



Calcareous Nannofossil Study of Well – AD1X, Offshore, Southeast Niger Delta Basin, Nigeria

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ABSTRACT

Lithostratigraphic and calcareous nannofossil biostratigraphic studies was carried out on ditch cutting samples from well - AD1X located in the offshore area of the Niger Delta. The Agbada Formation sediments are made up of shales and sandstones which are grey in colour with intercalations of fine to medium grained sandstone beds. The sediments yielded relatively rich calcareous nannofossils with significant variations in abundance and diversity. Some Niger Delta index fossils present in the study include; *Discoaster pentaradiatus*, *Amaurolithus delicatus*, *Discoaster asymmetricus*, *Discoaster quinqueramus* and *Helicosphaera sellii*. Late Miocene to Early Pliocene age was assigned to the studied well based on the occurrences of these index fossils, while a shallow marine environmental condition of deposition was suggested due to the rich diversity of nannofossils.

Keywords: Nannofossil, Biostratigraphy, Niger Delta, Paleoenvironment

INTRODUCTION

Generally, micropaleontology is an important tool for the petroleum industry, finding practical uses in all stages of the exploration process. The two most common applications of micropaleontology in petroleum exploration are biostratigraphic and paleoenvironmental studies.

Calcareous nannofossils have been living in the world's oceans for at least 200 million years (from the Triassic Period), and they have evolved constantly over time. Therefore, they are used to produce global biostratigraphic and biochronologic frameworks and to provide reliable paleoenvironmental reconstructions of both Mesozoic and

Cenozoic. Calcareous nannofossils 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 present study documents the nannofossil assemblages within the well sediments; use the assemblages to date the sediments and reconstruct their paleoenvironment of deposition and thus contributing to the ongoing biostratigraphical investigations in the Niger Delta basin and other hydrocarbon rich basins. The well is located offshore depobelt approximately 60 km south-eastern part of Calabar, Nigeria (Fig. 1).

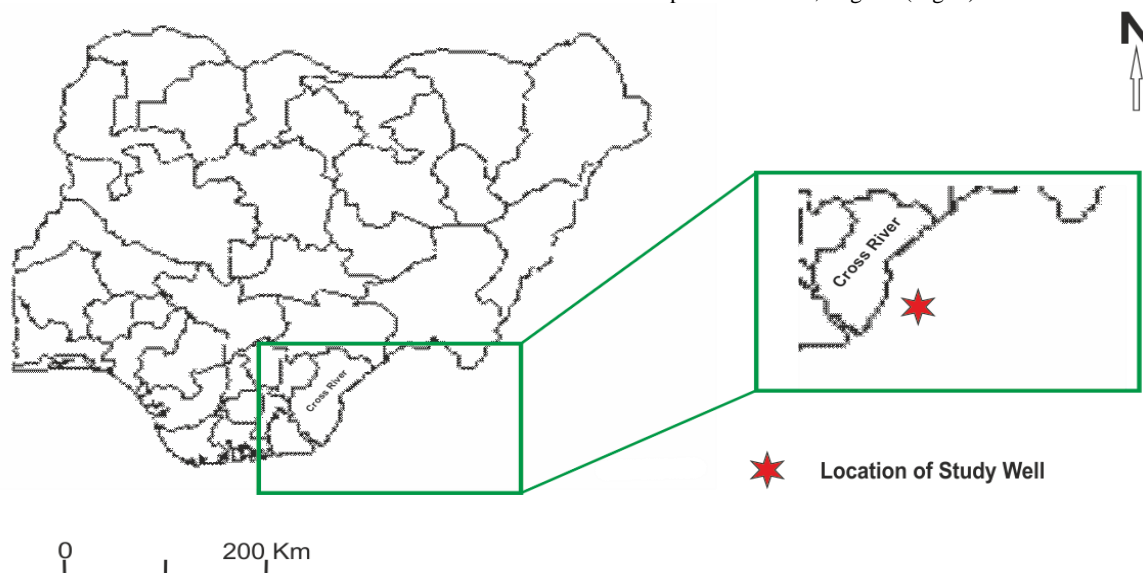


Figure 1: Location of study well

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Geological Framework of the Niger Delta

The present-day Niger Delta Complex is situated on the continental margin of the Gulf of Guinea. 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 north-eastern 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.

The Niger delta basin is one of the largest subaerial basins in Africa. It has an area of about 75,000 km², a total area of 300,000 km², and a sediment fill of 500,000 km³ (Kulke, 1995; Tuttle *et al.*, 2015). The Niger Delta Basin is believed to have originated by rift faulting of the Precambrian rocks during the Cretaceous times, it was formed by a failed rift junction during the separation of the South American plate and the African plate, as the South Atlantic began to open. Rifting in this basin started in the late Jurassic and ended in the mid Cretaceous. After rifting ceased, gravity tectonism became the primary deformational process. (Kulke, 1995). 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 (1967) recognized three subsurface stratigraphic units in the modern Niger Delta. The delta sequence is mainly a sequence of marine clays overlain by paralic sediments which were finally capped by continental sands.

The stratigraphy of Niger Delta Basin are as follows:

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 over pressured and believed to have formed during low stands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency. The thickness of this sequence is not known but may be up to 7000m in the central part of the basin (Doust and Omatsola, 1990). The formation crops out offshore in diapirs along the continental slope and onshore in the north-eastern 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, 1975; Ekweozor and Daukoru, 1984).

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 and seals. Most exploration wells in the Niger Delta, which reaches a maximum thickness of more than 3000 m, have their base 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 – 2,100 m (Ejedawe and Okoh, 1981), 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 occurs in highly porous and mainly freshwater bearing sands.

MATERIALS AND METHODS

Ninety-eight ditch cuttings samples from the interval 3,030 to 6,000 ft. at a 30 ft. interval of the Well-AD1X were processed for calcareous nannofossils studies. The methods employed in this research includes sampling of ditch cuttings, sample preparation of calcareous nannofossils (including washing, picking, description and analysis), statistical analysis of nannofossils populations were plotted using StratBug.

The samples were described, each sample was dried in the oven and examined under a 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.

The standard smear slide preparation method of Brasier (1980) for nannofossil was employed. About 5 g of cuttings was washed to remove the drilling mud. The sample 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 40 mm cover slip at a slightly hot temperature of between 60°C and 70°C. The dried cover slip was then mounted on a glass slide using adhesive under U.V. light. Detailed identification of forms (to species level where possible) was made of all taxa encountered in each slide. The cascading counting method of Styzen (1997) was employed in determining the relative abundance and diversity of the assemblages. Standard nannofossil zonation schemes of Martini (1971) and Okada and Bukry (1980) were employed. Photomicrographs of some of the microfossils were taken and the data from the slides and others were plotted on nannofossil distribution charts on a scale of 1:5000 using Stratbug biostratigraphic software (Fig. 2).

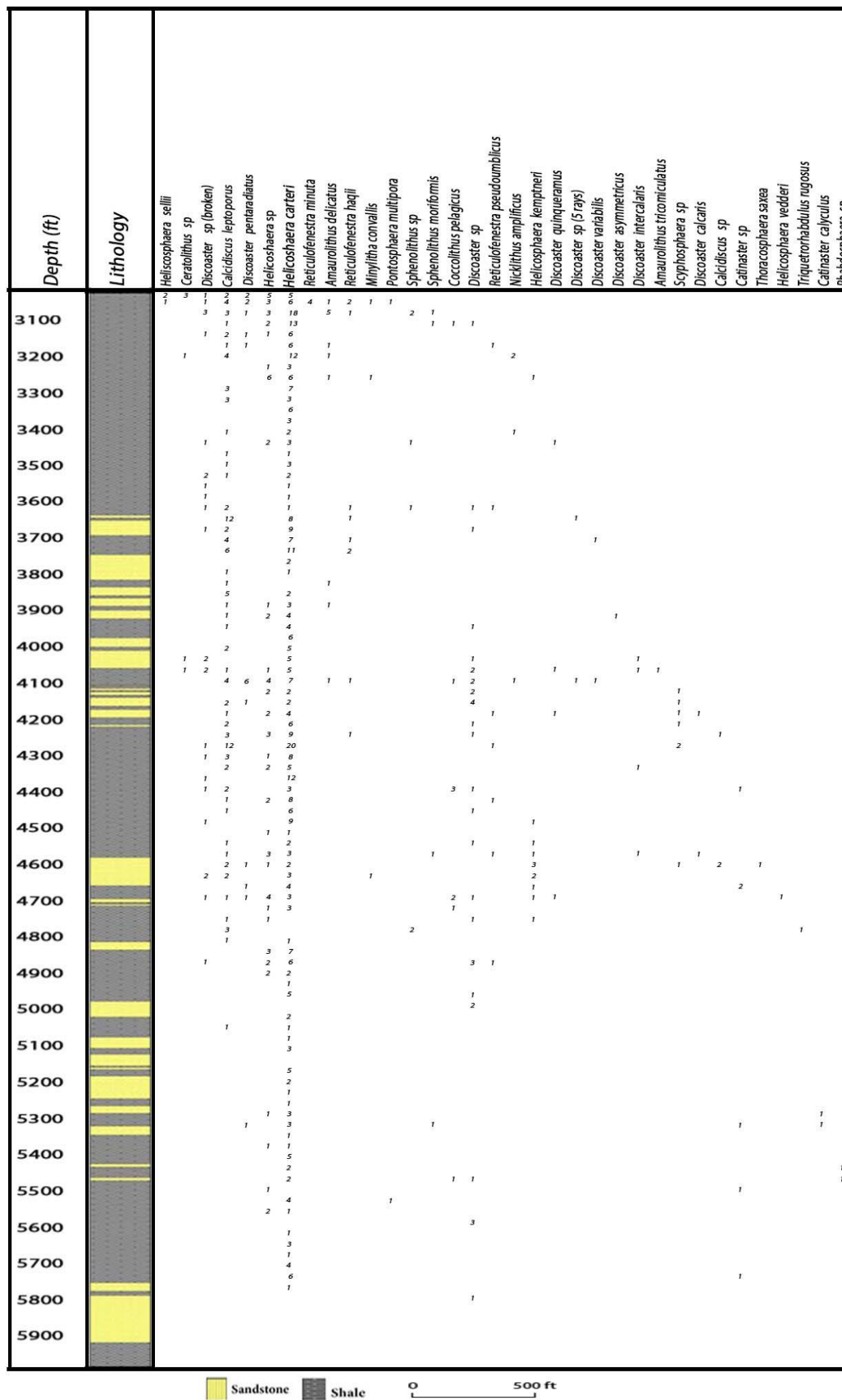


Figure 2: Nannofossil distribution chart for well-AD1X

RESULT

The Well lithology reveals two lithostratigraphic units (Fig 3);

Unit A occurs at depth intervals of 3040 ft. to 3360 ft. composed of thick shale deposit with very little or no sandstone. The gamma-ray value is high due to dominance of shale volume. The shale units have an average volume of more than ninety percent of the facies at the interval. The shale is brown in colour, fissile and poorly cemented.

Unit B occurs at the interval depth of 3960 to 5100 ft. The gamma-ray log pattern of this facies consists of serrated funnel-shaped and bell to blocky shaped patterns at certain intervals. Generally, thick shale units are intercalated with thin to fairly thick sandstones units. The sand/shale ratio is approximately 40:60. The sandstone units is fine to medium grained in texture, often well sorted with angular to sub rounded grains. The shale is brown to grey in colour, fissile and poorly cemented.

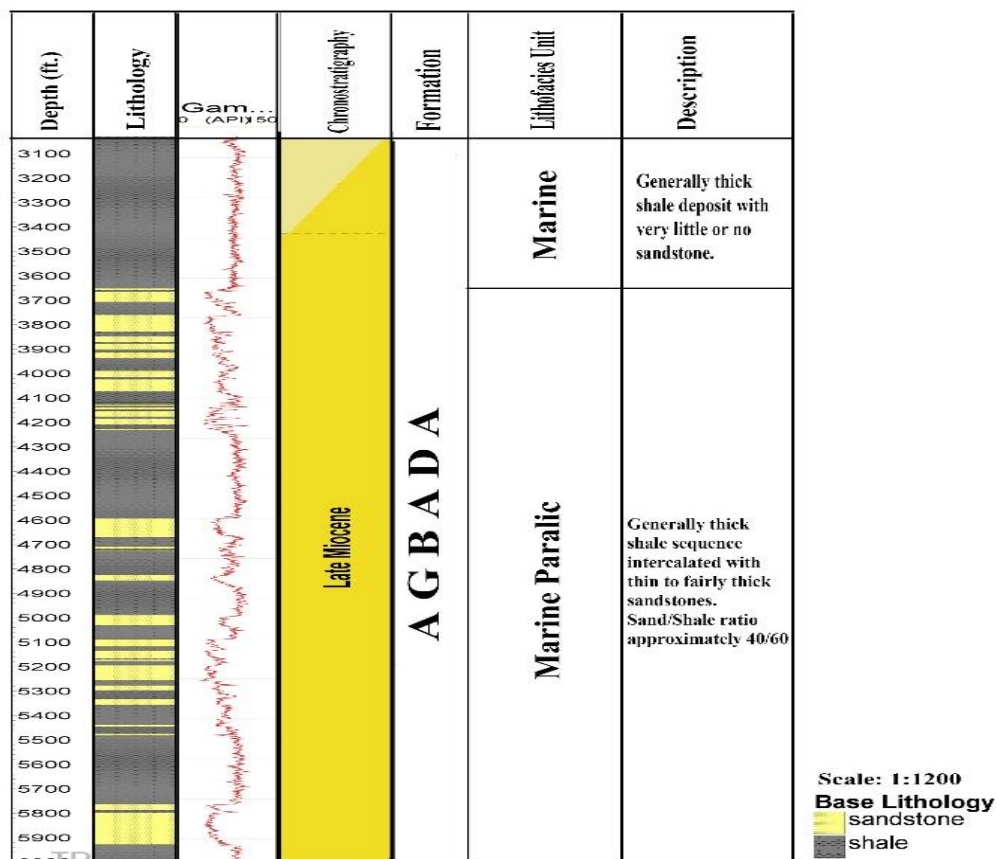


Figure 3: Lithostratigraphic units of well-AD1X

Ninety-eight ditch cuttings samples from the interval 3,030 to 6,000 ft. at a 30 ft. interval of the Well-AD1X were processed for calcareous nannofossils studies. The result of the analysis shows that the analysed intervals are characterized by fairly rich and diverse nannofossils which enhance the subdivision of the well section into zones. Moderate abundance and diverse nannofossil characterized the upper part of the well, while the lower part recorded sparsely to moderate nannofossils species abundance and diversity. Nannofossils such as *Discoaster pentaradiatus*, *Amaurolithus tricorniculatus*, *Nicklithus amplificus*, *Discoaster brouweri*, *Calcidiscus leptoporus*, *Amaurolithus delicatus*, *Reticulofenestra haqii*, *Helicosphaera kemptneri*, *Pontosphaera multipora*, *Sphenolithus moriformis*, *Discoaster asymmetricus*, *Discoaster quinqueramus*, *Helicosphaera sellii*, *Reticulofenestra pseudoumbilicus* and *Coccolithus pelagicus* were recorded in some depths. Thirty-four species of nannofossils were identified.

DISCUSSION

Age and Nannofossils Bioevents
 Late Miocene

The Late Miocene age is recognized at the base of NN11 - N13 of Martini (1979) based on the First Downhole Occurrence of *Discoaster quinqueramus* at 3,450 ft. and the Last Downhole Occurrence of *Discoaster quinqueramus* at 4,710 ft. The lower limit of this zone is marked by the base of *Discoaster quinqueramus* at 4,710 ft. In a similar development, the age is recognized between intervals of 4,710 to 6000 ft. based on Last Downhole Occurrence of *Discoaster quinqueramus* Zone (NN11 - NN10) of Martini (1979) at 4,710 ft. The lower limit of this zone is tentatively placed at Terminal depth (TD) 6,000 ft. In Well-AD1X, Late Miocene is defined by the base *Discoaster berggrenii* (NN11 - NN10) is at the depth intervals between 4,710 ft. to 6,000 ft. The interval age was based on the Last Downhole Occurrence of *Discoaster berggrenii* at 4,710 ft. The lower limit of this zone is tentatively placed at Terminal depth (TD) 6,000 ft.

Late Miocene-Early Pliocene

In Well-AD1X, the Early Pliocene-Late Miocene is recognised by *Discoaster quinqueramus* Zone (NN14 - NN12) of Martini (1979) based on *Amaurolithus delicatus* at 1,990 ft. and First Downhole Occurrence of *Discoaster quinqueramus* at 3,450 ft. The lower limit of this zone is marked by Top *Discoaster quinqueramus* at 3,450 ft.

Calcareous Nannofossil Biozonation (Fig. 4)

The recorded nannofossils were used in the zonation and age dating of the study interval.

The analysed section is dated Early Pliocene - Late Miocene based on the presence of nannofossil marker species. The zonation scheme of Martini (1971) was adopted in this study while ages in Ma were based on Berggren *et al.* (1995). Condensed Sections were correlated to the global cycle chart of Hardenbol *et al.* (1998).

- *Amaurolithus delicatus* /*Discoaster quinqueramus* (NN14 - NN12)

Stratigraphic Interval: 3,030 ft. to 3,450 ft.

Age: Early Pliocene – Late Miocene

Nannofossils Zone: NN14 – NN12

Top: Probably shallower than the first sample analysed

Base: Top *Discoaster quinqueramus*

Definition: The interval age was based on *Amaurolithus delicatus* at 1,990 ft. and First Downhole Occurrence of *Discoaster quinqueramus* at 3,450 ft.

Diagnostic Features: The interval was characterized by fairly rich and diverse nannofossils species. Some nannofossil taxa that characterized this interval includes; *Discoaster pentaradiatus*, *Nicklithus amplificus*, *Calcidiscus leptoporus*, *Amaurolithus delicatus*, *Reticulofenestra haqii*, *Helicosphaera kamptineri*, *Pontosphaera multipora*, *Sphenolithus moriformis*, *Discoaster asymmetricus*, *Discoaster quinqueramus*, *Helicosphaera sellii*, *Reticulofenestra pseudoumbilicus* and *Coccolithus pelagicus*.

The lower limit of this zone is marked by Top *Discoaster quinqueramus* at 3,450 ft.

- *Discoaster quinqueramus*/ *Scyphosphaera* sp. (NN11)

Stratigraphic Interval: 3,450 ft. to 4,100 ft.

Age: Late Miocene

Nannofossils Zone: NN11

Top: Top *Discoaster quinqueramus*

Base: Base *Discoaster variabilis*

Definition: The interval age was based on the First Downhole Occurrence of *Discoaster quinqueramus* at 3,450 ft. and the Last Downhole Occurrence of *Discoaster variabilis* at 4,100 ft.

Diagnostic Features: The interval characterized by rich and diverse nannofossils species. Some nannofossil taxa that characterized this interval include *Discoaster pentaradiatus*, *Amaurolithus tricorniculatus*, *Nicklithus amplificus*, *Calcidiscus leptoporus*, *Amaurolithus delicatus*, *Reticulofenestra haqii*, *Helicosphaera kamptineri*, *Pontosphaera multipora*, *Sphenolithus abies*, *Sphenolithus moriformis*, *Discoaster asymmetricus*, *Discoaster quinqueramus*, *Helicosphaera sellii*, *Reticulofenestra pseudoumbilicus* and *Coccolithus pelagicus*. The lower limit of this zone is marked by the Base of *Discoaster variabilis* at 4,100 ft.

- *Amaurolithus delicatus* / *Helicosphaera vedderi* Sub-zone (NN11 - NN10)

Stratigraphic Interval: 4,100 ft. to 4,710 ft.

Age: Late Miocene

Nannofossils Zone: NN11 - NN10

Top: Base *Amaurolithus delicatus*

Base: Base *Helicosphaera vedderi*

Definition: The interval age was based on Last Downhole Occurrence of *Discoaster quinqueramus* at 4,100 ft.

Diagnostic Features: This interval is characterized by the fairly rich occurrence of nannofossils.

Nannofossil taxa that characterized this interval include *Discoaster pentaradiatus*, *Amaurolithus tricorniculatus*, *Nicklithus amplificus*, *Calcidiscus leptoporus*, *Reticulofenestra haqii*, *Helicosphaera kamptineri*, *Pontosphaera multipora*, *Sphenolithus moriformis*, *Discoaster asymmetricus*, *Helicosphaera sellii*, *Reticulofenestra pseudoumbilicus* and *Coccolithus pelagicus*. The lower limit of this zone is tentatively placed at Base of *Helicosphaera vedderi* 4,710 ft.

- *Discoaster quinqueramus*/ *Helicosphaera carteri* (NN11 - NN10)

Stratigraphic Interval: 4,710 ft. to 5,800 ft.

Age: Late Miocene

Nannofossils Zone: NN11 - NN10

Top: Base *Discoaster quinqueramus*

Base: Base *Helicosphaera carteri*

Definition: The interval age was based on the Last Downhole Occurrence of *Discoaster quinqueramus* at 4,710 ft.

Diagnosis Features: This interval is characterized by the fairly rich occurrence of nannofossils.

Nannofossil taxa that characterized this interval include *Discoaster pentaradiatus*, *Amaurolithus tricorniculatus*, *Nicklithus amplificus*, *Calcidiscus leptoporus*, *Reticulofenestra haqii*, *Helicosphaera kamptineri*, *Pontosphaera multipora*, *Sphenolithus moriformis*, *Discoaster asymmetricus*, *Helicosphaera sellii*, *Reticulofenestra pseudoumbilicus* and *Coccolithus pelagicus*. The lower limit of this zone is tentatively placed at *Helicosphaera carteri* 5,800 ft.

Paleoenvironmental Reconstruction

The reconstruction of the paleoenvironment of the sediments deposited within the studied interval is dependent on the environmental marker forms recovered from nannofossil present in the assemblages. Calcareous nannofossil stratigraphical distribution of the well shows high abundance and diversity in the studied well interval. 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, 1969; Aubry, 1992; Bollmann *et al.*, 1993; Brand, 1994; Roth, 1994). The high diversities of nannofossils recorded in the studied interval suggests stable oligotrophic mid ocean gyre habitats. This is supported by the presence of *Discoasters*; *Discoasters* are a diverse, selected group, common in oligotrophic, warm, deep water and stable environments (Haq, 1980; Lohmann and Carlson, 1981; Flores and Sierro, 1987; Chepstow-Lusty *et al.*, 1989, 1992; Aubry, 1992; Young, 1998), but rare or absent at high fertility equatorial sites (Chepstow-Lusty *et al.*, 1992; Chapman and Chepstow-Lusty, 1997) and in marginal seas (Perch-Nielsen, 1985). The presence of *Discoasters* is a consequence of environmental stability, particularly salinity and nutrient stability.

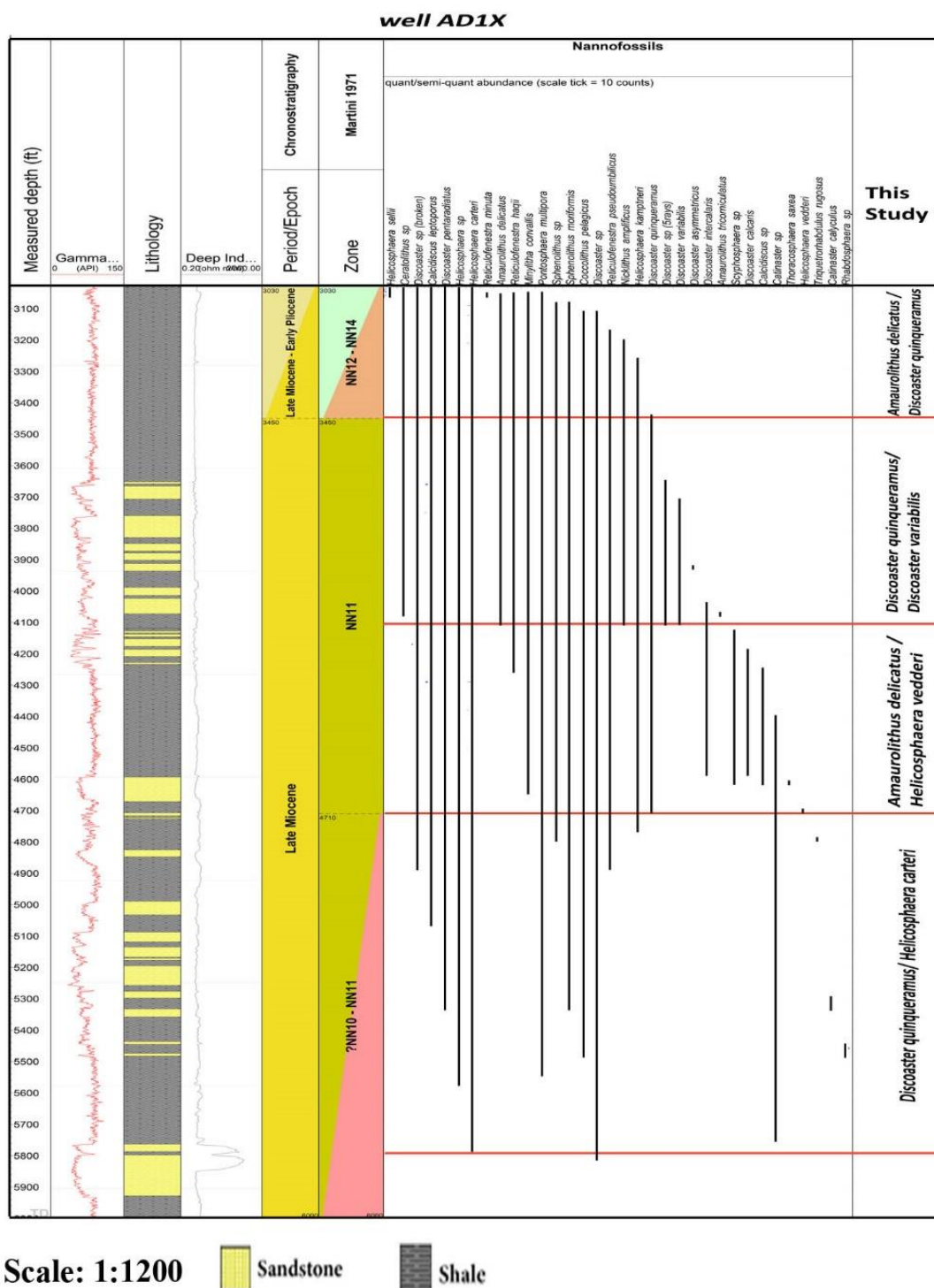


Figure 4: Nanno-zonation of well-AD1X

CONCLUSION

Lithological and Calcareous nannofossil studies of the well has resulted in the interpretation of the biostratigraphy and environment of deposition of the sediments lying between the intervals of 3,030 to 6,000 ft. A lithologic analysis of the section shows that the samples are made up of shale and sandstone. Based on the nannofossil assemblages, it was inferred that during the

Late Miocene-Early Pliocene the studied interval was characterized by shallow marine environmental conditions.

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