

Integrated Biostratigraphic Study of Well Etankpini 005(ET005) based on Foraminiferal and Palynological Analysis, Calabar Flank; South Eastern Nigeria.

By

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Abstract : The Cretaceous formations penetrated by well ET005, Etankpini, Calabar Flank, consist of a sequence of dark grey fissile fossiliferous shales (the Ekenkpon Formation) at the base and greyish, fine grain oolitic marl (the New Netim Formation) at the top. The upper greyish, fine grain oolitic marl suggests a paralic condition in a shallow marine environment. The shallow marginal marine environment is further supported by the high diversity of terrestrially derived palynomorphs such as *Polyporisorites spp*, *Selaginella myosurus* and low values of sub-order *Classopollis*. A major transgression deposited the dark grey fissile fossiliferous shales during the Late Cenomanian-Early Turonian times and the rich planktonic faunal assemblages encountered at certain levels indicate continuous deposition in an open marine environment (Middle neritic and outer neritic environments). Cenomanian-Early Turonian age is assigned to the sediments penetrated by well ET005 and this is supported by the co-occurrences of *Classopollis spp*, *Classopollis classoides*, *Classopollis jardinei*, *Trifarites africaensis*, *Cretaceiporites mulleri*, *Trifarites rugosa* and *Steevesipollenites binodosus (palynoflora)* as well as the co-occurrences of *Hedbergella crassa*, *Hedbergella planispira*, *Heterohelix moremani*, *Heterohelix reussi* and *Globigerinelloides caseyi(microfauna)*.

Index terms: Age, Cretaceous, Ekenkpon Formation, Foraminifera, New Netim Formation, Paleoenvironment, Palynomorphs,

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1. INTRODUCTION

Foraminifera are protozoa which occur in a variety of brackish and marine environments, from coastal to deep areas. They are generally abundant and respond quickly to environmental changes. When foraminiferal analysis is combined with palynological analysis (integrated biostratigraphy), micropaleontologist can easily undertake age determination and paleoenvironmental studies of a formation. This work adopted this approach in identifying the planktonic and benthonic foraminiferal species as well as palynomorphs in Well ET005 in order to establish the age(s), predict paleobathymetry and ancient depositional environment(s) of the Cretaceous rock sequences penetrated by this well. The obtained result compared favorably with the existing stratigraphy of the Calabar Flank. Well ET005 is situated at Longitude N621582 and Latitude E732112 in

Etankpini, Calabar Flank, South Eastern Nigeria (fig. 1)

1.1 GEOLOGIC SETTING AND STRATIGRAPHY OF THE CALABAR FLANK

The term Calabar Flank was first introduced by [1], as part of the Southern Nigeria sedimentary basin that is bounded by the Oban Massif to the North and the Calabar hinge line delineating the Niger Delta Basin in the South [2]. It is also separated from the Ikpe platform to the West by a NE-SW trending fault. In the East, it extends up to the Cameroun Volcanic ridge. It served as the gateway to all marine transgression into the Benue trough and is located between two hydrocarbon provinces, the Tertiary Niger Delta and the Cretaceous Douala basin in Cameroun [3].

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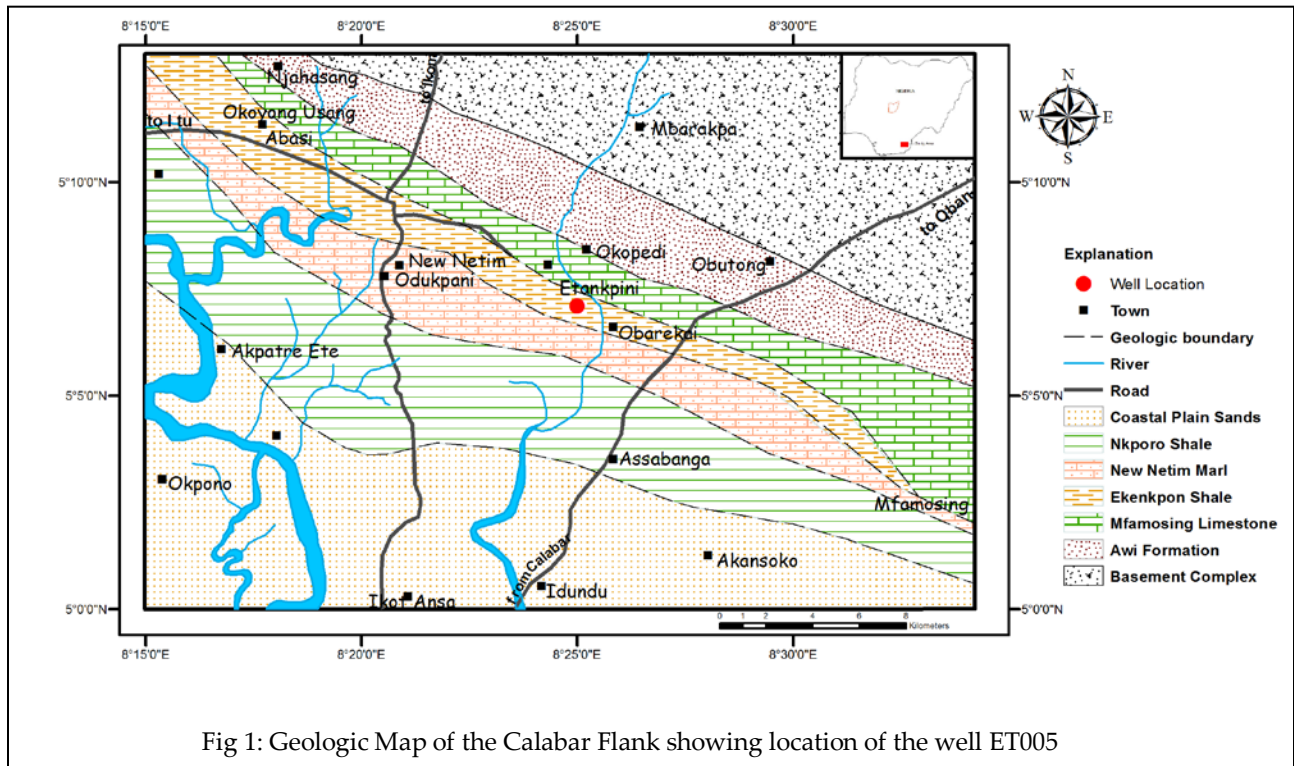


Fig 1: Geologic Map of the Calabar Flank showing location of the well ET005

Structurally, the Calabar Flank consists of basements horsts and grabens that aligned in a NW-SE direction like other South Atlantic (fig. 2) marginal basin in West Africa [3]. The Calabar Flank shows striking stratigraphic similarities with other coeval marginal basin of the South Atlantic Ocean. Sedimentation started in the Calabar Flank with the deposition of fluvio-deltaic clastics (the Awi Sandstone) of

probably Aptain age on the Precambrian crystalline basement complex, the Oban Massif. This was followed by the first marine transgression in the Mid Albian which account for the deposition of the Mfamosing Limestone, particularly on the horst and relatively stable platform areas and their flanks.

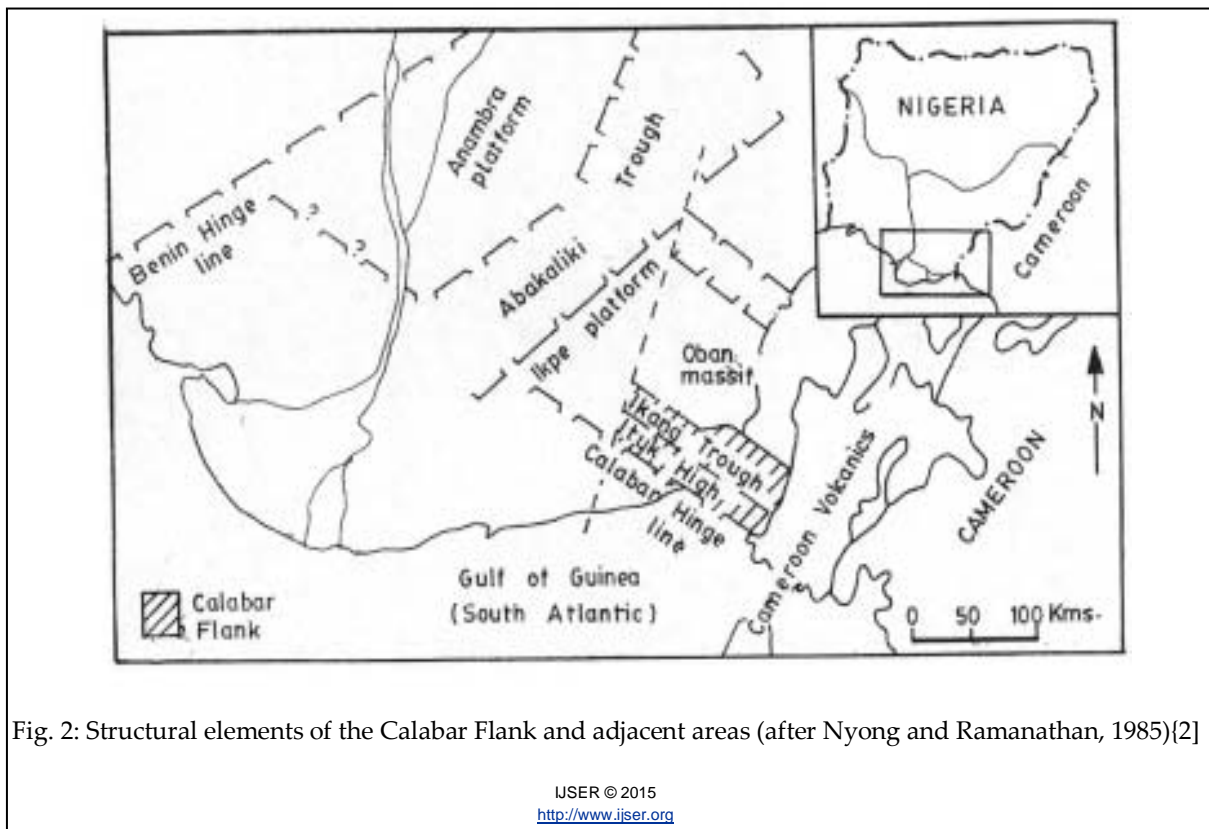


Fig. 2: Structural elements of the Calabar Flank and adjacent areas (after Nyong and Ramanathan, 1985)[2]

The Mfamosing Limestone is overlain by the thick sequence of black to grey shale unit, the Ekenkpon Formation[3]. The formation is characterized by minor intercalation of marls; calcereous mudstone and oysters beds. This shale unit was deposited during the late Cenomanian-Turonian times. The Ekenkpon Shale is overlain by a thick marl unit; the New Netim Marl [4]. This unit is nodular and shaly at the base and is interbedded with thin layer of shales in the upper section. Foraminifera [2] suggest early Coniacian age for this marl unit. The New Netim marl is unconformably overlain by carbonaceous dark grey shale, the Nkporo formation [5]. The shale unit was deposited during the late Campanian-Maastrichtian times. The Nkporo Shale caps the Cretaceous sequence in the Calabar Flank. The Nkporo Shale sequence is overlain by a pebbly sandstone unit of the Tertiary Benin Formation.

1.2 LITERATURE REVIEW OF THE CALABAR FLANK

Earliest biostratigraphic studies of the Calabar Flank were conducted by [5]and [6a]. [5] used ammonites to assign a Cenomanian age to the lower part and a Turonian age to the upper part of the Odukpani type section. The Cenomanian age assigned to the lower Limestone (Mfamosing Limestone) at Odukpani was later supported by [6b] and [7]using foraminiferal evidence. Fayose ,1979 [7] already pointed out that the basal arenaceous member of the Odukpani Formation is both petrologically and structurally correlatable with Mamfe Formation of Albian age. The Mfamosing Limestone was however dated more accurately as Albian age using ammonites [8] and foraminifera [9], [10]. Nair *et al*, 1981[9] found that the Mfamosing Limestone is devoid of foraminifera but pointed out that the overlying shale contains

Late Albian to Earliest Cenomanian planktonic foraminifera assemblage. Hence, they asserted that the underlying limestone is not younger than Late Albian.

Fayose ,1979[7] working on the carbonate/shale sequence of the Eze-Aku Shales, exposed at the Nkalagu Limestone quarry in the Lower Benue Trough, found abundant species of *Heterohelix* and *Hedbergella* suborder and some ostracodes such as *Brachyocythere*, *Ovocytheridea* and *Paracypris* which gave a Lower Turonian age. Petters ,1982[10] also, used *Hedbergella planispira*; *Heterohelix moremani*; *Guembelitria harrisi* and *Praebulimina fang* assemblages found in the Nkalagu Formation to assign a Turonian age to the Eze-Aku Shales. This agrees with the Early Turonian ammonite age given by [5].

Odebode and Skarby ,1980[11] carried out foraminifera studies of outcrop samples along Calabar- Itu highway and established Santonian - Campanian age for the lower part of the Nkporo Shale using the species of the suborder *Rugoglobigerina*, *Heterohelix*, *Ventilabrella*, *Globotruncana* and *Gabonita*. However, more accurate dating for the Nkporo shale was presented by [2] and [12] who used species of *Heterohelix reussi*, *Globotruncana fornicata*, *G. trincaniata* and *Rugoglobigerina sp.* to assign Late Campanian age for the lower part of the Nkporo Shale, while the upper part was dated Maestrichtian based on the presence of *Bolivina afra*, *Gabonita elongata*, *Gabonita lata* and *Praebulimina bantu*. The Maestrichtian age agrees with the works of [5] and [10]which depended on ammonite and foraminifera assemblages respectively. Fig. 3 shows different views as presented by various workers on the ages of Cretaceous sediments in the Calabar Flank

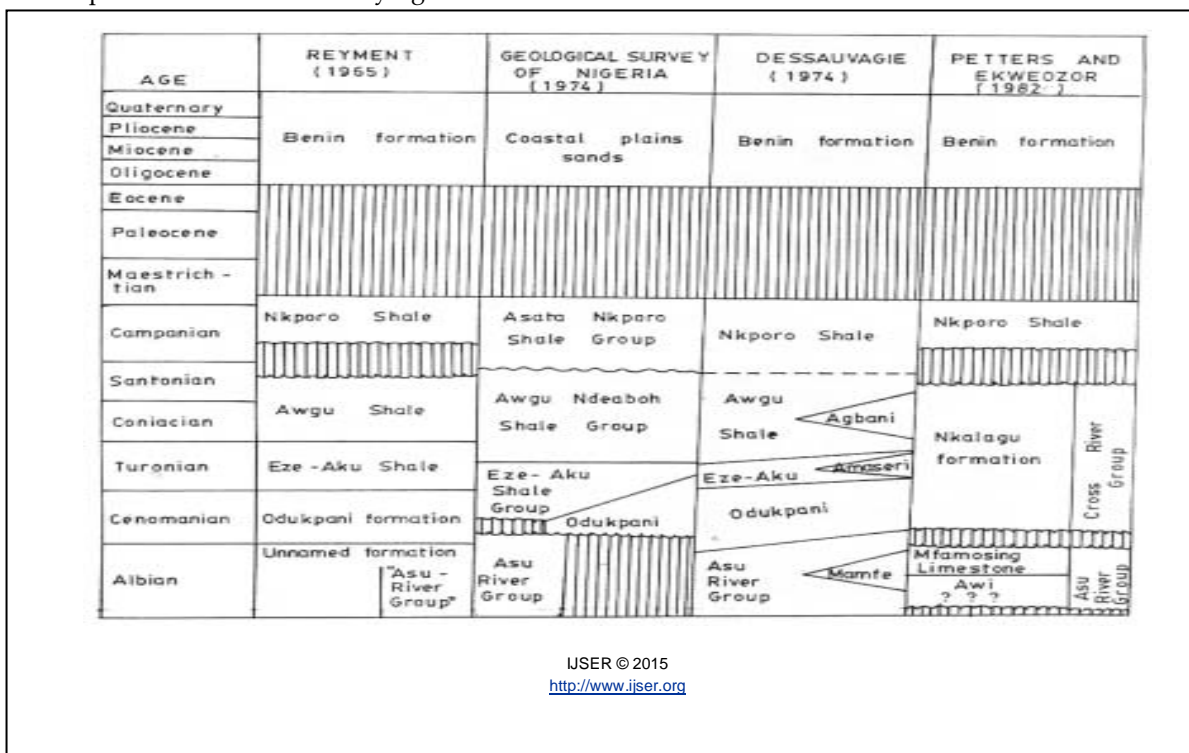


Fig. 3. Different views on the ages of Cretaceous sediments in the Calabar Flank
 (After Adegbie and Bassey,2007)[24]

2. METHODOLOGY

2.1 Micropaleontology

Samples for foraminifera studies were collected at 5m interval from core samples obtained from well ET005 drilled to a depth of 42.12m. These samples were later composited at 10m interval. Each sample was prepared in the laboratory following the standard procedures for foraminifera sample preparation as outlined by [13] and [14]. The identification of the foraminifera was done by comparing picked forms with previously published forms using a binocular microscope. Quantitative analysis was done using the number of species count per sample to establish diversity and abundance of forms.

2.2 Palynology

The obtained core samples were also analyzed for palynomorphs. Samples preparation was by the usual maceration techniques for acid insoluble microfossils which includes dissolution of carbonates and silicate using hydrochloric acid and hydrofluoric acid. 40% concentrated Nitric acid (HNO₃) (for oxidation of humic matter) and 1%

Potassium hydroxide (KOH) for acid neutralization and dissolution of humic matter. Concentration was by sieving using 200 and 400 mesh nylon screens and pipetting the organic residue from a watch glass. Slides of temporary strew mounts using glycerin jelly was made for each of the samples. Transmitted light microscope was used for studying the palynomorphs. The palynomorphs were counted and recorded. Analysis was done by comparison with published work to identify the various forms of palynomorphs.

3. RESULTS AND DISCUSSION

3.1 Lithostratigraphy

Two distinct lithologic units were recognized in the sampled section of well ET005 consisting of about 20m of greyish fine grained oolitic marl overlying thick (17.12m) dark grey fissile fossiliferous shales at the base and capped by a 5m thick dark brownish clayey laterite. These rock units compared favourably with some of the stratigraphic units of the Calabar Flank (the New Netim Marl and the Ekenkpon Shale) outlined by Adeleye and Fayose (1978), Nyong (1995) and Essien et al (2005). The Lithostratigraphy of well ET005 is presented in Fig 4

Depth (m)	Lithology	Lithological Description	Formation
0-5	- . - - - - . - - .	Dark brownish clayey laterite	
5-25		Greyish; fine grain oolitic Marl	New Netim Marl
25-42.12		Dark grey fissile Fossiliferous shale	Ekenkpon Shale

Fig. 4: Lithostratigraphy of sediment penetrated by well ET005

3.2 Foraminiferal biostratigraphy

The analysed samples yielded a total of sixteen (16) foraminifera species comprising both planktonic (14) and benthonic (2) species.

The lower section of the study well yielded more planktonic foraminiferal forms than the middle and upper sections

which were characterized by some barren intervals. The planktonic forms are dominated by long-ranging fauna of the (*Hedbergella crassa*, *Heterohelix moremani*, *Heterohelix reussi*, *Hedbergella planispira*), However some of the encountered forms (*Globigerinoides caseyi*) also have restricted stratigraphic range.

The biostratigraphic range chart of foraminiferal species, depth of occurrence and their counts are presented in fig. 5

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Well Name : ET

Well Code : ET-OB

Interval : 0m - 42m

Scale : 1:750

FORAMINIFERAL DISTRIBUTION/STRATIGRAPHIC CHART OF WELL ET-005

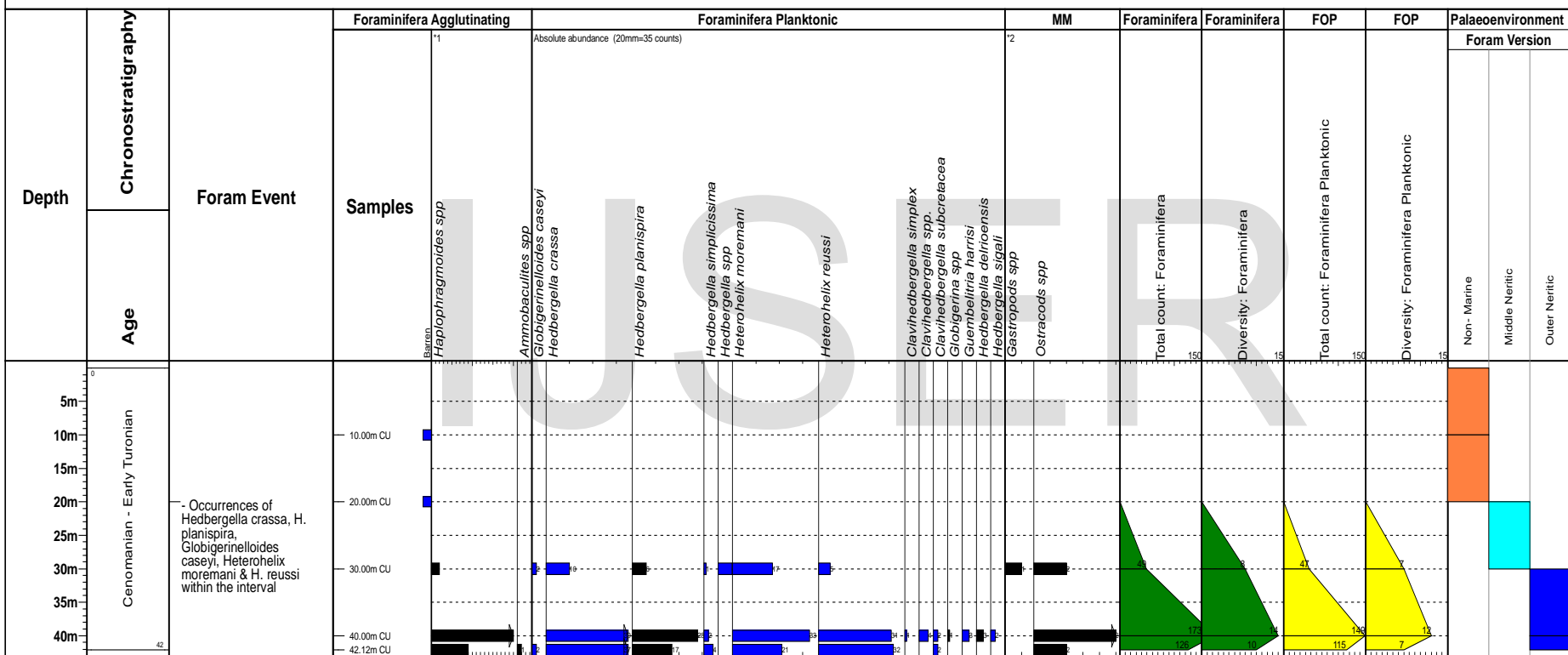


Fig 5: Foraminiferal range chart(chart 1)

Age determination using Foraminifera is carried out on the basis of Last Appearance Datum (LAD) or First Downhole Occurrence (FDO) and First Appearance Datum (FAD) or Last Downhole Occurrence (LDO) of index forms.

The Cenomanian-Turonian age is assigned to well ET005 on the basis of planktonic index forms; *Hedbergella crassa*, *Heterohelix moremani*, *Heterohelix reussi*, *Hedbergella planispira* and *Globigerinoides caseyi*.

The planktonic species: *Hedbergella delrioensis*, *Hedbergella planispira*, *Hedbergella spp* were initially described from Cenomanian sediments in the Ituk-2 Well [7]. Sediments of Turonian age were also recognized on the basis of the occurrence of *Heterohelix reussi*, *Heterohelix moremani*, *Heterohelix simplicissima* and *Globigerinelloides caseyi*. [10]. Similar assemblages have been reported by Fayose (1979), on the

Turonian sediments in Ituk-2 well, and [10] from road-cut samples of the Eze-Aku Shales at km 24.8 on the Calabar-Itu highway. The presence of species belonging to *Heterohelix* genera which are mainly restricted to Turonian age and *Hedbergella* genera which are mostly Cenomanian forms further confirms this age. Esseim and Edoho, 2012 [18] also reported similar assemblages from the New Netim Marl.

3.3 Palynostratigraphy

The core samples yielded spores, palmae and associated elements like dinoflagellate, chitinous microforaminifera test linings and other undifferentiated spores and pollen.. The biostratigraphic range chart of palynomorphs species, depth of occurrence and their counts is presented in fig. 6

PALYNOSTRATIGRAPHIC DISTRIBUTION CHART OF WELL ET-005

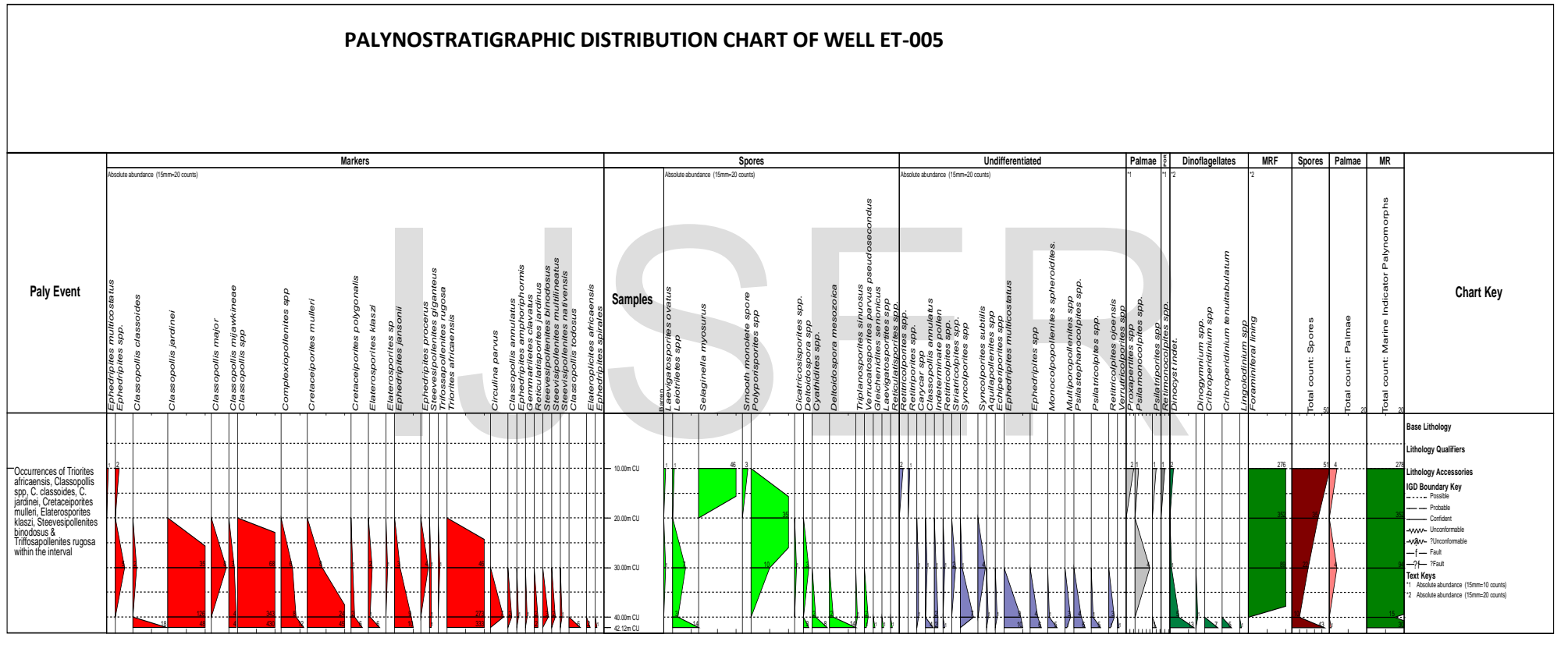


Fig. 6 Palynomorphs range chart

The study section yielded wide age diagnostic palynomorphs namely *Ephedripites* sp, *E. procerus*, *E. multicosatus*, *Complexiopollenites* sp, *Steevesipollenites gigantus* and *Trifossapollenites rugosa*. All these forms are used as Cretaceous marker from Albian- Cenomanian [19] but the co-occurrences of *Triorites africaensis*, *Classopollis* spp, *Classopollis classoides*, *Classopollis jardinei*, *Cretaceipirites mulleri*, *Triffosapollenites rugosa* and *Steevesipollenites binodosus* points solely to Cenomanian- Early Turonain for the study well (well ET005). Similar species have already been recorded in Nigeria by [20]

The top occurrence of diagnostic palynoflora such as *Triffosapollites rugosa* recorded at 30m in this study have been used to represent Cenomanian in West Africa [19]. Esseini and Ufot, 2010 [21] also reported this palynoflora in Calabar Flank.

3.4 Paleoenvironmental studies

The distribution of any particular fossil assemblage in any stratigraphic section may be controlled either by paleoecological factors or as a result of evolution [22]. Any changes in fossil assemblages that correspond with lithology is probably due to environmental tolerance of the fossil species rather than to evolution. Some fossils serve as environmental indicators and are used to interpret ancient environment of deposition of sediments. Studies of modern foraminiferal ecology have provided criteria for the reconstruction of marine paleoenvironments. Foraminifera are also in many respects ideal zonal indices for ancient marine rocks.

Based on the biostratigraphic boundaries recognized and the lithostratigraphic studies, the Cretaceous sediments recovered are grouped into two formations which are correlatable with

depositional environments. They are the New Netim Marl and Ekenkpon Shale.

The application of palynological data to paleoenvironmental reconstruction can give reliable inference on the paleoenvironment condition. In this study, the relative abundance of terrestrially derived pollen and spore and marine derived dinoflagellates together with foram test lining as well as the suborder *Classopollis* were used to interpret the depositional environments of the studied interval. The decrease in pollen grains with distance from the shore [19] was also taken into consideration.

The techniques of Planktonic/Benthonic (P/B) ratio which has been used by many micropaleontologist to determine water depth in marine environment [10] and [7] was also considered in this study. The Planktonic/Benthonic foraminiferal (P/B) ratio in the study well ranged from 0-100% and attempts were made to interpret the ancient environments based on this. The use of foraminiferal (P/B) ratio together with palynological considerations greatly enhanced the paleoenvironmental interpretation of well ET005.

The samples of New Netim Marl were barren of foraminifera. This suggests a protected, paralic and occasionally open shallow marine depositional environment. This is supported further by the dominance of terrestrially derived palynomorphs (*Selaginella myosurus*, Smooth *monolete* spore, *Polyporisorites* spp) and minor inclusions of sub order *Classopollis* as well as dinoflagellates and foraminiferal lining. The greyish fine grained oolitic marl was deposited at the beginning of the regressive phase which began in the Early Turonain immediately after the shale deposition.

The Ekenkpon Shale shows low arenaceous species and a dominance of *Heterohelix* and *Hedbergella* faunal, probably due to deep water paleoecologic conditions (open ocean). This open ocean setting is further supported by the dominance of planktonic species and dinoflagellates as well as foraminiferal test

lining with high inclusion of suborder *Classopollis*. The dark grey fissile fossiliferous shale was deposited at the beginning of the Cenomanian- Early Turonain Transgression.

Fig. 7 shows the age and lithostratigraphic summary as well as the depositional environment and sea level curve for well ET005

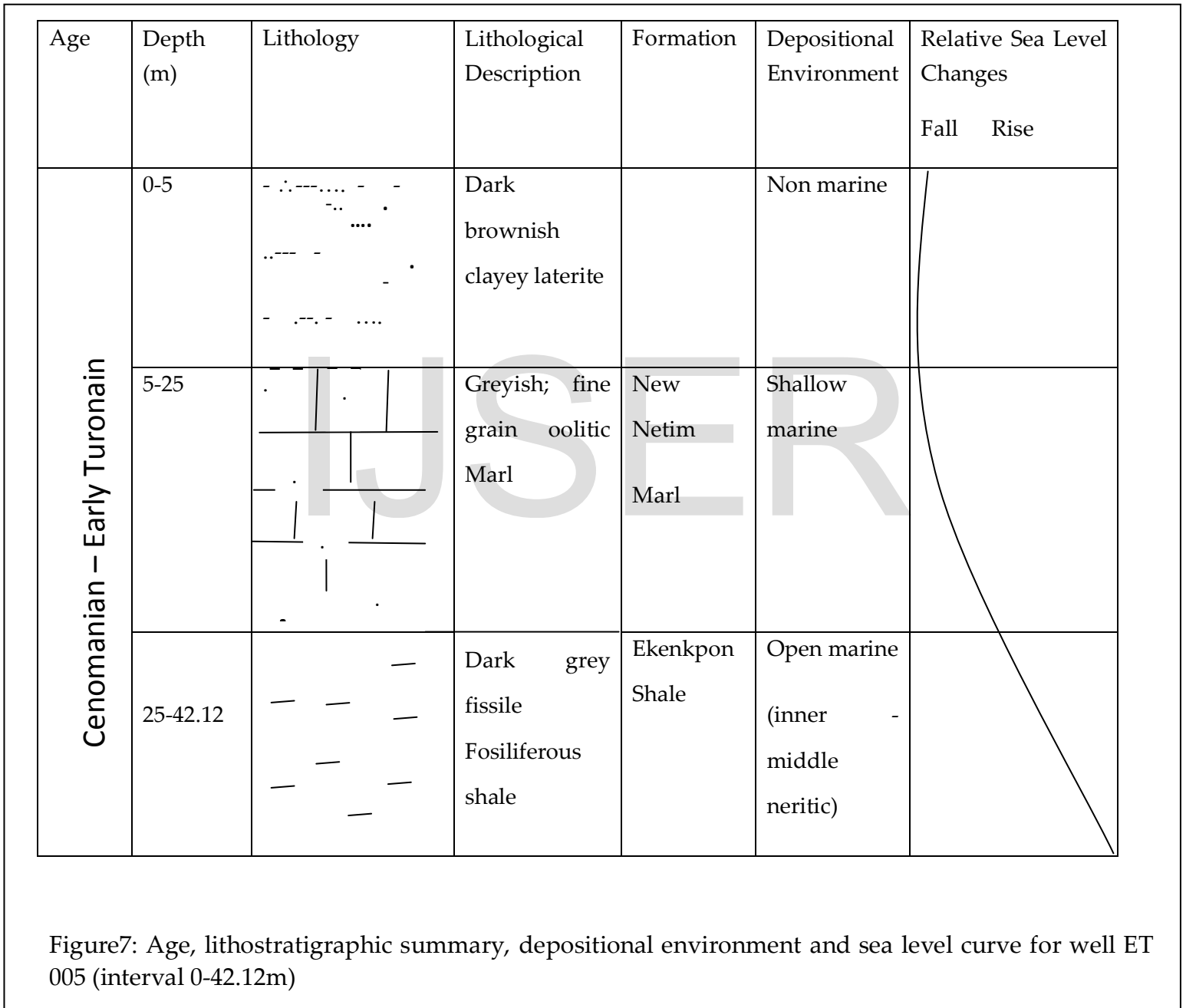


Figure7: Age, lithostratigraphic summary, depositional environment and sea level curve for well ET 005 (interval 0-42.12m)

Foraminiferal types (Agglutinating and calcereous planktonic) found also enhanced in the interpretation of the paleoenvironment.

According to Miller *et al*, 1982[23] low Oxygen, low pH and more corrosive bottom waters favour the development of Agglutinating

benthic forms and complete absence of calcareous benthic which suggest total oxygen-deficient bottom conditions during deposition. On this basis, the Agglutinating foraminifera forms (*Ammobacullites spp* and *Haplophragmiodes spp*) found in well ET005 suggest deposition in an oxygen-deficient environment as well as low salinities.

4. CONCLUSION

Well ET005 (interval 0-42.12m) located in Etankpini, Calabar Flank was studied for its sedimentological and biostratigraphic (micropaleontological and palynological) content. The studied interval penetrated a lateritic layer as well as marl and shale lithologic units. These lithologic units belong to the New Netim Marl and the Ekenkpon Shale respectively of the Calabar Flank. Biostratigraphic results reveal a fairly high abundant and low diversity of foraminiferal species together with high abundant and diversity of Palynomorph. The integration of these results enable the assignment of a Cenomanian to Early-Turonian age to the study well. This was made possible by the presence of the following pollen and spores: *Classopollis jardinei*, *Ephedripites procerus*, *Elaterosporites sp* and *Steevesipollenites sp* and foraminifera: *Hedbergella crassa*, *H.planispira*, *Heterohelix moremani*, *H. reussi*. The upper marl unit (New Netim Marl) suggests a paralic condition in a shallow marine environment while the lower shale unit (Ekenkpon Shale) suggests an open ocean of great depth. This inference was based on the environmentally significant foraminiferal taxa and palynomorph recovered from well ET005. The lithostratigraphy of the studied section of well ET005 is in conformity with the stratigraphy of the surface rocks exposed in the Calabar Flank.

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