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Palynology and Paleoenvironments of the Upper Araromi Formation, Dahomey Basin, Nigeria

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ABSTRACT

A detailed understanding of the biostratigraphy of the Dahomey Basin in southwestern Nigeria will broaden our knowledge of the Basin which traversed different West African countries especially as Nigeria is working towards increasing her petroleum output. The palynological investigation of eight surface outcrops from Ifon town of the Upper Araromi Formation processed using conventional methods of disaggregation and removal of carbonates and silicates with hydrochloric acid and hydrofluoric acid and further treatment with hot hydrochloric acid (HCl), wet-sieving over a 5-micron sieve and the Branson Sonifier 250 used for the complete removal of silt and clay particles. Each residue was prepared for study as strewn mounts using Loctite. The samples yielded a rich assemblage of Maastrichtian-Paleocene palynomorphs among which were common *Ariadnaesporites spinosa*, *A. nigeriensis*, *Ariadnaesporites* sp., *Foveotriletes margaritae*, *Rugulatisporites caperatus*, *Distaverrusporites simplex*, *Cingulatisporites ornatus*, *Zlivisporis blanensis*, with dinoflagellate cysts, diatom frustules and abundant palm pollen *Longapertites marginatus*, *L. vaneendenburgi*, *L. microfoveolatus*, *Proxapertites operculatus*, *Monocolpopollenites sphaeroidites*, *Spinizonocolpites echinatus*, *S. baculatus*, *S. kostinensis*, *Retidiporites magdalenensis*, *Mauritidites lehmanii*, *Tubistephanocolpites cylindricus*, *Echitriporites trianguliformis*, *E. longispinosus*, *Monocolpites marginatus*, *Retimonocolpites nigeriensis*, *Racemonocolpites racematus* and *Arecipites* sp. The palynological age assigned to the samples were based on already published ranges of the palynostratigraphically important taxa. The preponderance of these palm pollen, together with diatom frustules and a dinoflagellate cyst suite dominated by Gonyaulaceleans, indicates sediment deposition in a highly productive shallow marine environment.

Key words: Upper Araromi Formation, Maastrichtian-Paleocene, palms, diatom frustules, dinoflagellate cysts

INTRODUCTION

Considerable work had been done in the past to ascertain the age of the Cretaceous sediments of the Dahomey Basin, Nigeria (Bankole *et al.*, 2006, 2007; Billman, 1976; Jan Du Chene, 1987, 2000; Salami, 1987). It is a coastal sedimentary basin and one of the passive margin basins of the West African Atlantic coast. It extends from southeastern Ghana to the western flank of the Nigerian Niger Delta along the Gulf of Guinea. It is bounded on the west by

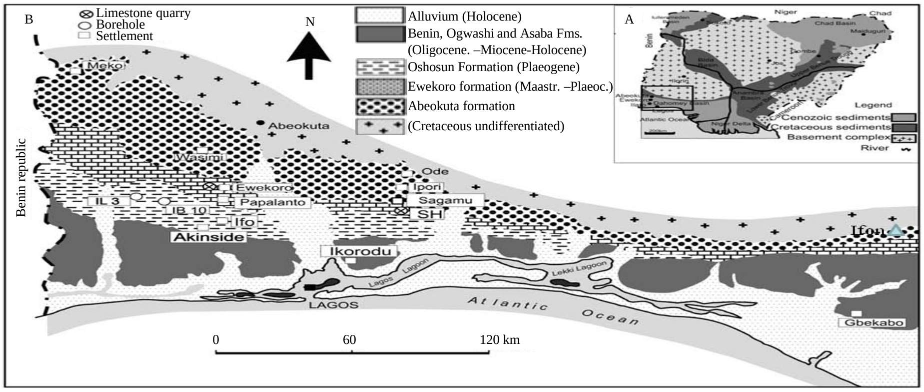

Fig. 1: Geological sketch Map of Nigeria. The rectangle show the area covered by B.B shows the Geological map of the Eastern Dahomey basin while the triangle shows the studied area within the Abeokuta formation (Modified after Bankole *et al.*, 2007)

the Ghana ridge, the extension of the Romanche Fracture Zones, while on the east it is bounded by the Benin Hinge line. The origin is closely related to the rifting and separation of the African and South American plates during the Late Jurassic and Early Cretaceous (Adegoke, 1977; Elvsborg and Dalode, 1985; Omatsola and Adegoke, 1981). The basin is generally long with a total length of about 800 km, narrow and parallel to the coastline. It stretches from southeastern Ghana through Togo and Benin Republics to the western margin of the Niger Delta (Fig. 1). The eastern part of the basin constituting the Nigerian portions, extends from the boundary between Nigeria and the Republic of Benin to the Benin Hinge Line (Olabode, 2007).

The revised Cretaceous stratigraphy of the Dahomey Basin in decreasing order of age consists of (1) the Semen Formation, (2) Ise Formation (3) Afowo Formation and Araromi Formation (Adegoke, 1992). The Araromi Formation is the youngest Cretaceous Formation of the Abeokuta group which according to Omatsola and Adegoke (1981), encompasses from the base, the basal member of the Ise Formation which is equivalent to the unnamed older folded sediments of (Billman, 1976) dated Neocomian; the upper Ise Formation composed of the Unnamed Albian Sands of (Billman, 1976) which is of Albian age is overlain by the Turonian Afowo Formation of Omatsola and Adegoke (1981) which Billman named the Abeokuta Formation. Overlying the Abeokuta Formation of Billman is the Senonian Awgu Formation which is further overlain by the Maastrichtian-Paleocene Nkporo shale (Billman, 1976) which is equivalent to the Araromi and Ewekoro Formations to which Omatsola and Adegoke (1981) ascribed a Maastrichtian-Basal Paleocene age for the former while the greater part of the latter is of Paleocene age. Furthermore, Bankole *et al.* (2006) dated the youngest Formation in the Dahomey Basin (the Oshosun Formation) Late Paleocene-Early Eocene. The age of the Araromi Formation from which the samples for this study were collected along the Ifon –Sabongida road in Ondo State have been studied by Jan Du Chene (1977, 1987) who proposed the age to range from Maastrichtian to Paleocene based on the palynofloral assemblages from the tar sand bearing sections of the Formation near Agbabu. The Araromi Formation is equivalent to the lower part of the Nkporo Shale of Billman (1976) and the informal "Araromi Shale" of Reyment (1965). The formation is composed of fine to medium grained sands at the base, grading upwards into shale and siltstone with interbeds of limestone and marls. Also common are thin lignite bands. The shales are light grey to black, mostly marine with very high organic content.

Salami (1987) reported from microfloral analysis that the basal part of the Araromi shale considered a subsurface equivalent of the Abeokuta Formation indicated an Upper Maastrichtian age while the upper parts are of Paleocene to Eocene ages, respectively. Salami's paleoenvironmental deductions using recovered pollen, spores and dinoflagellate cysts inferred a continental environment of deposition for outcrops of the upper Abeokuta Group, while the overlying Araromi shales indicated brackish water or marginal marine environments of deposition. The preponderance of dinoflagellate cysts and abundant wood particles and fungal spores concurred with this proposed depositional environment.

Adegoke (1992) had reported a Maastrichtian to Paleocene age for the Cretaceous strata around Ifon-Sabongida from which the studied samples were collected.

Alves *et al.* (2005) having worked on the palynofacies and nannofossils from cored well section of the Araromi Formation onshore in southern Nigeria reported that the palynofacies was dominated by palynomorphs mainly dinoflagellates and amorphous organic matter of algal origin. This they opined indicated open marine settings. Again, from the palynofacies distribution patterns they inferred depositional environments which ranged from a very proximal oxic shelf to a distal dysoxic-anoxic deep-water environment. The calcareous nannofossil biostratigraphy indicated a Late Cretaceous (Maastrichtian) to early Eocene age. They further noted variable nannofossil abundance, diversity and preservation throughout the section they studied.

Bankole *et al.* (2006) used the occurrences of diagnostic dinoflagellate cysts to confirm the Late Paleocene-Eocene age for the newly exposed section of the Oshosun Formation in the Sagamu quarry, Dahomey Basin, South-Western, Nigeria. They recorded abundant occurrences of diagnostic dinoflagellate genera such as *Apectodinium, Kallosphaeridium* (*K. brevibarbatum, K. capulatum, K. yorubaense*), *Ifecysta, Senegalinium* (*S. orei*) and *Hafniasphaera* (*H. septata*). They further inferred marginal marine depositional environments based on these dinocysts, sporadic occurrences of pollen and spores and the freshwater algae *Derbaya glyptosperma*.

The present study was undertaken to determine the age of the Araromi Formation around Ifon town through the use of diagnostic palynomorphs and also infer the paleoenvironments whether they are different from those earlier proposed for the Formation from other locations by earlier workers. The findings would broaden our knowledge of the stratigraphy of the Dahomey Basin and further highlight the preponderance of palm pollen in the Late Cretaceous-Early Tertiary of Nigeria to confirm the provenance of the palm province of Herngreen and Chlonova (1981), Herngreen *et al.* (1996) and Morley (2000) in Nigeria.

MATERIALS AND METHODS

For this research, eight surface outcrop samples obtained at Ifon town in Ondo state Nigeria in March 2009, were processed using standard palynological techniques involving treatments with HCL and HF. Full details of the laboratory procedure are given in Durugbo *et al.* (2010). Two microscope slides stained with Safranin O were studied between March and April 2009. All the palynomorphs present were enumerated. The sample number and associated England Finder localities of diagnostic palynomorphs are given (Fig. 2, 3 and 4) and transmitted light photomicrographs were taken at magnifications of 400 and 1000 on a Leitz Dialux 20 EB microscope with an attached Motic 2.0 camera at the Paleobotanical laboratory of the University of Lagos. The different palynomorphs (pollen, spores) were identified using local palynological catalogues of Lawal and Moullade (1986), Germeraad *et al.* (1968), Salard-Cheboldaeff (1981, 1990), Hoeken-Klinkenberg (1964, 1966). For

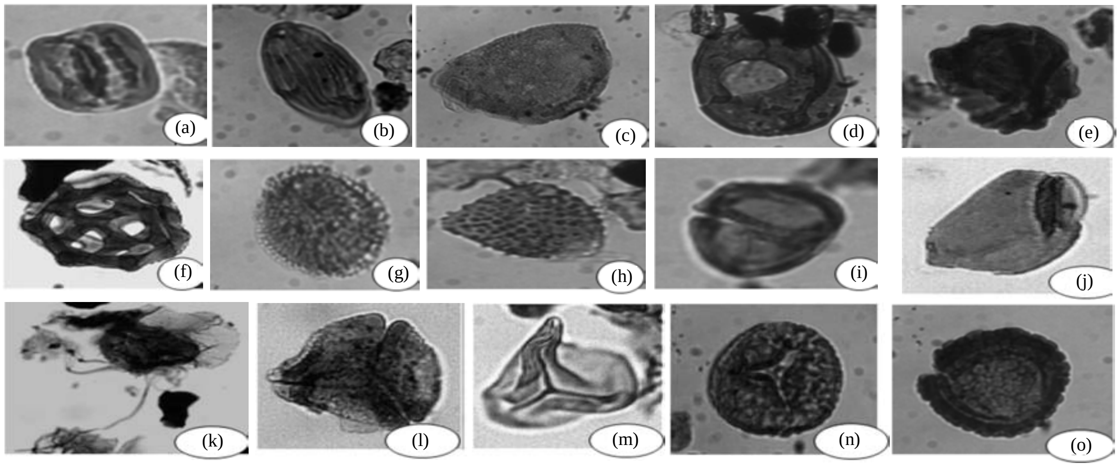

Fig. 2(a-o): Photomicrographs of the palynomorphs recovered from the different Araromi sample, (a)*Tubistephanocolpites cylindricus* sample 2 (J24/2), (b) *Ephedripites multicostatus* sample 2 (K33/2), (c) *Longapertites vaneendenburgi* sample 2 (R23/4), (d) *Milfordia* sp. sample 2 (R21/4), (e) *Ctenolophonidites costatus* sample 2 (R21/0), (f) *Buttinea andreevi* sample 7 (T46/4), (g) *Constructipollenites ineffectus* sample 2 (Q38/2), (h) *Echitriporites trianguliformis* sample 2 (T39/3), (i) *Monocolpopollenites sphaeroidites* sample 2 (M42/2) (j) *Retidiporites magdalenensis* sample 5 (D48/3), (k) *Ariadnaesporites nigeriensis* sample 4 (J44/1), (l) *Syncolporites marginatus* sample 5 (Q25/3), (m) *Cyathidites minor* sample 2 (S38/1), (n) *Rugulatisporites caperatus* sample 2 (Q36/4)and (o) *Cingulatisporites ornatus* sample 2 (M30/4)

dinoflagellates and acritarchs, monographs of Powell (1992), Jan Du Chene (1987) and Sluijs *et al.* (2003) were used. Generally, species nomenclature for dinoflagellate cysts followed Fensome and Williams (2004). The slides, residues, unprocessed samples, CD copies and duplicate prints are in the palynological collections of the Biological Sciences Department, Redeemer's University, Mowe, Ogun State, Nigeria.

RESULTS

The different palynomorph species recovered in the eight samples are enumerated in Appendix (Table A1), while the percentages for each palynomorph groups recovered are presented in Table 1. Photomicrographs of some of the recovered palynomorphs are displayed in Fig. 2, 3 and 4. Each has the sample number and associated "England Finder" coordinates. Altogether 2904 palynomorphs were recorded among which the palms dominated with a total of 1065 accounting for about 36.70% of the whole assemblage. *Retidiporites magdalenensis, Monocolpites marginatus*, *Longapertites vaneendenburgi*, *Longapertites marginatus*, *Echitriporites trianguliformis* and *Monocolpopollenites sphaeroidites* dominated the palm assemblage in decreasing order. These palms dominated in samples 2, 4, and 7. The palms were followed successively by the spores (27.75%); other pollen (16.30%); diatom frustules (10.43%); dinocysts (4.27%); algae and others with (2.82%) and (1.76%), respectively. The commonest spore species were *Cyathidites minor*, *Cyathidites australis*, *Cingulatisporites ornatus*, *Deltoidospora* sp.,

Table 1: Percentage occurrence of the different palynomorph groups in the studied samples

	Miospore groups (%)							
Miospore group	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Total spores	27.27	24.9	22.47	30.1	40.39	4.17	27.83	14.29
Total palms	13.63	39.37	17.98	37.38	36.77	0	39.35	01
Total other pollen	9.1	16.86	6.18	15.05	14.48	4.17	19.29	0
Total dinoflagellate cysts	0	2.01	25.28	5.82	1.39	0	3.93	0
Total diatom frustules	50	11.78	24.16	9.22	6.41	89.58	3.36	85.71
Total algae	0	2.78	1.68	1.94	0.56	2.08	4.13	0
Total others	0	2.3	2.25	0.49	0	0	2.11	0
	100	100	100	100	100	100	100	100

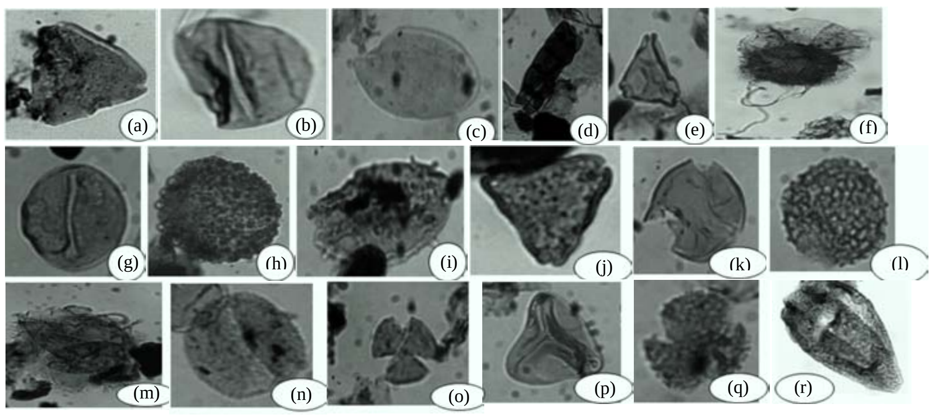

Fig. 3(a-r): Photomicrographs of the palynomorphs recovered from the different Araromi sample, (a) *Proteacidites dehaani* sample 2(J24/2), (b) *Monocolpites marginatus* sample 7 (T46/4), (c) *Longapertites microfoveolatus* sample 2(R21/0), (d) Fungal spore sample 7 (T35/0), (e) *Triorites* sp. sample 2 (P29/1), (f) *Ariadnaesporites spinosa* sample 7 (P31/2), (g) *Monocolpites marginatus* sample 7 (V36/2), (h) *Distaverrusporites simplex* sample 2 (M33/2), (i) *Mauritidites crassiexinus* sample 2 (Q38/2), (j) *Proteacidites dehaani* sample 5 (S35/1), (k) *Psilatricolporites* sp. sample 2 (M29/4), (l) *Retimonocolpites* sp. sample 2 (T39/3), (m) *Ariadnaesporites* sp. sample 4 (J44/1), (n) *Arecipites* sp. sample 2 (J24/2), (o) *Retitricolpites* sp. sample 2 (T39/3), (p) *Cyathidites australis* sample 5 (C45/2), (q) *Ilexpollenites* sp. sample 2 (T39/3) and (r) *Longapertites vaneendenburgi* sample 5 (R23/4)

Rugulatisporites caperatus and *Gleicheniidites senonicus*. The spores dominated in samples 2 and 7. Common dinoflagellate cysts especially *Cleistosphaeridium* sp., *Exochosphaeridium* sp., *Florentinia* sp., *Operculodinium* sp., *Diphyes colligerum*, *Oligosphaeridium* cf. complex, *Apectodinium* sp., *Spiniferites* sp. and the acritarch *Leiosphaeridia* sp. characterized the Araromi samples. These dinocysts and diatom frustules characterized sample 3 suggesting a more pronounced marine transgression (Salami, 1986, 1988). The diatoms also dominated samples 6 and 8. There appeared to be an inverse relationship between the dominance of the diatom frustules and palms. Just as Vadja-Santivanez (1999) inferred for the samples from Bolivia dominated by palm pollen, a warm humid climate is suggested for these sediments.

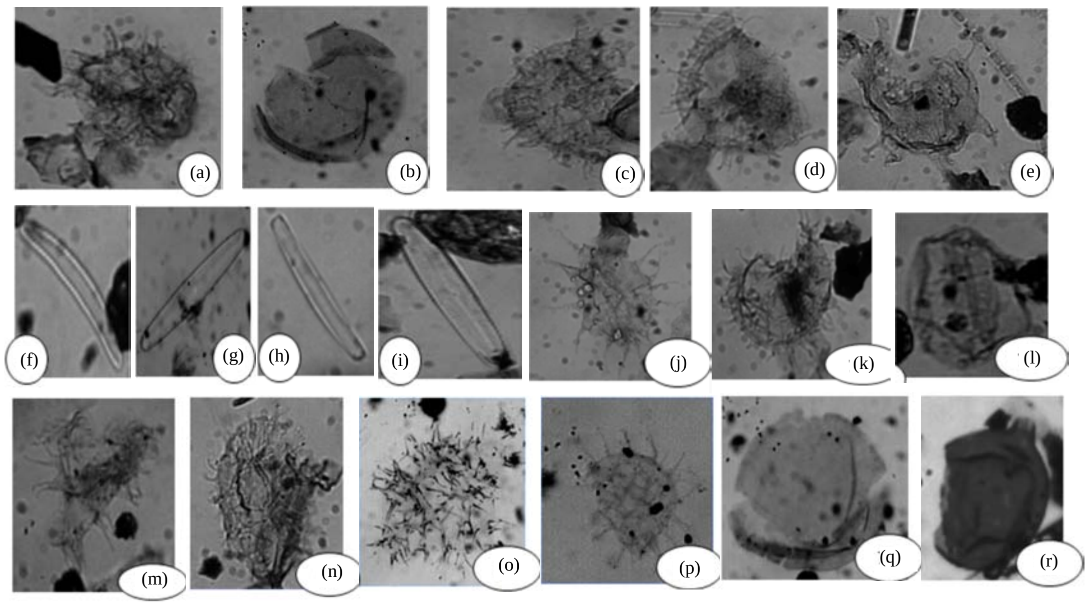

Fig. 4(a-r): Photomicrographs of the palynomorphs recovered from the different Araromi sample, (a) *Exochosphaeridium cf. bifidum* sample 2 (M35/2), (b) *Kallosphaeridium* cf. capulatum sample 3 (R35/0), (c) *Diphyes colligerum* sample 2 (R30/3), (d) *Cleistosphaeridium* sp. sample 2 (F31/2), (e) *Oligosphaeridium cf. complex* sample 7 (M41/1), (f-i) Diatom frustules sample 2 (J44/2,Q43/3,K34/3,L54/2), (j) *Pediastrum* sp. sample 7 (X25/4), (k) *Coronifera oceanica* sample 7 (Q25/2), (l) *Leiosphaeridia* sp. sample 3 (N35/3), (m) Indeterminate dinocyst sample 2 (M42/0), (n) *Exochosphaeridium cf. bifidum* sample 7 (Q44/2), (o) *Apectodinium* sp. sample 3 (K44/1), (p) *Spiniferites ramosus* sample 3 (N25/3), (q) *Kallosphaeridium* cf. capulatum sample 3 (W41/3) and (r) Fungal spore sample 2 (M34/0)

Among the dinoflagellate cysts, peridiniods were rare being represented by *Pareodinia* sp., *Ifecysta* sp., and *Apectodinium* sp. Gonyaulacealens accounted for over 90% of the dinocyst assemblage indicating more open marine conditions. Diatom frustules were recovered in all the samples with the highest number got from sample 2 which tied with sample 7, as the most productive samples notwithstanding that more spores and pollen were recovered from sample 7. Furthermore, samples 5 and 3 yielded appreciable numbers of palynomorphs while the least productive was sample 8 from which only a spore and six diatom frustules were counted. This common record of spores especially in samples 7, 2 and 5 is noteworthy. It appears to suggest a fern spike produced by diverse pteridophytes around this time slice in the Dahomey Basin.

The preponderance of palm pollen (Table 1), supports the Cretaceous-Early Tertiary palm province of Herngreen (1980), Herngreen and Chlonova (1981), Herngreen *et al.* (1996) and Morley (2000). Bankole *et al.* (2006) and Ojo and Akande (2006) had also inferred the palm province for the Late Paleocene to Early Eocene Oshosun Formation of the Dahomey Basin and the Upper Cretaceous Patti Formation of southern Bida Basin, Nigeria, respectively. This province traversed the whole of the southern hemisphere just as Eisawi and Shrank (2008), Jaramillo *et al.* (2007), Van Der Hammen and Wijmstra (1964) and Kaska (1989) have all reported.

These data also suggested the presence of several trophic levels, including primary producers diatoms (dinoflagellate cysts) and higher plants all thriving together in a marginal marine/nearshore environment. The presence of these diatom frustules which are all pennate forms noted to thrive in freshwaters (Dutta, 1980), seems to indicate acidic situations as their presence are widely used in river and lake biomonitoring programs as indicators of acidification, eutrophication and pollution.

Furthermore, the common records of the Salvinialean spores (*Ariadnaesporites spinosa, Ariadnaesporites nigeriensis* and *Ariadnaesporites* sp.) which had been recovered from the Upper Cretaceous of south eastern Nigeria (Odebode and Skarby, 1980) and in the Late Maastrichtian-Danian Nsukka Formation, Anambra Basin, Nigeria (Umeji and Nwajide, 2007); in the Maastrichtian of Somalia (Shrank, 1994a), Upper Cretaceous-Lower Paleogene of Sudan (Kaska, 1989) and the Campanian-Maastrichtian of Sudan (Shrank, 1994b) all these together with *Rugulatisporites caperatus, Distaverrusporites simplex, Cingulatisporites ornatus, Zlivisporis blanensis, Proteacidites sigalii, P. dehaani, Buttinea andreevi, Constructipollenites ineffectus, Monocolpopollenites sphaeroidites*, support the Late Cretaceous age earlier defined for the Araromi Formation (Hoeken-Klinkenberg, 1964). Eisawi and Shrank (2008) had further reported the occurrence of *Ariadnaesporites spinosa* in the Upper Cretaceous of the Melut Basin, Sudan. The common records of *Ariadnaesporites* sp. and their numerous hair like processes co-occurring with the diatom frustules, common dinoflagellate cysts especially *Spiniferites ramosus, Cleistosphaeridium* sp., *Exochosphaeridium* sp. and abundant palm pollen, common diatom frustules, plant debris in the studied samples suggests sediment deposition in a swampy shallow marine/nearshore environment with some lakes (Kaska, 1989); Eisawi and Shrank (2008). The results of the present study gives further credence to the age assignments earlier suggested by Araromi shales by Salami (1987).

Age determination: The palynological age assigned to the samples were based on already published ranges of the palynostratigraphically important taxa especially *Buttinea andreevi, M. sphaeroidites, Ephedripites multicostatus, Constructipollenites ineffectus, Z. blanensis, Proteacidites sigalii, P. dehaani, F. margaritae, R. caperatus, C. ornatus, D. simplex, Kallosphaeridium* sp., *Florentinia* sp., *Exochosphaeridium* sp., *Ifecysta* sp. and *Coronifera oceanica*. Salard-Cheboldaeff (1990) had highlighted the ranges of *R. caperatus, C. ornatus, Buttinea andreevi, M. sphaeroidites, Ephedripites multicostatus* in Nigeria, Togo and Mali Basins together with other West Africa Basins as being from Campanian-Maastrichtian. Furthermore, Hoeken-Klinkenberg (1964) had listed *Syndemicolpites typicus, Longapertites marginatus, C. ineffectus, Echitriporites trianguliformis, R. caperatus, C. ornatus*, among the common palynomorphs from the Upper Cretaceous of Nigeria. Ogala *et al.* (2009) had also recovered majority of the listed palynomorphs from the Middle-Upper Maastrichtian Mamu coal facies in the Anambra Basin. Again, from the Gombe Formation in Gongola Basin, Ojo and Akande (2006) had recovered similar palynomorphs. Moreover, the dinoflagellate cysts *Kallosphaeridium* sp., *Florentinia* sp., *Exochosphaeridium* sp., *Ifecysta* sp. and *Coronifera oceanica* have been recovered from Paleocene and Maastrichtian sediments in the Anambra Basin by Umeji and Nwajide (2007). Moreover, Adegoke (1992) had reported a Maastrichtian to Paleocene age for the Cretaceous strata around Ifon-Sabongida from which the studied samples were collected. Again, Salami (1983, 1986, 1988) had recovered majority of the palynomorphs reported from this study to which he had inferred upper Cretaceous to Early Tertiary ages.

CONCLUSION

The age of the Araromi Formation around Ifon is Late Maastrichtian-Paleocene which concurs with the results of some earlier workers. Among the palynomorphs recovered in the present study were common diatom frustules and Salvinia spores which most of the earlier investigators did not report. The sediments were deposited in a swampy shallow marine/nearshore environment with some lakes as revealed by the common records of palm pollen, pteridophyte spores, fungal spores, and freshwater algae co-occurring with dinoflagellate cysts dominated by Gonyaulacealens.

APPENDIX

Table A1: Palynomorphs recovered in the Araromi samples Dahomey Basin, Nigeria

	Sample								
Taxon	1	2	3	4	5	6	7	8	Total
Spores									
Ariadnaesporites nigeriensis					1		1		2
Ariadnaesporites spinosa				2	2		3		7
Ariadnaesporites sp.		5		2	1		7		15
Cingulatisporites ornatus		19		2	11		17		49
Cyathidites minor	2	123	22	32	52		157	1	389
Cyathidites australis		38		5	7		40		90
Deltoidospora sp.		23	12		21		17		73
Distaverrusporites simplex		11		2	3		9		25
Foveotriletes margaritae		6			4	1	13		24
Gleichenidites senonicus		1	2	10	23		3		39
Laevigatosporites sp.		10			18		9		37
Perotriletes pannuceus	1								1
Polypodiaceoisporites sp.							2		2
Rugulatisporites caperatus		13		2	2		10		27
Verrucatosporites sp.	2	11	3			1			17
Zlivisporis blanensis				5					5
Indeterminate spore	1		1				2		4
Total	6	260	40	62	145	2	290	1	806
Pollen (palms)									
Arecipites spp.		1				0		0	1
Echitriporites longispinosus					3	0	6	0	9
Echitriporites trianguliformis		28		4	8	0	43	0	83
Longapertites marginatus	1	35	3	6	13	0	38	0	96
Longapertites microfoveolatus		11		6		0	3	0	20
Longapertites vaneendenburgi		78		6		0	35	0	119
Mauritidites lehmanii		6				0	7	0	13
Monocolpites marginatus	1	127	5	13	14	0	70	0	230
Monocolpopollenites sphaeroidites		24		9	14	0	28	0	75
Monocolpites sp.		1			5	0		0	6
Monosulcites sp.			4		19	0		0	23
Proxapertites cursus			1			0		0	1
Proxapertites operculatus		10	2		1	0	18	0	31
Psilamonocolpites medius				3		0	16	0	19
Racemonocolpites racematus		8				0	2	0	10
Retidiporites magdalenensis		77	16	19	39	0	137	0	288
Retimonocolpites nigeriensis			1	5	5	0	1	0	12

Table A1: Continue

	Sample								
Taxon	1	2	3	4	5	6	7	8	Total
Spinizonocolpites baculatus				3	2	0		0	5
Spinizonocolpites echinatus	1	1				0		0	2
Spinizonocolpites kostinensis						0	1	0	1
Tubistephanocolpites cylindricus		2		3	9	0	7	0	21
Total	3	409	32	77	132	0	412	0	1065
Other pollen									
Aquilapollenites minimus	0				5		1	0	6
Auriculopollenites reticulatus	0	1			1		2	0	4
Bombacacidites sp.	0	1						0	1
Buttinea andreevi	0	1		2				0	3
Constructipollenites ineffectus	0	52		9	11		83	0	155
Corsinipollenites jussiaensis	0	1					3	0	4
Cretaceaeporites infrabaculatus	0				1			0	1
Cricotriporites operculatus	0						1	0	1
Ctenolophonidites costatus	0	7			2		3	0	12
Ephedripites multicostatus	0	3		2	2		6	0	13
Ericipites pachyexinus	0		1		2		9	0	12
Graminidites sp.	0		5		4			0	9
Grimsdalea magnaclavata	0	4					6	0	10
Ilexpollenites chmurae	0	13					15	0	28
Ladakhiapollis sp.	0	1		1				0	2
Liliacidites sp.	0	1					1	0	2
Milfordia sp.	0	8		1	8			0	17
Monoporites annulatus	0	8					2	0	10
Nigeripollis gemmatus	0						1	0	1
Periretisyncolpites magnosagenarus	0	1			4		2	0	7
Proteacidites dehaani		1	2	3	2		6	0	14
Proteacidites sigalii		2					3	0	5
Proteacidites sp.		3					4	0	7
Psilatricolporites americana		8						0	8
Psilatricolporites sp.		3	2			1	3	0	9
Psilastephanocolporites laevigatus		12	1				11	0	24
Retitricolpites crassicostatus		4					6	0	10
Retitricolporites sp.		3				1	2	0	6
Retitricolpites obtusus							1	0	1
Rhoipites sp.							1	0	1
Rousea subtilis							1	0	1
Syncolporites marginatus		14		2	2		12	0	30
Syndemicolpites typicus		2		5			2	0	9
Tricolpites sp.	1			5				0	6
Triorites sp.	1	10		1	3		6	0	21
Verrutricolporites sp.		2					2	0	4
Indeterminate pollen		8			5		6	0	19
Total	2	174	11	31	52	2	201	0	473
Dinoflagellate cysts									
Achilleodinium sp.	0						1	0	1

Table A1: Continue

	Sample								
Taxon	1	2	3	4	5	6	7	8	Total
Apectodinium sp.	0		4				1	0	5
Cleistosphaeridium sp.			2	2			7	0	11
Cometodinium sp.	0		3				1	0	4
Coronifera oceanica			1	1			3	0	5
Diphyes colligerum	0	2	3				2	0	7
Exochosphaeridium sp.			2		2		5	0	9
Florentinia sp.	0	1	3	2	2			0	8
Hystrichosphaeridium sp.			2					0	2
Ifecysta sp.							1	0	1
Impagidinum celinea							1	0	1
Kallosphaeridium sp.			2					0	2
Oligosphaeridium cf. complex							2	0	2
Operculodinium sp.		7		3			1	0	11
Pareodinia sp.							1	0	1
Polysophaeridium sp.		1	5	1				0	7
Pterospermella sp.				1				1	1
Pyxidinopsis sp.							8	0	8
Spiniferites cornutus							1	0	1
Spiniferites perforatus			4					0	4
Spiniferites pseudofurcatus			1					0	1
Spiniferites ramosus			5	1				0	6
Spiniferites sp.			2					0	2
Indeterminate dinocysts		5	3	2			1	0	11
Leiosphaeridia sp.		5	3				5		13
Total									124
Diatom frustules									
Diatom frustules	11	123	43	19	23	43	35	6	303
Algae									
Botryococcus braunii		19		4		1	24	48	48
Pediastrum sp.		10	3		2		19	34	34
Total									82
Others									
Fungal spores/hypha		24	4				22	50	50
Foraminiferal wall lining					1			1	1
Total									51

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