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Microphytoplankton and Geological Boundaries in Maastrichtian to Lutetian Succession of Ajire-1 Well Anambra Basin, Nigeria

Lucas F. A.

Department of Geology
University of Benin, Benin-City, Nigeria
E-mail: drfalucas@gmail.com

ABSTRACT

Dinocysts and acritarchs recovered from Ajire-1 well were evaluated and appraised for their palynostratigraphic utilities. Interpretation of their bio-events allows the recognition, delineation and numerical age dating of five stage boundaries in the well section. These are from oldest to youngest Maastrichtian / Danian, Danian / Selandian, Selandian / Thanetian, Thanetian / Ypresian and Ypresian / Lutetian boundaries respectively. The last appearance datum [LAD] of *Paleocystodinium australinium* allows the recognition of early/late Selandian boundary. Comparison of the bio-events identified in this study with internationally established planktonic foraminiferal zonal schemes suggests numerical age estimates of the five stage boundaries as 65.0Ma, 60.9Ma, 59..2Ma 54.8Ma and 49.0Ma respectively. The early /late Selandian boundary is 60.0Ma.It is envisaged that the information documented in this paper would enhance the interpretation and age characterization of sub-surface sequence stratigraphic events in the southern Nigeria sedimentary basins.

Keywords: Microphytoplankton; Boundaries; Maastrichtian; Lutetian; Ajire-1 Well; Anambra Basin.

INTRODUCTION

This study is focused on Ajire-1 well drilled in 1972 by Shell Petroleum Development Company of Nigeria (SPDC). The well is located in the western part of Anambra basin at latitude 6°15' N and longitude 6°45' E (Fig.1). It has a total penetrated depth of 2500m. The Anambra basin is located between the Benue trough in the north and Niger delta in the south (Fig.1). It contains the thickest and most complete sub-surface

Maastrichtian to Lutetian sedimentary succession in southern Nigeria. Six sub-surface lithostratigraphic Formations- Owelli-Sandstone, Mamu, Ajali Sandstone, Nsukka Coal Measure, Imo Shale and Ameki sand/shale were penetrated by the drill in the well. (Fig.2) Previous detailed dinoflagellate cyst studies to delineate and age date geological stage boundaries in southern Nigeria are: Jan du Chene and Adediran (1984), Oloto (1994) and (Asadu and Lucas, 2003). Oloto (1994) was unable to identify all the three Paleocene stages (Danian, Selandian and Thanetian), instead separated the Danian completely from the Paleocene. Asadu and Lucas (2003) was able to delineate the Paleocene into Danian, Selandian and Thanetian in-line with standard global stratigraphic scale. However, the previous works could not numerically age-date the events and as such may not be optimally adequate for numerical age characterization of sequence stratigraphic events in southern Nigeria sedimentary basins. At the moment, in Nigeria, the Paleocene epoch is yet to be well defined and delineated in accordance with the agreement reached in the 1984 meeting of international sub-commission on Paleogene stratigraphy (ISPS) as well as in accordance with the outcome of the 1993 symposium on the stratigraphy of the Paleocene (Schmitz, 1994). The Paleocene epoch in the chronostratigraphic chart in use for the sub-surface sequence stratigraphic interpretation of southern Nigeria sedimentary basins is still sub-divided and defined into Danian and Selandian stages.

Furthermore, Okosun (1987) used ostracod events to sub-divide the Paleocene section in Araromi-I well into Danian and Thanetian stages.
There is therefore, a need to streamline the various disparities inherent in the characterization of the Maastrichtian to Lutetian stratigraphy of southern Nigeria sedimentary basins and bring it in line with the new standard global stratigraphic scale. This work is therefore, aimed at using dinocysts and acritarchs to recognize, delineate and numerically age date all the stage boundaries as well as to identify and document new bio-events and markers suitable for global correlation with other

parts of the world. It is also envisaged, that this work will bring in-line the Nigeria stratigraphy with the new standard global stratigraphic scale.

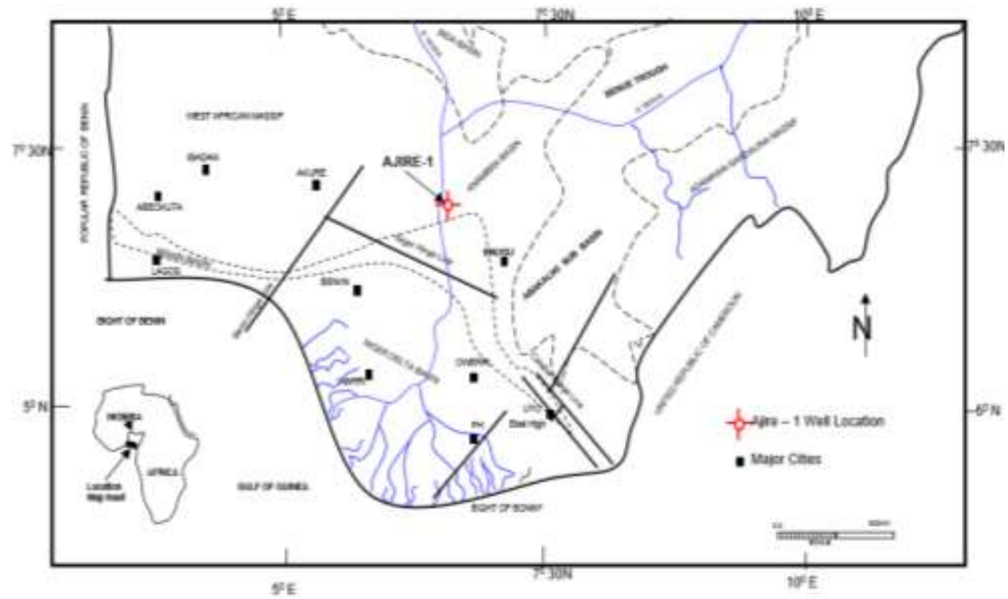

Fig. 1: Map of Southern Nigeria Sedimentary Basins showing Ajire-1 Well Location

MATERIAL AND METHODS

Fifty-one (51) sidewall samples recovered from the well were subjected to standard palynological maceration involving different stages of HCl, Hf, and HCl, Schultz's solution, KOH chemical digestions. The organic matter was recovered using zinc bromide solution of 2.2 specific gravity. The organic residue was subsequently mounted on a glass slide in Canada balsam medium for microscopic investigation and analysis.

RESULTS AND DISCUSSION

Age and Stage Boundaries

The identified dinocysts and acritarchs were evaluated, appraised and their bio-events used for the interpretation of the age and geological stage boundaries. The bio-event at each boundary was compared with international planktonic foraminiferal zones of Berggren, *et al.* (1995) in order to estimate their numerical ages. The reference slides in this paper were curated in the micropaleontological laboratory, center for palynological studies, University of Sheffield, England. All co-ordinates given are reverse England Finder's.

The recognition and delineation of age and stage boundaries have been possible by comparing the dinocysts/acritarchs identified in the well section to similar assemblages previously recovered and described from Cretaceous and Tertiary sections in Nigeria and other parts of the world. Notably among these previous works are Cookson and Eisenack (1965b,1965c), Morgenroth (1966a), William and Downie (1966), Drugg (1967,1970a), Grigorovich (1969a), Riegel (1974), Hansen (1977), Islam (1983c) Brown, *et al*. (1984b), Jan du chene and Adediran (1984), Berggren (1994), Brinkhuis, *et al.* (1994), Heilmann-clausen (1994) and Nohr-Hansen and Dam (1997). Review of the foregoing previous works made it possible to recognize and delineate six stages-Maastrichtian, Danian, Selandian, Thanetian, Ypresian and Lutetian. The bio-signals and assemblages in each of these stages are discussed in ascending order from the oldest (Maastrichtian) to the Youngest (Lutetian).

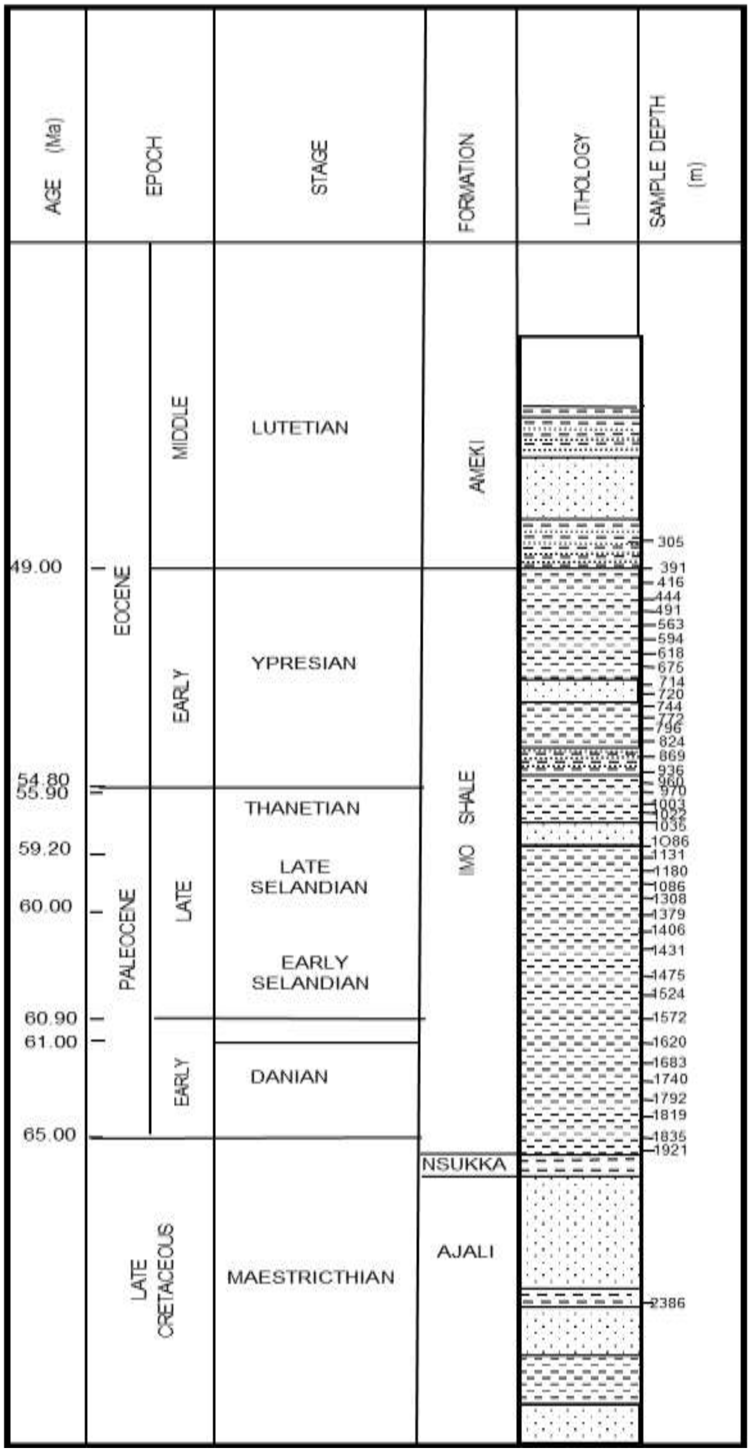

Fig. 2: Lithostratigraphic section and Age of Ajire-1 well

AJIRE - 1 (BY FIRST APPEARANCE)

DEPTH (METERS)	AGE	STAGE	PALAEOCYSTODINIUM GOLZOWENSE	CERODINIUM BOLONIENSE	AREOLIGERA SENONENSE	DIPHYSES COLLIGERUM	LEPTODINIUM sp(A) (WILLIAM&BRIXDEAUX)	SPINIFERITES RAMOSUS RAMOSUS	TUBIOSPHAERA FILOSA	ESCHARISPHAERIDIA POCOCKII	CYMATIOSPHAERA RADIATA	DAMASSADINIUM CARLIFORNICA	PALAEOPERIDINIUM PYROPHORUM	ACHOMOSPHAERA ALCICORNU	CORDOSPHAERIDIUM INODES	HAFNIASPHAERA SEPTATA	OPERCULODINIUM HIRSUTUM	XENICODINIUM RUGULATUM	DICONODINIUM sp.	FIBROCYSTA OVALIS	MEMBRANOSPHAERA sp(111) (DRUGG)	SELENOPEMPHIX NEPHROIDES	SENONIASPHAERA INORNATA	SPINIFERITES MIRABILIS	ALTERBIDINIUM ACUTULUM	BATIACASPHAERA sp. (SCHRANK)	CARPATELLA CORNUTA	CERODINIUM DIEBELII	CORDOSPHAERIDIUM CHIMAERA	FIBROCYSTA RADIATA	HAFNIASPHAERA CRYPTOVESSICULATA	LEPTODINIUM MEMBRANIGERUM	LEPTODINIUM sp.	PALAEOCYSTODINIUM AUSTRALINUM	PTEROSPERMELLA AUREOLATA	PTEROSPERMELLA BARBARAE	SPINIDINIUM DENSISPINATUM	XENICODINIUM LUBRICUM	FIBROCYSTA VENTENSE	GLAPHYROCYSTA EXUBERANS	LEJEUNECYSTA cf. L. CINCTORIA	LEIOSPHAERIDIA sp.	PTEPOSPERMELLA DANICA	SYSTEMATOPHORA PLACACANTHA
305	ME	LUTETIAN						2																											4									
391	ME	LUTETIAN									2											2																						
416	EARLY EOCENE	YPRESIAN																																										
444	EARLY EOCENE	YPRESIAN									3																																	
491	EARLY EOCENE	YPRESIAN																																									2	
563	EARLY EOCENE	YPRESIAN									4											17																				80	4	2
594	EARLY EOCENE	YPRESIAN																																										
618	EARLY EOCENE	YPRESIAN																				1																						
675	EARLY EOCENE	YPRESIAN																				2																						
714	EARLY EOCENE	YPRESIAN																																										
720	EARLY EOCENE	YPRESIAN																				1																						
744	EARLY EOCENE	YPRESIAN							2		2											2																						
772	EARLY EOCENE	YPRESIAN						6			3					3						1																						
796	EARLY EOCENE	YPRESIAN				1		5								4						2																						
824	EARLY EOCENE	YPRESIAN				1					2											2																						
896	EARLY EOCENE	YPRESIAN						5	3													1																						
936	EARLY EOCENE	YPRESIAN						7			2					3																												
960	EARLY EOCENE	YPRESIAN																																										
970	LATE PALEOCENE	THANETIAN				4		12			2					10																												2
1003	LATE PALEOCENE	THANETIAN				21		3			1					7																							11					3
1022	LATE PALEOCENE	THANETIAN							1		3					5						1						1															1	
1035	LATE PALEOCENE	THANETIAN				2			10					1									1	1															24					12
1086	LATE PALEOCENE	THANETIAN				4			3		1			5		8																						5	1					1
1131	LATE PALEOCENE	LATE SELANDIAN			8	2		4	28							7																							5					4
1180	LATE PALEOCENE	LATE SELANDIAN						5	5							2												1											4					2
1229	LATE PALEOCENE	LATE SELANDIAN				1		1								2																							75					
1308	LATE PALEOCENE	LATE SELANDIAN	6			11		5			1					15																			1				89					6
1379	LATE PALEOCENE	EARLY SELANDIAN	2					11			1			6	2	6						2		1										2					4					2
1406	LATE PALEOCENE	EARLY SELANDIAN				3			26					1																									20					10
1431	LATE PALEOCENE	EARLY SELANDIAN	14					16	6							6						2		2										41				7		6	6			
1475	LATE PALEOCENE	EARLY SELANDIAN	6			4			15							3						2												6										
1524	LATE PALEOCENE	EARLY SELANDIAN	6			4		10	19							14								2		7					3	2			1			1	1		2	4		10
1572	LATE PALEOCENE		22		2			4			5					5							5								2			5				8		26	3	3		3
1620	LATE PALEOCENE	DANIAN	3		8	3		2			4	38				2		3										3							3	4		6				6	1	8
1683	DANIAN	DANIAN	1		3	15		14			1	13		4	2	2	4	14		4		3	4	5		1	2	4			3							15	3	3	2	1	1	1
1740	DANIAN	DANIAN				4		8			2	5	2	2		8	3	2	2	2		3		2	1	2	4	1	2	4	3	4	5	2	1	2	7	1						
1792	DANIAN	DANIAN		2	3	4						24				3		2	1	2	2	3	5	2																				
1819	DANIAN	DANIAN		2	43	24		20		5		5	4	2	3	17	2	3																										
1835	DANIAN	DANIAN			4			5		6	1	4	4																															
1921	LC	MAESTRICHTIAN			15	11	1	11	7																																			
2386	LC	MAESTRICHTIAN	30	10																																								

DEPTH (METERS)	TANYOSPHAERIDIUM MAGDALIUM	ACHOMOSPHAERA RAMULIFERA	CLADOPIXIDIUM EXILIMURATUM	APECTODINIUMM QUINEQUELATUM	APECTODINIUMM HOMOMORPHUM	SPONGODINIUM DELITIENSIS	CONOSPHAERIDIUM sp.	DAPSILIDILIUM PASTIELSII	GLAPHYROCYSTA ODINATA	HETERAULACACYSTA CAMPANULA	SPINIFERITES MEMBRANACEUS	THALASSIPHORA sp. (OLOTO MS)	CHYTROEISPHAERIDIA sp. (A) (OLOTO MS)	CRIBROPERIDINIUM GIUSEPPEI	EOCLADOPYXIS PENICULATUM	WETZELLIELA ASTROIDES	APECTODINIUM PARVUM	LEJEUNECYSTA PULCHRA	ACOMOSPHAERA SAGENA	BATIACASPHAERA EXPLANATA	CORDOSPHAERIDIUM GRACILE	SPINIFERITES PSEUDOFURCATUS	ADNATOSPHAERIDIUM RETICULENSE	PERISSEIASPHAERIDIUM PANNOSUM	CHYTROEISPHAERIDIA sp.	CLEISTOSPHAERIDIUM SPINULASTRUM	IFECYSTA PACHYDERMA	HYSIRICHOSPHAERIDIUM TUBIFERUM	KALLOSPHAERIDIUM YORUBAENSE	OPERCULODINIUM TIARA	ADNATOSPHAERIDIUM MULTISPINOSUM	CATILOPSIS ABDITA	FIBROCYSTA BIPOLARE	HYSTRICHOSPHAERIDIUM TIBUFERUM var. BREVISPINUM	HYSTRICHOSPHAERIDIUM SALPINGOPHORUM	POLYSPHAERIDIUM SUBTILE var. KTANA	PALAEOSTOMOCYSTIS LAEVIGATA	BATIACASPHAERA cf. B. BACULATA	CASSIDIUM FRAGILE	LEJEUNECCYSTA LATA	HYSTRICHOKOLPOMA RIGAUDAE	TUBIOSPHAERA GALATEA
305																																										
391													4																			4										
416																																										
444										2																																
491																																										
563		2																																						1		
594																																										
618																																2								3		
675																																								2		
714																																										
720													2																											2		
744								1					2																													
772		3									1		1																													
796																							6																			
824					3			2					7	2			5													3										2		1
896				2																																						2
936													8						1			1							3			2										
960																										4						2										
970		2						1					10						30			2										2										
1003		1			3					3					14									2		3			1											2		
1022			2	2						16		2			75		1					4							5			4						1	2			
1035				6	2										17		1				2	3			4									1								
1086				3													3				17	13		1	1			3	40									1				
1131				2					1						16		2	2				6					2		26							2					2	6
1180				4	3					12					4							2		15	3		20		54		1					9		1	3	1		
1229									40						40												8				2						1					
1308		4				3	1		1						5						3	12	2	1	6	2		1	9		16	1	2	2	1	22						
1379						3									4		11					19			30	1	2	4	11	5												
1406				1					5						8					2	7	8	2	5																		
1431		6		9	2				5		2				22				5	1	1	10																				
1475					21			1						2	40	2	2	3																								
1524					4		2	3			8		6	1	15	3																										
1572		6	3	4	3	6	3	5	15	4	2	2																														
1620		1	6																																							
1683	2																																									
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1792																																										
1819																																										
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1921																																										
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DEPTH (METERS)	CALIGODINIUM AMICULUM	DEFLANDRA DENTICULATA	GINGINODINIUM TABULATUM	HOMOTRYBLIUM TENUISPINOSUM	IMPAGIDINIUM DISPERTITUM	LEJEUNECYSTA sp..	TRIVALVADINIUM FORMOSUM	ALISOCYSTA MARGARITA	ADNATOSPHAERIDIUM MEMBRANIPHORUM	GLAPHYROCYSTA TEXTA	POLYSPHAERIDIUM SUBTILE	PTERODINIUM CINGULATUM	THALASSIPHORA DECREMENTA	CANNOSPHAEPOPSIS sp.	HOMOTRYBLIUM PALLIDIUM	KENLEYIA LOPHOPHORA	SELENOPENPHIX ELEGANTULA	AREOSPHAERIDIUM POLYPETELLUM	LEJEUNECYSTA SP. 111 (DRUGG)	LINGULODINIUM MACHAEROPHORUM	OPERCULODINIUM DIVERGENS	OPERCULODINIUM SEVERINII	IMPAGIDINIUM ASPINATUM	MURATODINIUM FIMBRATUM	SPINIDINIUM SAGITTULUM	ADNATOSPHAERIDIUM VITTATUM	APECTODINIUM FOLLICULUM	FIBROCYSTA LAPPACEA	DIPHYSES SPINULUM	GERDIOCYSTA CASSICULA	LEJEUNECYSTA SPATIOSA	LEJEUNECYSTA sp. (A)	LEJEUNECYSTA GLOBOSA	TUBIDERMODINIUM SULCATUM	CORDOSPHAERIDIUM MULTISPINOSUM	HOMOTRYBLIUM CALICULUM	OPERCULODINIUM ERINACEUM	LEJEUNECYSTA sp. (B)	LENTINIA Sp	MICHRYSTRIDIUM STELLATUM	BALTISPHAERIDIUM NANUM	DINOPTERYGIUM CLADOIDES
305																																										
391																																								4	39	3
416																																								2		
444																																										
491																	2			2																			2	2		
563							4									2	1					4										5	4					4	8	18		
594																								4													1					
618				1												5		2						43				2								1						
675																3								2					1													
714																		5						2											1							
720				3	2													4						2					1					10								
744				5											2																2		2	2								
772																2																	2									
796					10											1		9	2					8				18		3												
824					2										4	1	2					1					2	16		18	6	2										
896															2	5						2		3					1													
936							25					2									11			67		2	25															
960																15							2	5	4																	
970	3					2					2	20				39		2	2	8	2	2																				
1003	60			2		1	4					7	5		30	3	3																									
1022		2			1	7	23				7		1	1	2	1																										
1035				2			12	1	2	4	50	1	5																													
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LC: LATE CRETACEOUS
ME: MIDDLE EOCENE

Figure 3. Quantitative stratigraphic distribution of microplankton in Ajire -1 well

Maastrichtian

The absence of Danian diagnostic dinocysts and the presence of *Cerodinium boloniensis, Diphyses colligerum* and *Paleocystodinium golzowensis* at 2386m and 1921m suggests a Maastrichtian age. *C. boloniensis* was previously reported by Riegel (1974) from late Cretaceous dinocyst assemblage in southern Spain.

K/T (Maastrichtian/Danian) boundary

The K/T boundary is placed at 1835m based on the first stratigraphic occurrences of Danian diagnostic dinocysts. These are *Damassadinium californicum* and *Carpatella cornuta*. Other dinocyst events at about the boundary are *Paleoperidinium pyrophorum, Fibrocysta Ovalis, Spinidinium densispinatum* and *xenicodinium rugulatum* FADs. The FADs of *D. californicum* and *C.cornuta* are global indicators of K/T boundary. Both events have been used by Brinkhuis, *et al.* (1994) to delineate the K/T boundary at El Kef section in NW Tunisia. They also recognized the FAD of *S. densispinatum* in the Danian of El Kef section. Similarly Hansen (1977) used the two events to delineate the K/T boundary in Denmark.

Danian

The Danian is defined in this well as the interval from the K/T boundary at 1835m to the extinctions of *D.californicum, C. cornuta, X. rugulatum* and *F. ovalis* at 1820m. Grigorovich (1969a) originally described *C. cornuta* from the Danian of Carpathian section in Eastern Europe. Drugg (1967) reported occurrence of *D. Californicum, F.ovalis* and S.densispinatum from Danian deposits of upper Moreno Formation in Escarpardo Canyon, USA.

Danian/Selandian boundary

This boundary is placed at 1572m based on *Apectodinium homomorphum, Apectodinium quinequelatum and Spongodinium* delitiensis FADs with concurrent extinctions of Danian diagnostic markers. (Fig.3). Globally, the FAD of genus *Apectodinium* is used to delineate Danian /Selandian boundary. This event has been reported in the El Kef section, NW Tunisia and North Sea by various authors.

Selandian

The Selandian is defined as the interval from *Apectodinium homomorphum* FAD at 1572m to *Caligodinium amiculum, Deflandra denticulate, Ginginodinium tabulatum* FADs at 1086m. *S.delitiensis* reported from the Danian section of Nuusuaq/Annertuneq in West Greenland by Nohr-Hansen and Dam (1997) ranges from the base to top of Selandian in Ajire-1 well.

Selandian/Thanetian boundary

The Selandian/Thanetian boundary is placed at 1086m based on *C.amiculum, D. denticulata and G. tabulatum* FADs. Heilmann-C (1994) used *D. denticulata* FAD to delineate the Selandian/Thanetian boundary in the North Sea. This event is the base of *A. margarita* zone in the North Sea. Furthermore, *G. tabulatum* was originally described from the Paleocene shell bed in Pebble Point Formation, southwest Victoria, Australia by Cookson and Eisenack (1965c).

Thanetian

The Thanetian is defined as the interval from *C amiculum, D. denticulata and G.tabulatum* FADs at 1086m to *Areospharidium polypetellum* and *Operculodinium divergens, and C. amiculum* LADs at 960m. In this study, *C amiculum* ranges from the base to top of Thanetian (Fig.3). Drugg (1970b) reported occurrence of *C amiculum* from the Paleocene of the US Gulf Coast. The extinction of *Cassidium fragile* is at 1022m in the Thenetian (Fig.3). Drugg (1967) reported the occurrence of *C. fragile* in the Paleocene of Moreno Formation of Escarpardo Canyon, USA. The FAD of *Kenleyia lophophora* is in the Thanetian. Cookson and Eisenack (1965) reported occurrence of *K.*

lophophora in the Paleocene Dartmoor Formation in southwest Victoria, Australia.

Thanetian/Ypresian boundary

This boundary is placed at 960m based on the *Areospharidium polypetellum* and *operculodinium divergens* FADs*, and C. amiculum* LAD. Islam (1983) originally described *A polypetellum* from the early Eocene section (London Clay Formation) of Hampshire and London Basins. The occurrence of *A. polypetellum* at 960m allows correlation to the early Eocene of England and suggests a numerical age estimate of 54.8ma for the Thanetian/Ypresian boundary in this study. The FAD of *Muratodinium fimbratum* is at 970m just below the Thanetian/Ypresian boundary

Ypresian

The Ypresian is defined as the interval from *A. polypetellum* FAD and *C. amiculum* LAD at 960m to *Baltisphaeridium nanum* FAD at 418m. Other bio-events diagnostic of the Ypresian are *Gerdiocysta cassicula, Diphyses spinula and Spinidinium sagittulum* FADs. The three dinocysts species were originally described by Drugg (1970b) from the Eocene section of Upper Wilcox Formation in the US Gulf Coast. Also recovered from the Ypresian section of this well are typical Eocene diagnostic dinocyst species reported from the Eocene section of NW Europe (northern Germany and Belgium) by Morgenroth (1966a). These are *Operculodinium tiara, Operculodinium erinaceum* and *Tubidermodinium sulcatum.* (Fig.3). The acritarch species *Micrhystridium stellalum* occurs in the upper section of the Ypresian.

Ypresian/Lutetian boundary

This boundary is placed at 418m based on *Baltisphaeridium nanum* FAD. There is an influx of this acritarch species at the boundary.

CONCLUSION

Microphytoplankton (dinocysts and acritarchs) recovered from Ajire-1 well permitted the delineation of geological stage boundaries from the Maastrichtian to Lutetian succession. These are Maastrichtian/ Danian/ Selandian/ Thanetian/ Ypresian/ Lutetian boundaries respectively.

Comparison of the events at each boundary with assemblages in other parts of the world and subsequent comparison with the international plankton zonal scheme of Berggren *et al.* (1995) suggest their numerical age estimates as 65.0Ma, 60.9Ma, 59.2Ma, 54.8Ma and 49.0Ma respectively. The Paleocene epoch was characterized into three stages – Danian, Selandian and Thanetian in line with standard global stratigraphic scale. This study has therefore streamlined the various disparities inherent in the characterization of the Paleocene epoch of the Nigeria sedimentary basins.It is suggested that the information documented in this paper would enhance the interpretation of sub-surface sequence stratigraphy of Southern Nigeria sedimentary basins.

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Plate 1

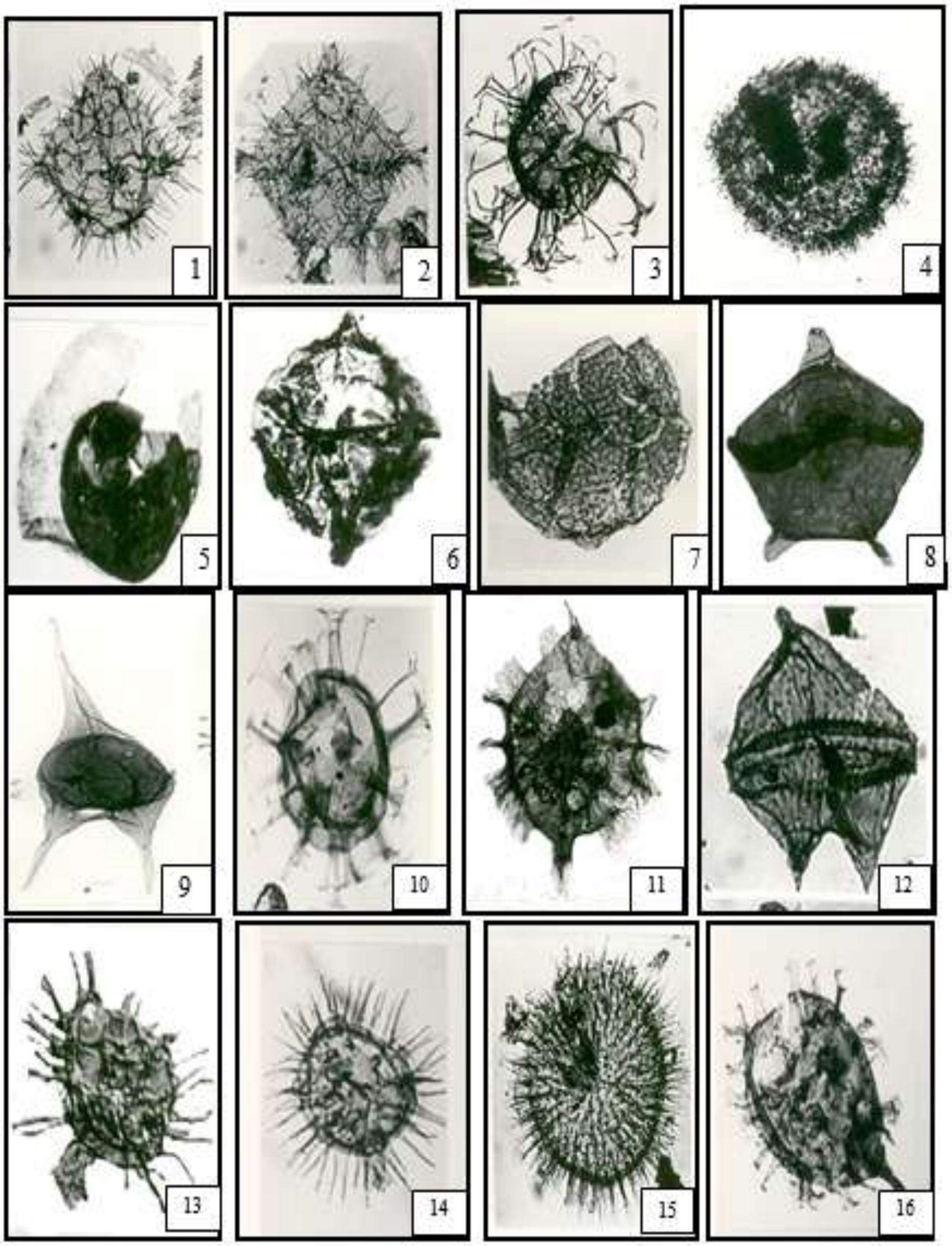

Plate 2

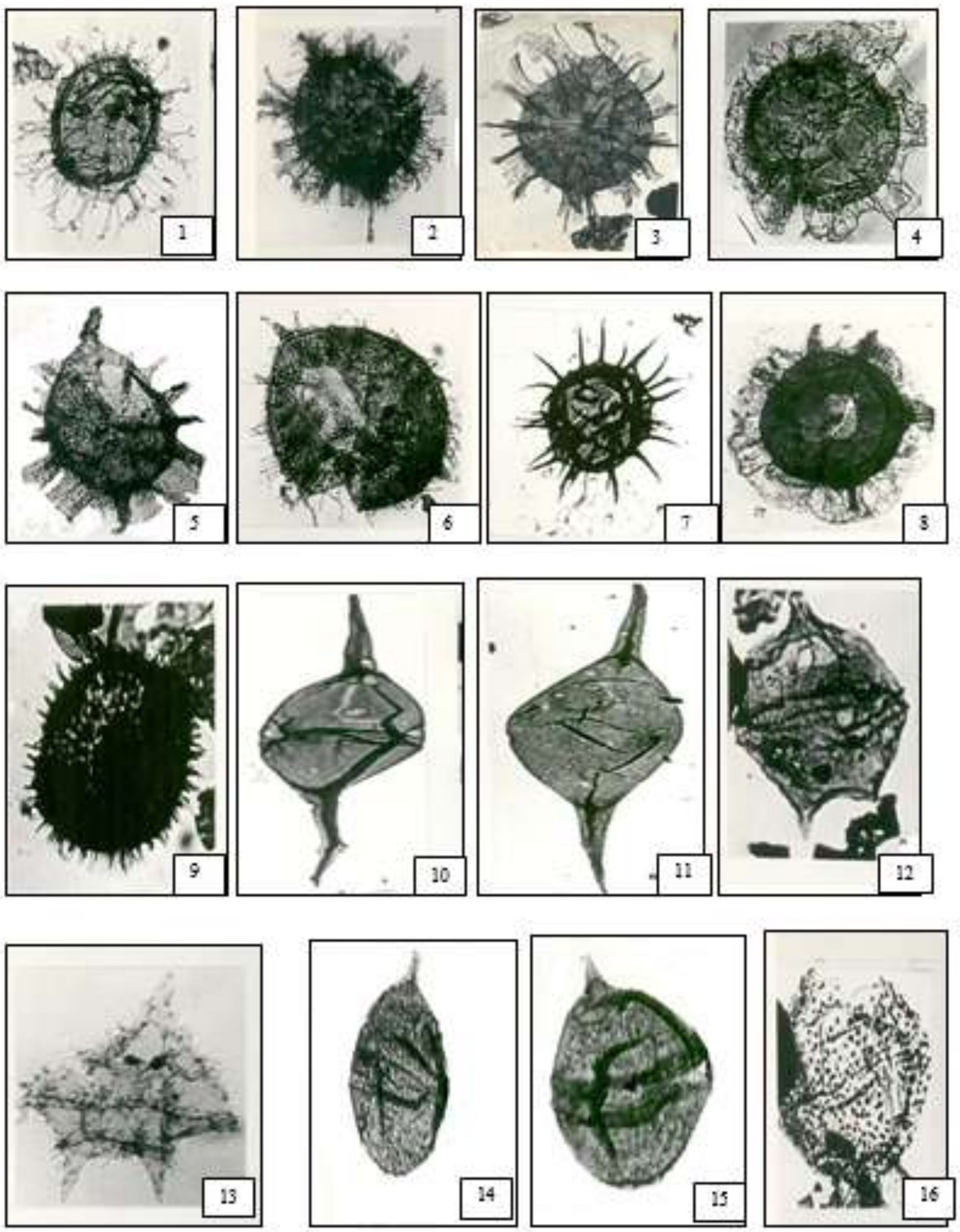

Plate 1

1. *Apectodinium homomorphum* Deflandre and Cookson 1955 AJ5240B3, V24/2, X750

2. *Apectodinium quinequelatum* Williams and Downie 1966 AJ5240B3, N19/3, X500
3. *Areosphaeridium polypetellum* Islam 1983 AJ2400B2, Q33/1, X700
4. *Baltisphaeridium nanum* Cookson 1965 AJ1302B2, V32/1(2), X500
5. *Caligodinium amiculum* Drugg 1970b AJ3343B1, D27/1(3), X750
6. *Carpatella cornuta* Grigorovich 1969 AJ5619B2, V43/3, X500
7. *Cassidium fragile* Harris 1965 AJ3933B1, D19/3(1), X500
8. *Cerodinium boloniensis* Riegel 1974 AJ5973B3, S36/4, X500
9. *Cerodinium diebelli* (Alberti) Stover and Evitt 1978 AJ5398B2, M27, X750
10. *Cordosphaeridium gracile* (Eisenack) Davey and Williams1966AJ3620H1, R22/1(2), X500
11. *Damassadinum californicum* (Drugg) Stover and Evitt 1978 AJ5619H2, I26/4, X500
12. *Deflandra denticulata* Alberti 1959 AJ3620B1, M30/2(4), X500
13. *Diphesis colligerum* (Deflandre and Cookson) Cookson 1965, AJ3242B1, M23/2, X500
14. *Diphesis spinula* (Drugg) Stover and Evitt 1978, AJ4360B2, H23/1, X500
15. *Eocladopyxis peniculatum* Cookson and Cranwell 1967, AJ3242B2, R26/2, X500
16. *Fibrocysta bipolare* (Cookson and Eisenack) Stover and Evitt 1978, AJ4360B2, G42/1, X500

PLATE 2

1. *Fibrocysta ovalis* Hansen 1977, AJ5619B2, K43/1, X500
2. *Fibrocysta radiate* Morgenroth 1966, AJ5799K2, H44/1, X500
3. *Fibrocysta ventense* (Eaton) Stover and Evitt 1978, AJ5799H1, L20/2, X500
4. *Gerdiocysta cassicula* (Drugg) Leingjarern *et al.*1980, AJ2745B1, T34/1(2) X500
5. *Ifecysta pachyderma* Jan du Chene and Adediran 1984, AJ4598B1, Q24/3(4) X500

6. *Kenleyia lophophora* Cookson and Eisenack 1965, AJ3242B2, N50/1 X500
7. *Michystridium stellatum* Deflandre 1945, AJ1877B1, P31/3, X500
8. *Muratodinium fimbratum* (Cookson and Eisenack) Drugg 1970, AJ3119B1, Y43/1, X500
9. *Operculodinium erinaceum* (Morgenroth) Stover and Evitt 1978, AJ1981B2, M37/3, X500
10. *Palaeocystodinium australinium* (Cookson) Lentin and Williams 1976, AJ4918B2, G29/1(3), X500
11. *Palaeocystodinium golzowese* Alberti 1961, AJ5799B2, L36/4, X500
12. *Palaeoperidinium pyrophorum* Ehrenberg 1838, AJ5799B2, J32/1, X500
13. *Spinidinium sagittulum* (Drugg) Lentin and Williams 1976, AJ3201B1, L37/2, X500
14. *Spongodinim delitiensis* AJ4598B2, O25/2(4), X500
15. *Spongodinium delitiensis* AJ5240B2, J35/4, X500
16. *Tubidermodinium sulcatum* Morgenroth 1966, AJ2400B2, K20/1, X500