JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL.31,1986,pp 9 — 15

AN UPPER CREATACEOUS ASSEMBLAGE FROM THE NKPORO SHALE OF CALABAR FLANK, NIGERIA

K.P.N. KUMARAN[1] AND R.M. RAMANATHAN[2]

1. DEPARTMENT OF BIOLOGICAL SCIENCES, UNIVERSITY OF CALABAR, CALABAR.
2. UNDP PETROLEUM OFFICE, MINISTRY OF NATURAL RESOURCES, BELMOPAN, BELIZE, CENTRAL AMERICA.

ABSTRACT

Assemblages of micro-, mega-plant fossils, and foraminifera are recorded from both outcrop and subsurface sediments of the Nkporo Shale of Calabar Flank, southeastern Nigeria. The predominance of epipelagic heterohelicids and hedbergellids with *Globotruncana* indicates that the lower part of the Nkporo Shale was deposited in a shallow shelf environment during the late Campanian. A subsequent withdrawal of the sea during the latest Campanian—early Maastrichtian is indicated by the occurrence of endemic West African benthic foraminifera such as *Gabonita elongata, G. lata, Praebulimina bantu* and *Heterohelix* spp. along with agglutinated foraminifera. The low diversity of agglutinated foraminifera and the occurrence of aquatic plants, e.g., Salviniaceae, marshy monocotyledons, and dicotyledonous leaf impressions indicate a final regression in the Nkporo Shale. Thus, the Nkporo Shale, composed mainly of highly fissile dark grey to black carbonaceous shale, represents a cycle of transgression during the Campanian followed by a regressive phase in the latest Campanian—early Maastrichtian.

INTRODUCTION

The Calabar Flank is located in the easternmost part of the southern Nigerian sedimentary basin (Fig. 1). The basin has NW-SE trend of crustal block faults of horst and graben structure, and about 1,000 m of Cretaceous sediments are exposed in outcrop sections. The youngest lithologic unit of the Cretaceous sequence, the Nkporo Shale, is highly fissile dark grey to black carbonaceous shale interbedded with thin ironstone beds and intercalated with sandstones, marls and gypsum. It outcrops as a narrow band all along the Calabar Flank extending into the Benue Trough of Nigeria (Fig. 2), where it was first described by Tattam (1944) as Nkporo Shales. Reyment (1965) redefined the Nkporo Shale and described its stratigraphic relationship with the adjoining unit in the type locality near Nkporo in eastern Nigeria. In Calabar Flank, the Nkporo Shale unconformably overlies the Turonian (?) Eze-Aku Formation and underlies the Late Tertiary Benin Formation (Table 1).

Fossil fauna reported from the Nkporo Shale (Reyment, 1965) include cephalopods, pelecypods, gastropods, foraminifera, and ostracods. The occurrence of ammonites: *Libycoceras, Sphenodiscus* and *Baculites;* ostracods: *Veenia, Togonia,* and *Soudanella*; and foraminifera: *Afrobolivina, Gabonella, Rugoglobigerina* and *Globotruncana* are significant. Reyment (1965, p. 52) inferred a shallow water origin for this lithounit.

Although a Campanian-Maastrichtian age is generally

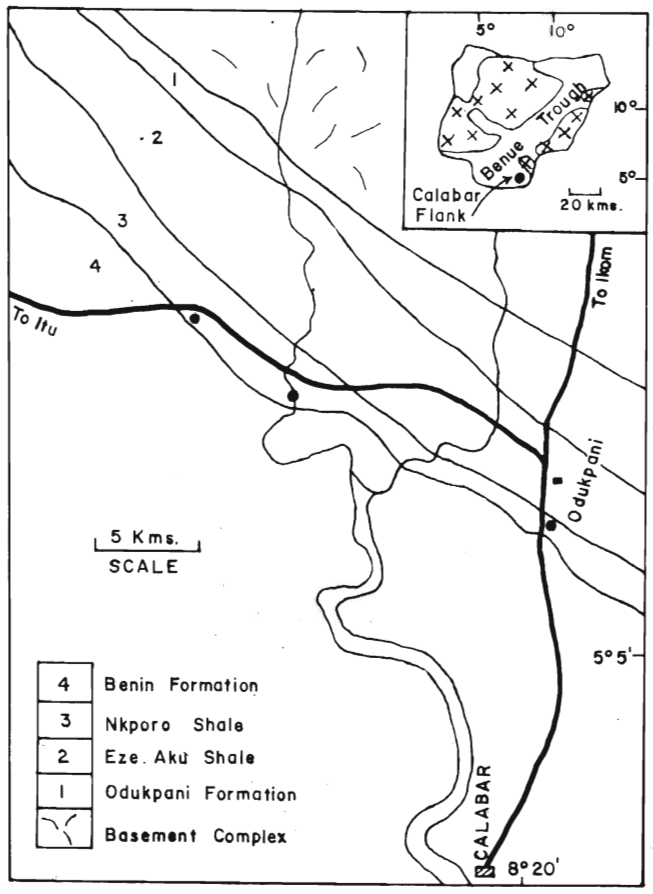


Fig. 1. Geological sketch map of Calabar flank based on Geological survey of Nigeria map (1974) and Dessaunagic (1975)

assigned to the Nkporo Shale and its lateral equivalents, Reyment (1965) referred these formations entirely to the Maastrichtian. Petters (1980) also supported a Maastrichtian age for Nkporo Shale on the basis of foraminiferal evidence. However, Murat (1972), Dessauvagie (1975) and Kogbe (1976) considered this entire formation to range from upper Campanian to Maastrichtian.

A detailed study of the fossil foraminifera and micro- and mega- plants from outcrop and subsurface sections of Nkporo Shale of Calabar Flank was undertaken to determine the age range and depositional environment of the formation.

The Salviniaceous fossils are described here since this is their first reported occurrence of vegetative and reproductive structures from Nigeria.

The results of the foraminiferal distribution in both outcrops as well as subsurface sections are discussed here but their systematics and biostratigraphy are to be published elsewhere.

MATERIAL AND METHODS

The locations of the outcrop sections and BH-2 borehole from which the samples are studied here are shown in Figure 3.

The use of hydrogen peroxide solution for separation of foraminifera was found to be highly satisfactory due to the high organic content of the samples.

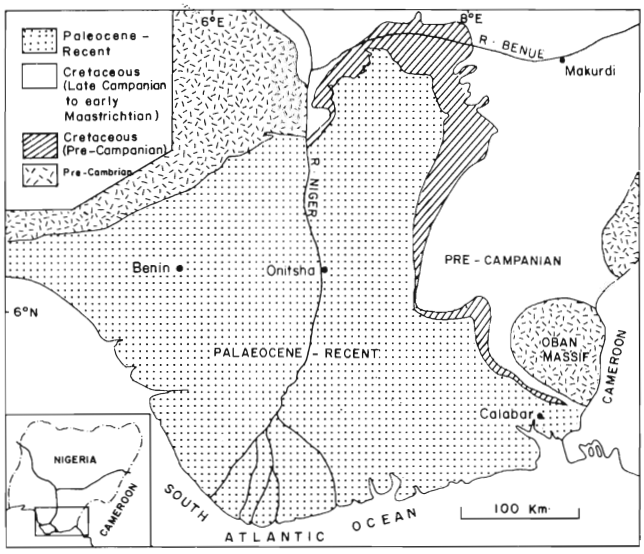


Fig. 2.The outcrop limit of NK poro shale in Southern Nigeria.

The conventional method of digesting the sediments with HF for release of plant microfossils was followed. The mega-plant fossils were studied under reflected light. Paraffin oil was applied to discern clearly the venation pattern of the leaf impressions.

Table 1. Stratigraphic succession of Calabar Flank.

CHRONO - STRATI - GRAPHY	LITHOSTRATIGRAPHY	
	GROUP/ FORMATION	DESCRIPTION
LATE TERTIARY	Benin Formation	Ferrugenous sandstones interbedded with minor ironstones
EARLY TERTIARY		
MAAS - TRICHTIAN	Nkporo Shale	Black carbonaceous highly fissile shales
CAMPANIAN		
SANTONIAN		
CONIACIAN		
TURONIAN	Odukpani Group: Eze - Aku Fm.	Interbedded Lst. and silty grey shale
CENOMANIAN	Odukpani Group: New Ntim Fm.	Black shale with minor limestone
ALBIAN	Odukpani Group: Mfamosing Fm. / Awi Formation	Limestone with minor sands / Fluvio - deltaic sands
APTIAN		

FAUNAL AND FLORAL ASSEMBLAGES

ODUKPANI VILLAGE SECTION

The section at 0.5 km South of Odukpani Village (Fig. 3) yielded a rich assemblage of foraminifera dominated mainly by planktic species. Significant species of the assemblage are: *Globotruncana fornicata* Plummer, *G.* cf *tricarinata* (Quereau), *Rugoglobigerina subrugosa* (Gandolfi), *R. rugosa* (Plummer), *Heterohelix globulosa* (Ehrenberg), *H. pulchra* (Brotzen), *H. planata* (Cushman), *H. reussi* (Cushman) and *Hedbergella* spp.

G. fornicata is reported here for the first time from Nigeria in the Nkporo Shale. The specimens have long and narrow subcrescentic chambers on the spiral side some of which exhibit distinct undulations. In India, *G. fornicata* has been recorded from the late Campanian (Rasheed and Govindan, 1968; Rao, Mamgain and Sastry, 1968; Govindan, 1972). Although, this species has been reported from the Coniacian to early Maastrichtian in the western hemisphere (Bolli, 1957; Olsson, 1964, Pessagno, 1967; Barr 1968), it is mainly restricted to the Campanian in the coastal ranges of northern California (Douglas, 1969). *G. fornicata* mostly from the Campanian of southeastern Columbia are closely comparable to Nkporo specimens. The presence of *Heterohelix reussi* (Cushman) supports a late Campanian age for this section of the Nkporo Shale. The maximum range of *H. reussi* is well within the Campanian (Bandy, 1967; Cushman, 1946; Pessagno, 1967).

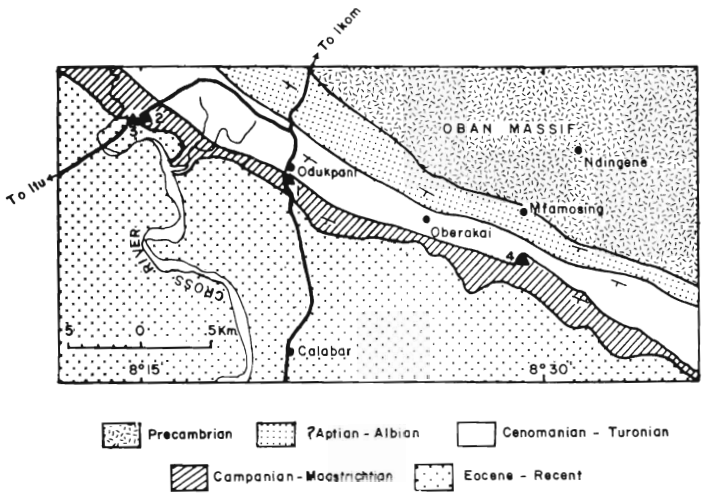


Fig. 3.Geological map of parts of Calabar Flank showing sample location, 1,0.5 km south Odukpani village, 2,36.8 km from Calabar along Calabar itu road 3,42 km from Calabar along Calabar-Itu highway, 4.B H 2well.

The floral assemblage of this section consists only of poorly preserved leaf impressions. Most of these fossils are fragmentary and could not be assigned to any particular group or taxon.

The preponderance of planktic foraminifera in this section and the absence of both agglutinated and calcareous benthics indicate probable anaerobic bottom conditions (Nyong and Ramanathan, 1985). Petters (1980) reported similar faunal assemblage from black shale intervals of Turonian to early Santonian age in the Benue Trough. He attributes such occurrences to strong oxygen minima caused by reduced oceanic circulation and high organic productivity. The dominance of largely epipelagic species of heterohelicids and hedbergellids in this section is further indicative of water depths not more than those of a shelf environment (Sliter, 1972).

CALABAR ITU HIGHWAY · SECTION AT 36.8 KM

The lower part of the section exposed along Calabar-Itu Highway at 36.8 km (Fig. 3) contains *Bolivina afra* (Reyment) and *Gabonita elongata* (De Klasz and Meijer) that have been reported from Campanian-Maastrichtian sediments of West Africa (De Klasz and Rerat, 1963; Reyment, 1965; Petters, 1982).

The upper part of the section has low foraminiferal species diversity and is dominated by *Ammobaculites* sp. However, this part is rich in plant fossils.

The floral assemblage consists of both micro- and fairly well preserved mega-fossils. The basal part of the fossiliferous bed contains abundant Salviniaceae, and the Prasinophycean algal cyst, *Pterospermella*. The upper part is dominated by the leaf impressions of *Salvinia* and angiosperms. *Salvinia*, a hydropterid heterosporous fern, dominates the assemblage. Even the entire specimens of *Salvinia* with crowded leaves were obtained from the shales. More than twenty specimens of leaf impressions have been collected. Aquatic angiosperms, especially monocotyledonous families of Aponogetonaceae and Potamogetonaceae (Pl. I—9 & 10) are also fairly represented. Leaf impressions (incomplete specimens) probably belonging to *Mitragyna* sp. and *Terminalia* sp. occur in the upper part of the section. These species are common in the swamp vegetation of Nigeria.

The microfossils include the pollen grains of *Mauritiidites* sp., *Longapertites* sp., and *Proxapertites* sp. and the seed remains of higher plants, e.g. *Spermatites* (see fig. 6).

The foraminiferal assemblage indicates a shallow inner neritic depositional environment for the lower part and probably *Pterospermella*, being a floating cyst, could have been carried by water currents and got deposited. The presence of *Azolla cretacea* (microspore, glochidia and massula). *Ariadnaesporites* (megaspores and microspores) and vegetative remains of *Salvinia* shows the existence of floating vegetation near the sedimentary basin during Nkporo Shale deposition. The relative abundance of Salviniaceous forms in the fossiliferous beds indicate that the source was near the depositional site. The free floating *Salvinia* could have been easily carried by water currents along with the sediments. The occurrence of Salviniaceous fossils and the relative abundance of angiosperms higher up in the section indicate a transitional near shore environment.

BH_2 WELL

The foraminiferal assemblages and plant microfossils of the section exposed along Calabar-Itu Highway at 36.8 km are closely similar to those of the interval between 15 and 11.4 meter of BH_2 -well representing the lower part of the Nkporo Shale. Here, the dominance of few calcareous benthic and planktic species was observed. The interval above 11.4 meter, representing the upper part, has low foraminiferal occurrence, consisting dominantly of agglutinated forms. The cuticles of plants, also occur in abundance in this part.

The occurrence of planktic and calcareous benthic species of foraminifera in the lower part indicates a neritic depositional environment, whereas the presence of agglutinated foraminifera in the upper part suggests a shallower, paralic environment.

CALABAR-ITU HIGHWAY · SECTION AT · 42 KM

The section exposed at 42 km along Calabar-Itu Highway is dominated by calcareous benthic species.

This section represents the uppermost part of the Nkporo Shale in Calabar Flank. The faunal elements are dominated by *Gabonita elongata* and *G. lata* (De Klasz and Meijer), and rare occurrence of *Bolivina afra, Heterohelix pulchra* (Brotzen), *H. planata* (Cushman), *Praebulimina bantu* De Klasz, Magne and Rerat, *Ammobaculites* sp., *Gavelinella* sp., and *Haplophragmoides* sp. *Praebulimina bantu* has been reported from the Maastrichtian of Gabon also (De Klasz *et al.*, 1963)

The influence of oxygen minima which affected the benthic species in the other sections examined is not observed in the section exposed at 42 km along Calabar-Itu Highway. This is evident in the mixed occurrence of arenaceous and calcareous benthic as well as planktic foraminifera. Therefore, this assemblage was most probably deposited in a shallow marine, relatively well oxygenated environment.

DISCUSSION

The section exposed at 0.50 km south of Odukpani Village represents the basal part of Nkporo Shale where this unit unconformably overlies the Eze-Aku Formation. It is rich in planktic foraminifera of Campanian age representing a transgressive facies associated with late Campanian eustatic sea level rise of the South Atlantic Ocean (Reyment, 1980).

The lower part of the section exposed at 36.8 km along Calabar-Itu Highway contains benthonic foraminifera, viz., *Bolivina afra, Gabonita elongata, Praebulimina bantu, Gavelinella* sp., *Trochammina* sp., and *Ammobaculities* sp.; the Prasinophycean algal cyst, *Pterospermella*, and *Azolla cretacea*. The foraminiferal assemblage indicates possible open marine neritic environment. The fresh-water *Azolla cretacea* was possibly transported through water channels to the marine depositional site. The fossiliferous Nkporo Shale beds of the Calabar Flank have been suggested as the Campanian in age on the basis of the earliest known appearance of *Azolla* (Odébòdé and Skarby, 1980). However, *Azolla cretacea* occurrence in the upper part of the same section associated with *Salvinia* may indicate a younger age for these beds, as the earliest appearance of *Salvinia* is considered to be in the Maastrichtian (Hall, 1974). Furthermore, the occurrence of angiosperm mega fossils like *Mitragyna* sp. and *Terminalia* sp.; pollen grains, viz., *Mauritiidites* sp., *Longapertites* sp., and *Proxapertites* sp. having taxomomic affinity with some of the modern marshy palms in the upper part of the section clearly reveals a younger aspect. Thus the Calabar-Itu Highway section at 36.8 km ranges from late Campanian to early Maastrichtian and represents a regressive facies of the Nkporo Shale.

The contact between the Nkporo Shale and the overlying late Tertiary Benin Formation is exposed at 42 km along Calabar-Itu Highway. The microfaunal assemblage of this section especially the foraminifera, described earlier suggests a Maastrichtian age and deposition under possible shallow marine conditions. Zaborski (1982) reported ammonite fauna of *Sphenodiscus lobatus costatus, Pachydiscus (P.)* aff. *dossantosi, P. (Neodermoceras)* sp. and *Baculites*, sp., and assigned an early Maastrichtian age to this part of the Nkporo Shale. The faunal data indicate that the age of the Nkporo Shale ranges from the late Campanian to early Maastrichtian and that the deposition was in a transgressive phase during the Campanian followed by slight regressive conditions during the early Maastrichtian.

SYSTEMATIC DESCRIPTION

Order Salviniales
Family Salviniaceae
Salvinia sp. cf. S. *auriculata* AUBL.
(Pl. I—4 & 5)

Description: Leaf impressions, shape cordate; largest more than 2 cm long with a maximum width of 2 cm; midrib distinct; trichome (hair) bases prominent as small depressions along the veins originating from the midrib, meshes visible clearly in some specimens; leaf margin entire, apical notch more prominent than the basal one; leaves grouped together in some cases.

Occurrence: Vegetative remains of Cretaceous Salviniaceae have been recorded rarely. *Salvinia* was recorded from the lower Tertiary of Enugu, Nigeria (Seward, 1924) and from the late Cretaceous of Mexico (Hall, 1974). The earliest occurrence of *Salvinia* is considered from the Maastrichtian (Hall, 1974)

Salvinia, an aquatic heterosporous fern has 12 extant species and is widely distributed in warm temperate to tropical regions. The specimens from the Nkporo Shale have a size comparable to *Salvinia formosa* Seward (1924). The West African extant species *S. nymphellula* (Alston, 1959) resembles the Nkporo specimens in shape but is smaller. The upper Cretaceous *S. elliptica* described by Hollick (1884) is smaller than Nkporo Shale specimens. Other fossil records of *Salvinia* range from the Eocene to the middle Pliocene (Reed, 1954 & 1965).

Azolla cretacea STANLEY, 1965
(Pl. I—1-3)

1965 *Azolla cretacea* Stanley, p. 256, pl. 33, figs. 1-5.

Occurrence: Odébòdé and Skarby (1980) figured a massula and associated microspores of Salviniaceae from

the Nkporo Shale. However, they did not describe the structural details. The figures are not clear enough to refer their specimens to *Azolla cretacea. Azolla* first appeared in the Campanian and became abundant in the upper Campanian-Maastrichtian strata (Srivastava, 1978).

Ariadnaesporites nigeriensis ODEBODE & SKARBY 1980

1980 *Ariadnaesporites nigerienses* Odébòdé and Skarby, p. 198, figs. 2-5, 8A, 9A, 10A

Remarks: The genus *Ariadneasporites* includes both megaspores and microspores. *A. nigeriensis* was described from the Nkporo Shale (Odébòdé and Skarby, 1980). We recovered only a few detached microspores and massulae but megaspores were rare.

Odébòdé and Skarby (1980) also found two other *Ariadnaesporites* spp. associated with six microspore species. One or more *Azolla* megaspore species, and several detached floats were also obtained from the black, silty shales of the section exposed at 42.5 km along Calabar-Itu Highway.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Hari Krishna Maheshwari, Birbal Sahni Institute of Palaeobotany Lucknow for critically reading the manuscript and to the Director of the same Institute for library facilities. Helpful suggestions from Dr. E.E. Nyong, Department of Geology, University of Calabar are gratefully acknowledged.

REFERENCES

ALSTON, A.H.G. 1959. The fern and fern-allies of West Tropical Africa-A supplement to the second edition of Flora of West Tropical Africa. The Whitefriars Press Ltd, Londeon, 89 pp.

BANDY, O.L. 1967. Cretaceous planktonic froaminiferal zonation. Micropaleontology, **13**(1): 1-31.

BARR. F.T. 1968. Late Cretaceous planktonic foraminifera from the coastal areas east of Susa (Apollonia), northeastern Libya. J.Paleontol. **42**(2): 308-321.

BOLLI, H.M. 1957. The genus Praeglobotruncana, Rotalipora, Globotruncana and Abathomphalus in the Upper Cretaceous of Trinidad, B.W.I. Bull. U.S. Nat. Mus **215**:51-60.

CUSHMAN, J.A. 1946 Upper Cretaceous foraminifera of the Gulf coastal region of the United States and adjacent aeas. U.S. Geol. Suru. Prof. Paper. **206**: 1-241.

DE KLASZ, I., MAGNE, J. & RERAT, D 1963. Quelques forme nouvelles dù Builminidae Caracteristiques du Cretace superieur du Gabon (Afrique equatoriale). Rev Micropaleont. **6**(3): 145-152.

DE KLASZ, I., RERAT, D. 1963. The stratigraphic range of the foraminiferal genus Gobonella in the Upper Cretaceous of Gabon (Equatorial Africa). Micropaleontology **9**(3): 325-326.

DESSAUVAGIE, T.F.J. 1975. Explanatory note to the geological map of Nigeria. Nigerian J. Min. Geol. **9**: 1-28.

DOUGLAS, R.G. 1969. Upper Cretaceous planktonic foraminifera in northern California-part I-systematics. *Micropaleontology*. **15**(2): 151-209.

GANDOLFI, R. 1955. The genus *Globotruncana* in southeastern Colombia *Bull. Amer. Paleont.* **36**(155) : 1-118.

GOVINDAN, A. 1972. Upper Cretaceous planktonic foraminifera from the Pondicherry area, South India. *Micropaleontology*: **18**(2): 160-193.

HALL, J.W. 1974. Cretaceous Salviniaceae. *Annls. Missouri Bot Garden.* **61** (2): 160-193.

KOGBE, C.A. 1976. *Geology of Nigeria.* Elizabethan Publishing Co., Lagos. 436 pp.

MURAT, R.C. 1972. Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In T.F.J. Dessauvagia and A.J. Whiteman (Editors), *African Geology, Geol.* Dept. University of Ibadan, Nigeria 251-256.

NYONG, E.E. & RAMANATHAN, RM. 1985. A record of oxygen deficient palaeoenvironments in the Cretaceous of the Calabar Flank, S.E. Nigeria *Journal of African Earth* Sciences. **3** (4): 455-460.

ODEBODE, OM & SKARBY, A. 1980. *Ariadnaesporites* (Salviniaceae) from the Cretaceous of Nigeria. Grana. **19**:197-209.

OLSSON, R.K. 1964. Late Cretaceous lanktonic froaminifera from New Jersey and Delaware. *Micropaleontology.* **10**(2): 157-188.

PESSAGNO, JR. E.A. 1967. Upper Cretaceous froaminifera from the Western Gulf Coastal Plain. *Paleontographica Americana.* **5**:245-445.

PETTERS, S.W. 1982. Biostratgrphy of Upper Cretaceous foraminifera of the Benure Trough, Nigeria. *J. Foram. Res.* **10**(3j): 191-204.

PETTERS, S.W. 1982. Central West African Cretaceous-Tertiary benthic foraminifera and stragigraphy. *Paleontographica.* **179**A: **1-104.**

RAO, B.R.J., MAMGAIN, V.D. & SASTRY, M.V.A., 1968. Globotruncana in Ariyalur Group of Trichnopoly Cretaceous, South India. *Geol. Soc. India, Mem.* **2**: 18-29.

RASHEED, D.A. & GOVINDAN, A. 1968. Upper Cretaceous foraminifera from Vridhachalam, South India. *Mem. Geol. Soc. India.* **2**: 66-84.

REED, C.F. 1954. Index Marsileataet Salviniata. *Bol. Soc. Brot. Ser. 2a* **28** : 5-61.

REED, C.F. 1965. Index Marsileata. *Bol. Soc. Brot. Ser 2a* **39**:259-302.

REYMENT, R.A. 1965. *Aspects of the Geology of Nigeria.* Ibadan Univ. Press, Nigeria, 145 pp.

REYMENT, R.A. 1980. Paleooceanology and Paleobiogeography of the Cretaceous south Atlantic Ocean. *Oceanologica Acta.* **3** (1): 127-133.

REYMENT, R.A. & BARBER, W.M. 1956 Nigerian and Camerouns in "Lexique Stratigraphique International". **4**:35-59.

SEWARD, A.C. 1924. On a collection of fossil plants from South-East Nigeria. *Bull. Geol. Surv. Nigeria.* **6**:66-81.

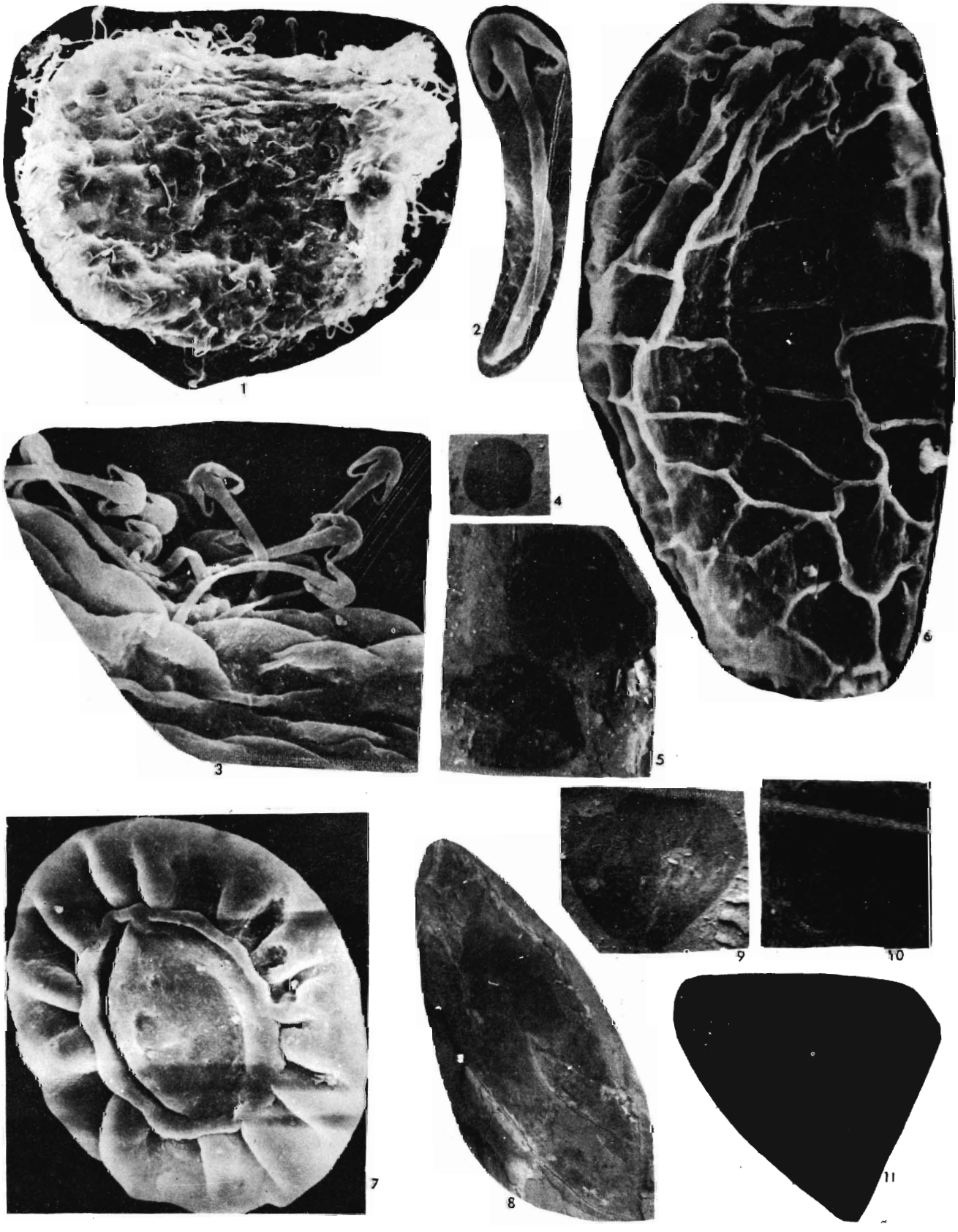
SIMPSON, A. 1955. The Nigerian coalfield: The Geology of part of Owerri and Benue povinces. *Bull Geol. Surv. Nigeria.* **24**:1-85.

SLITER, W.V. 1972. Cretaceous foraminifers-Depth habitats and their origin. *Nature* **239**:514-515.

SRIVASTAVA, S.K. 1978. Cretaceous Spore-Pollen Floras:A Global evaluation. *Biological Memoirs.* **3**(1) : 2-130.

TATTAM, C.M. 1944. A review of Nigerian stratigraphy. *Rep. Geol. Surv. Nigeria.* (1943):27-46.

ZABORSKI, P.M.P. 1982. Campanian and Maastrichtian sphenodiscid ammonites frm southern Nigeria. *Bull.Brit. Mus. (Nat Hist.) Geol Ser.* **36** :303-332.


1
2
3
4
5
6
7
8
9
10
11

EXPLANATION OF PLATE

PLATE I

1. *Azolla cretacea* Stanley; single grain slide No. NKR-18/3; X *ca* 320.
2. Glochidium showing non-septate stalk, anchor shaped tip and recurved prongs; Single grain slide No. NKR-18/3, X *ca* 1250.
3. Part of massula showing reticulum and the attached glochidia *ca* × 900.

4,5 *Salvinia* sp. cf. *S. auriculata* Aubl., UCG 7/371 and UCG 7/383; X 1.

6. *Spermatites* sp., Single grain slide No. NKR-19/1; X *ca* 640.
7. *Pterospermella* sp., Single grain slide No. NKR-7/2; *ca* 640.

8, 11. Unidentified dicot leaf impressions, UCG 7/293 and UCG 7/379; X 1.

9, 10. Unidentified monocot leaf impressions., UCG 7/197 and UCG 7/29 × 1.