THE GEOLOGICAL HISTORY OF SEDIMENTATION IN THE SUB-BASINS OF THE CALABAR FLANK, SOUTHEASTERN NIGERIA: PALYNOLOGICAL EVIDENCE FROM THE IKONO-1 WELL

O. P. UMEJI

(Received 17 January, 2006; Revision Accepted 14 February, 2006)

ABSTRACT

The oldest sediments overlying basement on Ituk High in Ikono-1 Well are Late Albian-Late Coniacian estuarine and marine shales from which the following index sporomorphs were recovered: Trachites afericaensis, Classopolis brasiliensis, Sphaerites legouange, Eulateropollenites jardinei, Cretarcorexorites polygonalis, Trilobites S.C.1 124 Jardiné & Maguire 1965, Ammonoceras australe and inaperturopollenites dubius. Fresh water algal remains, acritarchs, and dinoflagellate cysts. Crytopsphaeridia sp. Cyclonespharium sp. together with micro-faunifer linings were also recovered. Palynological data was used to interpret depositional history in the two sub basins of the Calabar Flank, the Ikang Trough and Ituk Basin. Neoconian-Aptian terrigenous Ave Formation and marine Aptian-Albian reported from Ikang Trough were not encountered in Ituk sub basin. The Ituk sub basin subsided only in the Late Albian and again in the Santonian. Sedimentation ended in both sub-basins during the Coniacian-Santonian uplift. Resumed deposition occurred in Ituk sub basin in the Campanian. The Coniacian is absent in the two sub-basins. Sedimentation continued into the Tertiary with progradation into the Niger Delta. In discussing the geology of the Calabar Flank, distinction should be made between the two sub basins.

KEYWORDS: Calabar Flank, sub-basins, palynomorphs, sedimentation

INTRODUCTION

The Calabar Flank sedimentary basin is located on the southeastern extremity of Nigeria (Fig 1a). It is bounded on the NW by the Ituk Platform, on the north by the Oban Hills, on the western border is the Cameroon volcanic line, and to the south lies the Calabar hinge line. The terms Calabar and Benin Flanks were first used by Murat (1972) to denote downfaulted margins flanking the Niger Delta on the northeastern and northwestern sides respectively. The Calabar Flank consists of NW-SE striking horsts, the Oban Massif and Ituk High, separated by a graben, the Ikang Trough (Fig 1a). The other marginal basin on Anaa are similarly characterized by horsts and grabens originating from the Africa-South America continental break-up and the opening of the South Atlantic Ocean. The downfaulted zones guided the transgressions and consequent sedimentation into the inland basins just as in the other sedimentary basins of Nigeria, Reymert (1985).

But for the strike of these boundary faults which in the Calabar Flank are NW-SE while in the Benue Trough are NE-SW, the Calabar Flank shares much with the Abakaliki Basin in the depositional history in pre-Santonian, and with the Akoko Syncline during the later times. Ikono-1 was among the five exploration wells drilled on Ituk High on OM, 12 in the 1960s and 1970s by SPDC-Nigeria Ltd. The others are Ituk-2, Urara-1, Anaa-1, Ikono-1 and ikpe-1, from SE to NW.

**Fig 1a. Structural elements of the Calabar Flank and adjacent areas (after Murat, 1972)**

O. P. Umeji, Department of Geology, University of Nigeria, Nsukka, Enugu State, Nigeria.
THE GEOLOGICAL HISTORY OF SEDIMENTATION IN THE SUB-BASINS OF THE CALABAR FLANK, SOUTHEASTERN NIGERIA: PALYNOLOGICAL EVIDENCE FROM THE IKONO-1 WELL

O. P. UMEJU

(Received 17 January, 2006; Revision Accepted 14 February, 2006)

ABSTRACT

The oldest sediments overlying basement on Ikot High in Ikono-1 Well are Late Albian-Late Cenomanian estuarine and marine shales from which the following index sporomorphs were recovered: Triarloses africanaes, Cassopolis brassilensis, Subrhopites legouxian, Elateropollenites jardinei, Crotocladopites polygonali, Trilites s capitardes Jardin & Maginot 1965, Aurororinates australis and Imperturpulinites dubius. Fresh water algal remains, acritarchs, and dinoflagellate cysts, Chrysophyta sp., Cyclonephytum sp., together with microforaminiferal linings were also recovered. Palynological data was used to interpret depositional history in the two sub basins of the Calabar Flank, the Ikong Trough and Ikot Basin. Necromian-Aptian tereogenus A and marine Aptian-Albian reported from Ikong Trough were not encountered in Ikot sub basin. The Ikot sub basin sediments only in the Late Albian and again in the Santonian. Sedimentation ended in both sub basins during the Coniacian-Santonian uplift. Resurfacem deposition occurred in Ikot sub basin in the Campanian. The Coniacian is absent in the two sub basins. Sedimentation continued into the Tertiary with progradation into the Niger Delta. In discussing the geology of the Calabar Flank, distinction should be made between the two sub basins.

KEYWORDS: Calabar Flank, sub-basins, palynomorphs, sedimentation

INTRODUCTION

The Calabar Flank sedimentary basin is located on the southeastern extremity of Nigeria (Fig 1a). It is bounded on the NW by the Ikpe Platform, on the north by the Oban Hills, on the western border is the Cameroon volcanic line, and to the south lies the Calabar hinge line. The terms Calabar and Benin Flanks were first used by Murai (1972) to denote downfaulted margins flanking the Niger Delta on the northeastern and northwestern sides respectively. The Calabar Flank consists of NW-SE striking horsts, the Oban Massif and Ikot High, separated by a graben, the Ikong Trough (Fig 1a). The other marginal basins of Africa are similarly characterized by horsts and grabens originating from the Africa-South America continental break-up and the opening of the South Atlantic Ocean. The down-faulted zones guided the transgressions and consequent sedimentation into the inland basins just as in the other sedimentary basins of Nigeria, Reynard (1965). But for the strike of these boundary faults which in the Calabar Flank are NW-SE while in the Benue Trough are NE-SW, the Calabar Flank shares much with the Abakaliki Basin in the depositional history in pre-Santonian, and with the Afikpo Syncline during the later times. Ikono-1 was among the five exploration wells drilled on Ikot High on OML 12 in the 1950s and 1960s by SPDC Nigeria Ltd. The others are Ikot-2, Uruan-1, Anua-1, Ikono-1 and Ikpe-1, from SE to NW.

Fig. 1a: Structural elements of the Calabar Flank and adjacent areas

(after Murai 1972)
Review of stratigraphy

The oldest sedimentary deposit outcropping in the Calabar Flank was named Odukpani Formation by Reymert (1965). It comprises basic arkosic sandstones and conglomerates up to 50 m thick overlain by Cenomanian marine limestones and shales. Adeleye and Fayose (1978) erected the name Awi Formation for the basal beds and retained the name Odukpani Formation for the rest of the overlying marine Albian-Turonian successions (Fig 2).

Murat (1970) recognized the Neocomian age of the basal grits while Ramanathan and Kumanan (1981) confirmed the age using the polymorphs from these basal beds in the CALCEMCO Core M-1 Well south of Mfamosing. The limestones and calcareous sandstones overlying the grits were deposited under paralic conditions. The upper part was laid under open marine conditions. This upper part was dated Aptian-Albian, Ramanathan and Kumanan (1981) and correlates to the Gboko Limestone. This is first Cretaceous marine transgression in the Southern Benue Trough, which obviously skirted the eastern basement massif from south to north following the Ikang Trough. At this time the Igbak High was still a platform.

The Odukpani Formation, as designated by Reymert (1965), contains beds of various ages. These are, the basal grits (the Awi Formation) of Neocomian age (Murat 1972, Ramanathan and Kumanan 1981); Late Aptian - Late Albian shales of the Awi River Group of Reymert (1965) Early-Late Cenomanian limestones and shales of Nkelegu Formation (Petters and Ekwezor, 1982) as well as shales of Late Cenomanian-Turonian Ekenkpon Shale, (Petters et al., 1995 and Nyong, 1995) (Figs. 2 & 3).

LITHOLOGICAL DESCRIPTIONS

The Ikono-1 Well is 3368 m (11,050 ft) deep, terminating on the basement. The lithological descriptions are shown in Fig 3. The published reports from Ikang Trough used in this work were drawn from Reymert, 1965; Nton. 1999. Ramanathan and Kumanan, 1981 and other articles synthesized from company files, Reijers (1996), silstone and subsidiary conglomerate. The base is not exposed at the type section but at Km 26 along the same road, a sharp contact with the basement outcrops, Nton (1999).

This conglomeratic and sandy basal unit of Awi Formation was not encountered in Ikono-1Well where the basal beds are fissile grey shales.

SAMPLING/ANALYTICAL TECHNIQUES

For the purpose of this work, twelve samples were taken from the well cuttings between the depths: 2432-3359 m at the following depths: 2432, 2456, 2932, 2993, 3042, 3054, 3145, 3176, 3213, 3249, 3286, 3359 m. 10 g of each sample were processed by the standard palynological techniques described by Gray (1965); in Kummel and Raup (1965), using HF to remove the silicates. Half of the sample (5 g) was stored for reference, and from which a drop was mounted for non-quantitative kerogen studies, while the
other half was subjected to oxidation using HNO₃ to remove organic matter. 2% Na OH to remove humic matter, and washing at each stage with 10μ nylon mesh. Samples were stained with Safranin O, dispersed in polyvinyl alcohol and mounted in DPX. Five slides were made for each sample (i.e. 1 g/slide) from which a minimum of 200 grains were counted. One slide was made from the unoxidized portion of each sample for kerogen analysis. Kerogen classification is based on Goodar et al. (1987).
Fig. 3. Lithologic section of Ikono-1 well

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithology</th>
<th>Description</th>
<th>Tectonic Envi.</th>
<th>Age</th>
<th>Fm/Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Soil</td>
<td></td>
<td>Terrestrial</td>
<td>Miocene</td>
<td>Benin</td>
</tr>
<tr>
<td>152</td>
<td>Coarse sandstone</td>
<td></td>
<td></td>
<td>Oligocene</td>
<td>Ogwashi-</td>
</tr>
<tr>
<td>305</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Asaba</td>
</tr>
<tr>
<td>610</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>914</td>
<td>Calcareous grey shale</td>
<td>Med. gr. Sst.</td>
<td></td>
<td>Eocene</td>
<td>Ameki</td>
</tr>
<tr>
<td>1219</td>
<td>Non calcareous grey shale</td>
<td></td>
<td></td>
<td>Danian</td>
<td>Imo Shale</td>
</tr>
<tr>
<td>1524</td>
<td></td>
<td>Coarse sandstone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1828</td>
<td>Non calcareous fissile grey shale</td>
<td></td>
<td>Marine</td>
<td>Late Campanian</td>
<td>Nkporo Shale</td>
</tr>
<tr>
<td>2134</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Formation</td>
</tr>
<tr>
<td>2438</td>
<td>Calc. grey shale with limestone bands</td>
<td></td>
<td></td>
<td>Turonian</td>
<td>Nkporo Group.</td>
</tr>
<tr>
<td>2743</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Eze-Aku Group.</td>
</tr>
<tr>
<td>3048</td>
<td>Non calc fissile black shale</td>
<td></td>
<td></td>
<td>Late Alb., Late Cenomanian</td>
<td>Asu River Group</td>
</tr>
<tr>
<td>3359</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3368</td>
<td></td>
<td>No data</td>
<td>Basement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sampled depth (m)</td>
<td>Lithology</td>
<td>Description</td>
<td>Age</td>
<td>Formation/Group</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-----------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>2225</td>
<td></td>
<td>Parallel-laminated, non-calcareous, fissile black shale with fragments of volcanic rocks</td>
<td>Cenomanian</td>
<td>Nkporo Fm.</td>
<td></td>
</tr>
<tr>
<td>2432</td>
<td></td>
<td>Fissile black shale with interbedded limestone bands</td>
<td>Turonian</td>
<td>Eze-Aku Group</td>
<td></td>
</tr>
<tr>
<td>2457</td>
<td></td>
<td>Calcareous fissile shale</td>
<td>Late Cenomanian</td>
<td>Mfinosime Limestone Fm.</td>
<td></td>
</tr>
<tr>
<td>2932</td>
<td></td>
<td>Hard, non-calcareous, fissile, black shale with volcanic fragments</td>
<td>Late Albian to Early Cenomanian</td>
<td>ASU River Group</td>
<td></td>
</tr>
<tr>
<td>2993</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3042</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3054</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3146</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3176</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3212</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3249</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3286</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3359</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3368</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3368 not sampled (TTO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. 6: Distribution of particulate organic matter with depth

<table>
<thead>
<tr>
<th>Particulate organic matter (%)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3359</td>
</tr>
<tr>
<td>Pollen</td>
<td>3</td>
</tr>
<tr>
<td>Microforaminifer linings</td>
<td>12</td>
</tr>
<tr>
<td>Dinoflagellate cysts</td>
<td>2</td>
</tr>
<tr>
<td>Trachaeids</td>
<td>4</td>
</tr>
<tr>
<td>Cuticles</td>
<td>12</td>
</tr>
<tr>
<td>Structureless organic matter</td>
<td>65</td>
</tr>
<tr>
<td>Marine source</td>
<td>75</td>
</tr>
<tr>
<td>Terrigenous source</td>
<td>25</td>
</tr>
</tbody>
</table>
Fig. 7. Distribution of species diversity with depth

![Graph showing species diversity with depth](image)

Fig. 8: Biostratigraphic distribution of sporomorphs from the basal sections of the Horor well

<table>
<thead>
<tr>
<th>Barr.</th>
<th>Apt</th>
<th>Albian</th>
<th>Cenomanian</th>
<th>Turonian - Conianian</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E M L</td>
<td>E M L</td>
<td>Spore/Pollen species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Apotrophiites jardinei</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Trilobites C.L 124</td>
<td>Inostracinae dahlia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stegodinoceras bimodale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Elateropollenites denuti</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Senegaapollinae carte</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cretaceouspollinae glyptodon</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cheasapollina brasiliensis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cacepinae lecanum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ammonites australis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Trinocerites africanaus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ephedriopsis sp. Ppr</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ephedriopsis multirostris</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Symulapollina subtillis</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 9: Schematic diagram of cretaceous paleogeographic and sedimentation history of the Calabar Flank.
The samples were very poor in palynomorphs at the lower horizons. Rarely could up to 200 grains be recovered, probably as a result of thermal destruction which also gave rise to the observed blackness of organic matter e.g. Fig. 11 nos. 12-14.

**3249-3569m. Hard, non-calcareous fissile black shale (Late Albian-Late Cenomanian)**


Only two grains of doubtful Afropollis jardinei were encountered. The absence of Afropollis jardinei in the Calabran Flank observed by Doyle et al. (1982) is still not conclusive from this work.

**Marine species:** Leiosphaeridia sp. species including, large and small, laevigate and scabrate forms Fig. 12, nos. 13-17.

Also present are Pterosporomorphs sp., Paleocystosoma cypari, Cycloniphellum sp., Batiacaphe sp., unidentified gonyaulacaceae (Fig. 12, nos. 1 & 2) and peridiniane (Fig. 11, no. 3) dinoflagellate cysts and microforaminifer linings.

Comber (1964) classified unoxidised acid-insoluble organic matter into palynomorphs, phytoplasts and amorphous organic matter. The simple grouping scheme is followed here.

**Kerogen:**
The kerogen of samples 3359 m depth from the non-calcareous shale has the following distribution. Fig. 6:

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>FM</th>
<th>Biocluster</th>
<th>Palaeoenvironment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1493</td>
<td>1628</td>
<td><em>Batiacaphera</em> compta, <em>Ceratophyllum</em>, <em>Cysphonites</em>, <em>Spiniferites</em></td>
<td>Spiniferites-Cystites-Celestophyllum-Areoligeri association of open marine conditions</td>
</tr>
<tr>
<td>1628</td>
<td>1628</td>
<td><em>Batiacaphera</em> compta <em>Ceratophyllum</em>, <em>Cysphonites</em>, <em>Spiniferites</em></td>
<td>Transgressive, deepening basin</td>
</tr>
<tr>
<td>1628</td>
<td>1628</td>
<td><em>Brackish water palms, Mauritiidites &amp; Proxaperites, Schizosporis, Leiosphaeridia</em> sp. 1, 2 &amp; 3</td>
<td>Cycloniphellum-Spiniferites-Areoligeri Association</td>
</tr>
<tr>
<td>2225</td>
<td>2225</td>
<td><em>Peridinoids</em> &lt; <em>gonyaulacoids, Brackish-water palms, Peridinoids, Mauritiidites, Rhizopodaceae</em></td>
<td>Brackish water nearshore marine</td>
</tr>
<tr>
<td>2456</td>
<td>2456</td>
<td><em>Ferimnifer linings, crustacean and coralline remints, Schizosporis</em></td>
<td>Leiosphaeridia-Celestaphyllum association</td>
</tr>
<tr>
<td>2932</td>
<td>2932</td>
<td><em>Ferimnifer linings, peridinoids &lt; gonyaulacoids, Schizosporis</em> crustacean remnants, <em>Tasmanites</em> sp</td>
<td>Low salinity, brackish water environment</td>
</tr>
<tr>
<td>1749</td>
<td>1749</td>
<td><em>Ferimnifer linings, peridinoids &lt; gonyaulacoids, Schizosporis</em> cuticles</td>
<td>Open marine environment</td>
</tr>
<tr>
<td>3340</td>
<td>3340</td>
<td><em>Ferimnifer linings, peridinoids &lt; gonyaulacoids, Schizosporis</em> cuticles</td>
<td>Nearshore marine</td>
</tr>
<tr>
<td>3359</td>
<td>3359</td>
<td><em>Ferimnifer linings, peridinoids &lt; gonyaulacoids, Schizosporis</em> cuticles</td>
<td>Tasmanites-Protolesaphyllum-Leiosphaeridia association-Low salinity environment</td>
</tr>
</tbody>
</table>

Fig. 10 Table showing Palaeoenvironments of Deposition.
Fig 11 Sporomorphs from Ikono-1 well (2432-3359 m)

Magnification: Nos 1-3, 4, 6-7 and 9 (X 400); others (X 1000)

1. Cyathidites minor Couper 1963
2. Trilites S.C. I. 124 Jardiné and Magloire 1965
3. Cingulites sp.
4. Lycopodiumspores sp.
5. Gnetaceepollenites diversus Stover 1964
6. Inaperturopollenites dubius
8. Afropolis jardinus Doyle, Jardiné and Doerenkamp 1982
9. Clasespollis brasiliensis Herngreen 1975
10. Senegalosporites petrobiasi Herngreen 1973
11. Elateropollenites jardinii Herngreen 1973
12. Senegalopollenites petrabiasi Herngreen 1973
13. Steevispollenites binodatus Stover 1964
14. Ephetrites multistratus Brenner 1963
15. Ephedrites irregularis Herngreen 1973
16. Galeacoma clevis Stover 1964
17. Trionites africanus Jardiné and Magloire 1965
18. Cretaceaepollites polygonalis (Jardiné and Magloire 1965) Herngreen 1973
19. Podocarpidites sp.
Figure 12 Dinoflagellate cysts from Ikono-1 well

Magnification No. 7, 8, 9, 13 and 15 X 400, others X 1000

1. Peridinoid indet
2. Peridinoid indet
3. Gonyaulacoid cyst indet
5. Microtinum setosum Sarjeant 1966
8. Exochospheeridium bifidum (Clarke and Verdier 1967) Clarke, Davey, Sarjeant and
9. Polysphaeridium subtile Davey and Williams 1966
10. Spinitetrites ramosus ramosus (Ehrenberg 1936) Loeblich and Loeblich 1966
11. Spinitetrites spinoflexus Jain and Millick 1973
12. Cyclonephelium ventrosum Davey 1969
13. Coronifer a caerulica Cookson and Eisenack 1958
15. Cleistosphaeridium pruniculare Davey 1969
Figure 13 Other palynomorphs from ikono-1 well

Magnification: All figures X 40

1. Schizosporis sp.
2. Schizophacus parvus (Cookson and Dettmann 1959) Pierce 1976
3. Schizosporis reticulatus Cookson and Dettmann 1959
4. Spermalites sp.
5. Schizosporis spriggi (Cookson and Dettmann 1959) Pierce 1976
6. Pterospermopsis cf. helios Sarjeant
7. Biserial loramini for lining
8. Trochosphial foraminifer lining
9. Pedialastrum sp. cf. P. boryanum (Turpin) Meneghini 1840
10. Maculataspores amplis Segroves 1967
11. Pterospermopsis auriculata Cookson and Eisenack 1958
12. Deullilites fexilis Hemer and Nygreen 1967
13. Leiosphaeridia sp. 4
14. Leiosphaeridia sp. 2
15. Leiosphaeridia sp. 3
16. Leiosphaeridia sp. 3
Terrigenous species: Fresh water algae, *Schizosponds spaggi* and *Maranites brasiliensis* Brito.

Marine species: *Microdinium setosum*, *Hysrichospheandrium tubiferum*, and *Polyphaenidium pumilum*. Others include microfossiliferous linings, crustacean, and coraline remains.

The age assignment is also based on the absence of the market species such as the Late Cenomanian *Glassellites brasiliensis* at the base and of the Lower Senonian *Orosendites senonicus* at the top.

Kerogen: The calcareous grey shale with limestone beds and volcanic ash was sampled at 3042 and 2932 m depth, (Fig. 12 c & d respectively). The 3042 m sample is from shale and the 2932 m sample, from the ash.

The results from the shale are distributed as follows (Fig. 6). The phytoclasts consist of tracheids only. The sample from the volcanic ash is barren as shown in Fig. 14 d.

2457-2225 m Parallel-laminated, non-calcareous, black shale (Nkporo Shale-Late Cenomanian)

Terrigenous species: The spore *Verneuilisporites ussensis* and pollens *Proxepatites cursus*, *Proxepatites magnus*, *Proxepatites operculatus*, *Maunites crassaflavus*, *Aquilopollesia senepilensis* and *Echinocarpites spinous* were recovered. Others are the fresh water algae, *Crassosphaera bellus*, *Gorgonasphaeridium rugosum* and *Pedastium cf P. polyanum*.

Marine species: *Plicatostomion australinum*, *Pheladinum gudianum*, *P. granulostomatum*, *Andalocella polymorpha*, *Ceratopsis danbed*, *Corallinae leptoderma*, *Cleidostephanidium aciculum*, *Florentina manteii*, *Aneiligera senonensis*, *Exochospheandrium bifidum*, *Polyphaenidium subtile*, *Cordosphaeridium varius*, *Aphonosphaera ramuliiforma*, *Spiniferites ramosus ramosus*, *Spiniferites ramosus gracilis*, *Trichodinium castrensenii*, *Leptoclinum subtile*, and *Bacilacaphera compta*.

---

Figure 14 Photomicrographs of the Kerogens from Ikonu 1 Well

Magnification X 400

a. Mfamosing Limestone Formation at 3359 metre depth (Non calcareous fissile shale)
b. Mfamosing Limestone Formation at 3249 metre depth (Calcareous fissile shale)
c. Nkalaghe Formation at 3042 metre depth (Shale interbedded with limestone)
d. Nkalaghe Formation at 2932 metre depth (the interbedded volcanic ash bed)
Also recovered were the acritarchs, Leiosphaeridia sp., Plagiothecium radiata, Cymatosphaeridium radiatum, Leiovalia crassa, and microfossilifer linings (Fig. 11). This assemblage falls within the Leiosphaeridia-Cleistothecaellida Association of Downie et al. (1971) which are restricted to brackish water low-salinity environments.

2226-1628 m Non-calcareous black shale (Nkporo Shale-Maastrichtian)

Terrigenous: The same sporomorphs content as in the underlying Late Campanian occurs with Praasperites magnus and Schizosphora parvus in addition.


All the species of Dinocysta disappear at the top of this unit and marks the end of the Maastrichtian, after reaching their peak abundance at 2628 m depth. Phelodinium gadilatum also disappears at the base of the Danian in Gbeko-1 well of the Benin Flank. Oloto (1990). The presence of Fibrocysta axialis, Heterohacysta pusula, Glosinocycts eubrunones, Apectodinium homomorphum, Ecolycopodites pacificus, Hemitrichites abbreviatum indicates the beginning of the Danian.

Acritarchs: included Leiovalia crassa, Schizosphere parvus, Cystophora baurus, Plagiothecium velata and Gorgonophyseidium magnus.

1628-1493 m Grey shale (Imo Shale - Danian)

Terrigenous species: Only two species of trilobite spores, Cystidites minor and Cystidites australis were encountered.

Marine species: The marine species include Ceratophasis diebeli, Paleocystodinium gol donek, and Actinodinium pleculatum. Hystrichokopme rigidaee, Cyclonephelium deperdussin, Spiniferites ramusus gracilis, Cordiosphaeridium varianum, Areoligera senonis, Pliodinium cingulatum, Diphyes olligerum, Cleistotheciaellida polyctes. This assemblage is referable to the Spiniferites-Cleistothecaellida-Cordiosphaeridium-Areoligera - Association of Downie et al. (1971).

1493-1189 m Non-calcareous grey to black shale (Imo Shale - Late Paleocene)

This depth is rich both in sporomorphs and marine species. The numerous species constituting the assemblage cannot be given here but suffice to mention that similar assemblage including Glosinocycta eubrunones, Cordiosphaeridium fibrosinsum, Turboxphaerella gestae, Namatosphaeropsis balcombei, Muraodinium limbatum, and Litosphaeridium spiniformum have also been recorded from the Paleocene of the Benin Flank by Jan du Chene and Adefararin (1984).

O.R. UMEJI

Over-maturation and blackening of the organic matter, shown in the palynomorphs of Fig. 11, nos. 12-16, 20-23, is attributed to burial and low grade metamorphism caused by volcanism. There was building up of carbonate banks and their subsequent destruction through the influx of clastic materials as the sea level continued to rise during the Turonian in Iikub sub-basin. Sedimentation continued on Iluk High till the end of the Turonian (Coniacian-Santonian uplift). The uplift shifted the depositional axis to the south west of Ikang sub-basin. This is similar to that of the Southern Benue Trough where, the Santonian uplift ended sedimentation and the depositional basin shifted westwards to the Anambra Basin. Turonian beds are overlain by the Campanian with a major sequence boundary. Fig. 5. Late Campanian microfossils were recovered from the beds overlying the Turonian confirming that the Coniacian and Santonian are absent.

From the foregoing, it is obvious that only the Late Albain-Late Campanian marine part of Asu River Group is found in Ikon-1 well, which part is also found in many areas along the Benue Trough. The Nkporo Shale was deposited throughout the Late Campanian and Maastrichtian. Full marine conditions continued on Iluk Sub-basin so that the more clastic, nearshore deposits of Mamu, Aja and Nsukka Formations of Anambra Basin do not occur. The coarse-grained sandstone at the top of Nkporo Group marks the Cretaceous/Tertiary boundary in Ikon-1 well and the base of the Danian Iro Shale. The Eocene regression continued into the Oligocene and Miocene. The Miocene-Recent Benin Formation has buried the older formations so that they are only encountered in the subsurface.

AGE

The age of the recovered sporomorphs from the basal section is shown in Fig. 8. Triotites africaisensis is the index species of the Late Campanian of Senegal (Jardin and Magloire, 1965, Jardin, 1967) although it has also been identified from the Campanian of Gabon (Boitenhagen, 1983, Plate 2, fig. 24). The Zone II of Jardin and Magloire, (op cit.) of Middle-Late Campanian, contains the pollen, Classopolis brasiliensis, Triotites africaisensis, and Gelaecoceraceae clavis, Triotites africaisensis, Creacjepitesi polygonia, Classopolis brasiliensis, and Gelaecoceraceae clavis occur in the Late Albain-Early Campanian palynzone Vll of Jardin and Magloire (1965), the Classopolis brasiliensis Subzone of the Elateritimites-Elateritocerita-Sofreptites Zone of Hemergren (1975), the Zone 1a (Po-304 i.e. Alfropolis jardinius) Assemblage Zone of Lawal and Moullade (1985) and the top of the Late Albain-Early Campanian of Africa-South America Middle Cretaceous geophylogenetic province of Hemergren and Chinova (1981). The Albain-Campanian boundary is marked by the replacement of Classopolis classoides by C. brasiliensis and by the appearance of Triotites africaisensis. The rarity of Alfropolis jardinius and Classopolis classoides which are abundant in the Late Albain-Early Campanian Abakaliki Shale may be ecological. The elaters-bearing pollen are absent in the Turonian.

Muller et al. (1987) and Lawal and Moullade (1986) erected a Drosendorfian stage to cover the Early to middle Danian. The base is marked by the first appearance of D. senonisus and the top by its extinction. It also includes the first appearance at the base of the zone of Victorisporis, Anadrasporites-complex, Gabanosporis vigumaurii and Rettilcoporites sp. At the top, the extinction of Senagelasporites petrosauri and Victorisporis occurred. This palynzone is known in Gabon (Boitenhagen, 1976). The above species occur in Awgu Shale at Agboogugu road section of the southern Benue Trough. They were not recovered in this work showing that the presence of the Coniacian in Iluk sub basin is doubtful.

DISCUSSION

A sketch of the lithostratigraphy and geological history of the Calabar Flank is shown in Fig. 16. During the Late Albain-Early Campanian, the first marine flooding occurred on Iluk High depositing the paralaminated, non-calcareous shales over the basement, under estuarine or lagoonal conditions. This is the upper part of the Mfamosing Limestone Formation. The absence of the marine basal beds of Late Aptian-Early Albain age and the occurrence of Late Albain-Late Campanian marine shales with volcanic fragments in Iluk sub basin shows that its subsidence and sedimentation began much later than that of Ikang Trough and was accompanied by volcanism.
Gregory and Hart (1992) in a predictive model of the response of palynoflora to sea-level changes showed that the Lowstand Systems Tract (LST) is characterized by terrigenous dominance (> 65 % terrigenous) of the palynoflora. The Transgressive Systems Tract (TST) has marine dominated palynoflora (<50% terrigenous). The Highstand Systems Tract (HST), characterized by progradational to retrogradational electric log stacking patterns, has the progradational intervals dominated by terrigenous microflora while the retrogradational intervals are characterized by marine dominance (<50% terrigenous) to strong marine influence (50-65% terrigenous).

A plot of the percentage count of terrigenous species versus depth, (Fig. 6) shows the response of the palynoflora to sea-level changes. At the base, occurs a wide fluctuation with three peaks of marine dominance indicating flooding surfaces (FS), alternating with three peaks of terrigenous dominance of late Lowstand or early TST. In Fig. 7 the marine species diversity shows a smoother curve of late progradation or early Lowstand. The benthic microforaminfer linings and cuticles are highest at 3369 m. The fluctuation continues throughout the Turonian. It is difficult to pick the biofacies pattern owing to the barrenness of the samples within the calcareous units. The kerogen, however, shows 95% structureless organic matter which is attributed to marine source, Goodell et al. (1992). There is no difference in the palynoflora content between the non-calcareous shale with volcanic fragments at the base and the overlying calcareous shale.

Morley (1995) reported that within marine sediments, microspores are most abundantly represented in Lowstand sediments and least represented in those from Maximum Flooding Surfaces at the base of the Highstand. This trend is followed by the results.
shallow water, and held that these found in deeper water resulted from the dwarfing of larger forms. In this view, microforaminifer abundance occurs in association with fresh water algae indicating a shallow water origin, rather than dwarfing in deeper water. An open marine environment was established up the sequence during the Cenomanian-Turonian with the increase in transgression during which corals lived. The alternating limestones and shales with volcanic rock fragments are records of magmatism during the basin development. The Campanian transgression carried the dinoflagellate eco-
group, the Areoligeria Association of Downe et al. (1971),
dominated by Cyclolopheithium, Areoligera and
Glyosphycysta of normal salinity or open sea environment
Goodall (1992) cited Marshall and Balten (1988) that the
Cyclolopheithium group proliferated in low latitude nearshore
black shales in highly stressed environments during the
Cenomanian-Turonian; while the genera Glyosphycysta (and
Areoligera, Systemostephanus placititha, Riculicyclus and
Adnatosphaeridium) were dominant in transgressive phases
during the deepening of the basin in stressed environments.
The Cenomanian-Turonian oxygen-deficient conditions in the
Calabar Flank have been reported by many authors, Nyong and

The latest Maastrichtian transgression has the Spinieterites-
Cleistosphaeridium-Cordosphaeridium dinoflagellate eco-
group. Goodall (1992) found Spinieterites to be ubiquitous
though increasing in abundance within transgressive sequences
and declining during regressions. The abundance of
Dinogynnium indicates low salinity lagoonal or estuarine
conditions. The Danian was a period of highstand and return of
the Areoligera Association, with Ceratopyxis dieblica. The end
of Cretaceous transgression was followed by Highstand in the
Paleocene, progradation and regression in the Eocene and
Lowstand since the Oligocene.

CONCLUSION

Two distinct sedimentary sub basins existed in the
Calabar Flank during the Cretaceous, the Ikang Trough and
Ituk High. The age of the sedimentary fill of Ikono-1 Well
shows that Ituk High sustained different subsidence and
depositional histories compared to Ikang Trough. In discussing
the geology of the Calabar Flank, distinction should be made
between the two sub basins.

Sedimentation began in Ikang Trough during the Late Albian-
Late Alban but on the adjoining Ituk High, deposition did not
start until the Late Alban- Early Cenomanian. From the Early
Cenomanian onwards, stratigraphic changes are recorded in
the two areas thus, the Late Alban- Late Cenomanian
marine part of the Asu River Group is found in Ikono-1 Well,
which part is also found in many areas along the Benue
Trough. The marine conditions continued till the Late Turonian
when sedimentation ended in Ikang Trough.

The Coniacian and Santonian sediments were not found
Obviously, the teconic uplift of the Calabar Flank started about
this time. Sedimentation subsequently shifted to Ituk sub
basin where the Late Campanian-Late Maastrichtian Nkporo
Group overlies the calcareous beds of the Turonian
Nkporo Shale was deposited throughout the Campanian and
Maastichtian under normal marine conditions so that the
crasterial formations of Mannu, Ajali and Nsukka of
Anambra Basin do not occur in the Calabar Flank. The coarse-
grained sandstone at the top of Nkporo Group marks the
Cretaceous/Tertiary boundary in Ikono-1 well and the base of
the Danian Imo Shale. The rest of the Tertiary-Recent was one of
Lowstand.

ACKNOWLEDGEMENTS

The well-cuttings for this work were provided by SPDC Nigeria
The Departmental cartographer, Mr Finan Ugocwuku sketched the figures, Mr Dan Amogu did the sketch of
palaeoecological history. I remain indebted to them all.
REFERENCES


