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Foraminiferal and Calcareous Nannofossil studies of KR-1 Well, Offshore, Southwest Niger Delta Basin, Nigeria

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ABSTRACT
Lithostratigraphic, foraminiferal and calcareous nannofossil biostratigraphic studies have been carried out on ditch cutting samples from KR-1 well located in the offshore area of the Niger delta. The Agbada Formation sediments are made up of shales and sandy shales which are grey in colour with intercalations of medium to fine grained sandstone beds. The shales are fissile and slightly calcareous while the sandy shales are light grey, ferruginous and sub-fissile. The sediments yielded rare planktonic but relatively rich benthonic foraminifera and calcareous nannofossils with significant variations in abundance and diversity. The important foraminifera recovered are *Globigerina ciporoensis angustiumblicata*, *Globigerinoides praebulloides*, *Lenticulina inornata*, *Epistominella vitrea*, *Hanzawaia concentrica*, *Poroeponides lateralis*, *Quiqueloculina lamarckiana*, and *Brizalina mandoroveensis* while *Helicosphaera truempyi*, *Calcidiscus leptoporus*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus*, *Discoaster* and *Helicosphaera euphrati* constitute the principal nannofossils. Early Miocene age was assigned to the section using the top occurrences of some of these taxa while a marginal marine environment of deposition was suggested due to the low diversity of nannofossils and very low planktonic/bentonic ratio.

Introduction

The two most common applications of micropaleontology in petroleum exploration are biostratigraphic and paleo environmental deductions. Micropaleontology in general is an important tool for the petroleum industry, finding practical uses in all stages of the exploration process (Crux et al.[1]). Calcareous nannoplankton are photosynthetic plants. They are one of the primary organisms at the base of the food chain and play a crucial role in marine biogeochemical cycles. These algae have great abundance (millions of individuals per gram calcareous bearing sediment), wide biogeographical distribution (tropics to polar regions) and high evolutionary rates in the fossil record. These marine phytoplanktons comprise of coccoliths and nannoliths. Cocccoliths (2-30µm in size) are exoskeletal plates formed by coccolithophores, phytoplanktonic and haptophyte algae. Nannoliths are similar sized calcareous fossils which lack the characteristic features of coccoliths and so are of uncertain origin, although many are probably formed by Haptophytes (Bown and Young[2]). Coccolithophores occupy the surface waters, and are thus affected by changes in the surface water environment, particularly temperature and nutrient availability. A number of extant species exhibit a wide range of environmental tolerances, such as *Emiliania huxleyi*, which occupies nearly all coccolithophore habitats of the marine photic zone (Brand[3]). Surface temperature, salinity, fertility and bathymetry restrict the distributions of many species, with the greatest diversity in low latitude, openocean, oligotrophic and stratified habitats (Winter et al.[4]). Calcareous nannofossils have been living in the world's oceans for at least 200 million years (from the Triassic Period), and they have evolved and changed constantly over time. Therefore, they are used to produce global biostratigraphic and biochronologic frameworks (Martini[5]; Okada and Bukry[6]; Berggren et al.[7]) and to provide reliable paleoenvironmental reconstructions of both Mesozoic and Cenozoic eras (Erba[8]). The foraminifers (unicellular animals) are a part of the oceanic planktons. They are recognized from the beginning of the Paleozoic Era to the Present. Certain forms of their lineages evolved rapidly which is useful for biochronology and for precise interregional correlation of geologic strata. Their ecologic sensitivity makes them especially useful in the study of existing and ancient environments. Biostratigraphic zonation schemes of one form or another have been established for the whole of the Phanerozoic time, including larger benthic and planktonic foraminiferal biozonation schemes, having a resolution in the order of 1-2 Ma and being globally applicable in the appropriate facies (Nazik[9]).

Calcreous nannofossils and foraminifera provide chronostratigraphic control and a wealth of paleoenvironmental information for the recognition of depositional sequences that develop in response to changes in relative sea level.

This work was carried out to: document the nannofossil and foraminiferal assemblages within the KR-1 well sediments; use the assemblages to date sediments and reconstruct their paleoenvironment of deposition and thus contribute to the ongoing biostratigraphical investigations in the Niger delta basin.

Geological Setting

The present-day Niger delta Complex is situated on the continental margin of the Gulf of Guinea in the southern part of Nigeria (Fig. 1). It is bounded in the north by outcrops of the Anambra Basin and the Abakaliki Anticlinorium, and delimited in the west by the Benin Flank – a northeast-southwest trending hinge line south of the West African basement massif. The Calabar Flank ─ a hinge line bordering the Oban massif ─ defines the northeastern boundary. The offshore boundary of the basin is defined by the Cameroon volcanic line to the east and the eastern boundary of the Dahomey Basin (the eastern-most West African transform-fault passive margin) to the west.

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The stratigraphy of the Niger Delta is intimately related to its structure. The development of each being dependent on interplay between sediment supply and subsidence rate. Short and Stauble[10] recognized three subsurface stratigraphic units in the modern Niger Delta. The delta sequence is mainly a sequence of marine clays overlain by parallic sediments which were finally capped by continental sands. The stratigraphy of Niger Delta Basin are as follows:

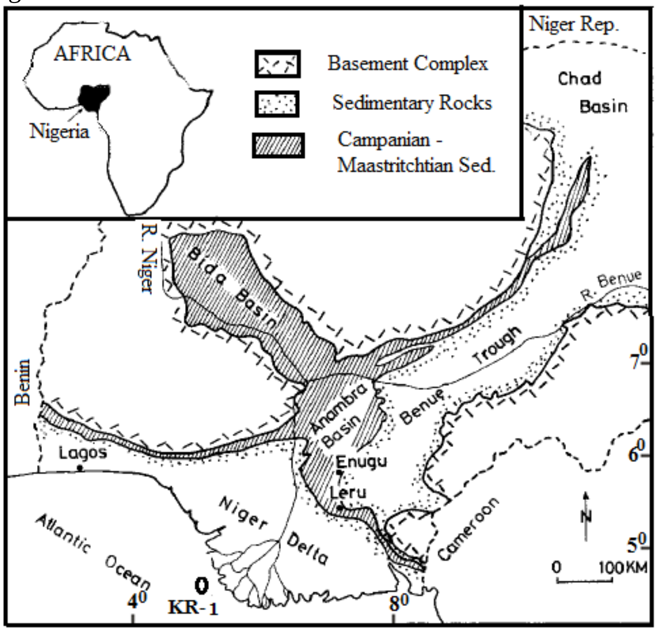


Fig 1. Simplified geologic map of Nigeria and location of KR-1 well

Akata Formation: - This formation underlies the entire delta and forms the lower most unit. It is a uniform shale development consisting of dark grey sandy, silty shale with plant remains at the top. The Akata formation is typically overpressured and believed to have formed during lowstands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency (Statcher[11]). The thickness of this sequence is not known but may be up to 7000m in the central part of the basin (Doust and Omatsola[12]). The formation crops out offshore in diapers along the continental slope and onshore in the northeastern part of the delta, where they are known as Imo Shale. It ranges in age from Paleocene to Recent and is believed to have been deposited in front of the advancing delta. The formation is important because it serves as the source rock for hydrocarbon in the Niger Delta (Weber and Daukoru[13]; Ekweozor and Daukoru[14]).

Agbada Formation: - The formation is a sequence of alternating shales and sands/sandstones; it is divisible into two subunits: the upper subunit in which the sands/sandstones constitute the thicker part and the lower subunit where shales form the thicker layers. Agbada Formation is very rich in microfauna which decreases upwards in abundance suggesting an increase in the rate of deposition at the delta front. As with the marine shales, the paralic sequence is present in all depobelts and ranges in age from Eocene-Recent. It is the hydrocarbon-prospective sequence in the basin with its sands serving as the reservoir rocks while the shales are contributory source rocks (Lambert-Aikhionbare and Ibe[15]) and seals. Most exploration wells in the Niger Delta, which reaches a maximum thickness of more than 3000m, have bottoms in this lithofacies and the major hydrocarbon accumulations are found in the several reservoir sands within it at intervals between Eocene and Pliocene.

Benin Formation: - The formation, which comprises of over 90% sandstones with shales intercalations, extends from the west across the entire Niger Delta area and southwards beyond the present coast line. The thickness of the formation varies from 0 – 2,100m (Ejedawe and Okoh[16]), this decreases rapidly in a seaward direction. It is made up of coarse grained, gravelly, poorly sorted, sub-angular to well rounded sands that contain lignite streaks and wood fragment. Generally, the formation ranges in age from Oligocene to Recent. Very little hydrocarbon accumulation has been associated with this highly porous and mainly freshwater bearing sands.

Materials and Methods

A subsample from each sample was dried in the oven and examined under a Leitz Wetzler binocular microscope. The colour, average grain size, roundness, sorting, and sand-shale percentages were determined. The presence of diagnostic minerals such as mica flakes, pyrite, glauconite and lignite was also noted.

Twenty five grammes of each sample were processed for their foraminiferal content using the standard preparation techniques. The weighed samples were soaked in kerosene and left overnight to disaggregate, followed by soaking in detergent solution overnight. The disaggregated samples were then washed-sieved under a running tap water over a 63 µm mesh sieve. The washed residues were then dried over a hot electric plate and sieved (when cooled) into three main size fractions, namely: coarse, medium and fine (250, 150 and 63 µm meshes). Each fraction was examined under a binocular microscope. All the foraminifera, ostracodes, shell fragments and other microfossils observed were picked with the aid of picking needle and counted. Foraminifera identification was made to genus and species levels where possible using the taxonomic scheme of Leoblich and Tappan[17] and other relevant foraminiferal literature (Fayose[18]; Murray[19]; Okosun and Liebau[20]; Petters[21,22,23]; Postuma[24]).

The standard smear slide preparation method for nannofossil was employed. This was adjusted to fit the lithology of samples. About 5 gm of cuttings was washed to remove the drilling mud. The subsample was gently crushed using mortar and pestle. The crushed material was dispersed in distilled water in a tube. A disposable glass pipette was employed to pipette the suspension for final slide making. The pipetted solvent was dried on a 22 x 40mm cover slip at a slightly hot temperature of between 60^o and 70^o C. The dried cover slip was then mounted on a glass slide using Norland adhesive cured under U.V. light. Eight traverses were studied in each slide. Detailed identification of forms (to species level where possible) was made of all taxa encountered in each slide . The cascading counting method of Styzen[25] was employed in determining the relative abundance and diversity of the assemblages. Standard nannofossil zonation schemes of Martini[5] and Okada and Bukry[6] were employed.

The photomicrographs of some of the microfossils were taken (see plates) and the data from the slides and others were plotted on nannofossil and foraminiferal distribution charts on a scale of 1:5000 using Stratabug biostratigraphic software (see charts).

Results and Discussion

Lithologically, the studied section of KR-1 well is made up of grey coloured, fissile and slightly calcareous shales, and sandy shales that are light grey, ferruginous and fissile (Fig. 2). These characteristics were acquired under anaerobic conditions with fluctuating salinities and limited water circulation. The included sand grains vary from fine to medium, angular to well rounded and moderately sorted. Glauconite, pyrite, muscovite flakes are the important accessories minrerals present.

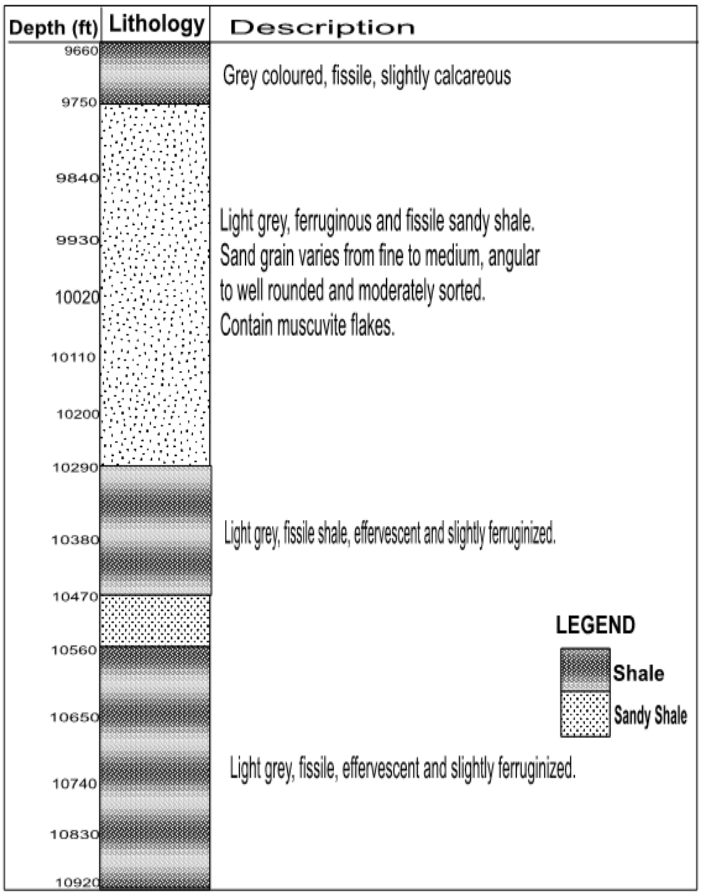
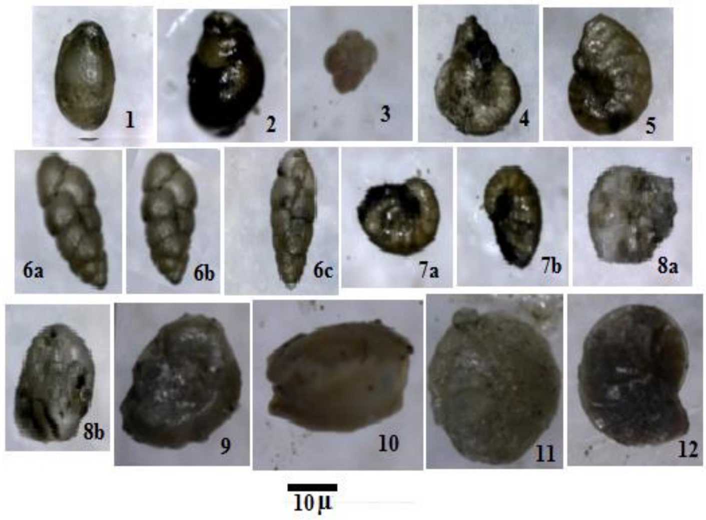


Fig 2. The litholog of KR-1 well

Foraminiferal Analysis: The analyzed samples yielded very few planktonics but relatively abundant and diverse benthonics that are useful for interpretation (see chart). A total of 51 taxa comprising two planktonics, 45 calcareous benthonics and four arenaceous benthonics foraminiferal species. Only *Globigerina ciporoensis angustiumblicata*, *Globigerinoides praebulloides* and some indeterminates that were not identifiable to generic/species are the planktonics recovered. The benthonics forms which are moderately well preserved are: *Cancris auriculs, Eponides* spp., *Hopkinsina Bononiensis, Lenticulina inornata, Cibicidoides ungeranus, Floritus atlanticus, Floritus boueanum, Floritus* spp., *Lenticulina grandis, Norionella auris, Uvigerina subperegrina, Florilus ex. Gr. Costiferum, Ammonia beccarii, Epistominella vitrea, Eponides cf. Iojimaensis, Fursenkoina pundata, Hanzawaia concentrica, Poroeponides lateralis, Quinqueloculina lamarckiana, Bolivina* spp., *Buliminella aff. Subfusiformis* and *Brizalina mandoroveensis.* Some ostracodes, scaphopoda, gastropoda and shell fragments were also recovered.

Calcareous Nannofossil Analysis: The studied interval is relatively rich in calcareous nannofossils particularly the depth between 9930-10020 ft. The total number of nannofossils recovered is 112 consisting of nine species that was dominated by *Cyclicargolithus* and *Helicosphaera* species. The other recovered taxa are: *Helicosphaera truempyi, Calcidiscus leptoporus, Coccolithus pelagicus, Cyclicargolithus abisectus, Cyclicargolithus floridanus, Discoaster deflandrei, Helicosphaera euphratis, Helicosphaera intermedia, Helicosphaera* spp., *Micrantolithus* spp., *Reticulofenestra minuta, Sphenolithus moriformis, Sphenolithus* spp., *Catinaster calyculus* and *Coccolithus miopelagicus*.

Plate 1

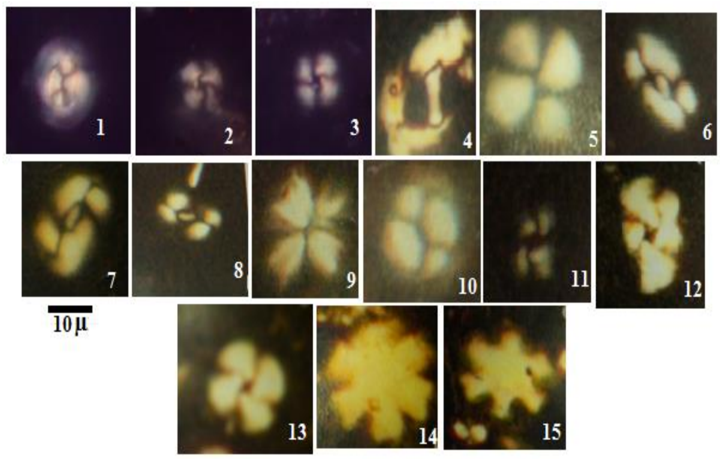


1. Ostracod
2. Gastropods
3. *Globigerina ciperensis angustiumblicata* (d'Orbigny)
4. *Hanzawaia concentrica* Asano, 1944
5. *Nonionella auris* Cushman, 1926

6a, b, c. *Hopkinsina Bononiensis* Howe & Wallace, 1933
7a, b. *Florilus ex gr costiferum*
8a, b. *Eponides* cf *iojimaensis*

9. *Epononides* spp.
10. *Quinqueloculina lamarkiana* d'Orbigny 1826
11. *Lenticulina grandis*
12. *Lenticulina inornata* Lamarck, 1804

Plate 2



1. *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930

2, 3. *Cyclicargolithus floridanus* (Roth and Hay, 1967) Bukry, 197

4. *Helicosphaera truempyi* Biolzi and Perch-Nielsen, 1982
5. *Calcidiscus leptoporus* (Murray and Blackman, 1898) Loeblich and Tappan, 1978

6, 7, 8. *Helicosphaera intermedia* Martini, 1965 Hay and Mohler, 1967

9. *Sphenolithus moriformis* Bronnimann and Stradner, 1960 Bramlette and Wilcoxon, 1967
10. *Coccolithus miopelagius* Bukry, 1971
11. *Reticulofenestra minuta* Roth, 1970;

12, 13. *Cyclicargolithus abisectus* (Müller, 1970) Bukry, 1973

14, 15. *Discoaster deflandrei* Bramlette and Riedel, 1954

Biostratigraphy

The poor foraminiferal assemblage precludes a satisfactory dating of the studied interval but the recovery of some stratigraphically significant calcareous nannofossils enables assigning Early Miocene age to the interval using top occurrences of some taxa. The nannofossil assemblage shows a strong similarities to NN1 Zone of Martini[5], and especially CN1b, CN1c and CN2 Zones of Okada and Bukry[6]. The determining factors that constrain the age of the interval to Early Miocene are the top occurrences of *Helicosphaera truempyi*, *Discoaster deflandrei* and *Sphenolithus* spp. (Martini[5]; Okada and Bukry[6]). The absence of *Cyclicargolithus premacintyrei* supports the fact that the studied sediment cannot be younger than Early Miocene (Okada and Bukry[6]).

Paleoenvironment

The reconstruction of the paleoenvironment of the sediments deposited within the studied interval is dependent on the environmental marker forms recovered from both nannofossil and benthic foraminifera present in the assemblages.

Calcareous nannofossil stratigraphical distribution of KR-1 well shows high abundance and

diversity at the interval between 10020 ft and 9930 ft while the acme abundance and diversity of the benthonic foraminifera lie within 10920 ft to 10830 ft and 10560 ft to 10470 ft. High diversity of nannofossil assemblages are characteristic of stable, oligotrophic, mid ocean gyre habitats, whereas a decreased diversity is typical of highly fluctuating, eutrophic, unstable environments with extreme ecological conditions (Sanders[26]; Aubry[27]; Bollmann et al.[28]; Brand[3]; Roth[29]).

The low diversities of nannofossils recorded in the studied interval apart from the small section between 10020 ft and 9930 ft suggesting a fluctuating environment such as marginal marine. This is supported by the near absence of *Discoasters*; *Discoasters* are a diverse, k-selected group, common in oligotrophic, warm, deep water and stable environments (Haq[30]; Lohmann and Carlson[31]; Flores and Sierro[32]; Chepstow-Lusty et al.[33,34]; Aubry[35]; Young[35]), but rare or absent at high fertility equatorial sites (Chepstow-Lusty et al.[36]; Chapman and Chepstow-Lusty[36]) and in marginal seas (Perch-Nielsen[37]). The exclusion of *Discoasters* was therefore probably a function of environmental instability, particularly salinity and nutrient fluctuations (Bridget and Paul[38]).

Lithological and foraminiferal assemblages data also provide insights into the palaeoenvironment of Kr-1 well. The depth interval 10920-10380 ft probably lies between inner-middle neritic.

According to Boersma[40] inner to middle neritic environments are composed of shales, silts, sandy mud and poorly sorted sands; large and robust species that are often highly ornamented are present. Species diversity is high while species dominance is low. The planktics constitute 15-30% of the total fauna. Common taxa are *Ammonia beccari*, milolids, *Bolivina* sp., *Lenticulina* sp., *Uvigerina*, *Peregrina*, *Eponides* sp. and Nodosariids.

Though the above interval of the well is with a low average planktic/benthic ratio, the stratigraphic interval corresponds with the above description of Boersma[39] lithologically and by the presence of indicator faunas (see chart). The interval from 10380-9750 feet has few species dominating the benthic fauna, rare planktics, occurrence of *Quinqueliculina lamarkiana*, *Ammonia beccari*, *Lenticulina* sp., few ostracodes, shell fragments, pyrites, mica flakes and abundant ferruginous materials. This description depicts marginal marine to inner neritic environments (Phleger[40]; Boersma[39]; Murray[19]) (Fig. 3).

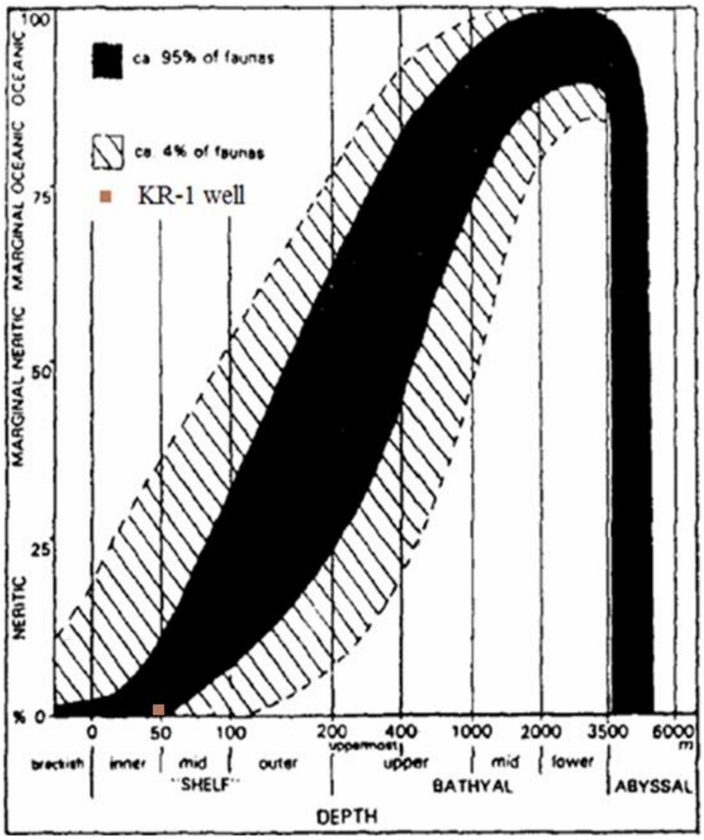
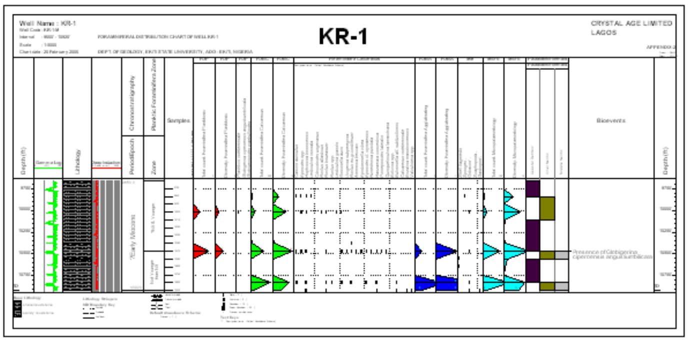
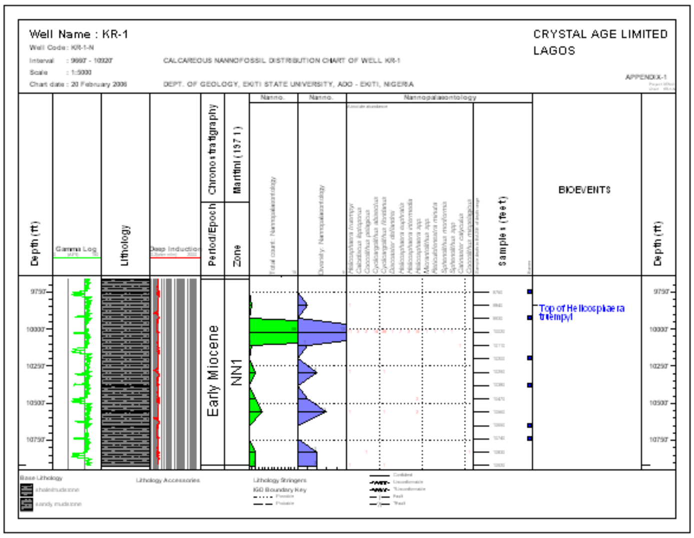


Fig 3. Variation in the ratio of planktonic to benthic foraminifera with depth (Hayward[41]). KR-1 well plotted in inner to mid shelf environment





Conclusion

Lithological, Foraminiferal and Calcareous nannofossil studies of Kr-1 well in the shallow offshore of western Niger Basin has resulted in the interpretation of the biostratigraphy and environment of deposition of the sediments lying between the interval of 9660-10920 ft. A lithologic analysis of the section shows that the samples are made up of shales and sandy shales which are grey in colour with intercalations of medium to fine grained sandstone beds. The shales are fissile and slightly calcareous while the sandy shales are ferruginous and sub-fissile. Based on the nannofossil assemblages and benthonic foraminiferal distribution, it was inferred that during the early Miocene the studied interval was characterized by shallow marine environmental conditions.

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