abundance in the relatively warm latest Miocene and earliest Pliocene sediments in the North Atlantic which agrees with the results from the Western Niger Delta. Again, the Early Pliocene – Early Pleistocene sections of wells BC and BD were characterized by common records of *Spiniferites* spp. (*S. bentorii*, *S. ramosus*, *S. elongatus*, *S. mirabilis*, *S. hyperacanthus*), *Operculodinium* spp., *Achomosphaera andalousiensis*, *A. ramulifera*, *Tuberculodinium vancampoe*, *Brigantidium* spp., *Bitectatodinium* spp., *Tectatodinium pellitum*, *Hystrichokolpoma rigaudiae*, *Impagidinium* spp., *Batiacasphaera* spp., and *Invertocysta lacrymosa*, which appeared among those listed by Schepper and Head (2009) in their review of Plio-Pleistocene assemblages from different parts of the world. The other species not encountered in the Western Niger delta could have arisen from environmental differences brought about by the review of sediments from varying latitudes.

Generally, the Miocene sections of the Western Niger Delta assemblage appear similar to that reported for the Lower Tagus Basin in Portugal by Castro *et al.* (2008). Although in the older Early Miocene (Burdigalian) sections they recovered *Polysphaeridium zoharyi*, *Cleistosphaeridium placacanthum*, and *Cribroperidinium tenuitabulatum*. In the Langhian they reported abundant records of *C. tenuitabulatum* with common *Polysphaeridium zoharyi* and *Operculodinium israelianum*, while in the Serravallian, they encountered frequent *Spiniferites* spp., *Spiniferites/Achomosphaera*, *O. israelianum*, *Hystrichosphaeropsis obscura*, and *Lingulodinium machaerophorum*. Furthermore, in the Tortonian, *Spiniferites/Achomosphaera*, *S. pseudofurcatus*, *L. machaerophorum* *Homotryblium* spp. were common. These all occurred with common peridinoids (*Selenopemphix nephroides*, *S. brevispinosa* and *Lejeunecysta* sp.) with the acritarchs *Cyclopsiella granosa* and *Quadrina* sp. All these species especially from the Langhian to the Tortonian were similar to those recovered in this study, especially in wells BA and BB except for the acritarchs *Cyclopsiella granosa* and *Quadrina* sp.

CONCLUSIONS

The dinoflagellate cysts recovered from this study offers the promise of erecting a dinocyst biozation for the Western Niger Delta after further studies. *Achomosphaera andalousiensis* documented for the first time in the Niger Delta whose LDO occurred close to the 11.6Ma in wells BA and well BB, appeared a notable event that needs further confirmation together with the occurrences of the *Homotryblium* species in the Middle Miocene of the Niger Delta. There is therefore an urgent need for more intensive studies which together with the conventional pollen and spores would be useful where the other microfossil groups are scarce.

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LIST OF FIGURES, PLATES AND TABLES

Fig. 1. Map of the Niger Delta showing the location of studied wells after Doust and Omatsola, 1990.

Plates 1-6. Photomicrography of the dinoflagellate cysts recovered in the studied wells with the Authority, well sample and England Finder coordinates of the dinoflagellate cysts.

All magnifications X400, Except Plate 2 # 10 = X1000

TABLES 1 - 4

Table 1: Distribution of dinoflagellate cysts and marine elemnts by sample depths in Well BA

Table 2: Distribution of dinoflagellate cysts and marine elemnts by sample depths in Well BB

Table 3: Distribution of dinoflagellate cysts and marine elemnts by sample depths in Well BC

Table 4: Distribution of dinoflagellate cysts and marine elemnts by sample depths in Well BD

PLATE 1

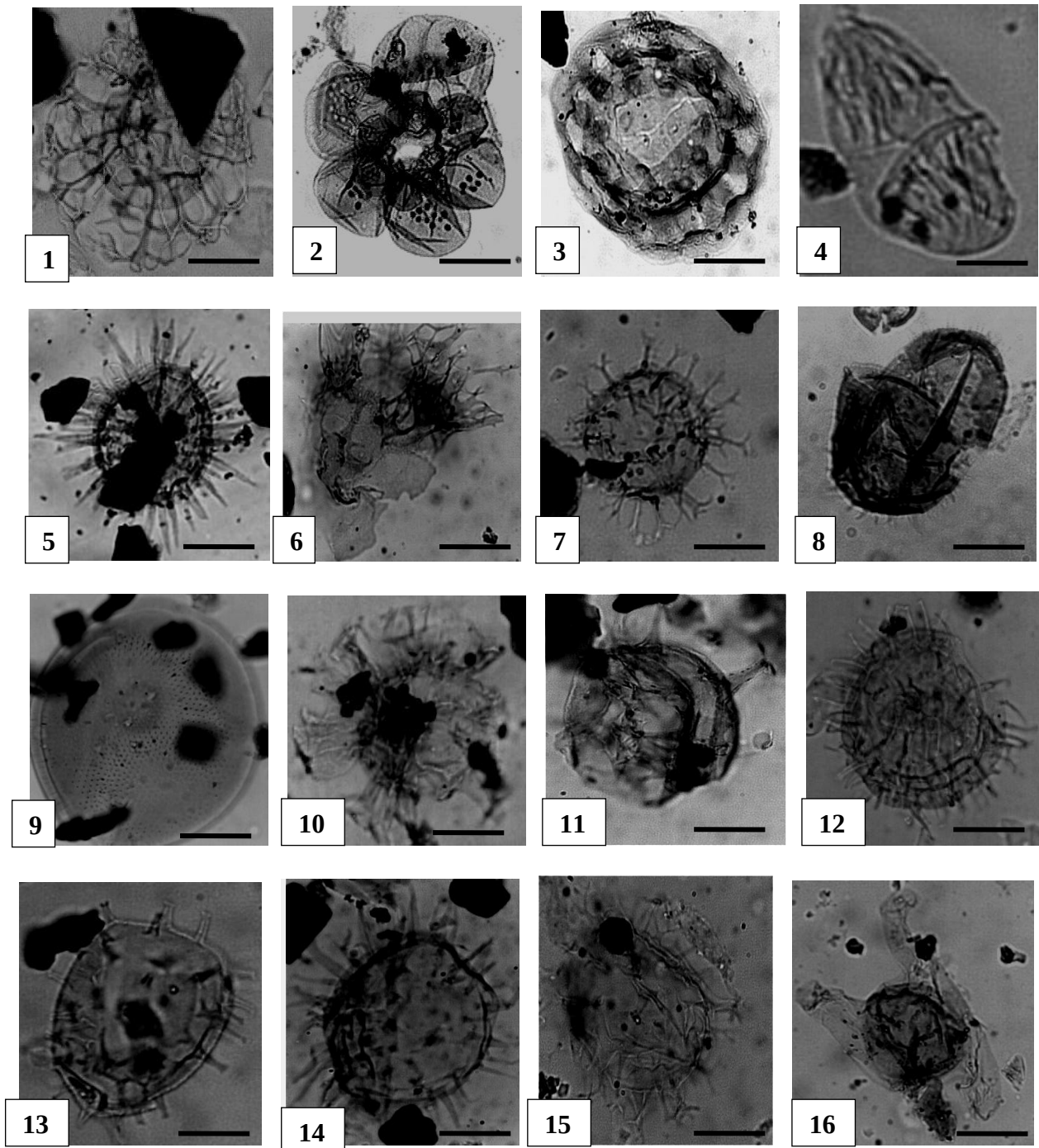


PLATE 2

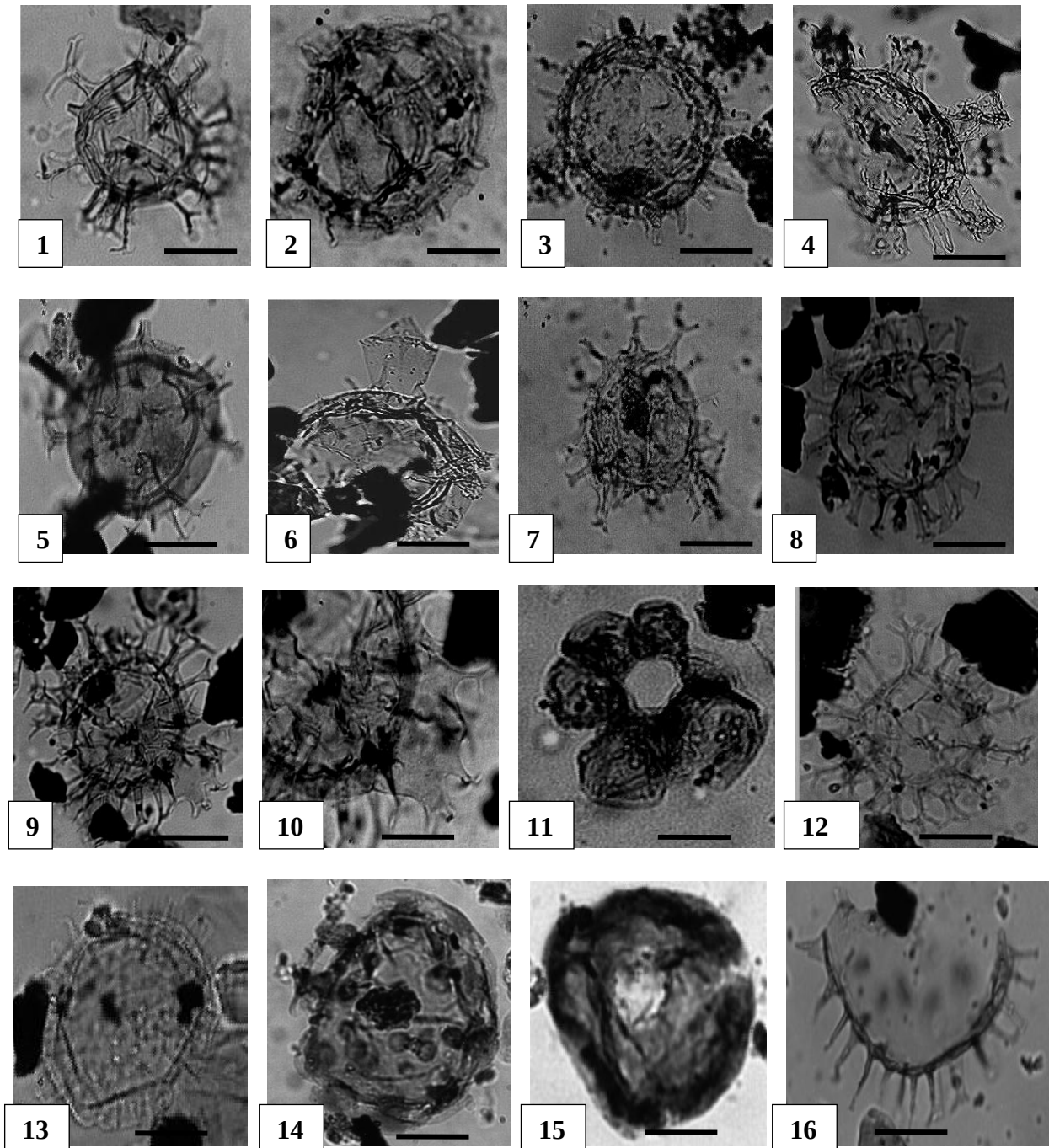


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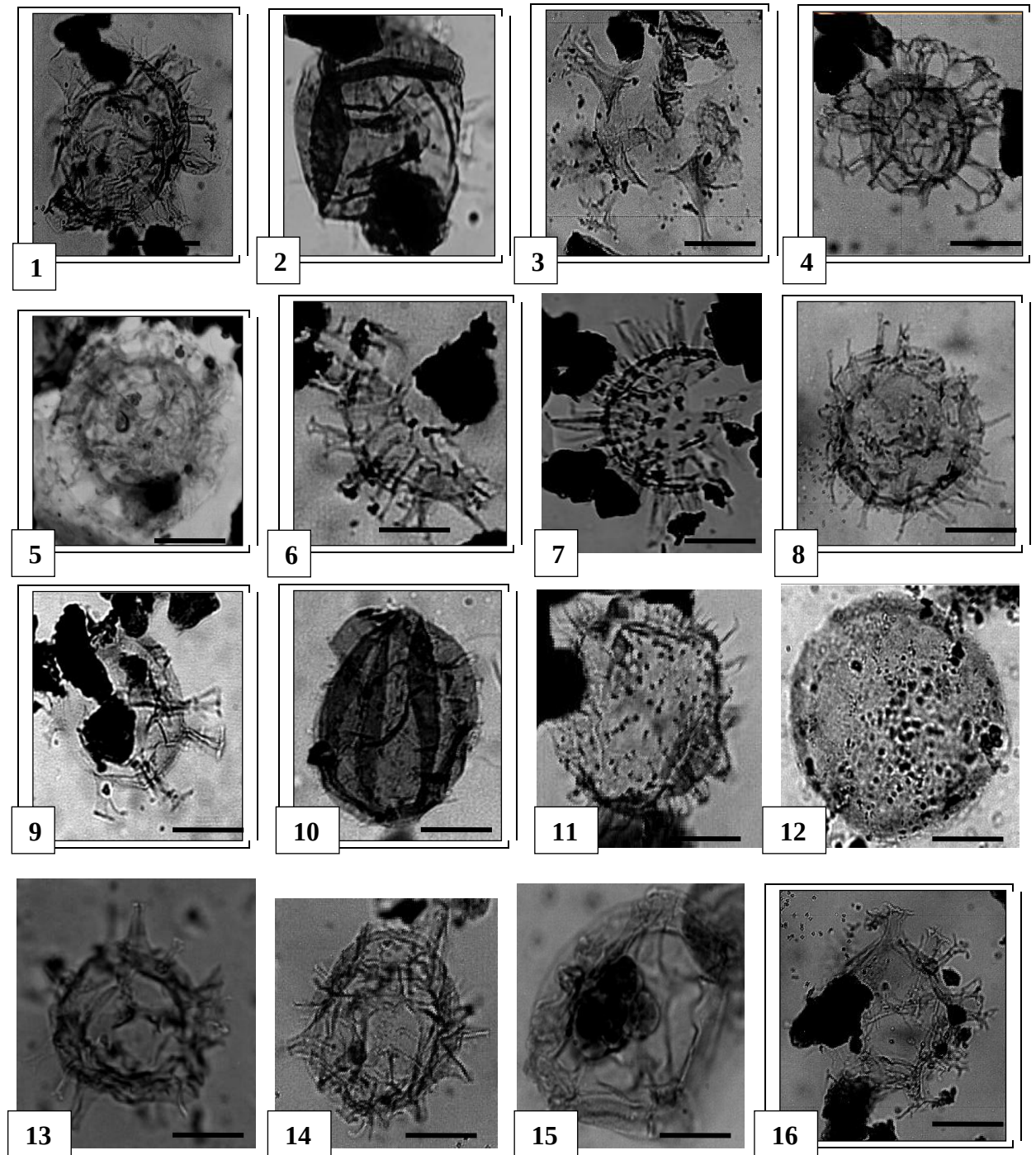


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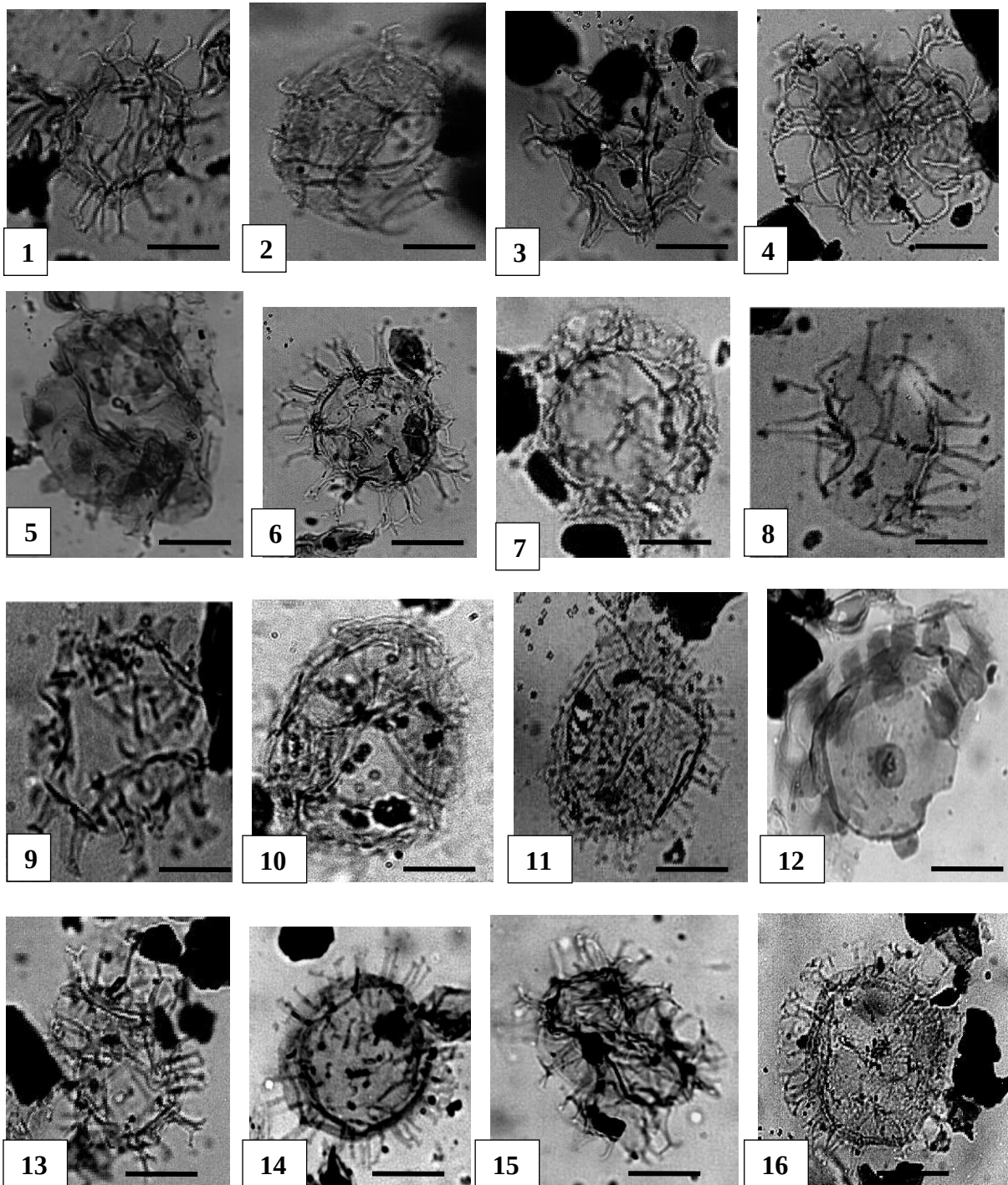


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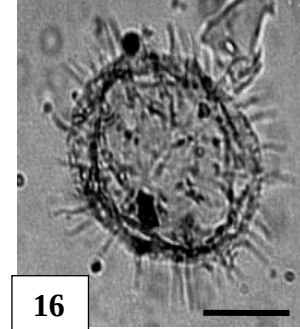
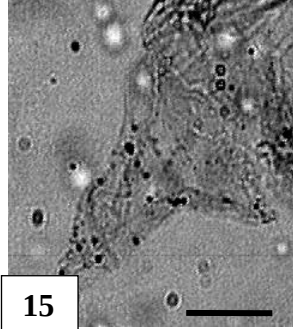
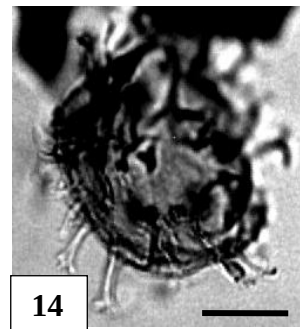
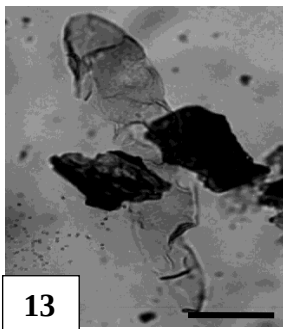
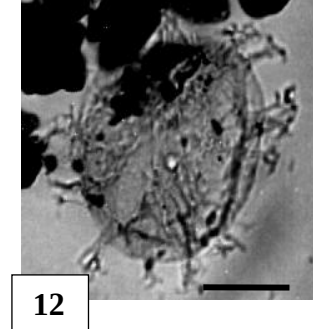
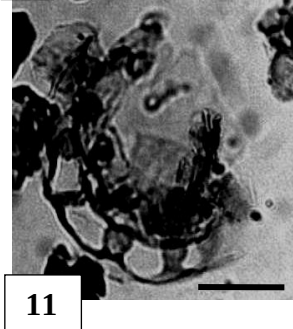
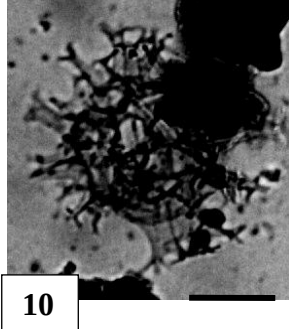
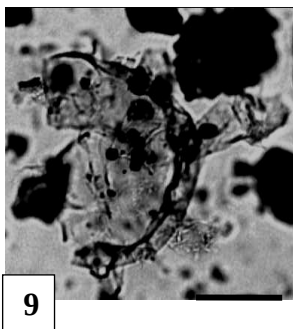
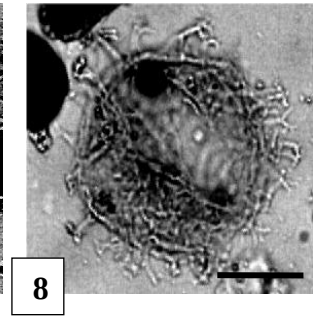
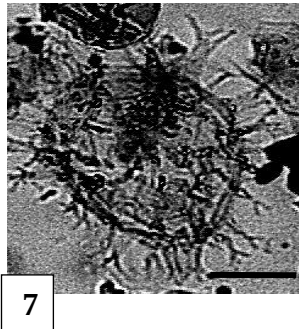
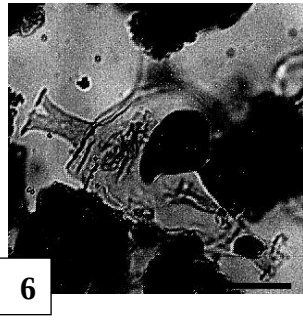
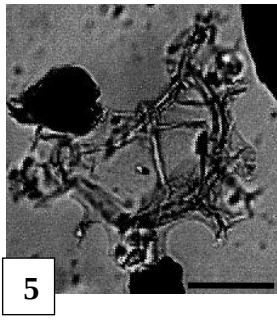
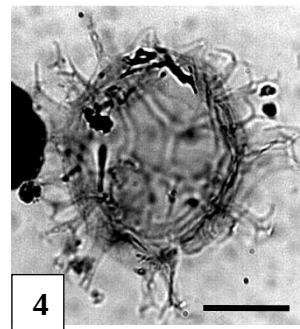
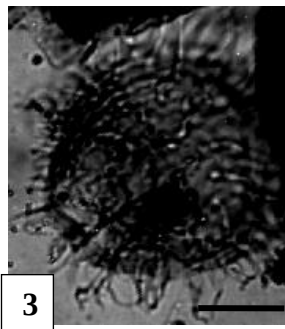
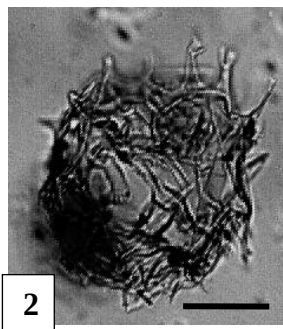
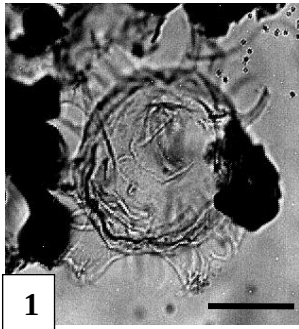
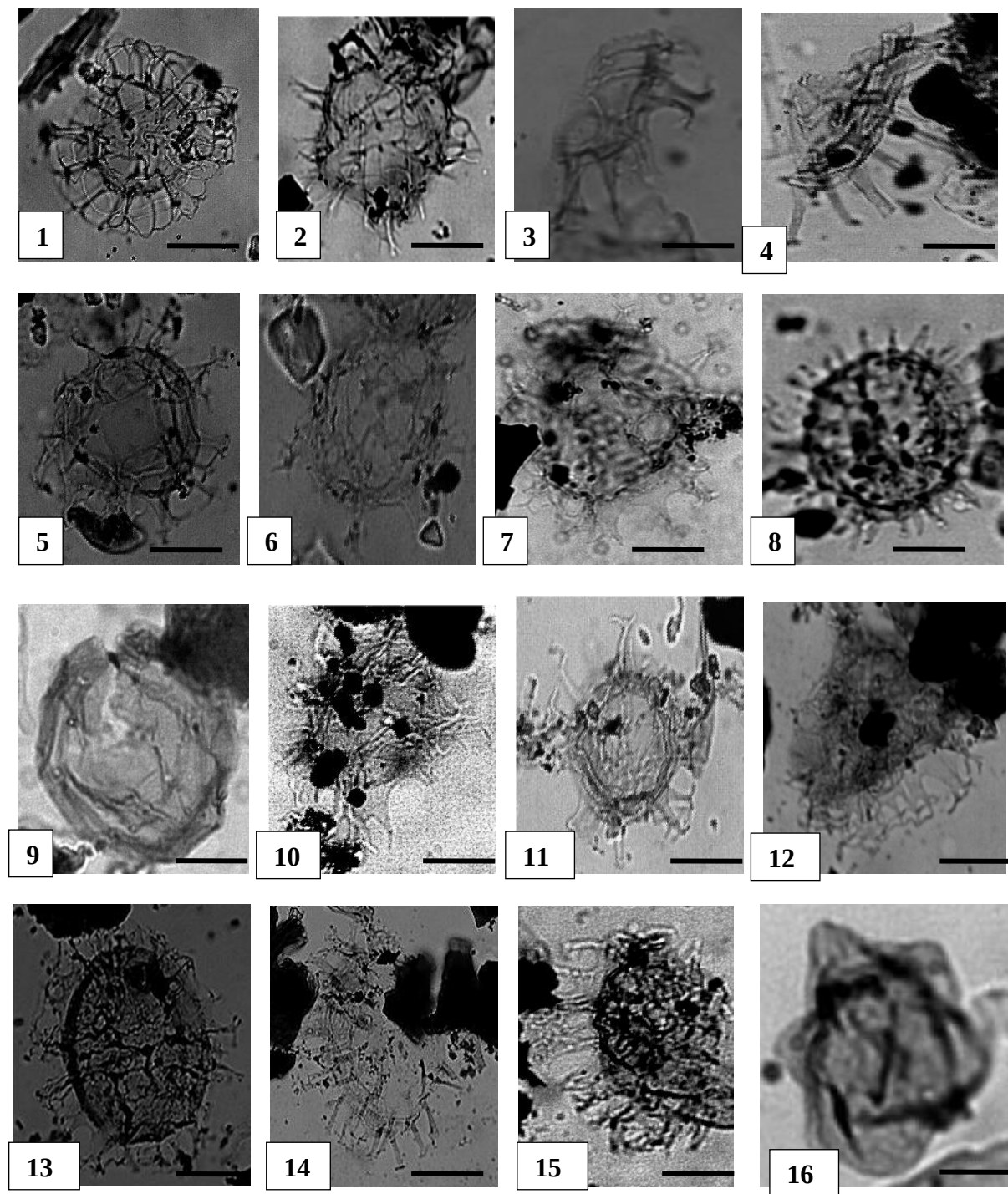


PLATE 6



10µm

Names of the dinoflagellate cysts recovered in the wells showing well, sample depth and England Finder location

PLATE 1

1. *Nematosphaeropsis labyrinthus* (Ostenfeld 1903); Reid 1974; Well BB(5050-5140) Q22/3
2. *Microforaminiferal Wall Linings* Well BB (5500-5590)V38/2
3. *Tuberculodinium vancampoe* (Rossignol,1964);Well BC(5910-6020ft) D32/4
4. *Dinogymnium euclaense* (Evitt, Clark and Verdier 1967); Well BC (6000-6090ft) G29/0
5. *Lingulodinium machaerophorum* (Deflandre and Cookson 1955); Well BA(10980-11070ft) G28/4
6. *Systematophora cf. ancryea* (Cookson and Eisenack 1965); Well BC(3660-3750ft) T33/2
7. *Spiniferites ramosus*(Deflandre and Cookson,1955)Cookson and Eisenack 1974;Well BC (4650-4740ft) T43/4
8. *Sumatradinium* sp.Well BA(4050-4140ft) K19/4
9. *Tasmanites* sp. Well BB (4960-5050ft) N31/2
10. *Cordosphaeridium cantharellum*(Brosius,1963); Well BB(4960-5050ft) R46/0
11. *Achomosphaera* sp. Well BC (9860-9950ft) P45/2
12. *Operculodinium centropum* (Deflandre and Cookson,1955) Wall 1967;Well BB(4960-5050ft) D43/2
13. *Polysphaeridium zoharyi* (Rossignol 1964); Well BC (1980-2040ft) O34/4
14. *Lingulodinium machaerophorum* (Deflandre and Cookson 1955); Well BC (6090-6180) F38/4
15. *Achomosphaera andalousiensis*(Jan du Chêne, 1977) emend Jan du Chêne and Londeix,1988; Well BC(4650-4740ft) K33/3
16. *Muderongia* sp. Well BC (8160-8250ft) T37/4

PLATE 2

1. *Achomosphaera ramulifera* (Deflandre, 1937) Evitt 1963; Well BB (4690-4780ft) C35/4
2. *Impagidinium* sp. (Stover and Evitt, 1978, Harland,1983);Well BC(6180-6270ft) O42/1
3. *Lingulodinium cf. sadoense* (Deflandre and Cookson 1955): Well BD(7650-7740FT)V34/4
4. *Hystrichokolpoma rigaudiae* (Deflandre and Cookson 1955); Well BA(9460-9550ft)G33/1
5. *Achomosphaera ramulifera* (Deflandre 1937) Evitt 1963;Well BD(3780-3870ft) P27/3
6. *Hystrichokolpoma cf. cinctum* (Deflandre and Cookson, 1955); Well BA(6750-6840ft)C34/1
7. *Spiniferites hyperacanthus* (Deflandre and Cookson,1955) Cookson and Eisenack 1974; Well BD(5400-5490ft)C31/4
8. *Homotryblium pallidum* (Davey and Williams 1955); Well BA(10530-10620ft) Q43/1
9. *Spiniferites mirabilis* (Rossignol 1963) Sarjeant 1970; Well BA (3960- 4050ft) J38/2
10. *Spiniferites mirabilis* showing the extension
11. *Microforaminiferal Wall Linings* Well BB (5500-5590ft) H24/1
12. *Achomosphaera andalousiensis* (Jan du Chêne, 1977) emend Jan du Chêne and Londeix,1988; Well BA (3880-3970ft) F29/1
13. *Operculodinium israelianum*(Rossignol,1962) Wall 1967; Well BC(1980-2040) J41/0
14. *Tuberculodinium vancampoe* (Rossignol,1964); Well BC(1980-2040ft) G32/1
15. *Brigantodinium cf. cariacense* (Wall) Reid 1977; well BC (5100-5190 ft) K31/4
16. *Polysphaeridium zoharyi*(Rossignol 1964); well BD (8370-8460 ft) C36/4

PLATE 3

1. *Hystrichokolpoma rigaudiae* (Deflandre and Cookson, 1955); Well BA(9630-9720ft) E38/2
2. *Sumatradinium* spp. Well BA(7390-7480ft) N30/2
3. *Homotryblium cf. vallum*(Drugg and Loeblich,Jr. 1967) Well BA(4590-4680) M44/3
4. *Nematosphaeropsis labyrinthus* (Ostenfeld 1903); Reid 1974; Well BA(7830-7920 ft) E41/3
5. *Cf.Unipontidinium aquaeductum* Well BA(11160 -11250ft) P23/2
6. *Polysphaeridium zoharyi* (Rossignol 1964) Well BB(4960-5050ft) D43/2
7. *Lingulodinium machaerophorum*(Deflandre and Cookson 1955)Well BA(10440-10530ft)N29/1
8. *Operculodinium centropum* (Deflandre and Cookson,1955) Wall 1967;Well BA(10800-10890 ft) Y32/2
9. *Homotryblium plectilum*((Drugg and Loeblich,Jr. 1967) Well BA(7830-7920)Q48/1
10. *Sumatradinium* sp. Well BB(4690-4780ft)D40/2
11. *Operculodinium israelianum* (Rossignol,1962) Wall 1967;Well BD(3690-3780 ft) R30/0
12. *Tectatodinium pellitum*(Wall 1967); Well BC(5460- 5550ft)O19/1
13. *Spiniferites bulloideus* (Deflandre & Cookson 1955) Sarjeant 1970;Well BD(5400-5490) C19/4
14. *Spiniferites bulloideus* (Deflandre & Cookson 1955) Sarjeant 1970; Well BD(4860-4950) J37/2

15. *Impagidinium* sp. (Stover & Evitt, 1978, Harland,1983); well BC (5640-5730ft) G27/2
16. *Spiniferites* sp. Well BA (11770- 11790 ft) R17/4

PLATE 4

- 1.*Spiniferites hyperacanthus* (Deflandre & Cookson,1955) Cookson & Eisenack 1974;
Well BD(4590-4680) N25/4
- 2.*Impagidinium* sp. (Stover & Evitt, 1978, Harland,1983); Well BD(4590-4680) L39/4
- 3.*Spiniferites bentorii* (Rossignol 1964) Wall & Dale 1970; Well BD(5170-5260) M28/2
- 4.*Nematosphaeropsis labyrinthus* (Ostenfeld 1903, Reid 1974) Well BD(5760-5850) O31/3
- 5.*Tuberculodinium vancampoe*(Rossignol,1964); well BD(4680-4770) M44/1
- 6.*Spiniferites hyperacanthus*(Deflandre & Cookson,1955) Cookson & Eisenack 1974);
Well BD (4770-4860) W22/3
- 7.*Impagidinium* sp. (Stover & Evitt, 1978, Harland,1983); Well BD(7830-7920) P22/3
- 8.*Melitasphaeridium choanophorum* (Deflandre & Cookson,1955) Harland and Hill, 1979;
Well BB(4960-5050) R46/0
- 9.*Spiniferites cf. rubinus* Well BC(3970-4060) K33/1
10. *Impagidinium* sp. (Stover & Evitt, 1978, Harland,1983); Well
11. *Operculodinium centrocarpum*(Deflandre & Cookson,1955) Wall 1967; Well BD(3780-3870) S38/3
12. *Tuberculodinium vancampoe*(Rossignol 1964); Well BC(5730-5820) U32/2
13. *Spiniferites delicatus*(Reid 1974); Well BD(3780-3870) T39/1
14. *Polysphaeridium zoharyi*(Rossignol 1964); well BC(5010-5100) S20/4
15. *Spiniferites hyperacanthus* (Deflandre & Cookson,1955) Cookson & Eisenack 1974;
Well BC (5100-5190) K31/4
16. *Systematophora* sp. Well BA(7920-8010ft) R50/4

PLATE 5

1. *Hystriocholpoma rigaudiae* (Deflandre and Cookson, 1955) Meren-66(9630-9720) E38/2
2. *Impagidinium* sp. (Stover & Evitt, 1978, Harland,1983);Well BD(5670-5760ft)T45/3
3. *Operculodinium centrocarpum* (Deflandre & Cookson,1955) Wall 1967; well BA
(10980-11070 ft)L38/4
4. *Achomphaera ramulifera* (Deflandre 1937) Evitt 1963; Well BC(4650-4740ft)T19/1
5. *Spiniferites bentorii* (Rossignol 1964) Wall & Dale 1970;well BD(7650-7740) P30/1
6. *Homotryblium cf. plectilum*(Drugg and Loeblich,Jr. 1967) Well BA(4590-4680) M44/3
7. *Spiniferites ramosus* (Ehrenberg,1838) Mantell, 1854);well BC(6630-6720)G33/3
8. *Spiniferites cf. tripodes* (Morzadec-Kerfourn 1966) Lentin & Williams 1973;
Well BA (11610-11700) F24/3
9. *Hystriocholpoma rigaudiae* (Deflandre and Cookson, 1955); Well BA(11700-11770) P39/1
10. *Spiniferites cf. pseudofurcatus* (Klumpp1953) Sarjeant 1970; Well BA(11520-11610 ft) V35/1
11. *Tuberculodinium vancampoe*(Rossignol,1964); Well BA(4050-4140ft) L21/2
12. *Achomphaera* sp. well BA (10440-10530 ft) C36/4
13. *?Wallodinium* sp. Well BA(8100-8190) W41/1
14. *Spiniferites cf bentorii* Well BC(10400-10490ft) M28/4
15. *Odontochitina cf. costata* Well BC(3160-3250ft) K33/1
16. *Homotryblium cf. vallum*(Drugg and Loeblich,Jr. 1967) Well BA(4590-4680ft) M44/3

PLATE 6

1. *Nematosphaeropsis lemniscata*(Bujak 1984 emend Wrenn 1988); Well BD(3780-3870ft) R19/2
2. *Cf. Operculodinium cenrocarpum* (Deflandre & Cookson,1955) Wall 1967;Well BC
(1980-2040ft) N26/1
3. *Spiniferites* sp. Well BC(1980-2040ft) L21/2
4. *Polysphaeridium zoharyi*(Rossignol 1964); Well BD (8370-8460 ft) C36/4
5. *Spiniferites bentori* (Deflandre & Cookson,1955) Wall 1967; Well BD(3290-3380ft) N47/2
6. *Spiniferites delicatus* (Ehrenberg,1838) Mantell 1854);Well BD (3780-3870ft) T39/1
7. *Spiniferites mirabilis* (Rossignol 1963) Sarjeant 1970; Well BC(5640-5730ft) K37/4
8. *Lingulodinium machaerophorum*(Deflandre and Cookson 1955);Well BC (7080-7170) U18/3
9. *Leiosphaeridia* sp. Well BC(6000-6090ft) H31/4

10. *Spiniferites membranaceus* (Rossignol 1963) Sarjeant 1970; Well BC(6090-6180ft) L37/4
11. *Spiniferites ramosus* (Ehrenberg, 1838) Mantell, 1854; Well BD(4140-4200 ft) X39/2
12. ?*Systematophora* sp. Well BA(11340-11430) 024/1
13. ?*Glaphyrocysta* sp. Well BA(11070-11160) T36/3
14. *Polysphaeridium zoharyi* (Rossignol 1964);
15. ?*Systematophora* sp. Well BA(10980-11070ft) F18/2
16. *Protoperidinium* sp. well BA(6630-6720) Y43/3

All magnifications X400, Except Plate 2 # 10 = X1000