

Palynomorphs of the First Down-Hole Shale Occurrence in Three Contiguous Basins in Nigeria: Implication on the K-Pg Boundary

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Abstract. Attempt was made to retrieve palynomorph and calcareous nannofossil from samples retrieved from first down-hole shale occurrence in three contiguous basins (Anambra, Bida and Benin Basins) in Nigeria with a view to determining their ages, paleoecology and the K-Pg boundary. A total of one hundred and sixteen species were recovered from all the samples. The occurrence of *Echitriporites trianguliformis* in the Anambra basin suggests ages of Campanian to Maastrichtian, while the common occurrence of *Retitricolporites* sp which is Paleocene to Eocene in samples from Anambra and Bida Basins confirms age relation. This modern palm (*Retitricolporites* sp) and fungal spores as well as the absence of algae spores and nannofossil suggest swamp environment of deposition and a hot tropical to subtropical climate. Its absence in the Benin basin suggests a little deviation in the age of deposition. An observed spike in the occurrence of *Cyathidites* sp and *Laevigatosporites* sp in the Okeluse samples suggest K-Pg boundary.

Keywords: K-Pg boundary, Nigeria, palynomorphs, *Cyathidites* sp, *Laevigatosporites* sp.

Highlight:

The first down-hole shales in three contiguous basins were studied for K-Pg boundary
The shales contain long-ranging forms like *Echitriporites trianguliformis*
Cyathidites sp and *Laevigatosporites* sp spikes suggest K-Pg boundary
Absence of nannofossil and fungal spore suggests swamp environment of deposition
Further study using Iridium anomaly recommended

1 Introduction

The relict of the K-Pg boundary resulting from the asteroid impact on the biosphere that occurred about 66 Ma ago has been recorded worldwide. The impact led to abrupt global ecosystems disruptions and a global extinction of several fossil groups. Major losses with widespread changes in terrestrial and marine biotic representation were also recorded within groups that did not go extinct. According to Vadja and Bercovici (2014), about 350 k-pg boundary sections have been described globally, among which 105 are terrestrial deposits. Prominent among the evidence of this event is occurrence of iridium anomaly, which has been used extensively to define the boundary (Slimani et al., 2010). Notwithstanding, records show that the K-Pg boundary is not marked by a mass extinction of dinoflagellate cyst species, but shows important changes in relative abundances of different species or group of morphologically related species in a section in northern Mexico (Slimani et al., 2010). The dynamics of the plant cover is another major component of the biological response across the K-Pg interval and associated destabilization worldwide suggesting the usefulness of palynology in the identification of the boundary.

In Nigeria, the K-Pg boundary appears yet to be identified at outcrops, in spite of the numerous outcrops already described in the literature. The area around the central portion of Nigeria at the interception of the Bida Basin, Anambra Basin and the Dahomey Basin constitute the best target area to get this boundary at outcrop. This is because by the beginning of the Paleogene evidence abound that the focus of sedimentation in most of the cratonic basins in Nigeria shifted southward from the central

area and northward i.e. to the Bornu sub-Basins of the mega- Chad Basin. Generally, the formation of the cratonic basins in Nigeria followed the break-up of the South American and African continents in the Early Cretaceous (Murat, 1972; Burke, 1996) but various lines of evidence abound to support the evolution of the Bida and Anambra Basins during the Anambra-Benin phase (Campanian-Mid Eocene) of the three phases of the development of the southern Nigerian sedimentary basins. On the Geological Survey Map of Nigeria, the area is expressed as being covered by the Nkporo shale (Fig.1A).

The primary focus of this study is to examine palynological evidence for the establishment of the K-Pg boundary in the area around the interception of these three contiguous basins: the Bida Basin, the Anambra Basin and the southwestern Nigerian portion of the Dahomey Basin in Nigeria. The study also examines the possible biostratigraphic relationship among the three contiguous basins in terms of a merger during the transition between the Cretaceous and Paleogene. The study is based on outcrop and very shallow borehole drilled for ground water exploitation.

2 Geological Background

2.1 Basin Evolution

The evolution of sedimentary basins in the West Central Africa Rift Systems (Genick, 1993), which includes the hydrocarbon rich, Gulf of Guinea Province and that of the West-Central Coastal Province (Brownfield and Charpentier (2006) has been described in a framework classified into pre-rift, syn-rift and post rift. The pre-rift incorporates Pan-African orogenic events, which in addition to creating cratons likely generated major lineaments or incipient faulted areas along which rifting occurred during the syn-rift phases in the Cretaceous. The most prominent rifting event is the separation of the African and the South American plates. Other events include formation of sedimentary basins along the presage fault zones. Post-rift events include the closing of the formed basins and some volcanic activities. In addition, the post rift events led to significant change in the focus of sedimentation along the faulted zones.

In Nigeria, while no evidence of the pre-rift sedimentation has been shown, Syn-rift sedimentation in the Abakali-Benue axis including Bornu sub-basin of the Mega-Chad Basin and Dahomey Embayment (Aptian –Santonian) are well documented. Following the collision of the African and the Eurasian Plates in the Santonian, and movement reversal of the African plate, all the already formed basins were subjected to compression that resulted in folding and faulting. Folding in the Abakaliki-Benue trough axis caused a change in sedimentation axis southward leading to the formation of the Anambra Basin. The Anambra Basin is a synclinal structure consisting of more than 5,000m thick of Upper Cretaceous to Recent sediments representing the third phase of marine sedimentation in the Benue Trough (Ladipo, 1988; Akande and Erdtmann, 1998). The Bida Basin is often taken to be a northwesterly extension of the Anambra Basin or an extension (N/W-S/E) of the Benue rift. It has been described as a rifted, sag Basin or a gently down-warped trough (Brownfield and Charpentier, 2006). Importantly, the geology indicates a rift related origin (King 1950; Kogbe et al., 1981; Ojo and Ajakaiye, 1989), which associates with the Benue Trough system. The basin consists of Upper Cretaceous clastic sequence of sandstones, shales, siltstones and ironstones.

The Nigerian portion of the Dahomey Basin extends from the boundary between Nigeria and Republic of Benin to the Benin Hinge Line down to the Atlantic Ocean (offshore). At the onshore area of the basin, both the Cretaceous and Tertiary rocks outcrop.

2.2 Stratigraphic Consideration

Based on Figure 2, the stratigraphic units where the K-Pg boundary could be found in the study area consist of Araromi Shale/Imo Formations in the Benue Basin, Imo and Nsukka/Ajali/Mamu/ Enugu/ Nkporo in the Anambra Basin and the Agbaja/Patti/Lokoja/Batati/Enagi/Sakpa and Bida Formations in the Bida Basin. All these formations have been studied at outcrop. An outcropped section of Enugu shale at Agbogugu, Anambra Basin contains *Ammobacultiesamabensis*, *Hapfragmoides sahelense*, *Siroplectammia hausorum textularia gilbedina*, *Ammobaculties sp* and *Haplophragmoides sp* (*Omoboriowo et al., 2012*). These are benthos that span from Campanian to Maastrichtian, deposited in

a coastal swamp, tidal flat to estuarine, delta front to inner neritic environments of deposition (Omoboriowo, et al., 2012).

The Mamu Formation that is characterized by fossiliferous dark gray, indurated, fissile shale, overlain by intercalation of sand and shale facies sequence with coal inter-beds inferring deposition under shallow marine conditions has been dated Middle-Upper Maastrichtian in the Anambra Basin (Ogala et al, 2009).

Within the Bida Basin the oldest facies have been dated Campanian (Adeleye, 1989). Outcrops of the Patti Formation within the basin occur in Ahoko. This formation consists of sandstones, siltstones, claystones and shales interbedded with bioturbated ironstones. Argillaceous units are said to predominate in the central parts of the basin. The siltstones of the Patti Formation are commonly parallel stratified with occasional soft sedimentary structures (e.g. slumps), and other structures such as wave ripples, convolute laminations, load structures (Obaje, 2009). The age of the Bida Formation is uncertain and has been speculated to be Campanian – Maastrichtian (Nwajide, 2013). Specifically, in the south eastern part of the Bida Basin where the microfloral assemblages of the Patti Formation had been studied, a Maastrichtian age was assigned to the formation.

Mebradu (1983) studied two outcropped sections at Ugbogui and Ofumwegbe along Benin-Lagos expressway in the western flank of the Anambra Basin (Fig.1B) and found that the sediment could be the regressive upper Cretaceous sediments (Campanian –Paleocene) or lateral equivalent of lower Imo formation of Paleocene age. This calls for a further review of his result.

3 Methodology

3.1 Sample Location

Samples were obtained from ten locations for this study. In the Anambra Basin samples were taken from Arimogija (N06°49'42.0¹¹, E005°42'49.7¹¹), Omolege junction (N06°48'55.7¹¹, E005°38'33.1¹¹) along Okeluse road, Ute (N06°50'49.2¹¹, E005°36'42.3¹¹) and at Odiase camp (N06°57'53.1¹¹, E005°44'38.1¹¹) (Fig.1C). At Ute two samples were taken from shallow water borehole at two depths interval 140 and 200 ft. Three samples were collected from Ahoko area (E006°51.474¹ and N08°18.831¹) along road cut at about 7 km away from Gerinya junction, at Ahoko-Ebira along Lokoja Abuja express way in Bida basin (Fig. 1D).

3.2 Palynomorphs

Each of the samples was subjected to palynomorphs and calcareous nannofossils analysis. Fifteen grams of each of the samples were treated with 45% Hydrofluoric acid (HF) in a fume cupboard to remove silicate materials from the sample. Distilled water was used for rinsing. Hydrochloric acid (HCl) was added to each of the samples and heated on hot plate for about 25- 30 minutes. Distilled water was added and left for one hour before decantation to eliminate the acid content. Brason Sonifier was used for sieving before the samples were centrifuged for about 3-5 minutes in order to separate the heavy material from the floating palynomorphs and lighter palynodebris.

The floating palynomorphs and lighter palynodebris were pipetted from the test tubes and uniformly spread over cover slips and allowed to dry for about one hour. Two drops of Canada balsam was used to glue the slide with the cover slip. The cover slips containing the dried residue were gently mounted over the glass slides. The slides were then allowed to dry under the sunlight for about 5-10 minutes.

The identification was done by using a light transmitted binocular microscope. Each prepared slide was scanned in turn on the movable stage microscope from end to end horizontally until the entire area of the cover slip was covered. Species name and the number of times each species encountered was counted and recorded on the palynology analysis sheet. Photomicrographs of the observable forms were taken.

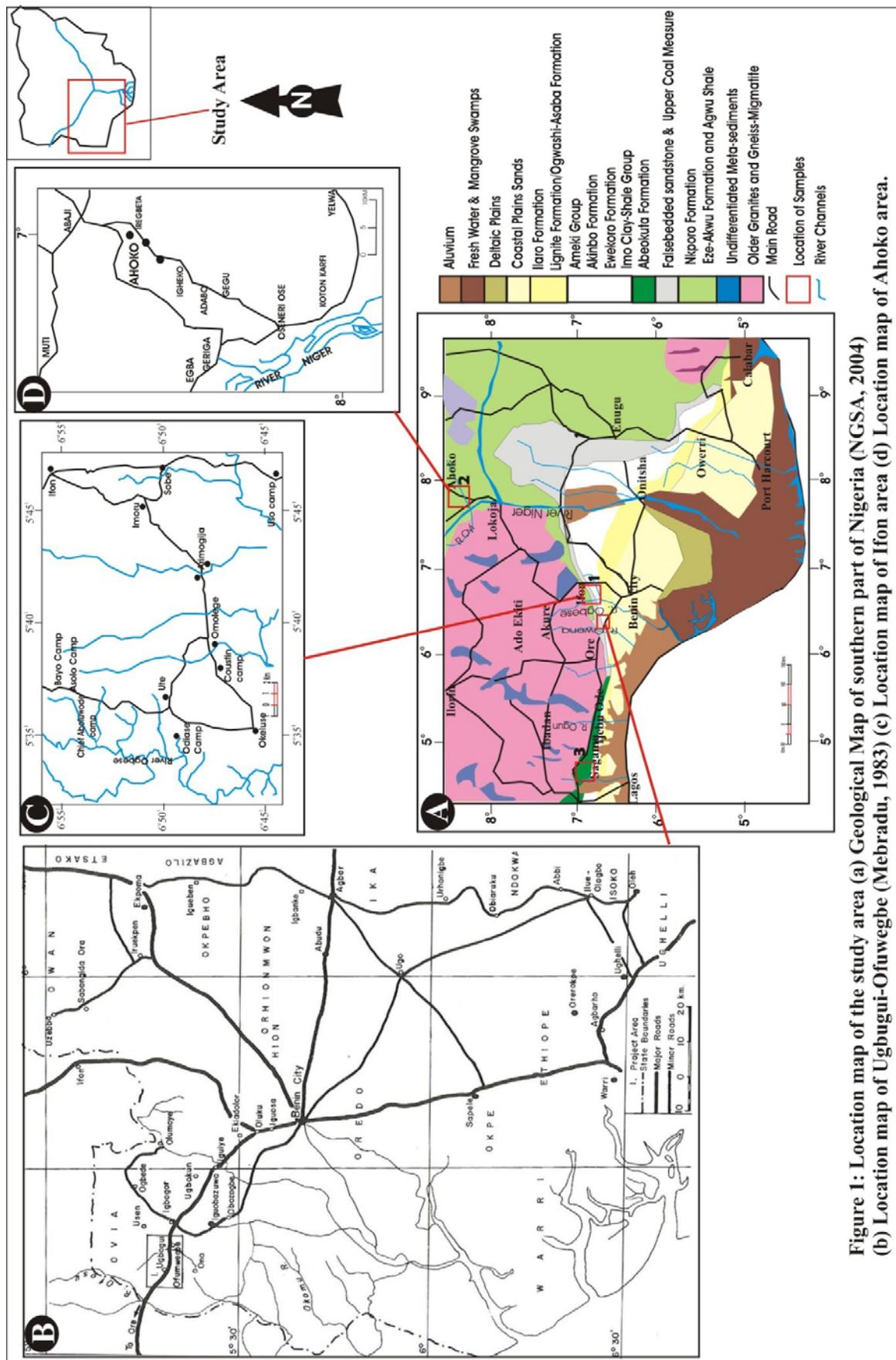


Figure 1: Location map of the study area (a) Geological Map of southern part of Nigeria (NGSA, 2004) (b) Location map of Ugbugui-Ofuwegbe (Mebradu, 1983) (c) Location map of Ifon area (d) Location map of Ahoko area.

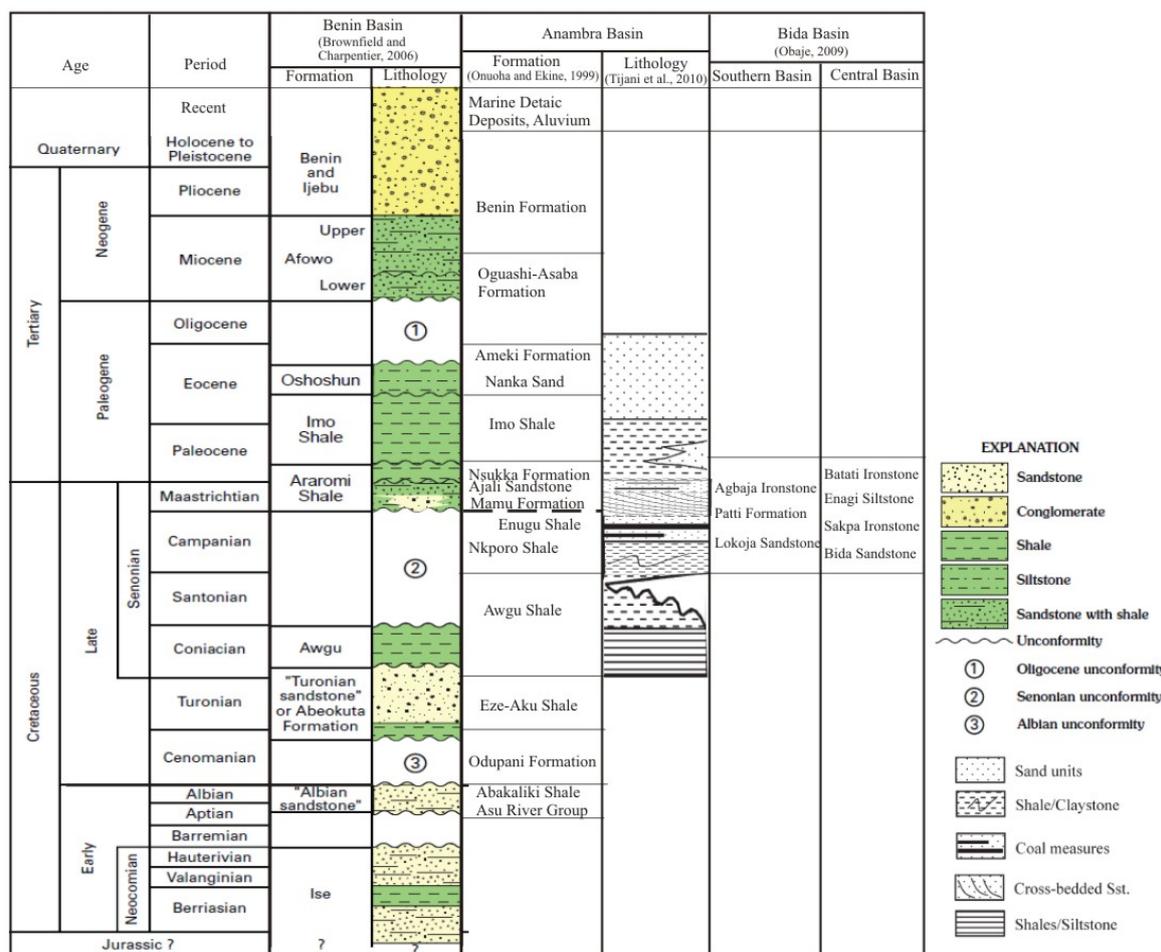


Figure 2. Stratigraphy of the Benin (Offshore and Onshore), Anambra and Bida basins.

3.3 Calcareous Nannofossils

Five grams of each sample was pulverized using mortar and pestle gently to avoid destroying the nannofossils in the sediment. The pulverized samples were then collected into the beaker and stirred in distilled water and then allowed to settle. The floating portion was gently collected with the disposable pipettes and spread on slides on the hot plate. The fluid on the slides was allowed to dry while still on the hot plate and finally covered using Canada balsam with the cover slips.

4 Presentation and Interpretation of Data

The palynological distribution chart is presented in Figure 3. The palynomorph recovery was moderate to poor. Only sediments collected from the Anambra and few from Bida Basins contain palynomorphs. In all, one hundred and sixteen forms made up of 65 species were recovered. No nannofossil was recovered from all the samples. The Anambra basin whose sediments are represented by L1 to L5 actually shows significant abundance of palynomorphs. Only location B2 among the samples collected in Ahoko section of the Bida Basin contains relatively few palynomorphs, while the other two samples (B1 and B3) are completely barren. Similarly, the Benin Basin samples (C1 and C2) exhibit very poor palynomorphs recovery and were deemed barren. Of the recovered forms (Fig. 3), only *Retitricolporites*

sp., *Tricolporites sp* are common to both the Anambra and Bida Basins while *Laevigatosporites sp* is common to all the three basins.

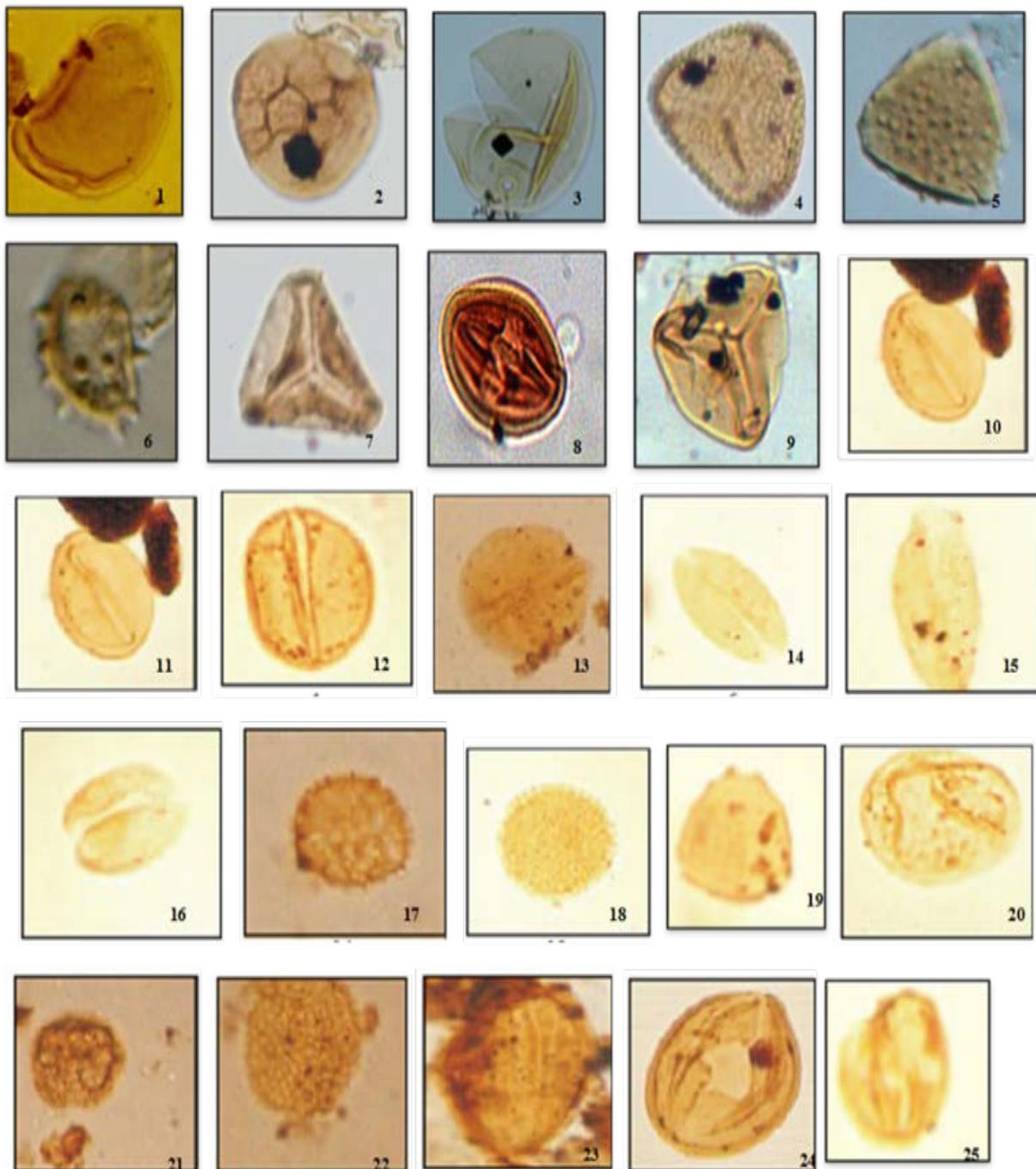


Figure 3. Palynological distribution chart of palynomorphs recovered from first down-hole shale from basins in the central portion of Nigeria.

L O C A T I O N	DEPTH IN FEET	Taxonomic Groups																										Number of Species found	Total Count										
		Cyathidites sp	Periretisyncolpites sp	Acrostichum aureum	Baculiporites sp	Constructipollenites ineffectus	Dinoflagellates indeterminate	Droseridites sp	Echitriporites trianguliformis	Foveotriletes margaritae	Fungal spore	Gleichenidites sp	Gleichenidites sp	Gnetaceapollenites diversus	Inaperturopollenites sp	Laevigatosporites sp	Leiosphaeridae sp	Longaperites sp	Malgoccolporites sp	Milfordia sp	Monocolpites sp	Monoporites annulatus	Monosulcites sp	Operculodinium sp	Podocarpidites sp	Pollen indeterminate	Protacidites sp			Proxaperites sp	Psilamocolpites sp	Psilatriporites sp	Retidiporites sp	Retimonocolpites sp	Retitricolporites sp	Sapoxacea sp	Tricolporites sp	Tricolporopollenites sp	Verrucatosporites sp
L1		1	-	-	-	-	-	-	-	-	1	1	-	1	1	3	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	10	12
L3		-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3	3	
L4		2	1	-	-	-	-	-	-	-	-	-	2	-	1	3	-	1	-	1	1	-	-	-	-	-	-	-	-	-	1	-	2	-	2	-	10	17	
B1		-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	
B2		-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	3	4		
B3		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	
C1		-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	
C2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	
L5	140	6	-	4	-	2	-	-	1	-	1	-	1	4	1	1	1	3	4	2	2	-	-	3	1	1	4	-	1	2	1	2	4	2	-	24	54		
L5	200	2	-	2	1	1	1	1	1	1	1	-	1	4	1	1	2	2	2	2	2	-	-	1	1	2	-	-	1	1	2	-	-	-	-	17	23		
Total Species		11	1	6	1	3	1	1	1	1	4	2	2	1	4	8	5	6	1	4	7	5	3	1	1	4	1	1	2	6	1	5	6	2	2	65	116		

Plate 1. All figures x 400

1. Laevigatosporites sp
2. Zlivisporites blaneensis
3. Monoporites annulatus
4. Foveotriletes margaritae
5. Echitriporites trianguliformis
6. Droseridites sp
7. Gleichenidites senonicus
8. Leiosphaeridia sp
9. Cyathidites sp
- 10-13. Monocolpites marginatus (Ogala et al, 2009)
- 14-16. Monosulcites sp (Lawal and Moullade, 1986)
- 15-18. Constructipollenites ineffectus (Ogala et al 2009)
19. Echitriporites trianguliformis (Ogala et al, 2009)
20. Inaperturopollenites sp (Lawal and Moullade, 1986)
- 21-22. Zlivisporites blaneensis (Ogala et al, 2009)
23. Retimonocolpites sp. (Lawal and Moullade, 1986)
- 24-25. Tricolporopollenites sp (Jardine and Magloire, 1965)

5 Discussion

5.1 Age Assignment

Prominent among the recovered species is *Echitriporites trianguliformis* Van hoeken-Klinkenberg, 1964, which Mebradu et al., 1986 also recovered from the same section. Atta-Petters and Salami (2004) described two morphotypes (the finely and the coarsely echinate forms) of this species. The recovered one in this study appears like the coarsely echinate forms Plate 1. 19. According to Germeraad et al (1968), *Echitriporites trianguliformis* is a marker species that is common in the Upper Cretaceous of northern South America and though also important in the Eocene of Nigeria meaning that it ranges from Maastrichtian to Eocene age. *Gleicheniidites* sp, *Zlivisporites blaneensis*, and *Leiosphaeridia* sp. form a good assemblage for Maastrichtian sediments. Another Maastrichtian-Eocene form recovered in this study is *Foveotriletes margaritae* (Van der Hammen) Germeraad et al., 1968 and Atta-Petters and Salami, 2004). The LAD of *Foveotriletes margaritae* is 56.07 Ma (Jaramillo et al., 2011). One of the distinctive species encountered in Murshe 1 well of the Bornu Basin Nigeria is *Zlivisporites blaneensis* (Ola-Buraimo, 2013). The form has been found in association with the other forms of the *Spinizonocolpites* Assemblage Zone of Lawal and Moullade (1986) used in dating a section of the Mamu coal facies in the Anambra Basin as Late Maastrichtian. The monosulcate pollen *Proxaperites* also occurs in the studied section. This species has been described as common in the Paleocene. With these, the sections studied contain long ranging forms that suggest their deposition during Maastrichtian to Paleocene. This is in line with the view of Mebradu (1983). In addition however the sediments collected from the Benin Basin appear younger in age.

Other important forms found in this study are *Foveotriletes margaritae* and *Monoporites annulatus*. According to Oloto (1994), *Foveotriletes margaritae* is a Maastrichtian fossil with biospore zone of A-1

and is equivalent to *Palaeocystodinium australinium* dinoflagellate cyst zone of Gbekobo -1 well of Nporo shale. In the same study, *Monoporites annulatus* was used as Eocene form that is equivalent to *Apectodinium cornufruticosum* and *Amiculosphaeraum bracula* dinoflagellate cyst zones of Gbekebo-1 and Nsukka -1, Imo shale and Ameki Formation.

5.2 Absence of Nannofossils

In this work, only sediments collected from the southwestern flank of Anambra and few from Bida basins contain palynomorphs that are good enough for geological deduction. All the samples analyzed are barren of nannofossils. Several reasons could be responsible for this. The most important ones are: harsh environmental condition specifically dry climate associated with the drop in sea level causing high salinity and fluvial processes related to the regressive phase; deep and unfavourable bottom water conditions. The issue of carbonate compensation depth (CCD) may not be what has affected nannofossils in the study area. Possibly, it must be a result of weathering that is characteristic of the study area.

5.3 Evidence of Environmental Destabilization at the K-Pg Boundary

Bercovici et al. (2012) demonstrated that long-ranging taxa with none or low biostratigraphical value can reveal paleoenvironmental variations across boundary interval. The occurrence of a fern-spore spike event has been shown to associate with the K-Pg boundary at multiple localities in North America (Orth et al., 1981; Tschudy et al., 1984; Fleming & Nichols, 1990; Sweet et al., 1999; Nichols & Johnson, 2002; Nichols, 2007; Rook et al., 2010; Bercovici et al., 2012) and in terrestrial and coastal sequences in New Zealand (Vajda et al., 2001, 2004; Vajda & Raine, 2003; Vajda & McLoughlin, 2004). Similarly, in the Western Interior, it is marked by a high occurrence (75% or more) of *Cyathidites* and *Laevigatosporites* within a narrow stratigraphic interval (Tschudy et al., 1984; Fleming & Nichols, 1988; Nichols & Fleming, 1990; Bercovici et al., 2012) which can be as thin as 1 cm (Sweet & Braman, 1992). In the Northern Southern America province (ASA) the effect of this impact has not been clearly defined (Vajda and Bercovici, 2014).

In this study a spike in the occurrence of *Cyathidites* and *Laevigatosporites* is observed in the shale collected at depth 140 ft within Okeluse town (Fig. 3). This sample also contains *Proteacidites*, which Song et al. (1995) reported its disappearance though among others at the K-Pg boundary within the Taizhou Formation of the Jiangsu Province. Similarly among the three spot samples in the Ahoko section, sample L4 also suggests a spike. In earlier study of the Nigerian coal deposits of the Southeastern Nigeria, Van hoeken-Klinkengerg (1964) observed an increase in the occurrence of *Longapertite marginatus* along the studied section, which was used to indicate a transition from Cretaceous to Tertiary. Although *Longapertite ssp* has not been globally used to define K-Pg boundary, in the Ahoko section sample L4 has 3 species suggesting a relatively high occurrence of the form.

Clearly, the number of samples studied makes it difficult to define any systematic increase or decrease in the occurrences of these two forms. Notwithstanding, these coincidences suggest further study of the section to really establish this boundary in Nigeria. Based on the few samples recovered, the sediments of sample L4 and depth 140ft suggest a more conducive marine condition (transgression) and likely marked the K-Pg boundary in the central portion of Nigeria.

6 Conclusions

The first down hole shales occurrence of the area around the intersections of three contiguous basins in Nigeria contain long-ranging forms like *Echitriporites trianguliformis*, *Gleicheniidites sp*, *Zlvisporites blaneensis*, *Leoisphaeridae sp* and *Foveotriletes margaritae* suggesting Maastrichtian to Paleocene. Notwithstanding, in spite of the few forms recovered, a presumed spike in the occurrence of *Cyathidites sp* and *Laevigatosporites sp* in Okeluse, samples at a depth of 140 ft and the lower part of Ahoko section suggest K-Pg boundary. An Iridium anomaly study is suggested for the sections to pin down the relict of this global event in Nigeria.

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