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PALEODEPOSITIONAL ENVIRONMENTS OF SOME LOWER TERTIARY SUBSURFACE SEDIMENTS IN THE CALABAR FLANK S.E. NIGERIA

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ABSTRACT

The occurrence of some Lower Tertiary sediments in the subsurface of the Calabar Flank Basin have been recently established based on the study of foraminiferal assemblages recovered from two onshore well; Ikono-1 and Uruan-1 respectively located on the western edge of the basin. Whereas no Tertiary marine sediments have hitherto been reported from outcrops, Cretaceous sediments abound at the several exposed surfaces which have been well studied in the Calabar Flank, thus it has been assumed to be entirely Cretaceous. This basin is included among the areas east of the Niger Delta, downdip of Abakaliki Plunge, which were reported to have shown repeated periods of erosion and or non-deposition during the middle and upper Eocene, thus, with no report from outcrops, Tertiary sediments were thought to have been completely eroded or were not at all deposited in Calabar Flank. These foraminiferal assemblages are fairly abundant and diverse, including the arenaceous and calcareous benthonics and the planktonics, mainly *acarininids* and the keeled *morozovellids*. The dominant arenaceous benthonics include the *haplophragmoides* and *trochaminas* in association with some calcareous forms, characterised marginal, shallow water inner neritic environment, while the associated planktonic counterparts, suggest a greater marine influence. Faunal trends such as the paucity of the planktonic and the co-occurrence of most of the calcareous forms together with the planktonics, especially the keeled forms has lend more support to this environmental synthesis. The entire foraminiferal assemblage indicates that the sediments studied were deposited on a shallow shelf, in a marginal inner neritic to probably middle neritic environment with the keeled *morozovellids* attesting to the influence of fully marine waters offshore.

KEYWORDS: Assemblages, Benthonic, Foraminifera, neritic, Paleoenvironment.

INTRODUCTION

Large areas east of the Niger Delta, downdip of the Abakiliki Plunge including the Calabar Flank Basin are reported to have shown repeated periods of erosion and or non-deposition during the middle and the upper Eocene (Murat, 1972). Incidentally, no Tertiary marine sediments have hitherto been reported from outcrops in the Calabar Flank apart from the widespread loose Recent deltaic sands. Cretaceous sediments however, outcrop in several sections and constitutes the only available study materials base on which previous geologic studies have been made and published. Some important publication include Reyment, 1955; Desauvagie, 1965, 1972; Murat, 1972; Fayose, 1977, 1978; Adeleye and Fayose, 1978; Odebode, 1982, 1983; Zaborski, 1983, 1985; Nyong and Ramanathan, 1985, Petters and Reijers, 1986, 1987 among many others. The basin thus became known to be entirely Cretaceous. However, recent studies of foraminiferal microfaunas recovered from subsurface samples obtained from two onshore wells of shell Petroleum Development Company of Nigeria, Ikono-1 and Uruan-1 wells respectively located on the western edge of the basin (Fig. 1a) have established the occurrences of Lower Tertiary sedimentary deposits (Paleocene-Eocene) in the Calabar Flank (Njoh and Nkeme, 1998, 2007).

The Calabar Flank (Murat, 1972) is part of the Southern Nigerian sedimentary basin. It is essentially a faulted continental marginal basin (Edet and Nyong, 1993), which consist of NW-SE trending crustal blocks of grabens and horst structures, the Ikang Trough and Ituk High. The basin is bounded to the north by the Precambriam Oban Massif Basement Complex and the Calabar hinge Line which delimits the Niger Delta Basin in the south. It is bounded in the west by the Afikpo Syncline and the Rio Del Rey Basin in the east (Fig. 1b).

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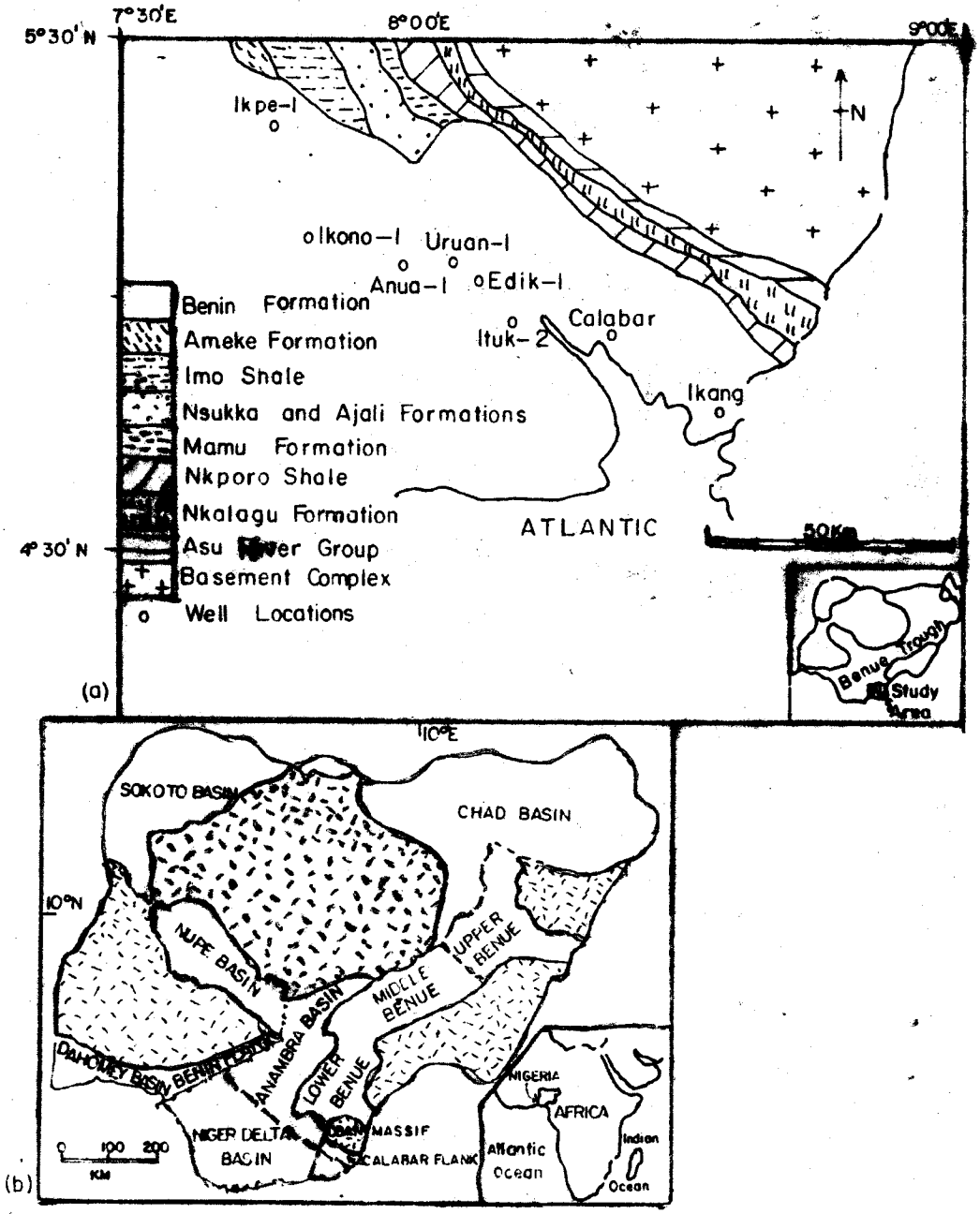

Figure 1(a): Location of Ikono-1 and Uruan-1 Wells
(b) Location of the Calabar Flank within the Framework of Nigerian Sedimentary Basin.

The Cretaceous stratigraphic framework of the basin shown on figure 2 comprises the Aptian-Albian Awi Formation which is lying uncomformably on the Basement Complex, the Albian-Cenomanian Mfamosing Limestone Formation overlies the Awi Formation. The limestone is overlain by the mid Cenomanian-Turonian Eze-Aku (Ekenkpong Shale, of Petters *et al.* 1995) Formation, above which is the Awgu (New Netim Marl, of Petters *et al.* 1995) Formation of Turonian-Early Santonian age. The Upper Cretaceous unit, the Campanian-Maastrichtian Nkporo Shale Formation is separated from the New Netim Marl by a Santonian-Early Companian uncomformity. The two recently established Paleogene units, the Imo Shale and the Eocene Ameki Formations successively overlies the Cretaceous sequences.

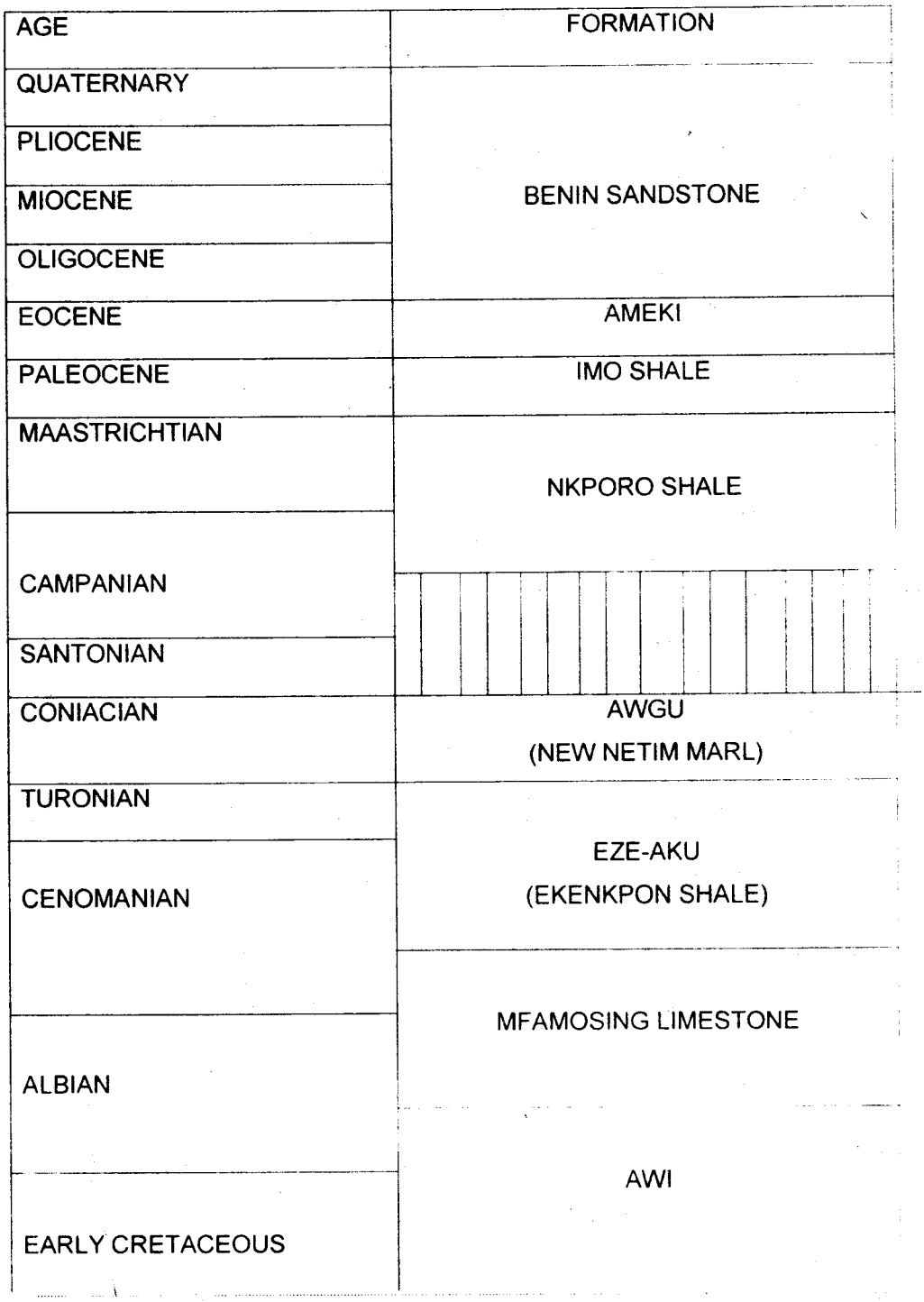

Fig. 2: The general stratigraphic framework of the Calabar Flank (Adapted from Petters et al, 1995)

The paleodepositional environments of the Cretaceous strata in this basin have been reconstructed by several authors including: Fayose, 1978; Odebode, 1983; Reijers and Petters, 1987 and Akpan, 1990. This paper is therefore an attempt to also reconstruct the paleoenvironments under which these recently established Tertiary sediments were deposited. This will undoubtedly provide a clearer picture of the basin framework of this somewhat obscured geologic period.

Regional paleo-oceanographic studies have noted that, the Tertiary marine transgression in the Gulf of Guinea and Southern Nigeria in particular could not be very extensive as previously thought, due to strong deltaic progradation which caused a rather southward shift in the shoreline (Petters, 1981).

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MATERIALS AND METHOD

The Ditch Cutting samples of the two wells; Ikono-1 and Uruan-1, from which the foraminiferal microfossils were studied, were obtained, courtesy of the NNPC/MOBIL Petroleum Geology chair at the University of Calabar. These samples were collected from these onshore wells that were drilled between 1958 and 1960 by Shell Petroleum Development Company of Nigeria Limited. Along the western edge of the Calabar Flank, in Akwa-Ibom state of Nigeria. Samples were selected at intervals of 6m and 12m. They were processed for micro- faunas, particularly for foraminifera following the standard procedures of foraminifera sample preparation outlined by Pessagno (1967), Zingula (1968), and Brasier (1980).

Foraminiferal counts were made from all the samples and a total of 115 species were recovered out of which 15 species were arenaceous benthonics, 71 species were calcareous, while the remaining 29 species were planktonics. With no Scanning Electron Microscope (SEM) available, picking and examination was done with a Wild Heerbrugg M3 binocular microscope, and the identification and analysis were made based on the type collections and monographys of Prof. Petters as well as with the aid of recent and relevant publications. Some of the index forms were drawn and described elsewhere. These have been preserved in carefully prepared slides and stored in the micropaleontology collection in the Department of Geology, University of Calabar.

Paleoenvironmental Synthesis.

The foraminiferal micro-faunas, particularly the benthonic forms have proved to be very good paleoenvrionmental indicators. Recent forms, like their fossils relatives are delicately sensitive to their environment, in which case, different species or mophortypes prefer and can only tolerate particular environments which may not be tolerated by others (Pflum and Frerichs, 1996; Adegoke *et al*, 1976; Culver and Buzas, Petters, 1981, and Culver 1988). This analysis has been concluded from several studies of Foraminiferal assemblages that characterized modern ecologies and have proven to be the most valuable methods for identifying ancient analogues. The fairly rich and diverse foraminiferal species recovered from the two wells provided adequate data base on which this paleoenvironmental synthesis has been made. Faunal trends exhibited by these forms such as the paucity of the planktonic forms in the upper levels of the wells where a few, mainly the arenaceous benthonics prevailed, the gradual increase in the planktonics downward and also the co-occurrence of the keeled forms with more open marine benthonics, lend more support to the establishment of marginal, shallow water inner nertiic to open shelf marine environment of deposition.

The Eocene upper parts of the wells studied, (750-1070m in Ikono-1 well and 950-1375m in Uruan-1 well), comprises mainly of unfossiliferous sands, followed by silty to sandy shale and dark-grey shale layers. This portion yielded predominantly *Haplophragmoides* and *Trochamina* arenaceous species together with a few individuals of *Fursenkoina* sp., *Nonion* sp., *Bulimina trigonalis* (Ten Dam), *Hopkinsina danvilensis* (Howe and Wallace), *Gavelinella danica* (De Klasz and Rerat), *Anomalinoids unboniferus* (Schwager) and *Eponides pseudoelevatus* (Graham, De Klasz and Rerat). This association suggests shallow marginal areas of inner neritic depositional environment. A few planktonics were also recorded thus, providing evidence of open marine waters.

While studying the modern benthonic foraminiferal biofacies off the Niger Delta, Adegoke *et al.* (1976) characterized an indigenous to mixed lagoonal biofacies as those areas of the littoral and brackish environment that are in direct contact with the sea such that at high tides, marine water invades lagoons and estuaries. The biofacies from such environment include the *trochaminas, haplophragmoides, ammobaculites, buliminas, cibicides, eponides* and *nonionellas.* Aubert and Berggren (1976) suggested a shallow water environment for the sediments in Djebel Mehiri Zebbeus area in Tunisia based on the association of *Haplophragmoides* sp., *Trochamina* sp., *Bulimina trigonalis*, with *Uvigerina* sp., and *Eponides elevatus.* The Ameki Formation was generally deposited under condition of reduced water depth, while its lateral equivalent, the Nanka Formation is basically a thick cross-bedded flasser and lenticular deltaic sandstone with intertidal Ophiomopha and Skelithos (Nwajide and Hoque, 1979).

The Palocene lower parts of the interval studied (1070-1440m in Ikono-1 well and 1275-4550m in Uruan-1 well) consists mainly of dark-grey shales which also yielded the following benthonic species *Bulimina Sp., Epistominella minuta* (Olsson), *Nonionellar* sp., *Anomalinoides uniboniferus, Loxostomum applinae, Forsenkoina* and *Gyroidinoides* sp. This benthonic assemblage co-occur with the bulk of the planktonics recovered in this study especially the keeled *Morozovellids.* This association is very indicative of increasing water depth or greater open marine influence probably of inner to middle neritic shelf environment.

Pettes (1979), recorded low alpha diversity values for similar benthonic foraminiferal assemblages which he recovered from the equivalent Paleocene Ewekoro and the Imo Shale Formations and suggested shallow inner neritic depths and also noted that the occurrence of keeled planktonic species such as *Morozovella angulata* (Bolli and Cita), *M. accustipira* (Bolli and Cita) and *M. eaqua* (Bolli and Cita), attest to the prevalence of fully oceanic marine conditions offshore (Petters and Olson, 1979). Though they placed the Uruan-1 well within the eastern part of the Niger Delta, Mebradu and Obeseki (1990) recorded a similar foraminiferal association at the upper section of the well, base on which comparative paleoenvironments of deposition were synthesized.

Therefore, these lower Tertiary sediments recently established in the subsurface of the Calabar Flank Basin were deposited on a shallow shelf environment, ranging from marginal areas of inner neritic to middle neritic sub-environment with open marine influence.

Within the Tertiary intervals examined in the two wells, the upper sections (750-1070m in Ikono-1 well

and 950-1375m in Uruan-1 well) are composed of sands, silty and dark-grey shales. The sandy layers were completely without microfossils while the silty to sandy shales and the dark-grey yielded mainly the arenaceous forms together with some calcareous benthic foraminifera. The few planktonic forms associated with these, permitted the assignment of the Eocene age. The lower section (1070-1440m in Ikono-1 well and 1275-4550m in Uruan-1 well), on the other hand, is composed mainly of the dark-grey shales which yielded the diverse calcareous benthonics in associated with a fairly abundant planktonic foraminiferal assemblages, including the keeled forms. This section was assigned a Paleocene age (Njoh and Nkeme, 1998, 2007).

SUMMARY AND CONCLUSION

Apart from the widespread loose deltaic sands (Benin Sands), no Tertiary sediments have been reported from outcrops in the Calabar Flank. Cretaceous strata are exposed at several localities and only these have been studied extensively and published, the basin is generally considered as entirely Cretaceous. However, the recent establishment of Tertuary sequences in the subsurface of this basin from foraminiferal evidence may as well have ushered in another domain for further research in the Calabar Flank.

The Tertiary sediments have revealed that the upper section is Eocene and the lower section is Paleocene. While the Eocene interval is composed of sands, silty to sandy shales and shales, yielding predominantly the arenaceous species and a few calcareous forms together with some planktonics, the Paleocene interval which is mainly dark-grey shales, yielded both the open marine calcareous forms and a diverse planktonic assemblage including the keeled *morozovellids.*

A close analysis of this entire assemblage of foraminifera recovered from the two wells show that the sediments were laid down in marginal areas; inner to probably middle neritic. The presence of the keeled *morozovellids* in the Paleocene sediments points to the fact that those sediments had greater open marine influence, it also attest to the presence of fully marine conditions offshore during this transgression.

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