A reappraisal of salviniaceous fossils and its implication on the age and depositional environment of Nkporo Shale of Calabar Flank, Nigeria

K. P. N. Kumaran, J. J. Edet and E. E. Nyong

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Integrated floral and faunal (foraminiferal) data permit a precise interpretation of the age and depositional environment of the outcrop section exposed along the Calabar-Itu Highway at 42.5 km point. The outcrop section belongs to the Nkporo Shale of the Calabar Flank from which *Ariadnaesporites nigeriensis* Odébòdé & Skarby was reported and described. The results obtained indicate an Early Maastrichtian age and deposition in a brackish swamp environment. The biostratigraphic and environmental significance of salviniaceous fossils have been consequently assessed.

Key-words—Ancient Salviniaceae, Pteridophytes, Nkporo Shale, Late Cretaceous, Calabar Flank (Nigeria).

K.P.N. Kumaran, Geology and Palaeontology Unit, Agharkar Research Institute, G.G. Agarkar Road, Pune 411 004, India.

J.J. Edet, Department of Geological Sciences, University College London, Gower Street, London WCIE 6BT, United Kingdom.

E.E. Nyong, Department of Geology, University of Calabar, PMB 1115, Calabar, Nigeria, West Africa.

सारांश

साल्वीनिएसीय अश्मित पादपों का पुनर्आकलन एवं नाइजीरिया में कलाबार पार्श्व की नपोरो शैल की आयु एवं निक्षेपणीय वातावरण में इसका महत्व

के०पी०एन० कुमारन, जे०जे० एडेट एवं ई०ई० न्याँग

वनस्पतिजातीय एवं जन्तुजातीय (फ़ोरामिनीफ़री) आँकड़ों के आधार पर कलाबार-इटु मार्ग पर 42.5 किलोमीटर की दूरी पर विगोपित एक दृश्यांस की यथार्थतम् आयु का आकलन एवं इसका निक्षेपणीय वातावरण अन्वेषित किये गये हैं। यह दृश्यांस कलाबार पार्श्व के नपोरो शैल से सम्बद्ध है जिससे कि ***एरिऐडनीस्पोराइटिस नाइजीरियेन्सिस*** अदेबॉद व स्कारबाई अभिलिखित एवं वर्णित किया गया है। उपलब्ध परिणामों से इसकी प्रारम्भिक मॉस्ट्रिक्शियन आयु तथा निक्षेपण के समय खारे जल एवं दलदली वातावरण का होना प्रदर्शित होता है। इसके अतिरिक्त अश्मित साल्वीनिएसीय पौधों का जैवस्तरिकीय एवं वातावरणीय महत्त्व भी विवेचित किया गया है।

SPORES of the Salviniaceae belonging to *Ariadnaesporites* (Potonié) Tschudy were reported for the first time from the Cretaceous of southeastern Nigeria by Odébòdé and Skarby (1980). Their report consisted essentially of systematic description of some new mega- and microspores of *Ariadnaesporites*, including the new megaspore species *A. nigeriensis* recovered from a section exposed at the 42.5 km point on the Calabar-Itu Highway. This outcrop, which lies on the Calabar Flank, was previously interpreted as freshwater deposits (based on the presence of *Pediastrum*, *Azolla* and also the absence of dinoflagellates and planktonic foraminifera). It was tentatively assigned a Campanian age on the basis of the association of *Azolla* sp. with *Ariadnaesporites nigeriensis* (Odébòdé & Skarby, 1980). This determination was, however, found to be inconsistent with other palynological, foraminiferal and ammonite data of Reyment (1965), Reyment and Tait (1972), Petters (1980, 1982), Zaborski (1982), Nyong and Ramanathan (1985), Kumaran and Ramanathan (1986), and Nyong, Kuhnt and Wiedmann (MS) on the age and depositional environment of the outcrops on the Calabar Flank.

We demonstrate that Odébòdé and Skarby's (1980) interpretation was based on insufficient information on the stratigraphy and palaeontology of the Calabar Flank, the mechanisms involved in the deposition of hydropterid spores such as *Ariadnaesporites*, *Azolla* and the green alga, *Pediastrum* and perhaps most importantly, the loss of smaller palynomorphs of stratigraphic and

environmental significance by using a single sieve (p. 197) with such a large mesh size as 125 μm.

GEOLOGICAL SETTING AND SAMPLE LOCATION

Murat (1970) first adopted the phrase "Calabar Flank" for the eastern-most region of southern Nigeria sedimentary basin. However, Nyong and Ramanathan (1985) gave a comprehensive review of the structural location of the Calabar Flank which is characterised by NE-SW trending crustal block faults of horst and graben structures bounded by the Cameroon volcanics in the east, the Ikpe platform in the west, the Oban Massif in the north and the Calabar hinge line in the south (Text-figure 1). This area contains about 1,000 meters of Cretaceous sediments in outcrop sections including the Albian sandstones and limestones of the Awi Formation (Adeleye & Fayose, 1978); the Cenomanian-Early Coniacian shales and marls variously referred to in the literature as Odukpani Formation (Reyment, 1965); Eze-Aku Formation (Reyment, 1965) and Nkalagu Formation (Petters & Ekweozor, 1982); the Campanian-Maastrichtian Nkporo Shale (Reyment, 1965) and the post Cretaceous sands of the Benin Formation. The outcrop section located at 42.5 km (latitude 5°13′42″ N and longitude 8°11′10″ E) on the Calabar-Itu Highway from which *Ariadnaesporites nigeriensis* was first reported, belongs to the uppermost part of the Nkporo Shale of the Calabar Flank (Text-figure 2).

The studied outcrop is a 4 metre thick mass of dark grey to black, carbonaceous, finely laminated, highly fissile shales with interbedded mudstones and gypsum bands. The samples studied were taken from different shale bands of the outcrop section (Text-figure 3).

Chemical treatment of samples for palynomorph concentration was accomplished using successively 40 per cent Hydrofluoric acid, 30 per cent Nitric acid and 5 per cent Potassium hydroxide. Sieving was done through a stack of 200, 230 and 400 mesh sieves to provide the added advantage of not losing the smaller palynomorphs. The associated foraminiferal content was analysed separately by using a 200 mesh sieve. All the samples and the slides are stored in the repository of the Department of Geology, University of Calabar, Nigeria.

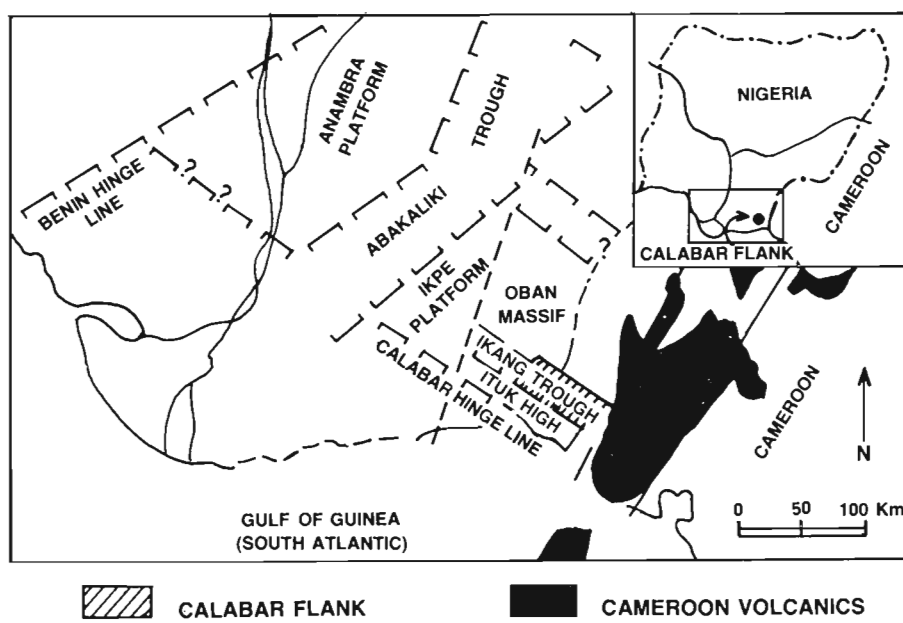
A list of palynomorphs and associated foraminifera recovered has been given as follows. These species are already known from the West African sediments and elsewhere.

Spores

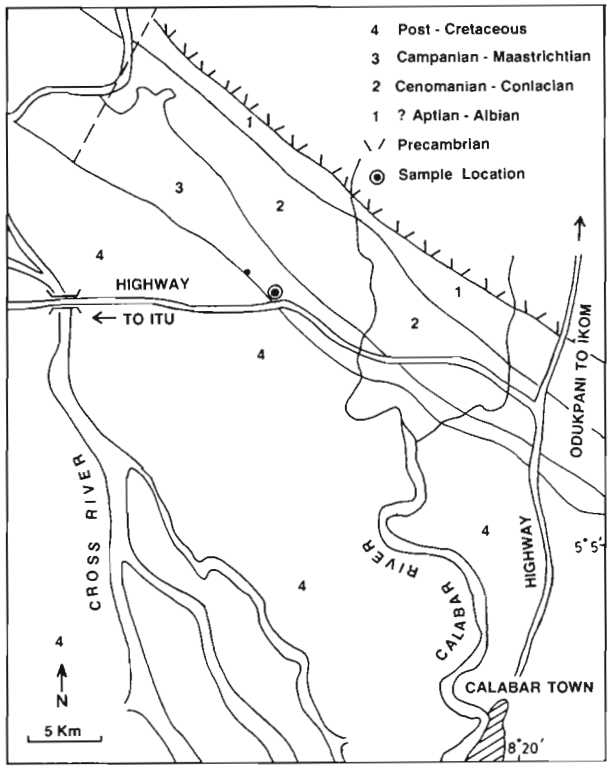
Ariadnaesporites nigeriensis Odébòdé & Skarby 1980
Ariadnaesporates sp.
Azolla cretacea Stanley 1965
Azolla circinata Oltz & Hall 1968
Cyathidites australis Couper 1953
Foveotriletes margaritae Germeraad *et al.* 1968
Verrucosisporites sp.
Pediastrum sp. (green alga)
Pterospermopsis sp. (Prasinophycean algal cyst)

Pollen

Bacutriporites orluensis Jan du Chêne *et al.* 1978
Echimonocolpites densus Gonzalez-Guzman 1967
Gemmatricolporites pilatus Jan du Chêne *et al.* 1978



Text-figure 1—Location map and structural elements of the Calabar Flank and adjacent areas (after Nyong & Ramanathan, 1985).



Text-figure 2—Geological map of the Calabar Flank showing sampling locality.

Longapertites marginatus Van Hoeken-Klinkenberg 1964

Longapertites microfoveolatus Jan du Chêne & Adegoke 1978

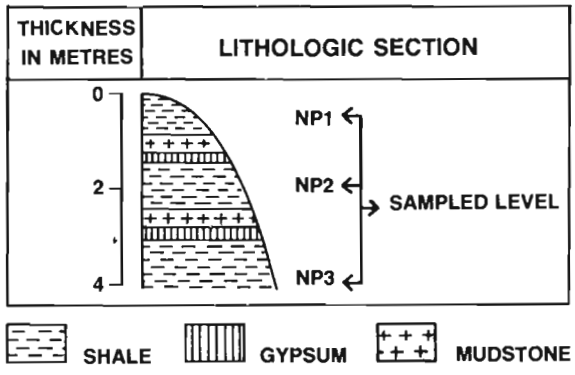
Longapertites sp. 3 sensu. Lawal & Moullade 1986

Monocolpites marginatus Van der Hammen 1954

Periretisyncolpites giganteus Kieser & Jan du Chêne 1979

Periretisyncolpites magnosagenatus Kieser & Jan du Chêne 1979

Echitriporites trianguliformis Van Hoeken-Klinkenberg 1964



Text-figure 3—Lithological section of outcrop at 42.5 km on the Calabar-Itu Highway showing sampled levels.

Proxapertites cursus Van Hoeken-Klinkenberg 1966

Proxapertites operculatus Van der Hammen 1956

Psilatricolpites sp.

Retidiporites magdalensis Van der Hammen & Garcia de Mutis 1965

Spinizonocolpites baculatus Muller 1968

Syncolporites ifeensis Jan du Chêne 1978

Tricolpites sp.

Ephedrepites strobilaceous (Kuyl *et al.*) Salami 1984

Dinoflagellates

Cerodinium diebelii (Alberti) Lentin & Williams 1987

Deflandrea laevigata Malloy 1972

Dinogymnium acuminatum Evitt, Clarke & Verdier 1967

Dinogymnium euclaense Cookson & Eisenack 1970

Palaeocystodinium australinum (Cookson) Lentin & Williams 1976

Palaeocystodinium benjaminii Drugg 1967

Palaeocystodinium gabonense Stover & Evitt 1978

Phelodinium tricuspe (O. Wetzel) Stover & Evitt 1978

Svalbardella sp.

Associated Foraminifera

Ammobaculites sp.

Bolivina afra Reyment 1959

Gabonita elongata De Klasz & Meijer 1960

Gabonita nigeriensis Odébòdé 1987

Praebulimina bantu De Klasz, Magne & Rerat 1963

Rugoglobigerina macrocephala Brönnimann 1952

Rugoglobigerina rugosa (Plummer) Brönnimann 1952

AGE OF THE OUTCROP SECTION

The palynofloral composition presented above from the outcrop of Nkporo Shale includes stratigraphically significant species comprising rare occurrences (<10%) of *Spinizonocolpites baculatus* and frequent to common occurrences (>10%) of *Echimonocolpites densus, Longapertites microfoveolatus, Monocolpites marginatus, Periretisyncolpites giganteus, P. magnosagenatus, Echitriporites trianguliformis, Retidiporites magdalensis* and *Foveotriletes margaritae*. These are endemic Maastrichtian species known from tropical and subtropical regions of the world (Jardiné & Magloire, 1965; Herngreen; 1975; Jan du Chêne, 1977, 1980; Jan du Chêne *et al.*, 1978a, 1978b, 1978c; Adegoke *et al.*, 1978; Baksi & Deb, 1981; Salami, 1985; Lawal & Moullade, 1986; Schrank, 1987).

Schrank (1987) found a few specimens of *Spinizonocolpites baculatus* from the Early Maastrichtian of Egypt. Lawal and Moullade (1986) recorded a peak occurrence of *S. baculatus* in the Late Maastrichtian of Nigeria. Hence, the rare occurrence of *S. baculatus* in the 42.5 km outcrop is significant and probably indicates an Early Maastrichtian age.

The foraminiferal assemblage from this outcrop consisting of *Rugoglobigerina rugosa, R. macrocephala, Gabonita elongata, G. nigeriensis, Bolivina afra* and *Praebulimina bantu,* is also suggestive of a Maastrichtian age as these forms have already been recorded from the west African sediments (De Klasz & Rerat, 1963; De Klasz *et al.*, 1963; Reyment, 1965; Petters, 1982; Jan du Chêne *et al.*, 1978b; Okosun, 1990). Nearby, at 42 km on the Calabar-Itu Highway, Kumaran and Ramanathan (1986) reported a similar Maastrichtian foraminiferal assemblage and Zaborski (1982) reported an ammonite fauna from adjacent strata including *Sphenodiscus lobatus costatus, Pachydiscus* aff. *P. dossantosi* and *Baculites* sp. which support an Early Maastrichtian age. Furthermore, the relative abundance of the dinoflagellates, *Cerodinium diebelli, Palaeocystodinium australinum, P. benjamini, P. gaboense, Phelodinium tricuspe* and *Svalbardella* sp. recovered from 42.5 km outcrop suggests a Maastrichtian age. The decreasing frequency of *Dinogymnium acuminatum* and *D. euclaense* and the abundance of *Cerodinium diebelii* are significant in fixing an age not older than Early Maastrichtian (Kumaran, MS). In addition, impression of *Salvinia* are common in the outcrop. The earliest previous report of this genus is Maastrichtian (Hall, 1974). Thus, the integrated floral and faunal data indicate an Early Maastrichtian age for the outcrop.

DEPOSITIONAL ENVIRONMENT

Although most of the palynomorphs encountered at the 42.5 km outcrop are of unknown botanical affinities, a general overview of the assemblage reveals the dominance of angiospermous pollen. Among the pteridophytic spores, the hydropterid ferns are more conspicuous than the non-hydropterids. The non-hydropterid spores are low in diversity, being mostly triletes with marshy fern (*Acrostichum* sp.) affinities. More diverse pollen assemblage consisting of *Echimonocolpites, Longapertites, Proxapertites* and *Spinizonocolpites* have usually been attributed to mangrove palms (Adegoke *et al.*, 1978; Salami, 1984; Frederiksen, 1985; Schrank, 1987). These pollen grains of mangrove palms and spores of marshy pteridophytes are indicative of deposition in brackish swamp environment.

The presence of dinoflagellates is usually indicative of deposition under brackish to marine conditions. Low ratio of dinoflagellates compared to miospores and dominance by only a few species with short apical processes are known to characterise brackish environments (Upshaw,1964; Mebradu, 1982; Salami, 1984). Similar trends have been observed in the dinoflagellates obtained from the outcrop section of Nkporo Shale. Besides, foraminiferal linings (= "microforaminifera") are frequent in all the palynological preparations made from the shale samples which indicate a shallow marine to brackish water depositional environment (Kumaran & Rajshekhar, 1992).

The occurrence of hydropterid spores of the Salviniaceae possessing 'float structures' (Hall, 1974), the green alga *Pediastrum* which possesses thin, delicate walls, and the prasinophycean *Pterospermopsis*, indicate probable transportation by water currents through channels to the brackish-swamp environment, as suggested by Rao and Kumaran (1988). Besides, the low ratio of megaspores to microspores of *Ariadnaesporites* is remarkable. Due to their larger sizes and thicker exine with endosporium spore body, they are less susceptible to transportation. Thus, their occurrence in low numbers in this brackish swamp environment reflects a relatively short distance of transportation from their original fresh water habitat, where the megaspores would otherwise show an appreciable frequency of occurrence. This interpretation is generally consistent, with the results from other '*Ariadnaesporites*-bearing' outcrops in the Anambra Basin of southeastern Nigeria (Edet, 1988).

CONCLUSION

The outcrop from which *A. nigeriensis* Odébòdé & Skarby was first reported, belongs to the Campanian-Maastrichtian Nkporo Shale of the Calabar Flank. Contrary to the previous report of Odébòdé and Skarby (1980), the palynological and associated foraminiferal evidences from the outcrop indicate an Early Maastrichtian age and deposition in brackish-swamp environment. The significant elements include spores and pollen grains, viz., *Echimonocolpites densus, Longapertites microfoveolatus, Monocolpites marginatus, Periretisyncolpites giganteus, P. magnosagenatus, Echitriporites trianguliformis, Retidiporites magdalensis, Spinizonocolpites baculatus* and *Foveotriletes margaritae*; dinoflagellates : *Palaeocystodinium australinum, P. benjaminii, Cerodinium diebelii, Dinogymnium euclaense, Deflandrea laevigata, Svalbardella* sp. and the foraminifera : *Bolivina afra, Gabonita elongata, G. nigeriensis, Praebulimina bantu, Rugoglobigerina macrocephala* and *R. rugosa.*

It should, however, be emphasized here that the actual biostratigraphic range of *A. nigeriensis* is not yet well established as the examination of more outcrops and well sections in a regional setting would be necessary.

REFERENCES

Adegoke OS, Jan du Chêne RE, Agumanu AE & Ajayi PO 1978. Palynology and age of the Kerri-Kerri Formation, Nigeria. *Rev. Esp. Micropal.* **10**(2) : 267-283.

Adeleye DR & Fayose EA 1978. Stratigraphy of the type section of Awi Formation, Odukpani area, southeastern Nigeria. *Nig. Jour. Min. Geol.* **15** : 33-37.

Baksi SK & Deb U 1981. Palynology of the Upper Cretaceous of the Bengal Basin, India. *Rev. Palaeobot. Palynol.* **31**(3/4) : 335-365.

De Klasz I, Magne J & Rerat D 1963. Quelques forme nouvelles du Buliminidae caracteristiques du Cretace superieur du Gabon (Afrique equatoriale). *Rev. Micropalaeont.* **6**(3) : 145-152.

De Klasz I & Rerat D 1963. The stratigraphic range of the foraminiferal genus *Gabonella* in the Upper Cretaceous of Gabon (equatorial Africa). *Micropalaeontology* **9**(3) : 325-326.

Edet JJ 1988. Palynostratigraphy of some Late Cretaceous sections in the Abakaliki and Anambra basins. *Unpublished M.Sc. Thesis*, Univ. of Calabar, Nigeria.

Frederiksen NO 1985. Review of Early Tertiary sporomorph palaeoecology. *Amer. Assoc. Stratigr. Palynol. Contr.* Ser. **15** : 1-92.

Hall JW 1974. Cretaceous Salviniaceae. *Annals Mo. bot. Gdn* **61**(2) 354-367.

Herngreen GFW 1975. Palynology of Middle and Upper Cretaceous strata in Brazil. *Meded. Rijks geol. Dienst* N.S. **26**(3) 34-91

Jan Du Chêne RE 1977 Some new pollen species of the Upper Maastrichtian Tar Sand, Abeokuta Formation, southern Nigeria. *Rev. Esp. Micropal.* **9**(2) : 191-201.

Jan Du Chêne RE 1980. Palynological study of the Tar Sands. Upper Maastrichtian of the south-west Nigeria. *Proc. IV Int. Palynol. Conf., Lucknow (1976-77)* **2** : 794-799. Birbal Sahni Institute of Palaeobotany, Lucknow.

Jan Du Chêne RE, Adegoke OS, Adediran SA & Petters SW 1978a. Palynology and foraminifera of the Lokoja Sandstone (Maastrichtian), Bida Basin, Nigeria. *Rev. Esp. Micropal.* **10**(3) : 379-393.

Jan Du Chêne RE, De Klasz I & Archibong EE 1978b. Biostratigraphic study of the borehole Ojo-1, S.W. Nigeria, with special emphasis on the Cretaceous microflora. *Rev. Micropal.* **21**(3) : 123-139.

Jan Du Chêne RE, Onyike MS & Sowunmi MA 1978c. Some new Eocene pollen of the Ogwashi-Asaba Formation, south-eastern Nigeria. *Rev. Esp. Micropal.* **10**(2) : 285-322.

Jardiné S & Magloire L 1965. Plynologie et stratigrapie du Cretace des Bassins du Senegal et de Cote d'Ivoire. *Mem. Bur. Rech. Geol. Min.* **32** 187-245.

Kumaran KPN. Palynology of the Upper Cretaceous Nkporo Shale Formation of the Calabar Flank, Nigeria (MS).

Kumaran KPN & Rajshekhar C 1992. Foraminiferal linings from Late Cretaceous-Palaeocene sediments of Ohafia-Ozu Abam area, Nigeria. *Curr. Sci.* **62**(3) : 311-313.

Kumaran KPN & Ramanathan Rm 1986. An Upper Cretaceous assemblage from the Nkporo Shale of Calabar Flank, Nigeria. *J. Palaeont. Soc. India* **31** : 9-15.

Lawal O & Moullade M 1986. Palynological biostratigraphy of Cretaceous sediments in the Upper Benue Basin, N.E. Nigeria. *Rev. Micropal.* **29**(1) : 61-83.

Mebradu S 1982. Stratigraphic palynology of Obi (Lafia), Plateau State of Nigeria. *Rev. Palaeobot. Palynol.* **36**(3/4) : 317-323.

Murat RC 1970. Stratigraphy and palaeogeography of the Cretaceous and Lower Tertiary in southern Nigeria. *In* : Dessauvagie TFJ & Whiteman AJ (Editors)—*African Geol.* : 251-266. University of Ibadan, Nigeria.

Nyong EE, Kuhnt, E & Wiedmann J. Cretaceous biostratigraphy and sedimentary facies succession in the Calabar Flank, south-east Nigeria (MS).

Nyong EE & Ramanathan Rm. 1985. A record of oxygen deficient palaeoenvironment in the Cretaceous of the Calabar Flank, south-east Nigeria. *J. African Earth Sci.* **3**(4) : 455-460.

Odébòdé MO & Skarby A 1980. *Ariadnaesporites* (Salviniaceae) from the Cretaceous of Nigeria. *Grana* **19** : 197-209.

Okosun EA 1990. A review of the Cretaceous stratigraphy of the Dahomey Embayment, West Africa. *Cretaceous Res.* **11**(1) : 17-27.

Petters SW 1980. Biostratigraphy of Upper Cretaceous foraminifera of the Benue Trough, Nigeria. *J. Foram. Res.* **10** : 191-204.

Petters SW 1982. Central West African Cretaceous-Tertiary benthic foraminifera and stratigraphy. *Palaeontographica* **179** : 1-104.

Petters SW & Ekweozor CM 1982. Petroleum geology of Benue Trough and southeastern Chad Basin, Nigeria. *Amer. Assoc. Petrol. Geol.* **66** : 1141-1149.

Rao VR & Kumaran KPN 1988. A short survey of palaeobotanical studies (Cretaceous and Tertiary) in Nigeria. *Rev. Palaeobot. Palynol.* **54** : 151-158.

Reyment RA 1965. *Aspect of the geology of Nigeria.* Ibadan Univ. Press, Nigeria.

Reyment RA & Tait EA 1972. Biostratigraphical dating of the early history of the South Atlantic Ocean. *Phil. Trans. R. Soc.* **B264** : 55-95.

Salami MB 1984. Late Cretaceous and Early Tertiary palynofacies of southern Nigeria. *Rev. Esp. Micropal.* **16** : 415-423.

Salami MB 1985. Upper Senonian and Lower Tertiary pollen grains from the southern Nigeria sedimentary basin. *Rev. Esp. Micropal.* **17**(1) : 5-26.

Schrank E 1987. Palaeozoic and Mesozoic palynomorphs from Northeast Africa (Egypt and Sudan) with special reference to Late Cretaceous pollen and dinoflagellates. *Berliner Geowiss. Abh.* (A), **75**(1) : 249-310.

Upshaw CF 1964. Palynological zonation of the Upper Cretaceous Frontier Formation near Dubois, Wyoming. *In* : Cross AT (Editor)—*Palynology in oil exploration, Soc. Econ. Palaeont. Miner Spec. Publ.* **11** 153-168.

Zaborski PMP 1982. Campanian and Maastrichtian Sphenodiscid ammonites from southern Nigeria. *Bull. Br. Mus. (Nat. Hist.) Geol.* Ser. **36** : 303-332.