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# CRETACEOUS BIOSTRATIGRAPHY OF OUTCROP SECTIONS IN THE IFON-AUCHI AREA OF THE BENIN FLANK, SOUTHWESTERN NIGERIA SEDIMENTARY BASIN.

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## ABSTRACT

The study is based on the use of biostratigraphic tools (palynology and micropaleontology), to determine the age of rock sections its paleodepositional environment to delineate the various rock boundaries in the Ifon-Auchi area of the Benin Flank that correlates with other basins within the Southern Nigerian Sedimentary Basins. In other to achieve this, outcrop samples were analysed for both palynological and micropaleontological characteristics. Results show that, The Mamu shale comprises pollen and spores' assemblages e.g. Buttinia Andreevi, Retidiporites Magdalenesis Constructipollenites Ineffectus, which indicate terrestrial fresh water paleo-environment gives an age of early to late Maastrichtian as well as Cretaceous Paleogene boundary for the rock unit. The pollen and spore assemblages particularly the preponderance of the type of spores may reflect swamp environment developed under humid climate. The occurrence of benthic forams in the sediments which include Ammobaculites Ammobaensis, A. Coprolithiformis, Haplophragmoids Hausa, H. Talokaensis, Textularis Hockleyensis, indicate restriction from open marine connection perhaps existed along the Benin Flank in Southwestern part of Nigeria and into the Anambra Basin.

***Keywords**: Biostratigraphy, Palynology, Micropaleontology, Sediment age, Depositional Environment, Shale.*

## INTRODUCTION

The present investigation focuses on the biostratigraphy and chronostratigraphy of the Upper Cretaceous Sediments of the north-eastern Benin Flank, which is a part of the south-western extension of Anambra Basin, Nigeria. The Benin Flank is the geographic area south of the crystalline basement complex, stretching from the western limits of the Okitipupa structure into the Anambra Basin to the east. Its southern limit is defined by the northern margins of the Niger Delta Basin. (Fig, 1).

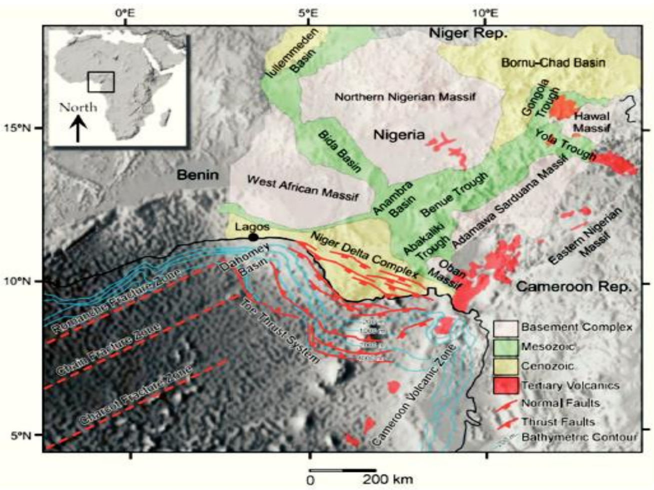


**Fig. 1:** Niger Delta Sedimentary Basin in Nigeria. Modified from Onuoha (1999).

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## LOCATION OF STUDY

The study area covers part of Ifon and Auchi sheets, 284 and 266 of the Geological Survey of Nigeria, and occupies an area of about 16,000 sq km. It is geographically located between latitudes $6^0$ 30´ to $7^0$ 30' North and Latitudes $5^0$ 30' to $6^0$ 40' east.

Basin with its southwestern extension – the Benin Flank is tied to the genesis and tectonics of the Benue Trough and is here summarized.There are different opinions as to the tectonic evolution leading to the inception of the Anambra Basin. One of such views (Murat, 1972) and possibly linked to the RRR rift model of Burke *et al*.

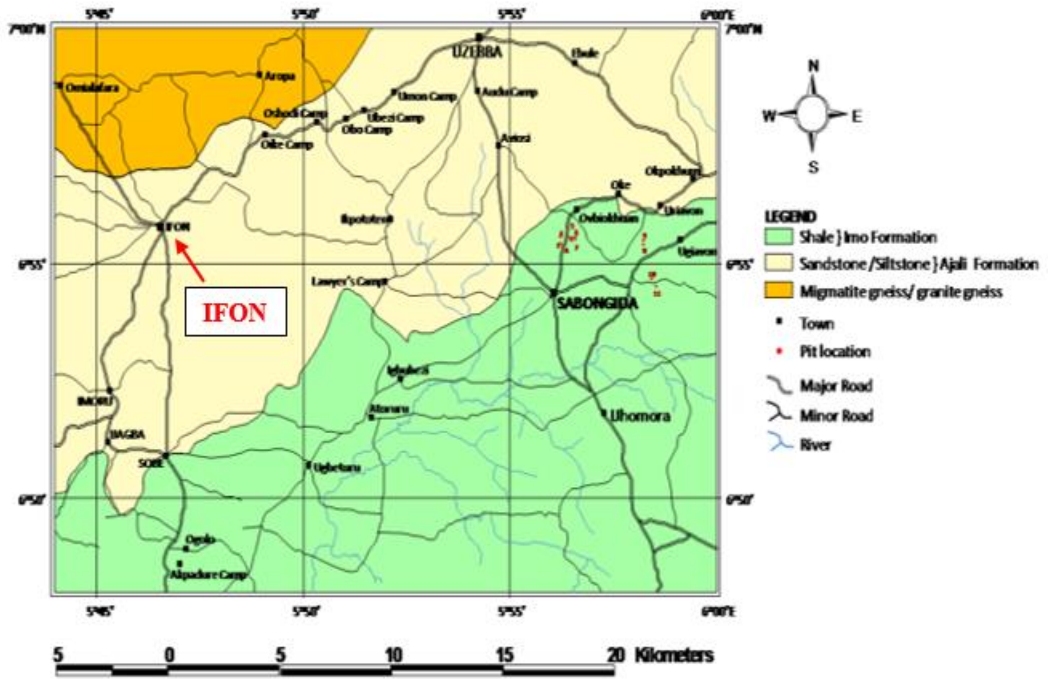


**Fig. 2: Geological Map of Study Area - Ifon – Auchi – (Modified from Adeoye et al, 2011, Geological Survey of Nigeria - G.S.NSheet 284 Ifon N.E,)**

## Geological Setting

The sedimentary rocks of Cretaceous to Recent ages outcrop south of the Precambrian crystalline rocks within the Benin Flank trending along NE-SW direction. The oldest outcropping sedimentary rocks are typically Campanian arenaceous facies, largely alluvial fans-type sediments under fluviatile condition. Successively younger rocks outcrop southwardly, maintaining the same general trend and this probably imply that these deposits represent products of regressive condition. The knowledge about the evolution and stratigraphy of the Anambra

(1971) of the Benue Trough and the subsequent Campano-Santonian closing, considers that the Anambra Basin, the Benin Flank and the Dahomey Basin (now Benin Basin) are closely associated with the compressional tectonics of the Lower Benue Trough succession and the emergence of the Abakaliki Anticlinorium. The uplift of this basin along a NE – SW axis was accompanied by tectonic inversion and down warping of the Anambra Platform and the Dahomey Basin (Murat, 1972; Merki, 1972).Olade (1975) thought of the Benue Trough as an aulacogen (that is, a rift that failed to spread into an ocean) while comparing it with the Canadian aulacogen ofPrecambrian age. He related it to the mantle plums or "hot spot" which resulted from the melting and rising of mantle material due to radiogenic heating of the base of the lithosphere. This caused rifting and break-up of the Gondwana supercontinent. According to Burke *et al.*, 1972, the rifting took place along three arms, two of which spread to become the Gulf of Guinea and South Atlantic, while the third arm became an aulacogen, (Fig. 3). In the present day, it is NE – SW trending > 1,500km long depression called the Benue Trough which traverses Nigeria and extends into the neighbouring Chad Republic. Benkhelil (1989) considers the Benue Trough to be the result of sinistral strike-slip faulting

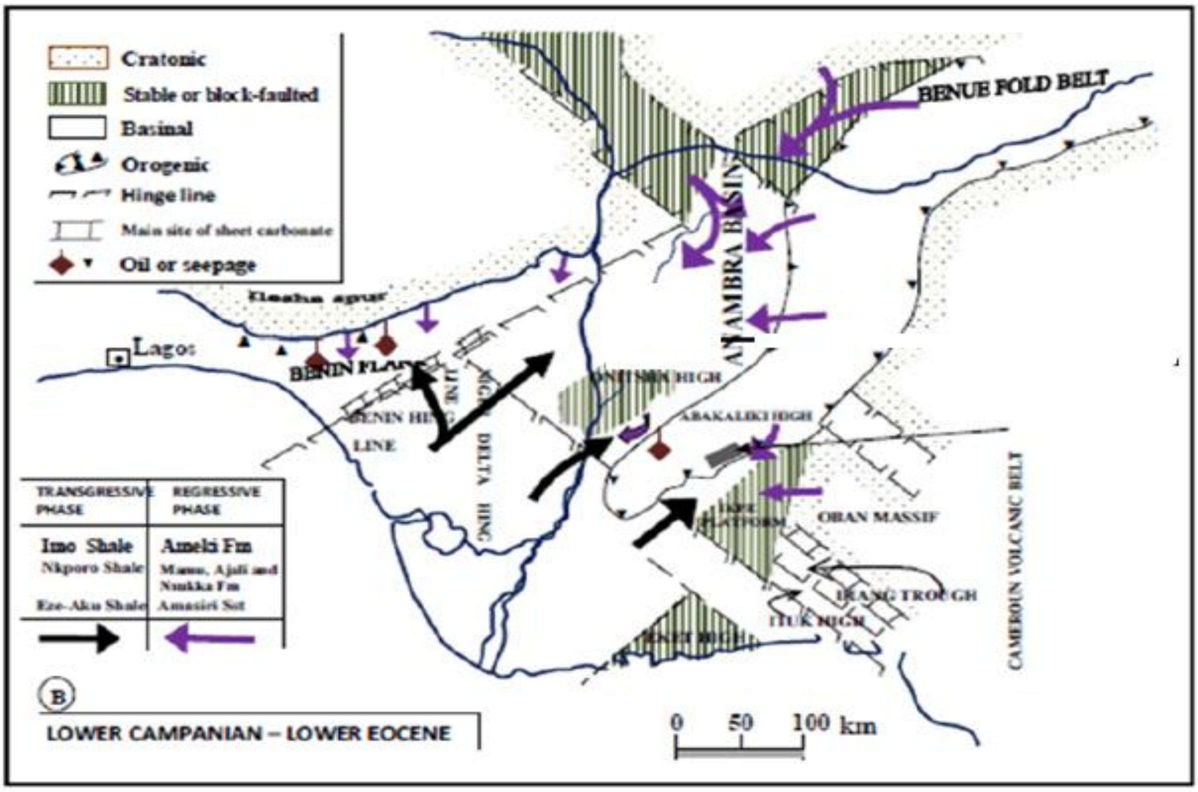


**Fig. 3: Tectonic Framework of the Benue Trough (Modified after Chidera*et al,* 2019)**

A major marine transgression in the Campanian into the Anambra Basin deposited mainly shales (prodelta) with subordinate sand (Nkporo Group). Gradual subsidence, followed by regression in the Maastritchtian saw the deposition of deltaic foresets and flood plains (coal measures – Mamu, Ajali and Nsukka Formations).

## MATERIALS AND METHODS

The methodology was executed in two stages. These include:

- Field study and sample collection
- Laboratory Analysis

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## Sample Collection

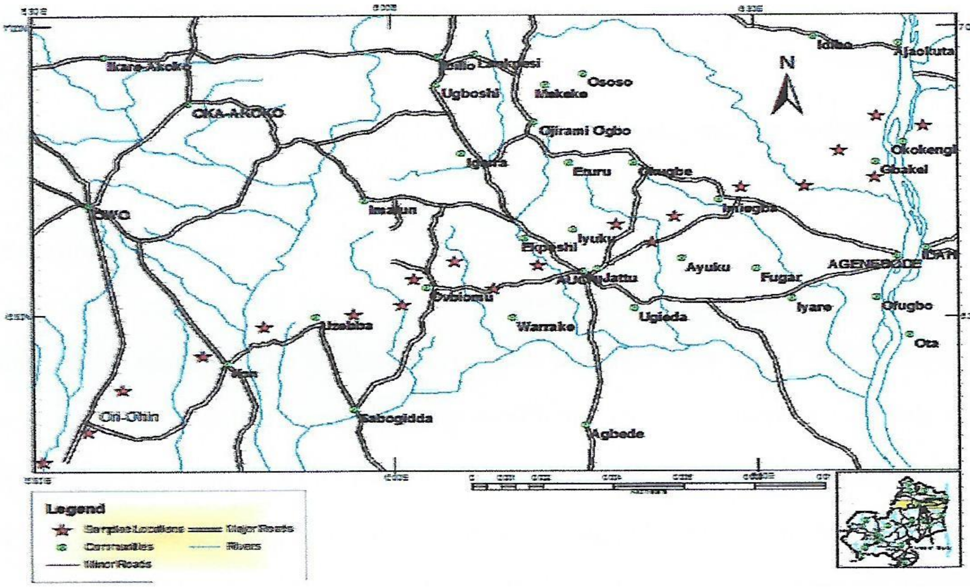


**Fig. 4: Map of Ifon – Auchi Area Showing the Sampled Location (Department of Geology, University of Benin, 2011)**

Samples of each rock unit taken from an outcrop were further studied in the laboratory. The samples were used for biofacies (palynological, micropaleontological) analysis.

The collection of the samples was done using geologic hammer, trowels or shovels making sure that weathered and loose surface materials were carefully scrapped off. Collected samples were preserved in well labelled polythene bags and sealed to avoid contamination. All field details were recorded in a field notebook. The collected samples were taken for further laboratory analysis.

### Laboratory Studies

The samples from the field were subjected to laboratorical evaluation.

### Palynological Analytical Methods

50 suitable surface rock samples obtained from the field were subjected to standard palynological technique (Wood et al., 1996) of maceration for the preparation of acid insoluble organic wall microfossils. 32% of hydrochloric acid was used to eliminate any carbonate present with 60% of hydrofluoric acid used in the elimination of silica or any silicate present. Oxidation with nitric acid was omitted for kerogen residues in order to preserve the colour of the organic debris for palynofacies analysis which was sometimes critical for identification. Sieving through 10um nylon sieve was done after neutralizing with 2% NaOH to clear off humic matter. Separation of the organic matter from the inorganic constituents was by zinc bromide solution (specific gravity of 2.1). The palynomorphs were stew-mounted in epoxyl-resin sealed with cover. Two slides were made from each studied samples. A light transmitting microscope (Olympus model) was used for the identification of the various palynomorphs using standard works of published authors (Van Hoeken – Klinkenberg 1964; Boltenhagen 1967; Gemeraad et al, 1968; SPDC pollen and spore album.

The entire palynomorphs including dinoflagellates in the palynological slides were counted. Frequency is shown as below:

| | | |
|---|---|---|
| > 15 % | - | very abundant |
| 10 – 15% | - | abundant |
| 5 – 10%` | - | common |
| 1 – 5% | - | occasional |
| < 1% | - | rare |

**Microforaminifera Analytical Method**

A portion of the 50 samples collected from different outcrop sections were subjected to standard method of micropaleontological preparation technique. About 30g of each sample was placed on aluminium dish and heated to dryness for 1 hour at a temperature of $100^0$C. Kerosene was immediately added and covered for 2hours. This was decanted and water added to the samples in the dish and soaked for 24hours. The water in the sample was decanted at a constant volume of 20cm$^3$ of sediment and washed over a 63µm sieve under running tap water to remove the mud and also to obtain good representation of small sized species (Clarke *et al*., 1994).

Samples were air-dried at low temperature in an oven and then sieved to separate to size 63µ,125 - 250µ, 250 - 500µ and greater than 500µ (fine – medium – coarse and larger fractions). These were spread over a standard picking tray. The foraminifera's content was picked, identified and counted under a binocular microscope. The percentage of species recovered was calculated for each sample. The data was used to determine the relative abundance of the foraminiferal assemblage and hence paleoenvironment of sediment deposition. Hand drawing of specimen was made of forms identified.

## RESULTS AND INTERPRETATION

**Palynological Biostratigraphy**

Samples yielded palynomorphs which are of low occurrence but well preserved; consisting of terrestrial (pollen and spores) and marine (dinoflagellate cysts, deflandra, acritarch and fungi spores) palynomorphs (plates 1 – 9).

Among the common to abundant miospore species found, include:

*Longapertities marginatus, Longapertites sp. Monocolpollenites spherodites, Maurittidites crassibaculites, Monocolpites marginatus, Monosulcites minimus, Longapertities microfeovolatus, Psilatricolporites laevigatus, Stephanocolpites costatus, Ctenolophonidites costatus, Constructipollenites ineffectus, Cingulatisporites ornatus, Rugulatisporites carperatus, Syncolporites sp.*

Also present but of low occurrence include:Buttinia andreevi, Spinozonocolpites baculatus, Echitriporites trianguliformis, Zlivisporis blanensis, Ariadnasporites longiprocessum, Rousea subtilis. Palynological analysis show that the pollen constitutes about 68%, spore about 20%, algae and fungi about 4%, while dinoflagellate, acritarch and deflandrea (marine microplankton) constitute about 8%. Among the microflora species which constitute the marine influence in the samples include: Dinogymnium acuminatum, Paleocystodinman sp. Spiriferites ramosus, Polysphaeridium subtile, Lejeunesysta hyaline, Cordosphaerdium inodes, Senegalinim bicavatum and Andalusiella sp

## Table 1: Palynomorphs Distribution Chart

| Depth(m) / Palynomorphs | Retimonocolpites Marginatus | Lograpertites Maginatus | Retidiporites Magdalinensis | Cyathidites Minor | Echitriporites Trianguliformis | Constrotipollenites Ineffectus | Taraus Fungi | Cirgulatisporite Ornatus | Monosulcitesp Sp. | Retimonocolpites Sp | Tricolporopollenites Sp | Clavatricolpites | Perretisyncolpites Giganteus | Monocolpites Marginatus | Longapertites Vaneenceburgi | Ephedripites Sp | Steevesipolinites Binodosus | Auriculidites Reticulatus | Distaverrusporites Simptex | Lavigatosporites Sp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | | | | | | | | | | | | | | | | | | | | |
| 6 | 5 | 25 | 7 | 63 | 59 | 4 | 25 | 11 | 110 | 2 | 1 | | 1 | 44 | | 4 | | 22 | | |
| 4 | | 5 | 1 | 3 | 2 | 2 | 3 | | 3 | 1 | | | 2 | 2 | 3 | 1 | | | | |
| 2 | | 6 | 2 | 8 | 3 | 5 | 8 | 1 | 6 | 7 | 1 | 5 | 2 | 6 | 3 | 1 | 2 | 6 | 1 | 5 |
| 0 | 3 | 3 | 24 | 75 | 1 | 62 | 3 | 1 | 34 | 25 | 2 | | | 4 | | | | | | |

| Depth(m) / Palynomorphs | Rugulatisporites Carperatus | Zlivisporis Blanensis | Deltoidsporites Sp. | Foveotrilies Margaritae | Longaperites Reticulatus | Longaperites Sp | Arriadnesporites Spinosus | Buttinea Andreevi | Monosulcites Magnosagenatus | Dicoroconia Adegokei | Monocolpollenites Sphaerodites | Stephanocolpites Constatus | Cycadopites Carpentieri | Triporites Sp. | Rousea Subtillis | Echimonocolpites Maior | Ctenolophonidites Costatus | Verucatotrilate Bullatus | Syncolpites Subtillis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | | | | | | | | | | | | | | | | | | | |
| 6 | 23 | 35 | 45 | 1 | 5 | 1 | 6 | 5 | | 2 | | 3 | 3 | 4 | 12 | 33 | 38 | | 33 |
| 4 | | 4 | | | 4 | 3 | 2 | 2 | 3 | | | | | | | | | 2 | |
| 2 | 2 | 2 | 4 | 1 | | | | | | | 2 | | | | 1 | | | | |
| 0 | 6 | | | | | | | | | | 1 | 3 | | | | | | | |

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**Table2: Range Chart of Selected Stratigraphically Important Pollen and Spores in Outcrop Sections within the Ifon – Auchi Area of Benin Flank**

| S/N | Campanian | | Maastrichtian | | Paleocene | | Eocene | | Age |
|---|---|---|---|---|---|---|---|---|---|
| | Early | Late | Early | Late | Early | Late | Early | Late | Species |
| 1 | — | — | — | | | | | | Distaverrusporites simplex |
| 2 | — | — | — | | | | | | Zivisporis blanensis |
| 3 | — | — | — | | | | | | Monocopollinites Sphaerodites |
| 4 | — | — | — | | | | | | Cingulatisporites Ornatus |
| 5 | — | — | — | | | | | | Auriculiidites Reticulates |
| 6 | — | — | — | — | | | | | Regulatisporites Caperatus |
| 7 | — | — | — | — | | | | | Buttinia Andreevi |
| 8 | | — | — | — | | | | | Constructipollinites Ineffectus |
| 9 | | | — | — | | | | | Proxapertites Anisosculptus |
| 10 | | | — | — | | | | | Verrucatotrilete Bullatus |
| 11 | | | | — | | | | | Longapertites Vanendenburgi |
| | | | | — | — | | | | Ariadnaesporites Spinosa |
| 12 | | | | — | — | | | | Ariadnaesporites Longiprocessum |
| 13 | | | | — | — | | | | Longapertites Inornatus |
| 14 | | | | — | — | | | | Maurittidites Crassibaculatus |
| 15 | | | | — | — | — | — | | Retidiporites Marginatus |
| 16 | | | | — | — | — | — | | Longapertites Marginatus |
| 17 | | | | — | — | — | — | | Monocolpites Marginatus |
| 18 | | | | — | — | — | — | | Spinozonocoplites Echinatus |
| 19 | | | | — | — | — | — | | Synocolporites Incomptus |
| 20 | | | | — | — | — | — | | Psilatricolporites Laevigatus |
| 21 | | | | — | — | — | — | | Periretisyncolpites Magnosagenatus |
| 22 | | | | — | — | — | — | — | Diporoconia Adegokei |
| 23 | | | | — | — | — | — | — | Ctenolophonidites Costatus |
| 24 | | | | — | — | | | | Echitriporites Trianguliformis |
| 25 | | | | | — | — | — | | Monoporites Annulatus |
| 26 | | | | | | | | | Tercus Fungi |
| 27 | | | | | — | — | — | | Longapertites Microfoveolatus |
| 28 | | | | | — | — | — | | Foveotrilate margaritae |
| 29 | | | | | — | — | — | | Poteacidites Dehaani |
| 30 | | | | | — | — | — | | Spinozonocoypites Baculatus |

## Systematic Palynology

Classification employed in this work is according to Potomie and Kremp (1954 – 56). Cingulatisporites ornatus Van Hocken Klinkenberg (1964).
Plate 1 – 9
Dimensions 43 x 38µm
Specimen 17 Coordinate 27.8 109.9

### Subturma Triporites Potonie, 1960

i. Echitriporites trianguliformic Van Hoeken – Klinkenberg, 1964 PL 13 Fig. 1
Dimensions: 35 x 35µm; Range 37 – 32 x 35 - 30µm
Specimen 12, Coordinate 52, 0, 120.2

ii. Triorites sp
PL 1, Fig. 2, PL 4, Fig. 1
Description: Subtriangular small pollen, sides moderately concave, triorate, pores sample, exine thin, finely echinate.
Dimension 27 x 21µm
Sample No 12
Coordinate 27.5; 123

iii. Deltoidospora Sp
Description: small, sub-deltoid trilete spore, with the trilete marks extending almost to the radial corners, "Cingulate", exine laevigate.
Dimensions: 25 x 24µm
S 12 Coordinates 36 – 0, 110.5
PL 1, Fig. 3.

iv. Mauriitides Crassibaculatus Van Hoeken – Klinkenberg. 1964
Plate 3, Fig. 4
Description: prolate, sometime spherical mono – sulcate pollen, sulcur long, as long as the longest diameter of grain, simple, exine thin, baculate,

bacula between 4 - 5µm diameter, moderate thick exine materials
Dimension 56 x 35µm equatorial corners, except the cingulum is relatively wide (7.3 – 7.9µm), uniform, marginate sometime crenulate.
Dimensions 48 x 40µm; Range 48 – 12 x 40 - 35µm (10 specimen)
Infratuma Apiculati (Bennie and Kidston) Potonie, 1958
Supturna Verurrucati Dybva and Jachowiez, 1968
Infratuma Murornati Potonie and Kremp, 1954

v. Rugulatisporites caperatus x 100
Van Hoeken – Klinkenberg, 1964
Plate 4, Fig. 8
Dimensions: 31 x 30µm; Coordinates 33.0, 124.2
Remarks: Spherical (amb four) in the palynological preparation which appear very distinct.

vi. Arindnasporites spinose, Skarby and Odebode, 1982
Plate 2, Fig. 8
Dimension: 65 x 54µm
Coordinate 48.0 x 125

vii. Ephedrepites Sp. (Kuyl *et al*., 1955; Salami, 1984
Plate 1, Fig. 6
Dimension 68 x 38µm
Location S1.0
Coordinates 40.01, 128.4
Description: Perprolate pollen with somewhat rounded extremities, bears 5 – 6 straight ridges on one side of the grain and several small inclined rides on the opposite sides; ectexine more prominent than endexine, which is restricted to areas between ridges.
Dimension: 33 x 23µm
Location: S15
Coordinates 29.1 – 110.0

viii. Subturma Monocolpates Inversen Trods – smith (1950)
Arecipites microreculatus Anderson 1960
Pl. 2, Fig. 8
Dimension: 30 x 27µm
Range 38 – 32 x 27µm (5 specimens)
Coordinates: 60.0, 110.1

ix. Auriculidites reticulates Elsik 1964
Plate 2, Fig. 3, 4.
Dimension: 54 x 30µm
S – 25 Coordinate 40.0, 120.2
Description: Oval pollen grains, probably is opolar with two auriculated structure at the extremities of the grain, monosulcate, sulcus long, exine thin (1.5 - 2µm). Muri uniform (about 0.2 - 03µm).
Dimension: 54 x 38µm

x. Longer pertites marginatus
Van Hoeken – Klinkenberg, 1964
Plate 5, Fig. 1, Pl 3, Fig. 8
Dimension 54 x 40µm
S. 2 Coordinates 44.9; 125.0

xi. Longapertites reticulates sp
Plate 5, Fig. 2.
Description: Sub – circular zonosulcate pollen sulcus long, encircles the grain, proximal surface moderately convex to straight, distal surface prominently convex to straight exine intectate, conspicuously recticulate, columella simple,

muri of uniform width, lumina of various shapes, along wides than muri.
Dimension: 63 x 45µm. range 60 – 70 x 40.55µm (6 specimens).

xii. Monocolpollenites spharoidites Jardine and Magloire, 1965
Plate 4, Fig. 7
Dimension: 24 x 20µm
S 30, Coordinates 24.3, 125.5
Mauriitides Crassibaculatus
Van Hoeken – Klinkenberg, 1964
Plate 1, Fig. 4
Description: prolate, sometimes oval monosuliate pollen, sulcus long, as long as the longest diameter of grain, simple, exine thin, baculate between 4.5 – 5.5µm long,
narrow in width (11.5 – 2.0µm), round at their tips, indented at the base by moderately thick exine materials.
Dimension: 56 x 36µm
S 25 Coordinates 46.9, 113.7
Subturma Polytyches Potonie, 1960
Infraturma Stephanocopati Potonic, 1970

xiii. Ctenophoniditites costatus
Van Hoeken – Klinkenberg, 1966
Plate 2, Fig. 10
Dimension: 45 x 35µm
S 30 Coordinates 48.0, 120.2
Turma PorosesPotonie, 1960
Subturma Diporines Potonie, 1960

xiv. Retidiporites Magdalenensis
Van der Hammen and Garcia de Muttis, 1966
Plate 2, Fig. 5, 6
Dimensions: 54 x 41µm
S. 16 Coordinates 53.0 – 120.3
Remarks considerable size variation exists in the studied specimens other range from 46 - 41µm
Subturms Triporines Potonie, 1960

xv. Echitriporites trianguliformis
Van Hoeken – Klinkenberg, 1964
Plate 1, Fig. 1
Dimensions: 35 x 35µm; Range: 37 – 32 x 35 - 30µm (15 specimens) coordinates 48.8, 118.3
Description: Triangular small pollen sides convex, triporate, exine thin, covered by numerous conical spines, current at this tips, distance between adjacent spines variable, spaces between spines are smooth.

xvi. Triorites Sp
Plate 1, Fig. 2
Description: Subtriangular small pollens, side is moderately concave, triorate, pore simple, exine thin, finely echinate.
Dimensions: 27 x 21µm
Coordinates 27.2 x 125.9

xvii. Ericipites Sp
Plate 1, Fig. 3
Descriptions: Tetrahedral small pollen, aperture indistinct but short, colpi shared between adjacent “grains”, exine moderate (3.0 – 3.5µm) ectexine and endexine layers bother probably compressed.
Dimension: 34 x 33µm
Coordinate 27.8 x 122.5

Turma Saccites Erdtmen 1947
Subturma Polysaccites cookson, 1947

xviii. Aquilapollenites sp
Plate 2, Fig. 3, 4
Description: Subtriangular pollen with concave side, polar area with two membraneous flaps (probably scars from the union of several grains) "equatorial" area displays three protrusions, exine thin, finely echinate.
Dimension: 42 x 37µm
Coordinate: 30 x 120.8
Infratuma Tuberini Potonie 1960

xix. Buttinia andreevi Boltenhagen, 1967
Plate 5, Fig. 4
Dimension: 58 x 45µm
Coordinate 58.2 105.1

xx. Deltoidosporal sp
Plate 3, Fig. 7
Description: Small, sub – deltoid trilete spore with the trilete marks extending almost to the radial corners, "cingulated" exine laevigate.
Dimensions 25 x 24µm
Coordinate 38.0 x 112.5
Subturma Zonotrilate Waltz 1935
Infraturma Cingulati Potonie and Klaus 1954

xxi. Cingulatisporites ornatus Van Hoeken – Klinkenberg 1964
Plate 4, Fig. 1
Description: Trilate microspore, central body round, occasionally triangular or subtriangular, sides are convex to straight trilet marks long. Simple arms reaching.

xxii. Ephedripites regularis sp x 1000 x Bolchowitina 1953
Pl. 4, Fig. 6
Description: Pollyplicate pollen grain, psilate, between the ridges furrow – like openings occur.
Size of grain 60 x 33µm
Width of ridge 5µm
Grooves < 1µm
Locality Obi Camp, Mamu Formation (Age Maastrichtian)

**Atlas of Palynomorphs Taxa from Outcrops On Benin Flank**

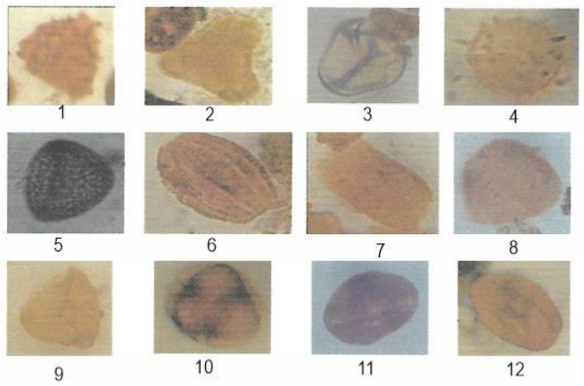



**Plate 1**

1. Echitriporites Trianguliformis (Van – Hoeken Klinkenberg 1964)
2. Triorites Africaensis
3. Cyathidites Minor
4. Spinozonocolpites baculatus (Muller 1968)
5. Foveotrilates margaritae (Van der Hammen), Germeraad, Hopping and Muller (1968)
6. Ephedripites regularis (Van Hoeken – Klinkerberg, 1964)

7. Retidiporites magdalenesis (Van der Hammen and Garcia, 1966)
8. Longapertites marginatus (Van Hoeken – Klinkerberg, 1964)
9. Deltoidsporites sp
10. Crassitricolpites costatus
11. Psilamonocolpites Medius
12. Nyssapollenites pseudocruciatus

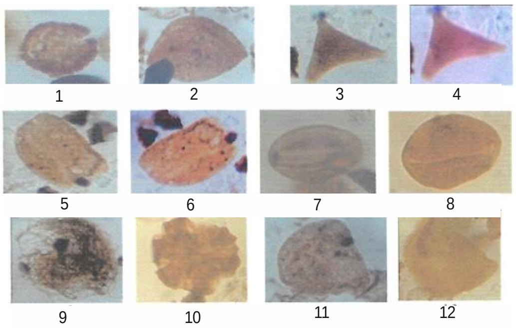



**Plate 2**

1. Cingulatisporties ornatus
2. Longapertites marginatus
3. Aquillapollenites minimus
4. Aquillapollenites minimus
5. Retidiporites magdalenensis
6. Retidiporites magdalenensis
7. Monocolpollenites shpaerodites
8. Nyssapollenites pseudocruciatus
9. Ariadnaesporites longiprocesus (Odebode and Skarby, 1981)
10. Ctenolophonidites costatus
11. Auriculidites recticulatus

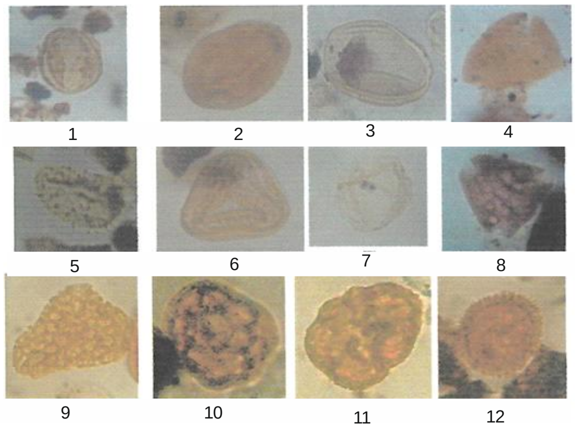



**Plate 3**

1. Echimonocolpites rarispinosus
2. Monocolpollenites sphaeroidites
3. Nyssapollenites pseudocruciatius
4. Longapertites microfeovolatus
5. Mauritiidites lehmani
6. Polypediasisporites sp
7. Monoporites annulatus
8. Rousea subtilis
9. Periretisynocolpites magnosagenatus
10. Proxapertites anisosculptuse
11. Verrucatotriles bulatus (Van Hoeken – Klinkerberg, 1964)
12. Constuctipollenites ineffectus

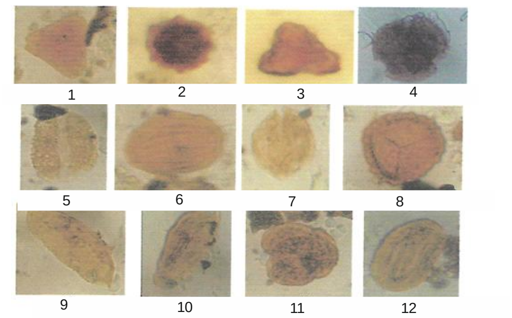



**Plate 4**

1. Triorites africaenesis (Sallard, 91)
2. Pollen "stephanocolporate (zonorate)" (in kulyl *et al* 1955)
3. Pollen indet
4. Tricolpites sp. I. (in Doyle at al., 1977)
5. Retimonocolpites sp
6. Ephedripite multicostatus – (Brenner 1963)
7. Monocolpites marginatus
8. Rugulatisporites carperatus
9. 9, 10 Monosulcites sp. S. l 52 (in Jardine and Magloire, 1965)
10. 11 Ericipites sp
11. 12 Tricoporopollenites sp SCI 141 (in Jardine and Magloire, 1965)

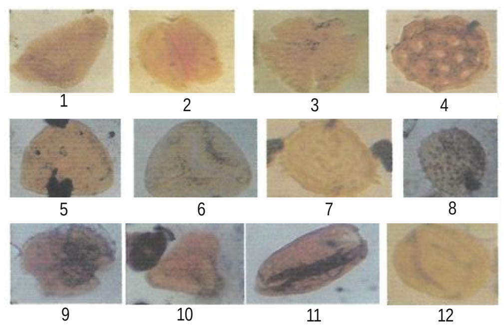



**Plate 5**

1. Longapertites microfeovolatus
2. Monocolpollenites marginatus
3. Tricolpites reticulates
4. Longapertites marginatus
5. Foveortrilate margaritae
6. 7 & 8 Spinozonocolpites baculatus
7. Tricolpites sp
8. Ephedripite sp
9. Pollen indet
10. Pollen indet
11. Pollen indet

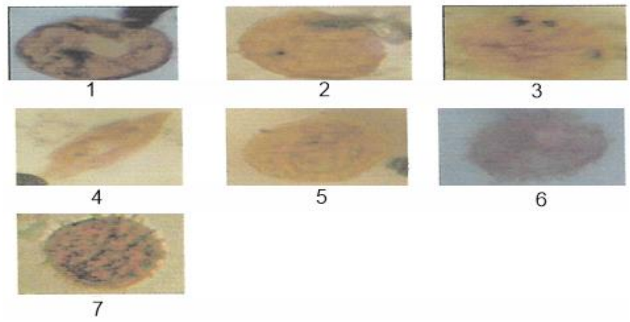



**Plate 6 (Dinocyst)**

1. Dinoflagellate cyst
2. Dinogymnium acuminatum (Evit et al., 1967)
3. Andalusiella sp
4. Palaeocystodinium golzowense (Albert; 1961)
5. Senegalinium laevigatum
6. Cyclonephelium decininckii

Hystrichosphaeridium sp

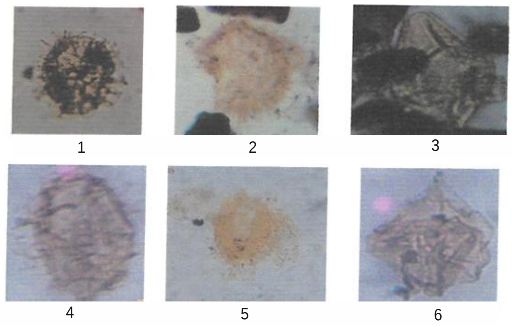



**Plate 7**

1. & 4 Spiriferites
2. Indet
3. Dinogymnium sp
4. Cordosphaeridium sp

Lejennecysta hyalineA

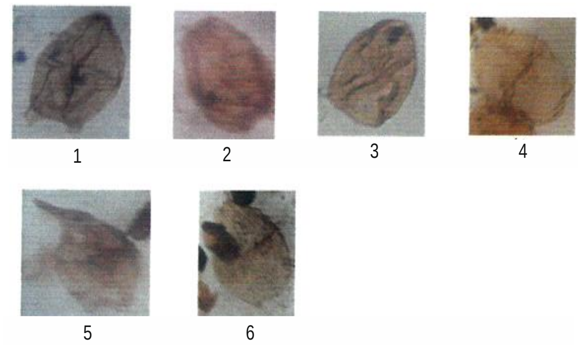
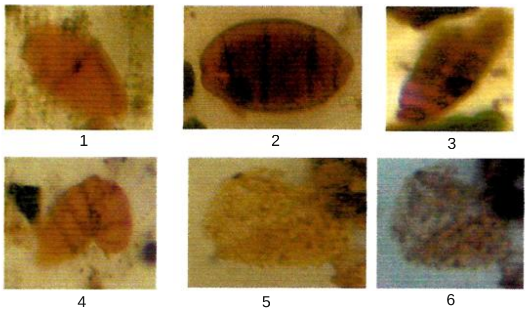



**Plate 8**

1. Senegalinium psilatum
2. Dinogymnium sp
3. Dinogymnium acuminatum
4. Deflandra sp




**Fungal Spore Plate 9:**
**(**Varieties of Fungi Spores)

## MICROPALEONTOLOGICAL BIOSTRATIGRAPHY

Analysis of the samples shows that the microfauna were dominantly benthic arenaceous foraminifera. Nine genera recovered from the samples yielded Ammobaculites ammobaensis, Amobaculites plummera, Amobaculities coprolithiformis, Haplophragmoides sahelienses, Textularia hockley – ensis, Trochammina dutsuna. They are shown in the figures. Their distribution and age range from Middle –Upper Maastrichtian (Fig 5)

**Fig 5: Benthonic Foraminifera Recovered from outcrop at Obi Camp and Ubezi River Sections, Mamu Formation**

### Foraminifera Taxonomic Classification East of the Benin Flank

Family - Lituolidae
De Brainville 1825
Sub -
Haplophragmoidinae Maync 1952
Genus - Haplophragmoides
Hause Petters 1979c
Occurrence - Abundant in the Lower Shale of the Middle – Late Maastrichtian Dukamaje Formation where it was originally described. Present in the Ifon – uzebba outcrop in this work. Fig 5.

Haplophragmoides saheliense Petters 1979c
Fig 5; No. 6
Occurrence - Rare in the lower shale of the Middle – Late Maastrichtian in the Dukamaje Formation. This also applies to the form described in the Obi Camp, Ifon – Ubezi outcrop of the Benin Flank.

Haplophragmoides Petters 1979c
No 4

It occurs commonly in the Lower and Upper Shale of the Middle to Late Maastrichtian. General remark: The Obi Camp specimen in the Benin Flank have thick, circular, weakly lobulete strepospiral tests. The axial periphery is broad. They have up to 10 rectangular chambers in the last whorl which is evolute revealing a slightly convex umbilicus on one side and a depression on opposite side. In both forms, the suture are depressed and the wall is fairly smooth with fine agglutinants and abundant cement. These forms exhibit variation in test distortion.

Sub family - Lituolinae De Brainville 1825

Genus - Ammobaculaites Cushman 1910

No 5

Remark: The specimen recovered from the ourcrop sections on the Ifon – Auchi area of the very Benin Flank is very similar to the plesiotype (C.C. 12610) from the Upper Cretaceous of Trimida (Cushman and Javis 1932). Both forms are elongate, slender, compressed and distinctly rooulate. The chambers are oblate cones which over – hang previous ones in both forms. The suture is strongly depressed and horizontal, and the wall appear sugary with little grains of nearly uniform size and small cement. The initial coiled end of test is small and involve and may be indistinguishable.

**Table 3: Abundance and Distribution Chart of Benthic Forams from Outcrop Sections on the Ifon-Uzebba Road Cut**

| AGE | FORMATION | DEPTH | LITHOLOGY | SAMPLES | *Ammobaculites Ammabensis* | *Haplophragmoides Hausa* | *Textularia Hockleyensis* | *Haplophragmoides Talokaensis* | *Ammobaculoides Plummerae* | *Haplophragmoides Saheliense* | *Haplophragmoides Sahanense* | *Ammobaculites Coprolithforms* | *Trochammina Dutsuna* | | *Carboniferous Wood* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UPPER CRETACEOUS | MAASTRICHIAN MAMU FORMATION | 20.0m | | | | | | | | | | | | | |
| | | 0.1 | | 6 | = = | xxxx | = = | xxxx | = = = | = = = | = = = | = = = | = = = | | |
| | | 2.5 | | | | | | | | | | | | | |
| | | 15.02 | | 5 | = = | xxxx | = = = | xxxx | = = | = = | = = | = = | = = | | |
| | | 2.0 | | 4 | = = | xxxx | = = | xxxx | = = = | xxxx | = = = | xxxx | = = = | | |
| | | 0.2 | | | | | | | | | | | | | |
| | | 2.5 | | 3 | = = = | xxxx | = = = | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | | |
| | | 0.3 | | | | | | | | | | | | | |
| | | 1.0 | | | | | | | | | | | | | |
| | | 6.5 0.2 | | 2 | xxxx | xxxx | :: | xxxx | xxxx | xxxx | xxxx | xxxx | xxxx | | |
| | | 1.5 | | 1 | = = = | : | :: | :: | :: | xxxx | xxxx | xxxx | xxxx | | |
| | | 1.4 | | | | | | | | | | | | | |
| | | 2.5 | | | | | | | | | | | | | |



Scaling:0–30 rare xxxx; 30–60common = =; 60–above abundant :: Key: Indurated Siltstone Mud Stone Clay Stone

**Table 4: Range Chart of Foraminera from Outcrop Section along Ifon – Uzebba Road**

| AGE SUMMARY | Forams Taxa | | Ammobaculites Ammabensis | Haplophragmoides Hausa | Textularia Hockleyensis | Haplophragmoides Talokaensis | Ammobaculoides Plummerae | Haplophragmoides Saheliense | Haplophragmoides Sahanense | Ammobaculites Coprolithforms | Trochammina Dutsuna |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATE | MAASTRICHIAN | | | | | | | | | |
| | MIDDLE | | | | | | | | | | |
| | EARLY | | | | | | | | | | |
| | CAMPANIAN | | | | | | | | | | |
| CRETACEOUS | SANTONIAN | | | | | | | | | | |
| | CONIACIAN | | | | | | | | | | |
| | TURONIAN | | | | | | | | | | |
| | CENOMANIAN | | | | | | | | | | |
| | ALBIAN | | | | | | | | | | |

## INTERPRETATION/DISCUSSION

### Biostratigraphic Age Deduction

The marine and continental deposits contain palynomorphs and, hence, are useful in dating the rocks. Several authors which include Germeraad *et al* (1968), Adegoke *et al*., (1978), Van Hoeken Klinkenberg (1964), Van der Hammen (1954), Jan du Chene (1976); 1978) among others have reliably used pollen grains and spores in various studies to date sedimentary rocks especially within the southern Nigeria sedimentary Basin.

In this study, the age determination of the stratigraphic rock units exposed in the Ifon – Auchi area of the Benin Flank were based on the stratigraphically important palynomorphs as well as foraminifera sp. recovered from the samples.
The very important stratigraphic indexes of both microfauna and flora, which were recovered in the studied samples, and used in the age assignment based on the works of authors include:
Zlivisporis blanensis – Paitova 1954
Monocolpollenites marginatus van der Hammer 1954
Buttinia andreevi – Boltenhagen 1967
Echitriporites trianguliformis – van Hoeken Klinkerberg, 1964
Retidiporites magdalenensis – Hammen and Garcia, 1965
Longapertites marginatus – van Hoeken – Klinkerberg, 1964
Rugulatisporites caperatus – van Hoeken – Klinkerberg, 1964
Cingulatisporites ornatus – van Hoeken – Klinkerberg, 1964
Retistephanocolpites williamsi – Germeraad, Muller, Hopping, 1968
Constructipollenites ineffectus – van Hoeken – Klinkerberg, 1964
Verrucatotrilate bullatus – van Hoeken – Klinkerberg, 1964
Longapartites vaneedenburgen – Germeraad et al., 1968
Tarsus fungi
Foviotrilate margaritae – Germeraad et al., 1968
Spinozonocolpites baculatus
Ariadnaesporites logiprocessum – Odebode and Skarby, 1980
The suit of marine Maastrichtian dinoflagellates also recovered from the sediments include:
Dinogymnium acuminatum, Dinogymnium euclaensis, Paleocystodinium Lejeunecysta hyaline, Spiriferites ramosus, Spiniferites, Senegalinium bicavatum. (PL 6)

The sections contain the association of Longapertites vaneedenburgi (late Maastrichtian to Danian and absent in the Paleocene – Germeraad et al., (1968), Constructipollenites ineffectus (Maastrichtian to Danian – Salami (1983) and Ariadnaesporites logiprocessum (Maastrichtian to Danian.

The index forms overlap with assemblage of marker species consisting of Rugulatisporites carperatus, Butinia andreevi, Cingulatisporites ornatus that had their last appearance in the Late Maastrichtian and absent in the Paleocene. It is therefore reasoned that these index species co – occurring with important Constuctipollenites ineffectus in the same sections are indicative of Maastrichtian age.

Although palynological works carried out by Van der Hemmen (1954), Van Hoeken – Klinkerberg (1964), and Salami (1990) have placed the age of some of these microflora to be Campanian – Maastrichtian. Some markers such as Monocolpites marginatus, Retidiporites magdalenesis, Foveotriletes margaritae, Buttinia adreevi, Retidiporites, magdalenesis and Rugulatisporites carperatus have been observed to be characteristics of the Maastrichtian. Lawal et al., (1978) made similar observations in their palynological biostratigraphy of Cretaceous sediments in the Upper Benue Basin of northeastern Nigeria.

The upper unit of the rock sequence is marked by frequent occurrence of species like Echitriporites trianguliformis, Monocolpites marginatus, Longapertites vaneedenburgi and Cingulatisporites ornatus. Van der Hammen (1954), Muller (1968),

Salard – Chebodaef (1979) has assigned Upper Maastrichtian or younger age to these marker species. Adegoke at al., (1978), recovered Buttinia andreevi and Distaverrusporites simplex from bituminous sand of Ondo State and suggested Maastrichtian age.

From the foregoing, it is very obvious that the palynomorphs recovered from the sedimentary outcrops in the Benin Flank in the Ifon – Auchi area are similar and the same age as those recovered from the Lower Coal Measures (Mamu Formation) in Enugu area by Van Hoeken –Klinkerberg (1964), Salami (1990) and those of Ondo State bituminous sands by Adegoke et al., (1978). The Ifon – Uzebba sediments through Ihiebe to Auchi – Ikabigbo area are therefore assigned Maastrichtian age on the basis of the occurrence and similarity of the important palynomorphs present, and thus support the occurrence of the Lower Coal Measures (Mamu Formation) in the Benin Flank. The restriction of spiniferites sp., Dinogyminimum accumulatum, Apectodimium homomorphum and Peridinacca sp, which do not range into Danian clearly indicate that samples are Maastrichtian age (Ojo et al., 2006).

**Depositional Environment**

The distribution pattern and species diversity of certain pollen grains, spores and dinoflagellates as well as foraminiferal and other organic matter in the sediments give close approximation of the environment of the deposition of the sediments. These criteria were applied in studying the paleoenvironment of the outcrops studied.

Lithologically, the sedimentary sections in the study area containing mircrofossils is Mamu Formation. It consists of an alternating sequence of thinly laminated to thickly laminated dark gray shales, indurated siltstone facies, mudstone and claystone.

The preponderance of thick shale horizons suggests a quiet water or low energy environment, but exposed to periodic inundation of silt – laden current. The presence of compressed carbonized woody fossils coupled with specks of organic matter may suggest a swamp condition, while the emanation of sulphur odour from the shale horizons, where specks of yellowish sulphur were observed is indicative of the reducing environment. The iron – stained lenticular bodies within the shales horizons at the outcrops near Ubezi River and Auchi shales may also be similar to the observation made by kruaskopf (1967), when he suggested that a local reducing environment of deposition prevailed in an area where the supply of ferrous iron precipitate is large and /or reducing environment is maintained by abundant organic matter, such as deltaic swamp, marshes and mangrove. It is necessary to state the suggestion by Burke *et al.* (1971, 1972), that there was the existence of a delta in Enugu area in the Campanian – Maastrichtian times. They indicated that the building activity of the delta prograded in southern direction till Tertiary times, while the Gulf of Guinea was the source of marine incursion and this extended to the western part of the country. Palynologically, the miospores association in the samples also indicated fresh water swamp vegetation as shown by a very large amount of spores. Monocolpites marginatus, Constructipollenites ineffectus, Deltoidsporites and Cyathidites minor are indicative of continental to near shore environment (Salami, 1990). Thus it could be interpreted that the fresh water swamp environment was surrounded by herbaceous and other vascular plants, which readily provide pollen to the depositional environment. Some of the recorded miospores, such as Longerpertites marginatus are similar to those ascribed to the palmae by Germeraad et al., (1968), while the herbaceous plants were also present. This fresh water swamp or marsh was inundated by marine or brackish water of short duration. The low occurrence of dinoflagellate cysts and Deflandrea including spiniferites, Lejeunecysta and Polysphaeridium are probably stragglers left behind in local pools after the withdrawal of the ocean. A mechanism by which a transgression may promote the deposition of organic – rich sediments has been described by Jenkys (1980).

The foraminiferal assemblage recovered from the shales in the Ifon – Uzebba road cuts within the Benin Flank include Ammobaculites. This genus according to Culver and Buzas (1981), are present in all ecological niches in modern seas. They are infaunal deposit feeders. The organism prefers muddy sediments of brackish water to normal marine in marsh to upper bathyal environments. The organisms are tolerant to low oxygen level. The forms recovered include Ammobaculites corprolitiformis and A. benuensis.

The geneus Haplophragmoides also recovered is infaunal and commonly found in muddy to sandy substrates. It occurs in marsh environments down to bathyal. It is also in estuaries and hypersaline lagoons as well as normal marine. The forms identified include H. talokaensis., H. Hausa, H. sahariense. Also present is the genus Trochammina which is both an epifaunal and infaunal deposit and plant feeder. It is tolerant to low oxygen level.
The presence of these benthonic arenaceous foraminifera support a shallow water depositional environment. This interpretation is in agreement with work carried out by Enu (1987); Guerin and Moullade (1979).

## CONCLUSION

The Mamu Formation identified consisted of a heterolith of shale alternating with siltstone, mudstone and clay. This formation consists of palynological and micropaleontological microfossils which have been used to give an age of Maastrichtian for the sediment (60.5m.y.). The preponderance of thick shale horizon suggests a quiet water or low energy environment, but exposed to periodic inundation of silt – lader current.
The miospore associations in the sample indicated fresh water swamp vegetation as shown by a very large amount of spores i.e Monocolpites marginatus and Constructipollenites ineffectus. The yellow sulphur in the sediment as well as iron stain in the siltstone horizons are all indicative of

a reducing environment. The fresh water swamp was inundated by marine or brackish water of short duration. The low occurrence of some dinocysts are probably stragglers left behind in local pools after the withdrawal of the ocean.It thus shows that the palynomorphs recovered from Mamu Formation within the Benin Flank are similar and of the same age as those recovered from Anambra Basin and those of the bituminous sand of the adjacent Benin/Dahomey Basin.

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