Palynostratigraphy, palynofacies and thermal maturation of the Nsukka Formation from an excavation site in Okigwe, southeastern Nigeria

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There is a dire need to assess the petroleum-generating potential of the Nigerian inland basins. The Nigerian Federal Government has in the last few years demarcated the inland basins, of which little is known palynologically, for oil and gas exploration activities. An input from Nigeria concerning events of the Cretaceous–Paleogene boundary would broaden our knowledge of the global event. This palynological study of the Nsukka Formation from an excavation site in Okigwe, southeastern Nigeria, revealed abundant records of pollen, spores and dinoflagellate cysts. Palm pollen *Longapertites marginatus*, *L. vaneendenburgi*, *L. microfoveolatus*, *Spinizonocolpites echinatus*, *S. baculatus* and *Foveomonocolpites bauchiensis* dominated the microfloral assemblage with common dinoflagellate cysts, especially *Ifecysta* spp., *Cordosphaeridium* spp., *Fibrocysta* spp., *Senegalinium* spp., *Cerodinium* spp., *Phelodinium* spp., *Spiniferites* spp. and *Hafniasphaera* spp., indicating alternating shallow to marginal marine depositional environments. The already published ranges of the palynostratigraphically important taxa such as *Buttinia andreevi*, *Monocolpopollenites sphaeroidites*, *Rugulatisporites caperatus*, *Zlivisporis blanensis*, *Cingulatisporites ornatus*, and the earliest Danian dinoflagellate cyst markers *Damassadinium californicum*, *Carpatella cornuta*, *Hafniasphaera septate* and *Senegalinium bicavatum*, enabled the delineation of the age as Late Maastrichtian–Middle Paleocene. The studied Nsukka sequences consist of alternating successions of fine-grained sandstones, well-bedded dark and sandy shales. The samples were dominated by terrestrial organic components, especially structured phytoclasts, black debris and unstructured phytoclasts/degraded wood elements, indicating deposition in predominantly nearshore environments, coupled with the dominance of peridinoids over gonyaulacoids. However, the basal samples were characterized by common amorphous organic matter co-occurring with dinoflagellate cysts, suggesting brief periods of marine transgressions. Using *Deltoidospora adriennis* as an index, the spore colouration index (SCI) ranged from 4 (golden yellow) to 4.5 (deep yellow), which correlates to vitrinite reflectance values of 0.4–<0.5, indicating that the sediments were immature for oil and gas generation.

Keywords: Nsukka Formation, Okigwe, palynomorphs, spore colouration, phytoclasts.

INTRODUCTION

Moore *et al.* (1991) defined palynology as the study of pollen grains produced by seed plants (angiosperms and gymnosperms) and spores (produced by pteridophytes, bryophytes, algae and fungi). Previously, however, Hyde & Williams (1944) had provided a broad definition to encompass all entities that survived the maceration process by such corrosive chemicals as HCl, HF, HNO_3, $NHOH_3$, etc. These entities Tschudy (1961) popularized as 'palynomorphs'. Agashe & Caulton (2009) gave credence to this and further posited that according to geologists palynology entails the study of such microfossils as pollen, spores, dermal appendages, cuticles, vascular elements, diatoms, desmids of plant origin, foraminifera, ostracods, microforaminifera, acritarchs, dinoflagellate cysts and hystrochospherids. Moore *et al.* (1991) enumerated the applications of palynology in different aspects of human endeavor, such as taxonomy, whereby taxonomists infer evolutionary relationships between extant plant populations and their fossil relatives. Under genetic and evolutionary studies, they reported that palynological studies could refine the taxonomic data by adding a time dimension to it. Melissopalynology is another application of palynology specifically to do with bees, honey and pollen. Forensic palynology is defined as the science of applying modern pollen and spores and other palynomorphs to help solve legal or criminal problems (Bryant & Mildenhall 1990). Furthermore, palynology has been useful in climate change studies. Moore *et al.* (1991) cited Webb (1980) who reported the possibility of erecting mathematical models between fossil pollen data and climatic variables from which past isotherms could be reconstructed. Durugbo *et al.* (2010) used the abundance of Graminae and savanna pollen over mangrove and other wet climate indicators to infer more pronounced dry periods in the Western Niger Delta. Again, combining the pollen data with the occurrence of two saline water tolerant dinoflagellate cysts, *Operculodinium centrocarpum* and *Polysphaeridium zoharyi*, they documented periods of sea level falls (glacial maxima) around 2.0 Ma and 2.7 Ma.

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Several other workers have also used palynomorphs as proxies in understanding the mechanisms of climate change (Morzadec-Kerfourn 1988, 1992; Poumot 1989; Morley 1995; Leroy & Dupont 1997, 2003; Pocknall *et al*. 2001; Molnar & Cane 2004; Sowunmi 2004). Moore *et al.* (1991) mentioned the application of palynological data in the study of human impact on vegetation, tracing vegetation history and correlating deposits and assigning tentative ages/dates and there are numerous other examples.

Palynology is a basic tool for developing stratigraphic and palaeoenvironmental frameworks for rock units. Particulate organic matter when analysed contributes to understanding ore genesis and diagenesis. It also helps in improving engineering practices and recovery of ore. Palynology is of greatest importance in biostratigraphy because pollen, spores, and other palynomorphs are abundant, durable, recognizable and readily available in sediments. Palynofloras from different regions can be correlated and biostratigraphic schemes put in place. The rock samples from different depths are processed in the laboratory, analysed under the microscope and the occurrences of the different palynomorphs recorded. The data so generated is used in determining the age of the rocks and in the interpretation of the palaeoenvironments in which the sediments were deposited.

In this study palynology was utilized for dating the Nsukka Formation from an excavation site in Okigwe, southeastern Nigeria, and to infer the palaeoenvironments based on the recovered palynomorphs and palynofacies. This paper is a further attempt to update our knowledge on the palynology of southeastern Nigeria and document the events of the K/T Boundary from Nigeria and to evaluate the thermal maturity of the Nsukka Formation around Okigwe as Nigeria desires to explore for hydrocarbons in her inland Basins.

Description of study site

The Anambra Basin, southeastern Nigeria, lies between longitudes 7°00′E and 7°31′E and latitudes 6°14′N and 6°34′N (Fig. 1). The excavation site is located on German Hill, Okigwe, southeastern Nigeria, with bearings N 05° 49′53.6 ″ and E 007°21′11.2″ taken with a Garmin 72 GPS (Fig. 2). The section was freshly excavated for the construction of a petrol station at the time of sample collection, between the 14 and 21 July 2008.

Stratigraphy of the study area

The southern Nigeria sedimentary basin, composed of the Southern Benue Trough, the Niger Delta, the Benin Embayment, the Anambra Basin, the Abakiliki Fold Belt, the Afikpo Syncline and the Calabar Flank, arose from the break-up of the South American and African continents in the Early Cretaceous (Burke 1996; Nwajide 1990; Murat 1972). Three sedimentary phases spanning Aptian-Albian to Plio-Pleistocene have characterized the region. These phases were: (a) the Abakiliki-Benue Phase of Aptian–Santonian age during which the Asu River Group, the Ezeaku and Awgu Formations together with the Benue Valley and Calabar Flank, were deposited. The second sedimentary phase which arose from the Santonian folding and uplift of the Abakiliki Platform and the dislocation of the depocenter into the Anambra Basin and Afikpo region, gave rise to the Nkporo Group, Mamu Formation, Ajali Sandstone, Nsukka Formation, Imo Formation and the Ameki Group, with ages ranging from Campanian to Eocene were deposited (Table 1). Consequently, the third

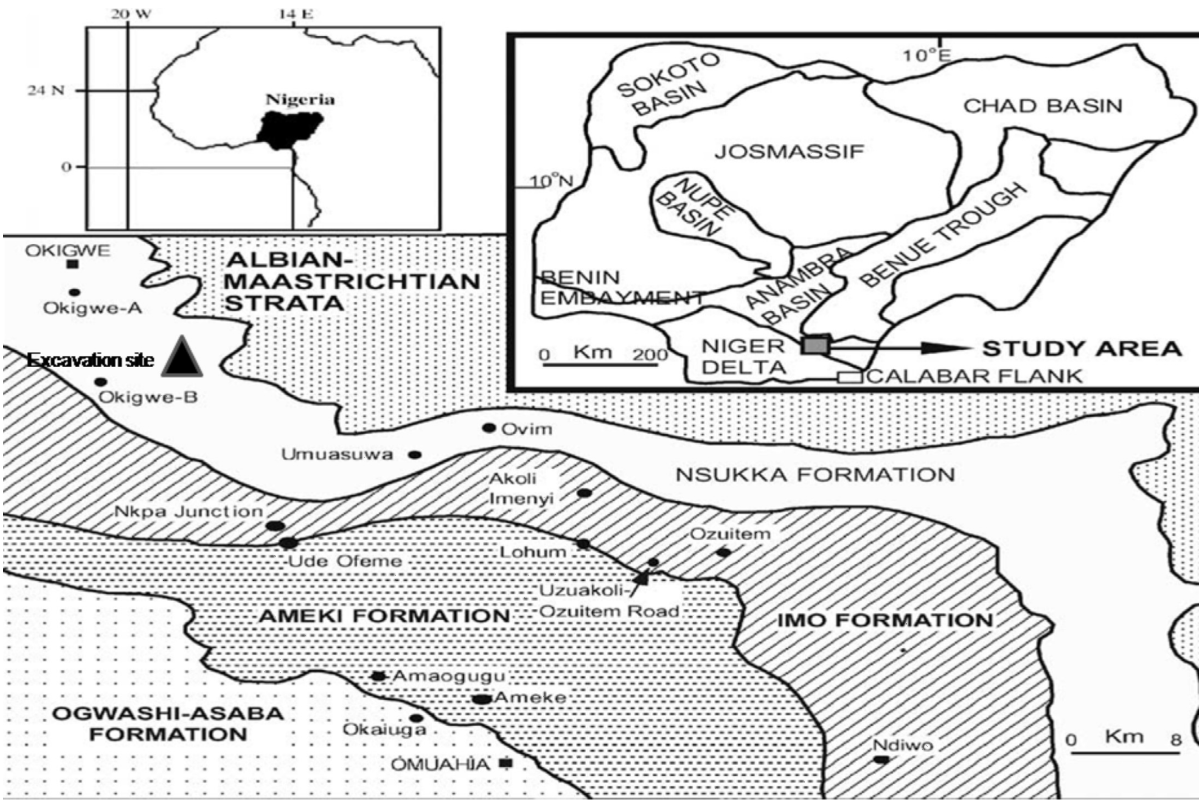

Figure 1. Map of the Anambra Basin showing the studied area. Modified after Umeji & Edet (2008). Large triangle marks excavation site.

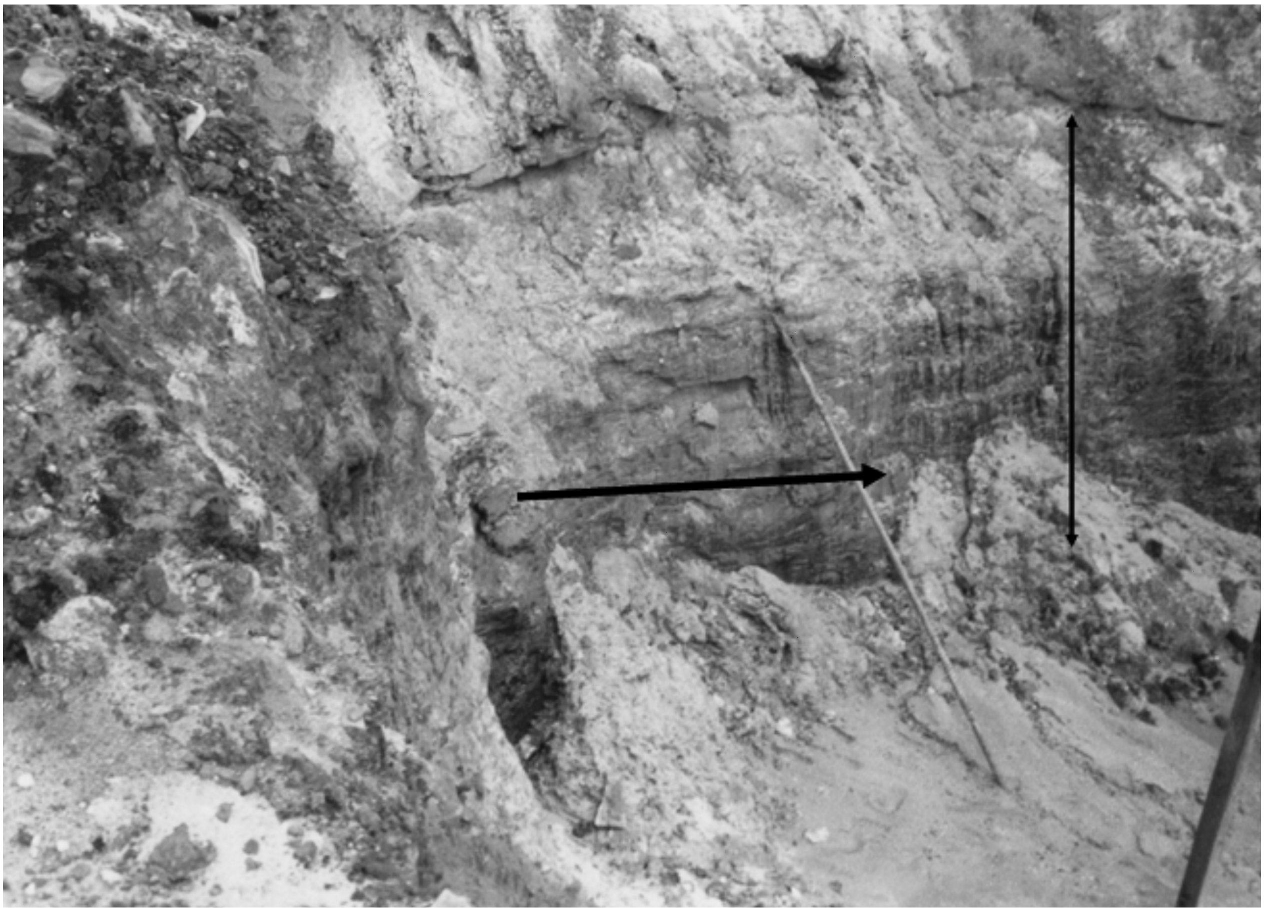

Figure 2. The excavation site on German Hill, Okigwe, southeastern Nigeria, with arrows showing the compactly bedded shales.

sedimentary phase which commenced in the Late Eocene led to the formation of the popular petroliferous Niger Delta (Obi *et al.* 2001). The Nsukka Formation which is part of the Anambra Basin and which conformably overlies the Ajali Sandstone, begins with coarse- to medium-grained sandstones and passes upward into well-bedded blue clays, fine-grained sandstones, and carbonaceous shales with thin bands of limestone (Obi *et al.* 2001; Reyment 1965). Obi *et al.* (2001) used sedimentological evidence to suggest that the Nsukka Formation represented a phase of fluvio-deltaic sedimentation that began close to the end of the Maastrichtian and continued during the Paleocene. According to Adegoke *et al*. (1980), Arua (1980) and Reyment (1965), a Paleocene age is inferred for the basal limestone unit based on ostracod and foraminiferal biostratigraphy, together with the

Table 1. Table of Formations, Niger Delta area (after Short & Stauble 1967).

SUBSURFACE			SURFACE OUTCROPS		
Youngest known age		Oldest known age	Youngest known age		Oldest known age
Recent	Benin Formation (Afam Clay Member)	Oligocene	Plio/Pleistocene	Benin Formation	Miocene
Recent	Agbada Formation	Eocene	Miocene	Ogwashi-Asaba Formation	Oligocene
			Eocene	Ameki Formation	Eocene
Recent	Akata Formation	Eocene	L. Eocene	Imo Shale Formation	Paleocene
			Paleocene	Nsukka Formation	Maastrichtian
			Maastrichtian	Ajali Formation	Maastrichtian
			Campanian		
			Campanian/ Maastrichtian	Mamu Formation Nkporo Shale	Campanian Santonian
EQUIVALENTS NOT KNOWN			Coniacian/Santonian	Awgu Shale	Turonian
			Turonian	Eze Aku Shale	Turonian
			Albian	Asu River Group	Albian

recovered microfauna. Lithology and trace fossils of the basal sandstone unit reflect foreshore and shoreface environments. According to Nfor (2003) the Anambra Basin is dominantly filled with clastic sediments constituting several distinct lithostratigraphic units ranging from Upper Campanian to Recent in age. The lithostratigraphic units have a thickness of up to 2500 m (Reyment 1965) and consist of: Nkporo Shale, Mamu Formation, Ajali Sandstone, Nsukka Formation, Imo Shale, Ameki Formation, Nanka Sands, Ogwashi-Asaba Formation, Benin Formation and the Alluvial Plain Sands. The source of the sediments into the basin is principally from the Cameroon massif and the Abakaliki synclinorium. The Ajali Formation bears false-bedded sandstone with associated clay and shale intervals in the bottom section (Reyment 1965). The Ajali Formation is successively underlain by materials belonging to the Nsukka and Mamu Formations. The Nsukka Formation, which is also called the Upper Coal Measure, bears sandstone, shale and coal, while the underlying Mamu Formation, which Akande *et al*. (1992) called the lower Maastrichtian Coal, conformably overlies the Nkporo Formation is followed successively by the other lithostratigraphic units mentioned earlier.

Previous studies of the sample area

Adebayo & Ojo (2004) using 41 outcrop samples from the Upper Cretaceous strata of the Anambra Basin recognized five informal palynological zones based on pollen and spores within the Maastrichtian. They inferred a swamp environment of deposition fringed by herbaceous vegetation based on the dominance of the trilete spores *Cingulatisporites ornatus*, *Foveotriletes margaritae*, *Verrucatotriletes bullatus* and *Zlivisporis blanensis* with common palm pollen. Oboh *et al*. (2005) studied 14 composite sections of the Paleogene successions outcropping in the Okigwe, Isuikwuato, Umuahia and Ozuitem areas in Imo and Abia States, respectively, of southeastern Nigeria. They documented a comprehensive sequence stratigraphy in the Anambra Basin/Afikpo syncline using data on the stratigraphic succession, textural/lithological variations, and sedimentary structures. They identified the lithofacies associations from the data generated and in addition processed 70 samples from the shale and siltstone horizons and studied their palynological contents. From these data they identified palynofacies assemblages using dispersed organic matter and palynomorph groups. Although there are different schemes for dispersed organic matter, they adopted a simplified scheme adapted to the types of organic components and palynomorph groups present in the sediments. They identified eight types of dispersed organic matter and palynomorph groups including spores and pollen, fungal remains, freshwater algae, marine palynomorphs (dinoflagellates, acritarchs, microforaminiferal inner linings), structured phytoclasts (wood, cuticles, parenchyma), unstructured phytoclasts (resins, comminuted and degraded fragments), black debris and amorphous organic matter. From point counting at least 300 particles of organic debris and palynomorph groups per sample, they converted them to associations based on rock types and five palynofacies assemblages (A–E) determined by the dominant phytoclast and other associated types.

Antolinez (2006) later studied a set of 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 their dinocyst contents. He found the dinocyst recovery very good to moderate, and the specimens were commonly well preserved. He compared the stratigraphic and quantitative data with detailed and well-calibrated dinocyst distributions from northwestern Europe and southern hemisphere, Tasmania and New Zealand and identified five informal zones (A to E). Zone A, which was the oldest stratigraphically, was characterized by the consistent occurrence of *Areoligera senonensis*, *Areoligera coronata*, *Palaeocystodinium bulliforme* and *Hafniasphaera septata*. Characteristic of Zone B was the occurrence of *Damassadinium cf. D. heterospinosum* in combination with abundant *Fibrocysta/Lanternosphaeridium* spp. and *Cordosphaeridium* spp.The dinocyst assemblages in zone C were characterized by the co-occurrence of abundant *Apectodinium* spp. and *Adnatosphaeridium* spp. Zone D revealed common occurrences of *Glaphyrocysta ordinata*, *Glaphyrocysta divaricata*, *Polysphaeridium subtile*, *Spiniferites microceras* and *Adnatosphaeridium* spp. Finally, the youngest zone, Zone E, was characterized by the occurrence of *Homotriblium abbreviatum*, *Homotriblium cf. H. oceanicum*, and *H. pallidum*. Antolinez concluded that his results could have impact 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 and subsidence curves.

The thermal maturation histories and timing of oil migration in this area also rely mostly on palynologically derived ages. Umeji & Nwajide (2007) analysed the stratotype type section of the Nsukka Formation at Ugwu-Nkalagu – Obukpa in Enugu state and the hypostratotype along a road section in Umulolo near Okigwe and established the type section. They recognized two facies, namely the lower shaly facies with coal which Tattam (1944) had called the 'Upper Coal Measures' and an upper sandy facies recognized earlier by Umeji (2000). They reported that both the type section (unit stratotype) and the type locality, lie within the lower shaly facies, while the hypostratotype lies within the type area in the upper non-coaly limestone facies. The coal samples were dominated by the palm pollen *Longapertites marginatus* which accounted for about 70% of the total count. *Proxapertites operculatus* (Arecceae), which was lacking in the interbedded coal, dominated the mudstone samples, accounting for about 50%. Other components of the samples include other pollen, algal fruiting bodies and monolete and trilete spores, making up 19%, 7% and 4%, respectively. Also common in the mudstone samples were the grass pollen *Monoporites annulatus* (Poaceae) and *Milfordia jardinei* (Restionaceae) especially in the Isi-Ayokpa and Nkalagu-Obukpa mudstones. The Nkalagu-Obukpa mudstones also yielded 2% dinoflagellate cysts made up of four species viz: *Areoligera senonensis*, *Cleistosphaeridium polypes*, *Coronifera oceanica* and *Dinogymnium acuminatum*. Umeji and Nwajide dated the type formation latest Maastrichtian–Danian. They also recovered other Paleogene sporomorphs such as *Echiperiporites icacinoides*, *Pachydermites diederixi*, *Verrucatosporites usmensis*, *Cricotriporites fragilis*, *Retistephanocolpites williamsi*, *Ctenolophonidites costatus*, *Echitricolporites spinosus*, *Myrtacidites psilatus*, *Retibrevitricolporites triangulatus*, *Psilatricolporites rotundus*, *Brevicolporityes molinae* and *Scabratriporites simpliformis*. Based on the ranges of these recovered palynofloras Umeji & Nwajide (2007) speculated that either these pollens range into the latest Maastrichtian or that sedimentation in the Anambra Basin did not terminate in the Danian but continued into the mid Tertiary. In addition, the Umulolo-1 samples yielded 27% dinoflagellate cysts and 73% sporomorphs. Dinoflagellate cysts such as *Phelodinium gaditanum*, *Exochosphaeridium phragmites*, *E. bifidum*, *Fibrocysta axialis* and *Pterodinium cingulatum* were recovered from the mudstone section. These cysts co-occurred with 30%, 25%, and 20% *Proxapertites operculatus*, *Longapertites marginatus* and *Longapertites microfoveolatus*, respectively. They inferred more marine conditions in the southern Umulolo sections than compared to marsh conditions in the northern type section, due to the absence of the pollen *Monoporites annulatus* in the former. Again, Oboh *et al*. (2007) in their biostratigraphic study of the Early Paleogene in West Africa, recovered six new species and one new combination of dinoflagellate cysts from the Alo-1 well of the lower Imo and upper Nsukka Formation, which were of Paleocene age, from Anambra Basin, Nigeria. These were recovered from the Paleocene–?lowermost Eocene portions of the Imo Formation. The new species were *Ifecysta fusiforma*, *Ifecysta heterospinosa*, *Paleocystodinium rafii* and *Wilsodinium stellatum*. They also transferred *Fibrocysta lappacea* of Drugg (1970) Stover & Evitt (1978) to *Ifecysta* and emended the diagnosis of the latter.

Later Umeji & Edet (2008) reported that exposures of the lower facies of the Nsukka Formation/Unadu River of Reyment (1965), where one or more species dominated the assemblage. Pond weeds (*Azolla cretacea*, *Zlivisporis blanensis* and *Ariadnaesporites nigeriensis*) dominated the Okotokoto samples. These co-occurred with common *Longapertites marginatus* and rare *Proxapertites cursus*, *Longapertites microfoveolatus*, *Longapertites vaneendenburgi*, *Psilatricolporites rotundiporis*, *Syncolporites marginatus*, *Retidiporites magdalenensis*, the algae *Ulvella nannae* and sparse records of the dinoflagellate cysts *Cordosphaeridium inodes*, *Danea californica* and *Exochosphaeridium bifidum*. In contrast, the Aku spring (Ugwu-Nkalagu-Obukpa-Type Section) yielded abundant grass pollen *Monoporites annulatus* with freshwater algae *Pseudoschizaea circula* and the Isi-Ayokpa mudstones also yielded *Monoporites annulatus* with freshwater algae *Pseudoschizaea circula*, common *Echitricolporites spinosus*, *Cyathidites minor*, *Foveotriletes margaritae*, *Leiotriletes adriennis*, *Polypodiisporites* sp., *Stephanocolpites evansii*, *Triporites iverseni* and *Azolla cretacea*. The assemblages from ripple laminated mudstones from Umulolo (Upper facies) were dominated by Tertiary palm pollen species *Proxapertites operculatus*, *Longapertites microfoveolatus*, with *Longapertites marginatus*, *L. vaneendenburgi* and abundant dinoflagellate cysts, especially *Ifecysta pachyderma*, *Phelodinium gaditanum*, *Senegalinium bicavatum*, *Ceratiopsis diebelii*, *Exochosphaeridium phragmites*, *Pterodinium cingulatum*, *Cleistosphaeridium diverspinosum*, *C. aciculare*, *Chytroeispaeridia chytroeides* and *Spiniferites ramosus*. On the other hand, the plastic shale samples from Umulolo were dominated by *Proxapertites operculatus*, *Longapertites marginatus*, *Longapertites vaneendenburgi*, *Cyathidites minor* and *Longapertites microfoveolatus*, together with slightly more dinoflagellate cysts (32%), than in the mudstone section. The most common dinocysts here were *Spiniferites ramosus*, *Hystrichokolpoma rigaudiae*, *Cordosphaeridium inodes*, *Kallosphaeridium orchiesense*, *Phelodinium magnificum*, *Cyclonephelium deconincki*, *Exochosphaeridium phragmites*, *Cleistosphaeridium diverspinosum*, *Danea californica*, *Adnatosphaeridium vittatum* and *Diphyes colligerum*, as well as microforaminiferal wall linings. Sporomorphs made up 68%, while algae were rare. Also recovered from the Umulolo samples were the typical Paleogene sporomorphs *Pachydermites diederixi*, *Echitricolporites spinosus*, *Bacutriporites orluensis*, *Ctenolophonidites costatus*, *Retistephanocolpites williamsi*, *Stephanocolpites evansii*, *Echiperiporites icacinioides*, *Psilatricolporites crassus*, *Psilatriporites rotundus*, *Monoporites annulatus*, *Longapertites microfoveolatus*, *Triporotetradites hoekeni*, *Proxapertites minutus*, *Zonocostites ramonae* and *Verrucatosporites usmensis*. They concluded that the presence of *Dinogymnium acuminatum* in the Nkalagu-Obukpa (type section) restricted the age to Late Maastrichtian, thereby confirming a Late Maastrichtian age to the type section of the Nsukka Formation in the North, while the age is Danian in the south around Umulolo where it is sharply overlain by the Imo Formation. Finally, Durugbo (2013) used the occurrence of abundant palm pollen *Longapertites marginatus*, *L. vaneendenburgi*, *Spinizonocolpites echinatus*, *S. baculatus*, *Retidiporites magdalenensis*, *Mauritidites crassiexinus*, *M. crassibaculatus*, together with the dinoflagellate cysts *Paleoperidinium pyrophorum*, *Phelodinium magnificum*, *P. africanum*, *Ifecysta fusiforma*, *I. heterospinosa*, *Fibrocysta lappacea*, *Homotryblium tenuispinosum*, *Diphyes colligerum*, *Cerodinium* spp., *Ceratiopsis* spp., *Apectodinium* spp., *Kallosphaeridium* spp., *Cordosphaeridium* spp., *Exochosphaeridium* spp., *Spiniferites* spp., *Cleistosphaeridium* spp., *Lejeunecysta* spp., *Apectodinium* spp. and *Homotryblium tenuispinosum* to date the Imo shale exposures at the Okigwe/Port Harcourt express road junction as Late Paleocene to Eocene.

Apart from palynological studies, different investigations to evaluate the thermal maturity, foraminiferal content and general hydrocarbon prospectivity of the Anambra Basin have been carried out (Petters 1977; Alix *et al*. 1981; Akande & Erdtman, 1998; Obaje *et al*. 1999; Ehinola *et al*. 2005; Akaegbobi *et al*. 2009; Onuigbo *et al*. 2012).

Akande *et al.* (2011) proposed more studies of the more than 8000 m Cretaceous-Tertiary sediments of the Lower Benue Anambra Basin. They also reported that previous

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drilling efforts had revealed both oil and gas reserves in the Anambra Basin at various stratigraphic intervals. The gas finds were in the Cenomanian-Turonian Eze-Aku shales, and dry gas in the Awgu Shale stratigraphic interval coupled with oil and gas in the post-Santonian (Maastrichtian) intervals of the Anambra Basin. Conclusively, they posited that these source rock facies had reached maturity and have generated and expelled hydrocarbons at some stages in the history of basin.

MATERIALS AND METHODS

Thirteen samples at every 20 cm intervals were collected from the excavation site (Fig. 2) in sterile plastic bags. The samples were taken to the Biological Sciences laboratory of Redeemer's University prior to preparation. 30 g of each sample was prepared using the standard palynological techniques of disaggregation and removal of carbonates and silicates with hydrochloric acid and hydrofluoric acid under a fume cupboard (Faegri & Iversen 1989). The samples were further treated with hot hydrochloric acid (HCl) and wet-sieved over a 5 micron mesh polypropylene sieve. The Branson Sonifier 250 was employed during sieving to facilitate complete removal of silt and clay particles. Each residue was oxidized using concentrated nitric acid (HNO_3) and prepared for study as strewn mounts using Loctite. The slides were stained with Safranin O to enhance the study of dinoflagellate cysts. For the palynofacies/kerogen study, the samples were not oxidized with HF acid in order to retain the original nature and colour of the palynomorphs. A Zeiss Axioskop 2 microscope with an attached Axiocam Cc 1 digital camera was used for the analysis at the palynology laboratory of the Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa. All the species present (pollen, spores, fungal remains, algae, dinoflagellate cysts and foraminiferal linings) were recorded (Supplemental information: Appendix A). The percentage occurrences of the different palynomorph groups are displayed in Fig. 3. Three hundred specimens of the different dispersed organic matter (pollen and spores, fungal remains, freshwater algae, marine palynomorphs, structured phytoclasts (wood, cuticles, parenchyma), unstructured phytoclasts (resins, comminuted and degraded fragments, black debris, and amorphous organic matter) were point counted and converted to percentages and presented in Fig. 4 (Oboh-Ikuenobe *et al.* 2005, 2012). The pollen and spores were identified using local palynological catalogues (Hoeken-Klinkinberg 1964, 1966; Jardine & Margloire 1965; Germeraad *et al.* 1968; Salard-Cheboldaeff 1981, 1990; Salami 1983, 1990; Lawal & Moullade 1986; Mahmoud & Schrank 2007). Dinoflagellates and other marine elements were identified based on various monographs (Brinkhuis *et al.* 2003; Edwards 1991; Fauconnier *et al.* 2004; Jan du Chêne 1987; Jan du Chène & Adeniran 1985; Powell 1992; Williams & Bujak 1977). The nomenclature follows Fensome & Williams (2004). Photomicrographs of the diagnostic palynomorphs were taken at magnifications of ×400 and the sample number and associated England Finder coordinates of the diagnostic palynomorphs are given (Figs 5–9). The slides, residues, unprocessed samples, and duplicate prints are housed in the palynological collections of the Biological Sciences Department, Redeemer's University, Ede, Osun State, Nigeria.

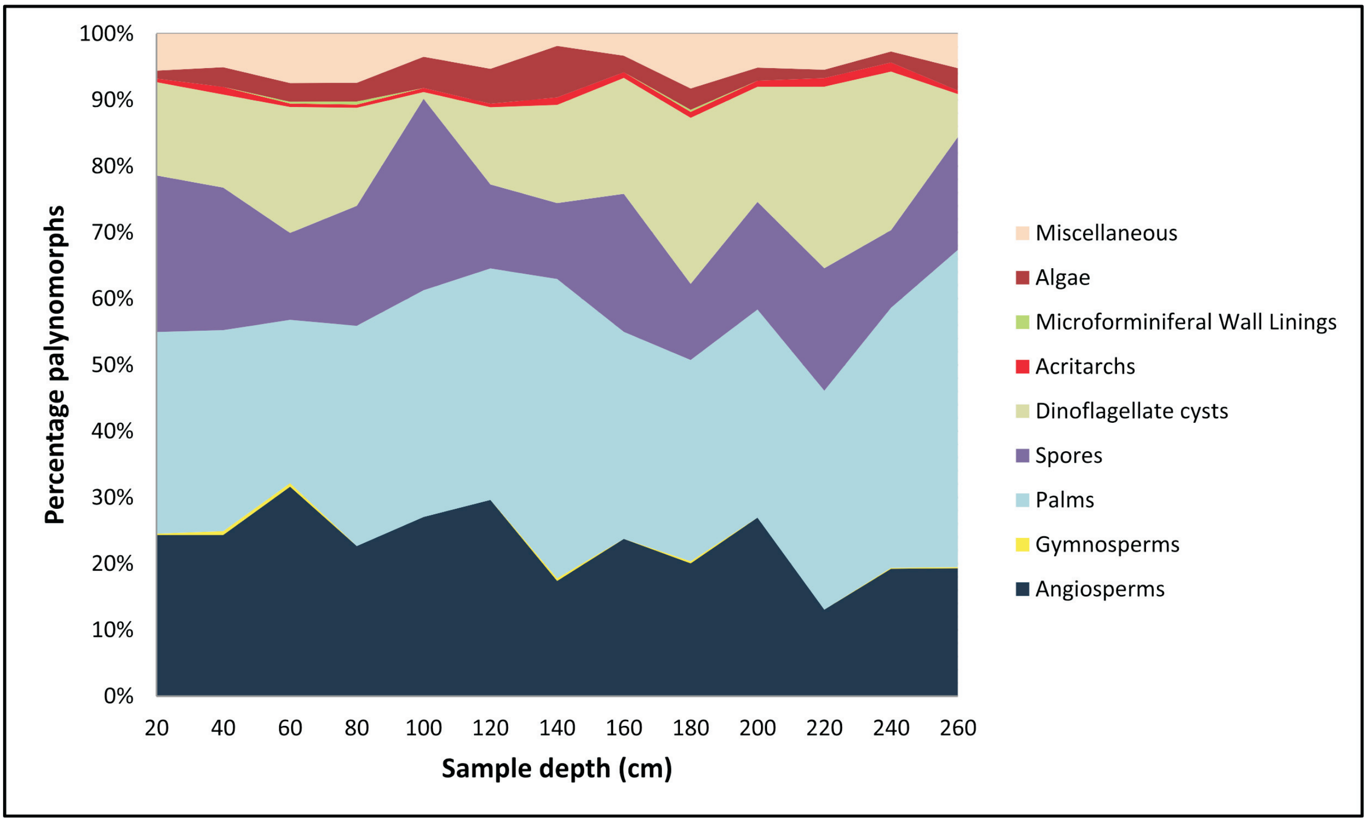

Figure 3. Percentage plot of the different palynomorphs groups in the Okigwe excavation samples.

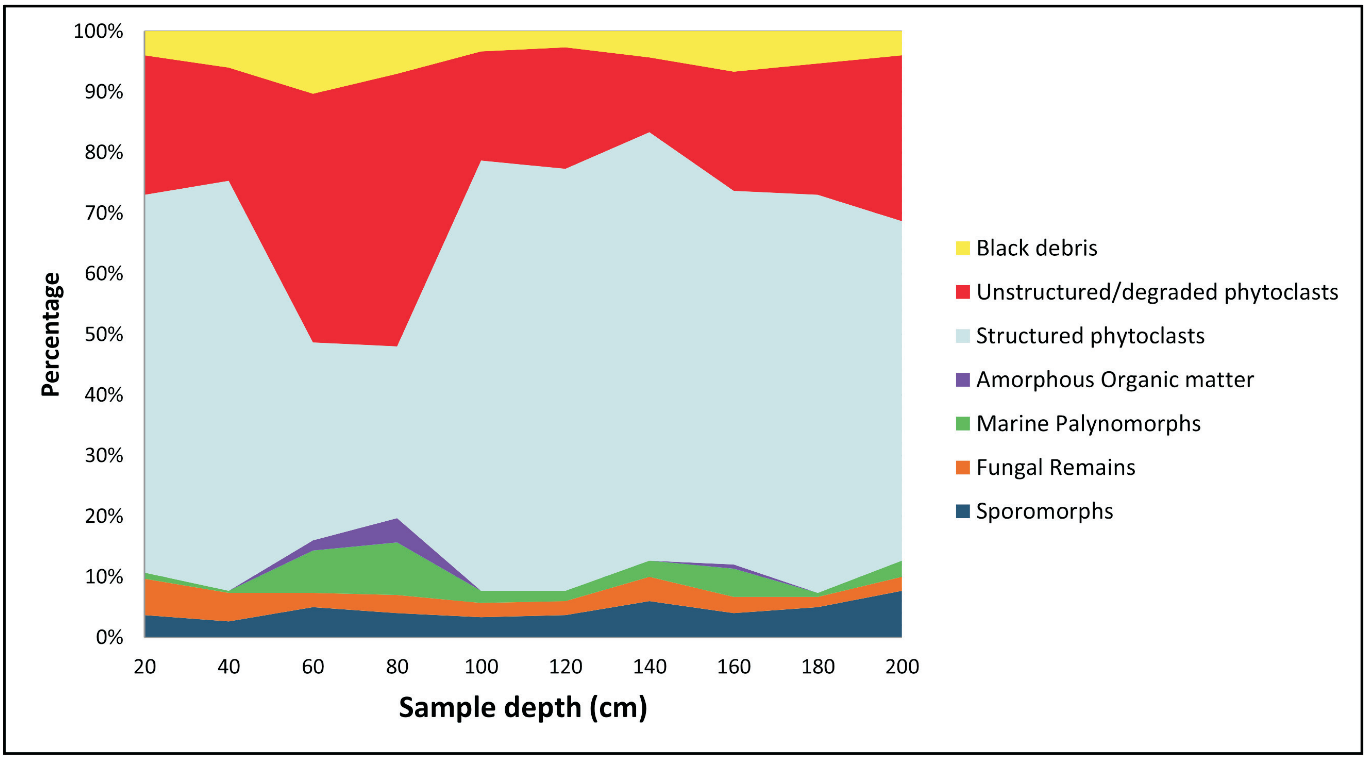

Figure 4. Percentage plot of Palynofacies Groups recorded per sample from the Okigwe samples. Plot on *x*-axis to 260 cm (depth).

RESULTS

Palynological assemblages

The palynomorphs recovered revealed an admixture of both continental and marine forms. The relative frequencies of the angiosperms, gymnosperms, dinoflagellate cysts, acritarchs, pteridophytes, algae and fungal elements, charred graminae cuticle and *incertae sedis* in the different samples are highlighted in Supplemental information (Appendix A), and displayed in Fig. 3. A total of 6168 palynomorphs were recovered in the 13 samples studied. Pollen species made up of 74 species dominated with a total count of 3537, out of which angiosperms dominated with 99.77%, while gymnosperms accounted for only 0.23% (Table 2).

Successively, the pteridophyte spores followed with counts of 1087; dinoflagellate cysts 1000; acritarchs 52, microforaminiferal wall linings 5; algae 175 and miscellaneous 312, composed of fungal elements, charred graminae cuticle and *incertae sedis*. An assessment of the pollen species revealed that palm pollen species dominated with about 19 species, and total counts of 2130; gymnosperms represented by two species had a total count of 10, contributing 0.28%, while the other pollen contributed 39.5% (Table 2). Overall, these palms accounted for 60.22% of the total pollen, and 34.53% of the total palynomorphs recovered.

Palynofacies

The visual estimation revealed the occurrence of three

Table 2. Total recovered palynomorphs groups per sample.

Sample number	Angiosperms	Gymnosperms	Palms	Spores	Dinoflagellate cysts	Acritarchs	Microforminiferal wall linings	Algae	Miscellaneous	Total
20CM	140	1	175	136	81	3	0	7	32	575
40CM	130	3	162	115	75	6	0	16	27	534
60CM	123	2	96	51	74	2	1	11	29	389
80CM	144	0	211	115	94	3	3	18	47	635
100CM	132	0	167	141	5	3	0	23	17	488
120CM	56	0	66	24	22	1	0	10	10	189
140CM	47	1	122	31	40	3	0	21	5	270
160CM	57	0	75	50	42	2	0	6	8	240
180CM	68	1	103	39	85	3	1	11	28	339
200CM	121	0	141	73	78	4	0	9	23	449
220CM	72	0	182	102	151	7	0	7	30	551
240CM	172	1	351	105	214	12	0	15	24	894
260CM	119	1	295	105	40	3	0	21	32	616
Total	1381	10	2146	1087	1000	52	5	175	312	6168

groups of dispersed organic matter and palynomorphs which dominated some of the samples. The most significant groups were the structured phytoclasts, unstructured/degraded phytoclasts and marine elements. The amorphous organic matter appeared to be directly related to the marine elements as they occurred commonly in samples with appreciable numbers of dinoflagellate cysts (Samples 3, 4, 8, 11). The percentage constituents of the different palynofacies assemblages per sample are outlined in Table 3 below.

Kerogen analysis

Using *Deltoisospora minor* as the palynomorph index, the kerogen analysis of the samples revealed a predominantly golden yellow to deep yellow colour of palynomorphs which corresponds to spore colour indices of 4.0–4.5. This is correlated to vitrinite reflectance values ranging between 0.4–<0.5 indicating immature oil and gas generation potentials (Dow 1977; Hunt 1996; Matchette-Downes 2009).

DISCUSSION

Palynostratigraphy

The studied samples are dated Late Maastrichtian–Middle Paleocene based on the presence of *Buttinea andreevi*, *Monocolpopollenites sphaeroidites*, *Zlivisporis blanensis*, *Constructipollenites ineffectus*, *Mauritidites lehmanii*, *Proteacidites sigalii*, *P. dehaani*, *Foveotriletes margaritae*, *Cingulatisporites ornatus*, *Distaverrusporites simplex* and *Rugulatisporites caperatus* (Fig. 11; Hoeken-Klinkkenberg 1964; Salami 1983, 1990).

Globally the events of the K/T boundary have been of special interest to palaeontologists. Slimani *et al.* (2010) together with other workers reported that organic walled phytoplankton survived the events of the K/T catastrophes. In the present study, the Cretaceous – (Pg) Tertiary boundary is taken at a depth of 180 cm, due to the Last Appearance Datum (LAD) of the aforementioned palynomorphs, namely *B. andreevi*, *M. sphaeroidites* and *Z. blanensis*, together with *Carpatella cornuta* and *Damassidinium californicum*, between 260–180 cm. In his range chart Salami (1983) highlighted the ranges of *B. andreevi* and *M. sphaeroidites* as terminating at the end of the Maastrichtian, however, *R. caperatus*, *D. simplex* and *C. ornatus*, continued into the Paleocene. Later, Salami & Atta-Petters (2004) further documented that the former ranged from Campanian to Maastrichtian in Nigeria. Furthermore, Germeraad *et al.* (1968) had given the ranges of *Buttinea andreevi*, *Proteacidites dehaani*, *Retidiporites magdalenensis*, *Longapertites vanendenburgi* and *Foveotriletes maragaritae* in Nigeria as not younger than Paleocene. Oboh-Ikuenobe *et al.* (2012) posited that *Achomosphaera alcicornu* appeared for the first time in mid-latitudes during the Danian, while *Phelodinium magnificum*, *Hafniasphaera septata*, *Cerodinium diebelii* and *Paleocystodinium golzowenze* are all associated with the Danian age. Slimani *et al.* (2010) linked the occurrences of *D. californicum*, *C. cornuta*, *Eisenackia circumtabulata*, *Membranilarnacia tenella* and *Senoniasphaera inornata* with the Danian of Morocco, while the Maastrichtian is characterized by latest occurrences of *Disphaerongena carposphaeropsis*, *Glaphyrocysta perforata* and *Manumiella seelandica*. In addition, they also recorded some of the species recovered from the Okigwe samples, especially *Cribroperidinium cooksoniae*, *Cordosphaeridium exilimurum*, *C. inodes*, *Riculacysta* sp., *Apteodinium fallax*, *Spiniferites cornuta*, *Pterodinium cingulatum*, *Fibrocysta bipolaris*, *Areoligera senonensis*, *Glaphyrocysta perforata*, *Phelodinium magnificum*, *P. africanum*, *Isabelidinium bakeri*, *Senagalinium bicavatum* and *S. microspinosum*, among others. This trend reveals the preponderance of these species in the Early Paleocene globally. Moreover, Hamdi *et al.* (2013) reported the presence of the majority of the dinoflagellate cysts reported here in their study of Cretaceous–Paleogene transition deposits from the Ellès section of northern Tunisia. They placed the K–Pg boundary just above the acme of *Manumiella seelandica* and the last appearance of *Dinogymnium* spp., *Alisogymnium euclaense* and *Pterodinium cretaceum* which were directly below the first appearance of the basal Danian markers: *D. californicum*, *Membranilarnacia? tenella*, *Senoniasphaera inornata* and *C. cornuta*. Apart from these they also recorded *Senagalinium bicavatum*, *S. microspinosum*, *Kallosphaeridium yorubaense*, *Cerodinium spp.*, *Phelodinium magnificum*, *P. africanum*, *Cordosphaeridium inodes*, *Glaphyrocysta perforata*, *Fibrocysta axialis*, *F. bipolaris*, *Achomosphsera alcicornu*, *A. regiensis*, *Apteodinium fallax*, *Cerodinium diebelii*, *Diphyes*

Table 3. Percentage counts of the different palynofacies groups per sample.

Sample depth	Sporomorphs	Fungal remains	Marine palynomorphs	Amorphous organic matter	Structured phytoclasts	Unstructured/ degraded phytoclasts	Black debris	Total (%)
20CM	3.67	6	1	0	62.33	23	4	100
40CM	2.67	4.67	0.33	0	67.66	18.67	6	100
60CM	5	2.33	7	1.67	32.67	41	10.33	100
80CM	4	3	8.67	4	28.33	45	7	100
100CM	3.34	2.33	2	0	71	18	3.33	100
120CM	3.67	2.33	1.67	0	69.66	20	2.67	100
140CM	6	4	2.67	0	70.67	12.33	4.33	100
160CM	4	2.67	4.67	0.67	61.66	19.66	6.67	100
180CM	5	1.67	0.67	0	65.66	21.67	5.33	100
200CM	7.67	2.33	2.67	0	56	27.33	4	100
220CM	20.67	4	14	2.67	22.66	30	6	100
240CM	19.67	3.67	1	0.33	55	14	6.33	100
260CM	14.67	2.33	1.67	0.67	54.66	19.33	6.67	100

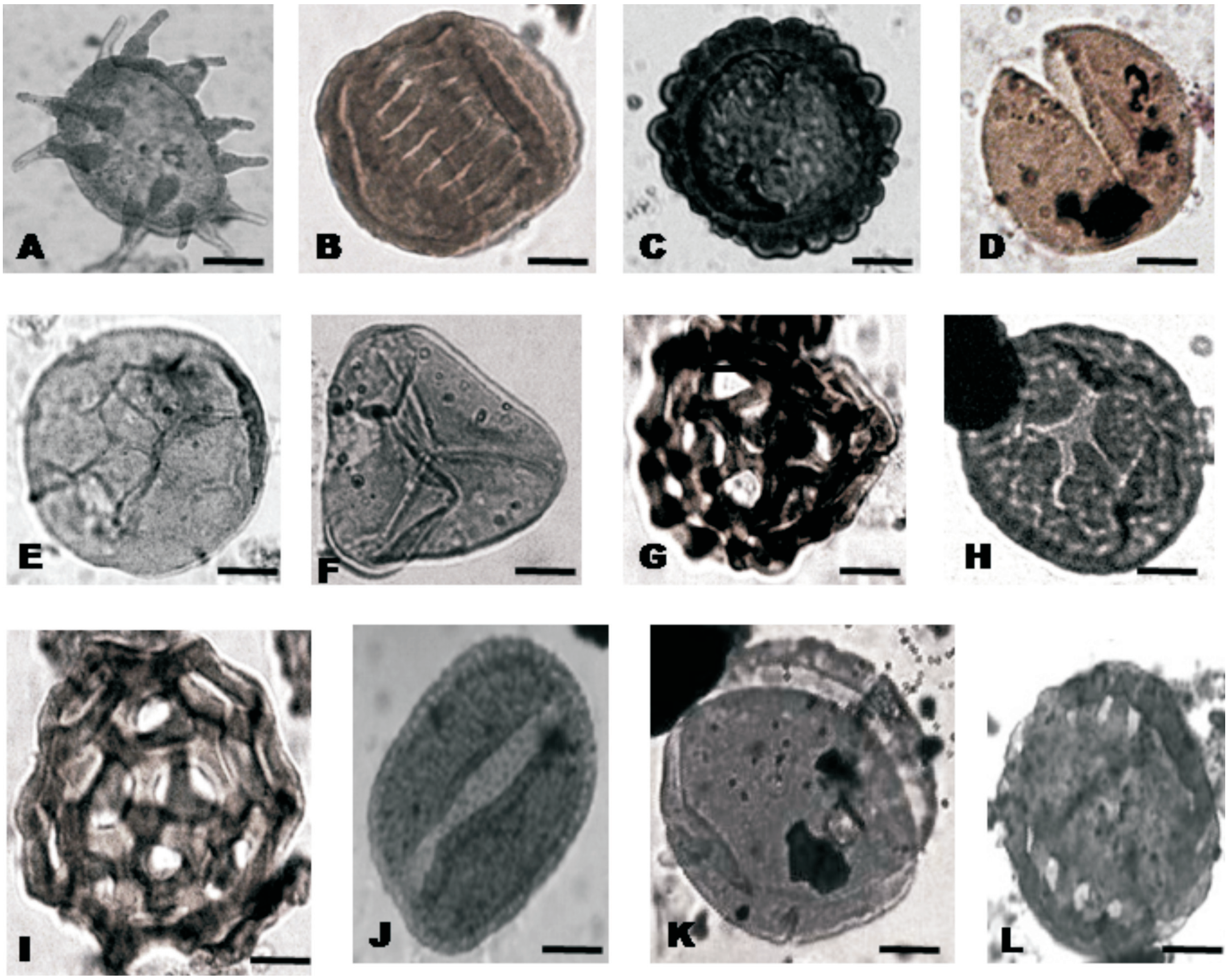

Figure 5. Photomicrographs of pollen and spores recovered from the studied Okigwe samples. **A**, *Spinizonocolpites echinatus* Muller 1968 (Sample 2 G33/3). **B**, *Tubistephanocolporites cylindricus* Salami 1985 (Sample11 G32/2). **C**, *Cingulatisporites ornatus* Martin, 1973 (Sample 12 P40/1). **D**, *Monocolpopollenites sphaeroidites* Jardine & Margloire 1965 (Sample12 G50/3). **E**, *Zlivisporis blanensis* Pacltova 1961 (Sample13 H41/2). **F**, *Cyathidites minor* Couper 1953 (Sample11 R29/1). **G**, *Buttinia andreevi* Boltenhagen 1967 (Sample13 V56/0). **H**, *Rugulatisporites caperatus* Van Hoeken-Klinkenberg 1964 (Sample 11S34/3). **I**, *Buttinia andreevi* Boltenhagen 1967 (Sample11 G31/1). **J**, *Foveomonocolpites bauchiensis* Jan du Chêne & Adegoke 1978 (Sample 4 R22/0). **K**, *Proxapertites operculatus* van derHammen 1956 (Sample12 K55/1). **L**, *Tubistephanocolporites cylindricus* Salami 1985 (Sample10 C41/2). All photomicrographs taken at ×400; scale bars = 12 μm.

colligerum, *Areoligera senonensis*, *Senegalinium bicavatum* and *S. microspinosum* which were also recovered in the present study. Conclusively, Grandstein *et al.* (2004) highlighted the First Appearance Datum (FAD) of *D. californicum* and *C. cornuta* at the top of Da-1 dated 64.96 Ma, while *C. corunta* has its FAD in the Selandian at Sel-2 at 60.98 Ma. The reason for the preponderance of these dinocysts is not farfetched because Vadja-Santivanez (1999) showed that the Upper Cretaceous strata in Venezuela, Brazil and Colombia were mostly marine with common dinoflagellate cysts, just as these studied sediments revealed. This suggests that the marine conditions must have continued into the early Paleogene. Although the typical Late Maastrichtian dinoflagellate marker genus *Dinogymnium* spp. was not recovered, possibly due to more saline conditions, the ranges of the dominant dinoflagellate genera *Ifecysta*, *Fibrocysta*, *Kallosphaeridium*, co-occurring with the aforementioned sporomorphs, concurs with the age assignment already reported for the Umulolo section, which is a few kilometers away from Okigwe town, by Umeji & Nwajide (2007). The common records of *Fibrocysta* spp., *Ifecysta* spp. and *Cordosphaeridium* spp. agrees with the Zone B of Antolinez (1999). It further concurs with the reports of Umeji & Edet (2008) who inferred a Late Maastrichtian age for the type section in the north, based on the presence of *Dinogymnium acuminatum*, while they dated the southern section around Umulolo, Danian. This Danian age is supported by the presence of most of the dinoflagallate cysts recovered from the Danian of Senegal by Jan du Chène (1987) especially *Fibrocysta* spp., *Ifecysta* spp., *Cerodinium* spp., *Cordosphaeridium* spp., *Kallosphaeridium* spp., *Spiniferites* spp., except *Tanyosphaeridium* spp. The recovery of some of the new species reported by Oboh *et al.* (2007), dated Paleocene–?lowermost Eocene, especially *Diphyes bifidum*, *Ifecysta fusiforma* and *Ifecysta heterospinosa* which were not recovered by Umeji & Nwajide (2007) and Umeji & Edet (2008), supports the age of the Okigwe excavation samples as ranging into the Middle Paleocene. This age assignment is further supported by the absence of the typical Late Paleocene (Thanetian–Eocene) dinoflagellate cysts, *Homotryblium tenuispinosum* and *Apectodinium*

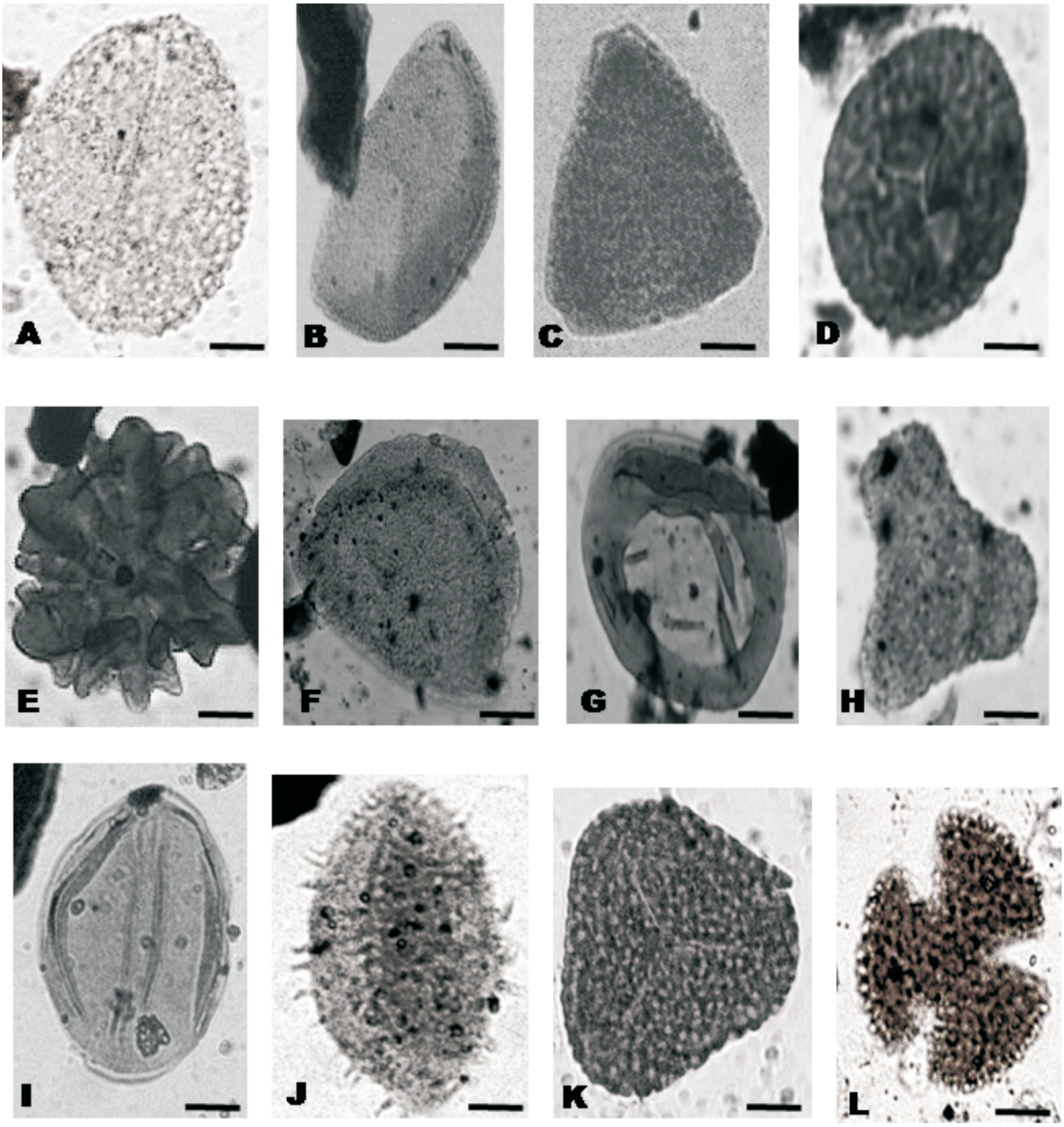

Figure 6. Pollen and spores recovered from the studied Okigwe samples. **A**, *Liliacidites cf. nigeriensis* (Van Hoeken-Klinkenberg 1966) Salami 1985, (Sample 7 T35/4). **B**, *Longapertites marginatus* van Hoeken Klinkenberg 1964 (Sample 6 G28/3). **C,** *Proteacidites dehaani* Germeraad, Hopping and Muller, 1968 (Sample 12 N42/0). **D,** *Rugulatisporites caperatus* Van Hoeken-Klinkenberg 1964 (Sample 8 S34/3). **E,** *Ctenolophonidites costatus* (van der Hammen & Garcia 1966) Germeraad *et al.* 1968 (Sample 10 Q21/3). **F**, *Longapertites vaneendenburgi* Germeraad *et al.* 1968 (Sample11 Q35/1). **G**, *Milfordia jardinei* Erdtman 1960 (Sample 11 J36/4). **H**, *Syndemicolpites typicus* Van Hoeken-Klinkenberg 1966 (Sample 11 O44/0). **I,** *Sapotaceoidaepollenites* sp. (Sample 1 K54/2). **J,** *Mauritiidites crassiexinus (*Jan du Chêne *et al.* Onyike and Sowunmi, 1978 (Sample 3 W34/1). **K**, *Foveotriletes margariae* Germeraad *et al.* 1968 (Sample 1 W46/4). **L,** *Retitricolporites americana* Wymstra 1964 (Sample 1 W46/4). All photomicrographs taken at ×400; scale bars = 12 μm.

homomorphum, which were not recorded in the samples studied. Comparing these results with those of Oboh *et al.* (2005) revealed that they had studied sediments younger than Middle Paleocene because they had dated their basal depositional sequence Upper Nsukka, with the overlying Imo Formation still dated Paleocene, while their youngest Formation (Ogwasi-Asaba) is of Eocene age, hence the recovery of such palynomorphs as *Praedapollis africanus*.

Palynofacies

The assemblage is generally dominated by unstructured phytoclasts, structured/degraded phytoclasts, with rare amorphous organic matter, except in Samples 3, 4, 8 and 11, which had appreciable counts of marine elements. The whole assemblage closely resembles palynofacies assemblage C of Oboh *et al.* (2005, 2012) due to the highest percentages of structured phytoclasts, with values ranging

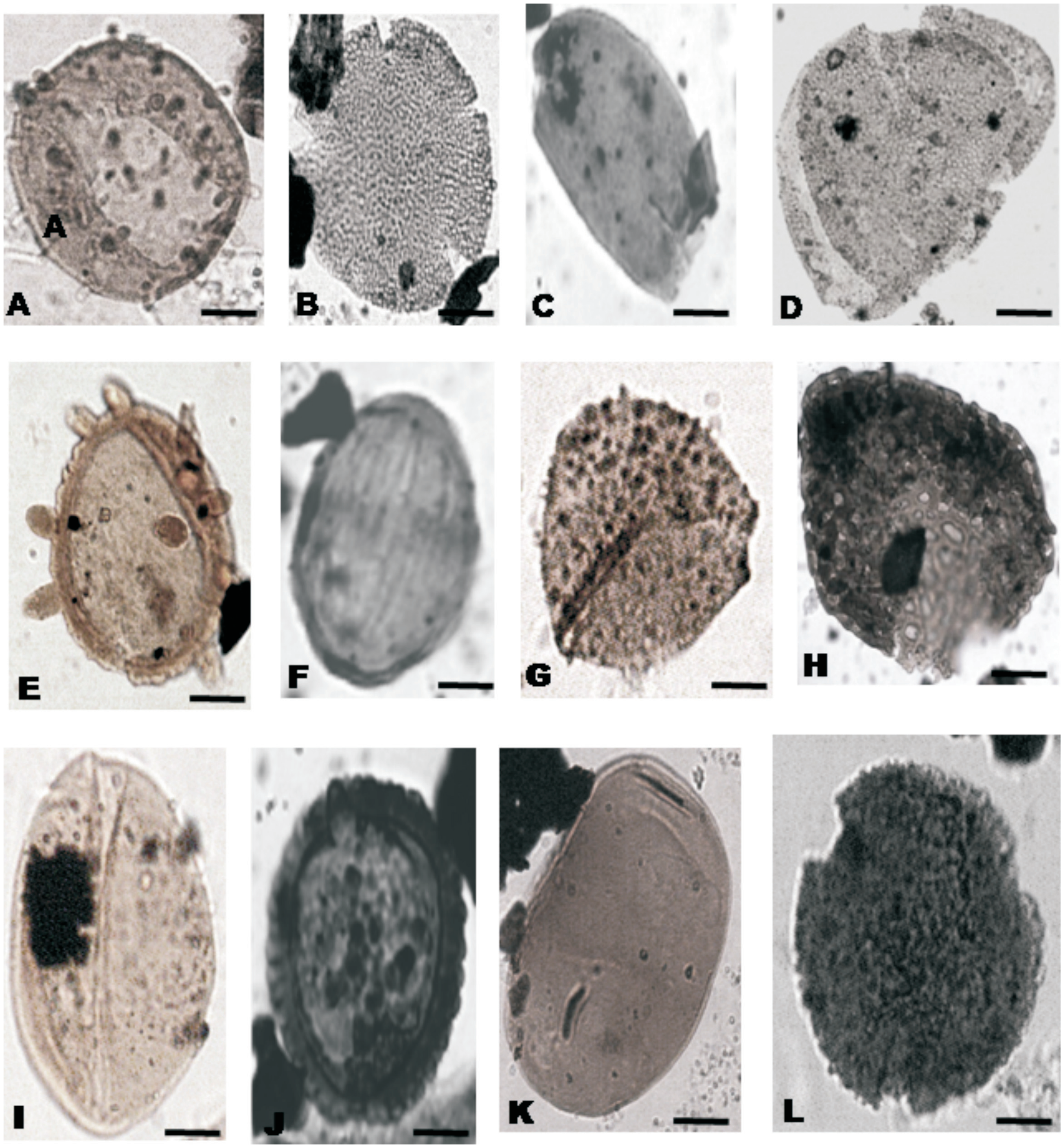

Figure 7. Pollen and spores recovered from the studied Okigwe samples. **A**, *Mauritiidites lehmanii* Salard-Cheboldaeff 1978 (Sample 6 G28/3). **B**, *Arecpites* sp. (Sample 11 S29/1). **C,** *Retidiporites magdalenensis* van der Hammen & Garcia 1966 (Sample11 K51/4). **D**, *Longapertites vaneendenburgi* Germeraad *et al.* 1968 (Sample11 Q35/1). **E**, *Spinizonocolpites baculatus* Muller 1968 (Sample 9 S33/4). **F,** *Ephedripites multicostatus* Brenner 1963 (Sample 3 S46/2). **G**, *Echitriporites trianguliformis* Van Hoeken-Klinkerberg 1964 (Sample 2 K51/4). **H**, *Periretisyncolpites giganteus* Kieser & Jan du Chêne 1979 (Sample 8 Q35/2). **I**, *Bombacacidites polanuris* Jaramillo *et al.* 2007 (Sample 13 C41/2). **J**, *Distaverrusporites simplex* Muller 1968 (Sample 3 O53/2). **K**, *Laevigatosporites discordatus* Pflug, 1953 (Sample 3 N36/3). **L,** *Nigeripollis gemmatus* Salami 1985 (Sample 6 S47/2). All photomicrographs taken at ×400; scale bars = 12 μm

from 36% to 65%. However, the percentages of amorphous organic matter were lower here. Although Oboh *et al.* (2005) reported 36% to 65% structured phytoclasts for palynofacies assemblage C, the Okigwe samples yielded a range of 22.67 to 70.67%. Again, in Samples 3, 4, and 11 the structured/degraded phytoclasts were more common than those of the structured; coincidentally, these samples recorded the highest amount of amorphous organic matter indicating that possibly these samples were undergoing rapid deterioration in deeper water settings. Finally, the palynofacies samples contained more sporomorphs than those studied by Oboh *et al*. (2005); here the range was between 2.67% in Sample 2, to 20.66% in Sample 11. Oboh *et al.* (2005) associated the highest pollen and spore content of 0.3–12% with their palynofacies assemblage D in which amorphous organic matter

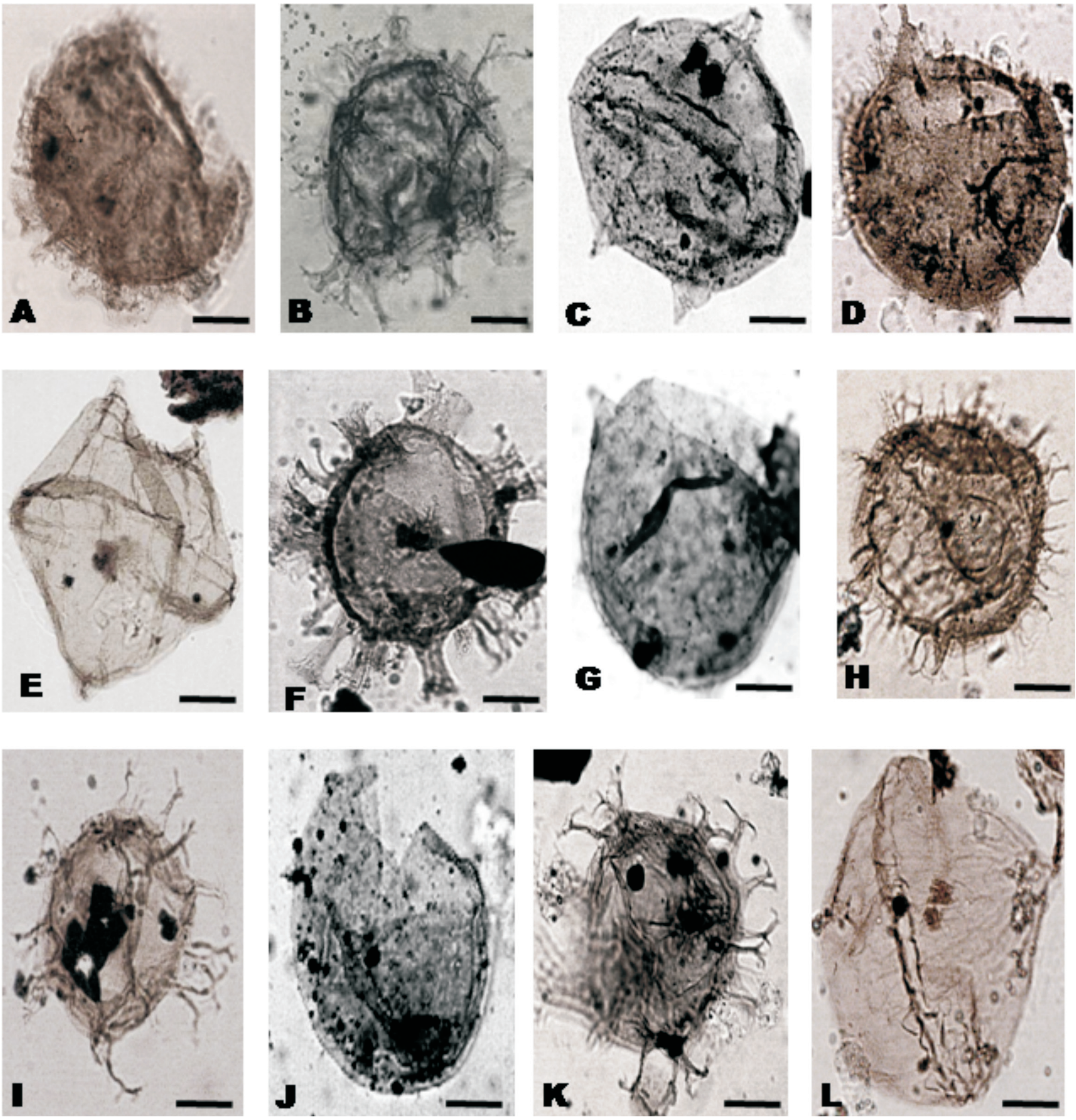

Figure 8. Dinoflagellate cysts recovered from the studied Okigwe samples. **A**, *Kenleyia* sp. (Sample 10 R41/4). **B**, *Damassadinium californicum* (Davey,1967) Fensome *et al.* 1993. (Sample 13 W36/1). **C**, *Cerodinium* spp. (Sample 6 N49/1). **D**, *Ifecysta fusiforma* Oboh *et al.* 2007 (Sample 11 R29/1). **E**, *Phelodinium magnificum* (Stanley, 1965) Stover & Evitt 1978 (Sample 10 G28/3). **F**, *Cordosphaeridium exilimurum* Davey & Williams 1966 (Sample 10 J40/4). **G**, *Cribroperidinium cooksoniae* Norvick 1976 (Sample 13 P46/3). **H,** *Exochosphaeridium phragmites* (Clarke & Verdier 1973) Clarke *et al.* 1968 (Sample 5 V56/0). **I**, *Achomosphaera* spp. (Sample 10 G28/3). **J**, *Kallosphaeridium yorubaense* Jan du Chêne & Adediran 1985 (Sample 11 R29/1). **K**. *Spiniferites multibrevis* Davey & Williams 1966 (Sample 11 R41/4). **L**, *Phelodinium africanum* Biffi & Grignani 1983 (Sample 5 U29/4). All photomicrographs taken at $\times 400$; scale bars $= 12\,\mu$m

dominated. Here the samples, as suggested earlier, were deposited not too far from the coast which accounted for the high counts of pollen and spores which generally decrease in number seawards (Shrank 1984; Quattrochio & Sarjeant 2003).

Paleoenvironmental interpretation

Workers such as Shrank (1984), Quattrochio & Sarjeant (2003) proposed that terrestrial components (sporomorphs and land derived detritus) in an assemblage decrease as the marine components (dinoflagellate cysts, foraminiferal linings etc) increase offshore (with distance away from terrigenous influx). In this study sporomorphs, especially palms, dominated the assemblages although microplankton were moderate in most of the samples. The depositional environments fluctuated between Outer/Middle Neritic as indicated by species of *Impagidinium*, *Kallosphaeridium*, *Trichodinium*, *Cribroperidinium/Spiniferites*, *Cordosphaeridium* and *Polysphaeridium*, to Coastal Deltaic environments, as inferred from the

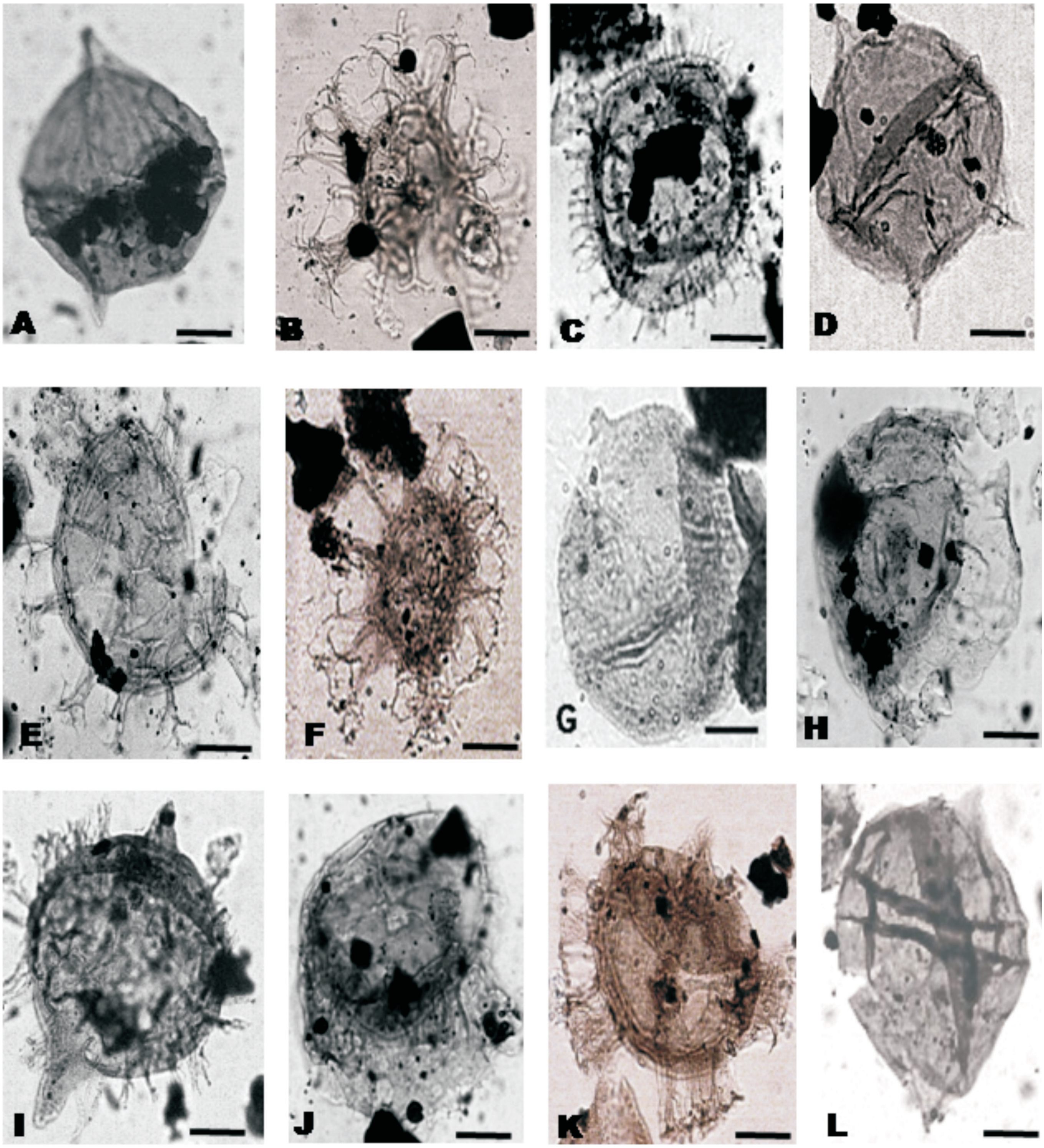

Figure 9. Dinoflagellate cysts recovered from the studied Okigwe samples. **A**, *Carpatella cornuta* Grogorovich 1969 (Sample 11 R41/4). **B**, *Damassadinium californicum (*Davey 1967) Fensome *et al.* 1993 (Sample 13 W36/1). **C**, *Cerodinium* spp. (Sample 6 N49/1). **D**, *Ifecysta fusiforma* Oboh *et al.* 2007 (Sample 11 R29/1). **E**, *Phelodinium magnificum* (Stanley, 1965) Stover & Evitt 1978 (Sample 10 G28/3). **F**, *Cordosphaeridium exilimurum* Davey & Williams 1966 (Sample 10 J40/4). **G,** *Cribroperidinium cooksoniae* Norvick 1976 (Sample 13 K41/2). **H**, *Exochosphaeridium phragmites* (Clarke & Verdier 1973) Clarke *et al*. 1968 (Sample 5 V56/0). **I**, *Achomosphaera* spp. (Sample 10 G28/3). **J**, *Kallosphaeridium yorubaense* Jan du Chêne & Adediran 1985 (Sample 11 R29/1). **K**, *Cordosphaeridium exilimurum* Davey and Williams,1966 (Sample 10 J40/4). **L,** *Fibrocysta lapacca* (Drugg 1970) Stover & Evitt 1978 (Sample 9 T38/2). All photomicrographs taken at ×400; scale bars = 12 μm.

variations in the percentages of Gonyaulacacealeans and Peridinaceae and dominance of palm pollen over other palynomorphs together with common freshwater algae. Just as Oboh *et al*. (2012) observed, the paucity of deeper water associated dinoflagellate cysts such as *Impagidinium* spp. and *Nematosphaeropsis/Adnatosphaeridium* spp. which together with the low diversity and dominance of inner neritic taxa that they had associated with relative proximity to the shoreline in their study of the Late Maastrichtian–Paleogene palynoflora of southern Missouri, the same trend which was evident in this present study. The results of the palynofacies analysis further corroborates this paleoenvironmental deduction due to the common records of structured phytoclasts, unstructured/degraded

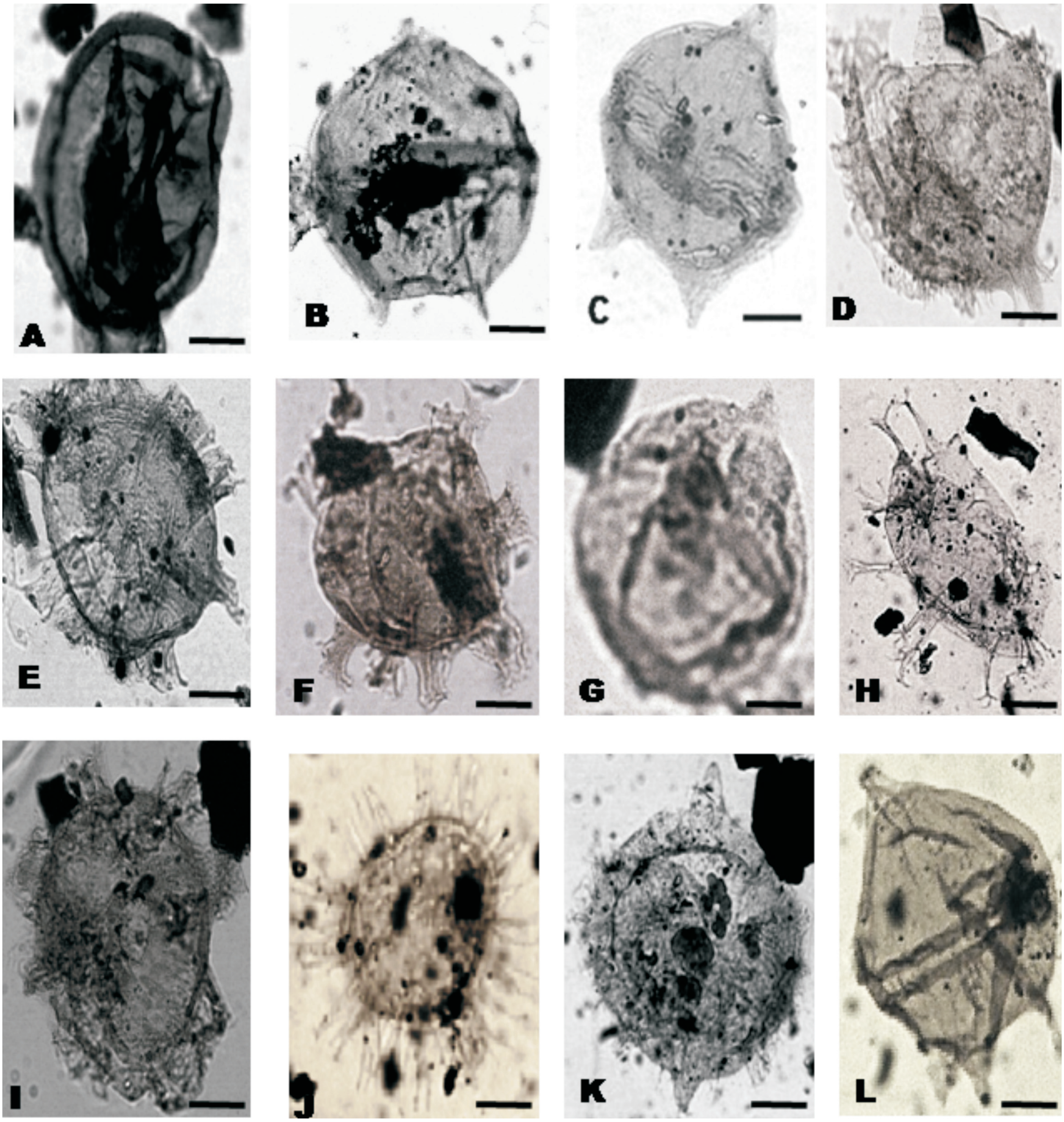

Figure 10. Dinoflagellate cysts recovered from the Ogikwe samples. **A**, *Selenopemphix nephroides* (Benedek 1972) Benedek & Sarjeant 1981 (Sample 4 J43/0). **B**, *Hafniasphaera delicata* Fensome *et al.* 2008 (Sample 11 R41/4). **C**, *Impagidinium* spp. (Sample 6 S47/2). **D**, *Achomosphaera alcicornu* Eisenack 1954 (Davey & Williams) (Sample 11 P41/3). **E**, *Adnatosphaeridium multispinosum* Williams & Downie, 1966 (Sample 4 G33/3). **F**, *Senegalinium bicavatum* Jain & Millipied 1973 (Sample 10 N36/3). **G**, *Adnatosphaeridium multispinosum* Williams & Downie 1966 (Sample 4 G33/3). **H**, *Glaphyrocysta semitecta* (Bujak in Bujak *et al.* 1990) Lentin & Williams 1981 (Sample 6 S47/2). **I**, *Fibrocysta bipolaris* (Cookson & Eisenack) Stover & Evitt 1978 (Sample 4 G33/3). **J**, *Riculacysta* spp. Soncini & Rauscher 1988 (Sample 4 J43/0). **K**, *Senegalinium microspinosum* (Boltenhagen 1977) Lentin & Williams 1980 (Sample 11 V56/0). **L**, *Spinidinium* spp. (Sample 1 K41/2). All photomicrographs taken at ×400; scale bars = 12 μm

phytoclasts, low amorphous organic matter and moderate records of dinoflagellate cysts. Continentally derived palynodebris (phytoclasts, fungal remains, sporomorphs, etc) and oceanic varieties (dinocysts, acritarchs, foraminiferal linings, marine amorphous organic matter) both occur in marine and marginal marine environments as demonstrated in this study (Jaramillo & Oboh-Ikuenobe 1999; Oboh *et al.* 2012). Furthermore as mentioned earlier, the dominance of terrestrially derived organic components in most of the studied samples indicated proximity to the source for those components, and agrees with the reports of Oboh *et al*. (2012). These findings concur with the results of Obi *et al.* (2001) who inferred from sedimentological evidence that the Nsukka Formation represented a fluvio-deltaic sedimentation phase which began close to the end of the Maastrichtian and continued during the Paleocene. The dinoflagellate assemblages of the Nsukka Formation from Okigwe are generally domi-

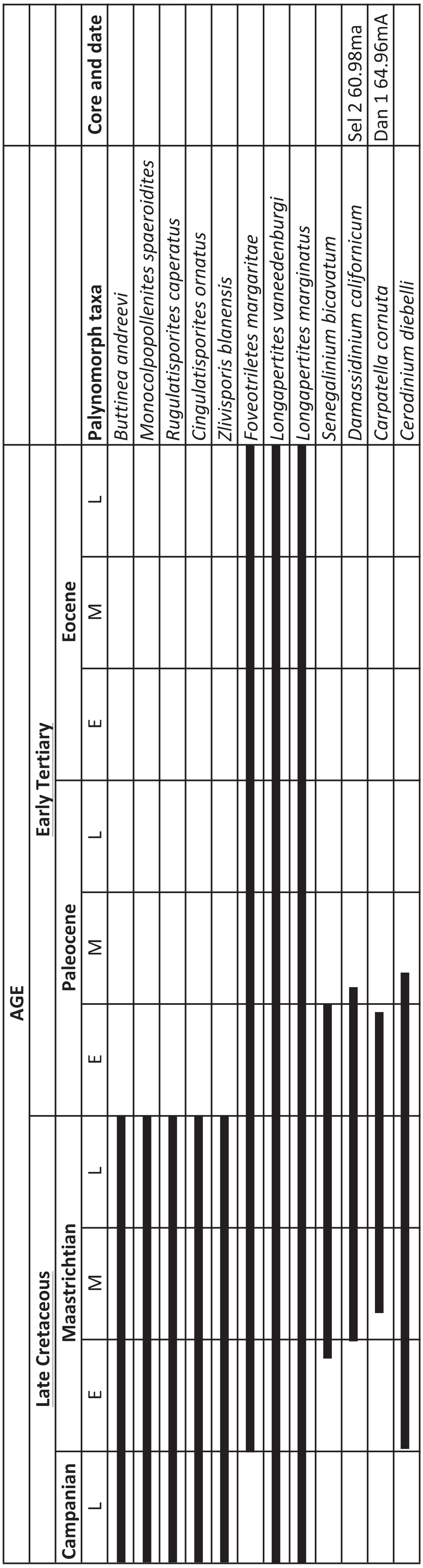

Figure 11. Range chart of the stratigraphically diagnostic taxa (after Atta-Peters & Salami 2004; Salami 1990; Gradstein *et al.* 2004).

nated by peridinoids with few chorate, proximate and proximochorate cysts. The peridinoids are generally associated with low salinity conditions (Harland 1978; Olusola 2010). On the other hand, those with gonyaulacoid affinity, *Cribroperidinium* spp. and *Spiniferites* spp., are common in sediments that formed in stable marine environments (Downie *et al.* 1971). Those with longer and more elaborate spines indicate offshore deep water (Harker *et al.* 1990).

CONCLUSION

The preponderance of palm pollen in the studied samples further supports the Late Cretaceous palm province which traversed the whole of the southern hemisphere. The recovery of moderate records of dinoflagellate cysts indicates some major transgressions in the Early Paleocene of the Anambra Basin. The sediments were deposited in nearshore environments and the spore colouration index revealed that the studied samples were not matured for oil and gas exploration.

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