BIOZONATION AND CORRELATION OF TWO WELLS IN NIGER DELTA USING CALCAREOUS NANNOFOSSILS

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Received: 19 November 2015 / Accepted: 05 June 2016 / Published online: 17 June 2016

Abstract Two wells drilled in the offshore of Niger Delta were biostratigraphically analyzed and correlated, based on their calcareous nannofossils content. The 98 analyzed samples were collected from the Well MAY-01 at interval range of 40ft. (12.19m) to 120ft (36.58m) from the depth of 4050ft. (1234.40m) to 11700ft. (3566.16m), while in the second well, Well MAY-02, at interval range of 30ft (9.12m) from the depth of 7200ft. (2194.56m) down to 9850ft. (3002.28m). In all, twenty calcareous nannofossil species were identified and used for biozonation and correlation. The distribution of the calcareous nannofossil species in the two wells enabled the establishment of zones belonging to the upper Miocene; NN9 and NN11, while NN10 was not recorded. The most abundant calcareous nannofossils identified are *Discoaster hamatus, Discoaster berggrenii, Discoaster quinqueramus, Ceratolithus armatus* and *Ceratolithus cristatus*. The two biozones of calcareous nannofossils identified from May-01 and May-02 wells were correlated based on their short stratigraphic range and found to be similar in the two studied successions.

Keywords: calcareous nannofossils, biozones, Niger Delta, upper Miocene-lower Pliocene.

INTRODUCTION

Calcareous nannofossils are fossil remains of golden brown, single-celled algae that live in the oceans (Haq & Boersma, 1978). The calcareous nannoplankton taxa are exclusively planktonic marine organisms, distributed from the open ocean, pelagic environnment to nearshore littoral and inshore lagoonal environnments. They are often widespread, abundant and well preserved in marine sediments in the geological record; thus, this group of organisms is very useful for biostratigraphic purpose.

Calcareous nannofossils occur in the Mesozoic or Cenozoic marine sediments with a fine carbonate fraction which has not undergone metamorphism, severe diagenesis and/or weathering. Nannofossils are generally straightforward to study, they occur in a wide range of lithologies and preparation is simple and fast. They are typically present at abundance of millions of specimens per gram, so samples for nannofossil work can be very small. Calcareous nannoplankton constitutes a diverse group of morphological forms, many of which are either clearly related or show some similarity to the extant coccolithophores (with coccolith-like shields). Other forms with no clear morphologic relationship to coccolithophores (e.g discoasters) occur as calcareous nannofossils within the same size fraction as coccoliths and may form a substantial part of the nannofossil assemblages (Young, 1998). Thus, both the coccolithophores and the associated non-coccolithophores are traditionally studied together by the nanno workers.

Most important hydrocarbon reservoirs in the Niger Delta are comprised in the paralic Agbada Formation. These reservoirs are usually located in zones with structural and stratigraphic complexity (Lehner & De Ruiter, 1977; Evamy et al. 1978). An excellent biostratigraphic framework is crucial for understanding the stratigraphy, characterization of the reservoirs and planning new exploration targets. This is important because different depositional settings imply different reservoir qualities in terms of architecture, connectivity, heterogeneity and porosity-permeability characteristics.

The study of calcareous nannofossils represents a major tool used by the biostratigrapher in the characterization of the reservoir strata and correlation in well site operation. The calcareous nannoplankton biostratigraphy is important in the accurate reconstruction of time of deposition at the basin scale and plays in the petroleum exploration successful work.

Martini (1971) established a calcareous nannoplankton zonation based mainly upon coastal plain sediments, while Bukry (1971) and Okada & Bukry (1980) based their zonation entirely on deep-sea samples that were collected as part of the Deep Sea Drilling Project.

This study aims to determine age of the lithostratigraphic units penetrated by two wells from the Niger Delta, following several biostratigraphic schemes as aforementioned. The identified calcareous nannofossil biozones were correlated in the two investigated well.

GEOLOGY OF THE STUDIED AREA

The Niger Delta is one of the largest Tertiary Delta systems and it is ranked among the major prolific deltaic hydrocarbon province. It is the most significant in the West African continental margin. It developed on the depression created following the separation of the South American plate consequent upon rifting at the Mid Atlantic ridge and other subsequent tectonic activities (Merki, 1972). The Niger Delta sits at the end of the Benue trough (Fig. 1) corresponding to the failed arm of the rift triple junction, which ceased in the Late Cretaceous (Lehner & De Ruiter, 1977; Correldor et al., 2005).

The coastal sedimentary basin of Nigeria has been the scene of three depositional cycles. The first began with a marine incursion in the middle Cretaceous and was terminated by a mild folding phase in the Late Cretaceous,

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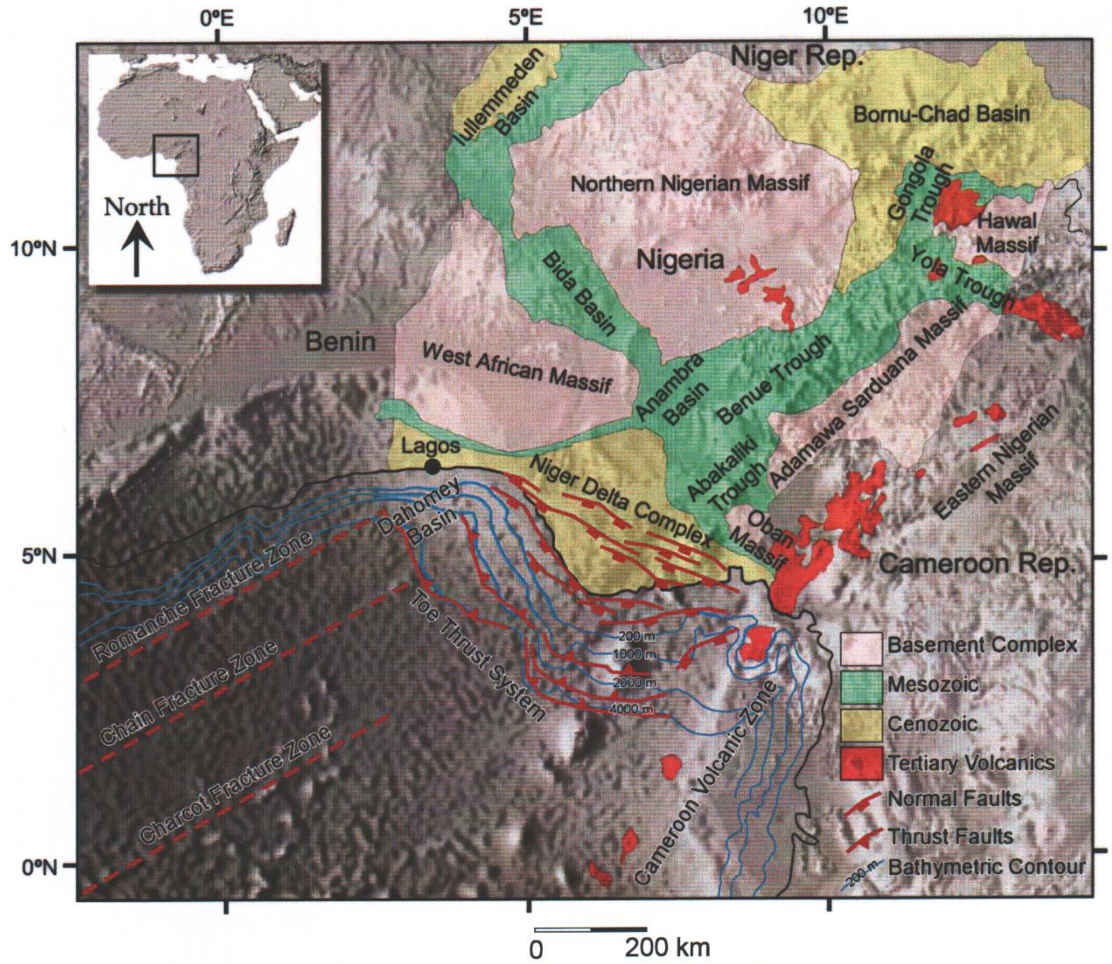

Fig. 1 Geologic map of the Niger Delta region (after Correldor et al. 2005)

i.e. within the Santonian times. The second included the growth of a proto-Niger Delta during the Late Cretaceous and ended in a major Paleocene marine transgression. The third cycle, from Eocene to Recent, marked the continuous growth of the main Niger Delta (Short & Stauble, 1967; Reijers et al., 1996).

Throughout its history, the delta has been fed by the Niger, Benue and Cross rivers, which drains more than 10^6 km² of continental lowland savannah. Generally, the Niger Delta shows a progradation over the subsiding continental-oceanic lithospheric transition zone during the Oligocene, spreading onto the oceanic crust of the Gulf of Guinea. The delta, since the Paleocene, prograded at a distance of more than 250 km from the Benin and Calabar flanks to the present delta front (Evamy et al, 1978; Doust & Omatsola, 1990).

Whilst the early Niger Delta is interpreted as being a river-dominated delta, the post-Oligocene delta is a typical wave-dominated, well-developed shoreface sands, beach ridges, tidal channels, mangrove and fresh water swamps. It shows an overall upward transition from marine shales (Akata Formation) through a sand-shale paralic interval (Agbada Formation) to continental sands of the Benin Formation. Depending on sea level changes, local subsidence and sediment supply, the delta experienced phases of regressions and transgressions. However, Weber & Daukoro (1975) reported that the sedimentation in the Niger Delta was mostly due to marine transgressive and regressive phases**.** On the other hand, Burke (1972) be lieved that the diminishing Benue-Abakaliki fold belt sediment sources was replaced by the Cameroon swell in the eastern Nigeria, which experienced extensive uplift in the Miocene and provided a large new source of sediments. The growth of the delta accelerated and the continental oceanic crust cooled and subsided further. The rapid subsidence which took place between Miocene and Pliocene in areas located over the unstable transition zone of continental oceanic crust enabled thick Akata, Agbada and Benin facies to accumulate (Fig. 2).

Short & Stauble (1967) presented a detailed work on the subsurface lithostratigraphy of the Niger Delta. They established a threefold lithostratigraphic subdivision in the subsurface of the delta. They are from the oldest to the youngest, Akata Formation which is predominantly composed of marine shales, sandy and silty beds, which are thought to have been laid down as turbidites and continental slope channel fills. This formation has high organic content and it constitutes the major source rock in the Niger Delta. Overlying this formation is the Agbada Formation consisting of interbedded sand with minor shales and lastly the Benin Formation comprising of massive continental sands and gravels, accounting for about 90% of all the lithofacies with a few shale intercalations, which becomes more abundant toward the base.

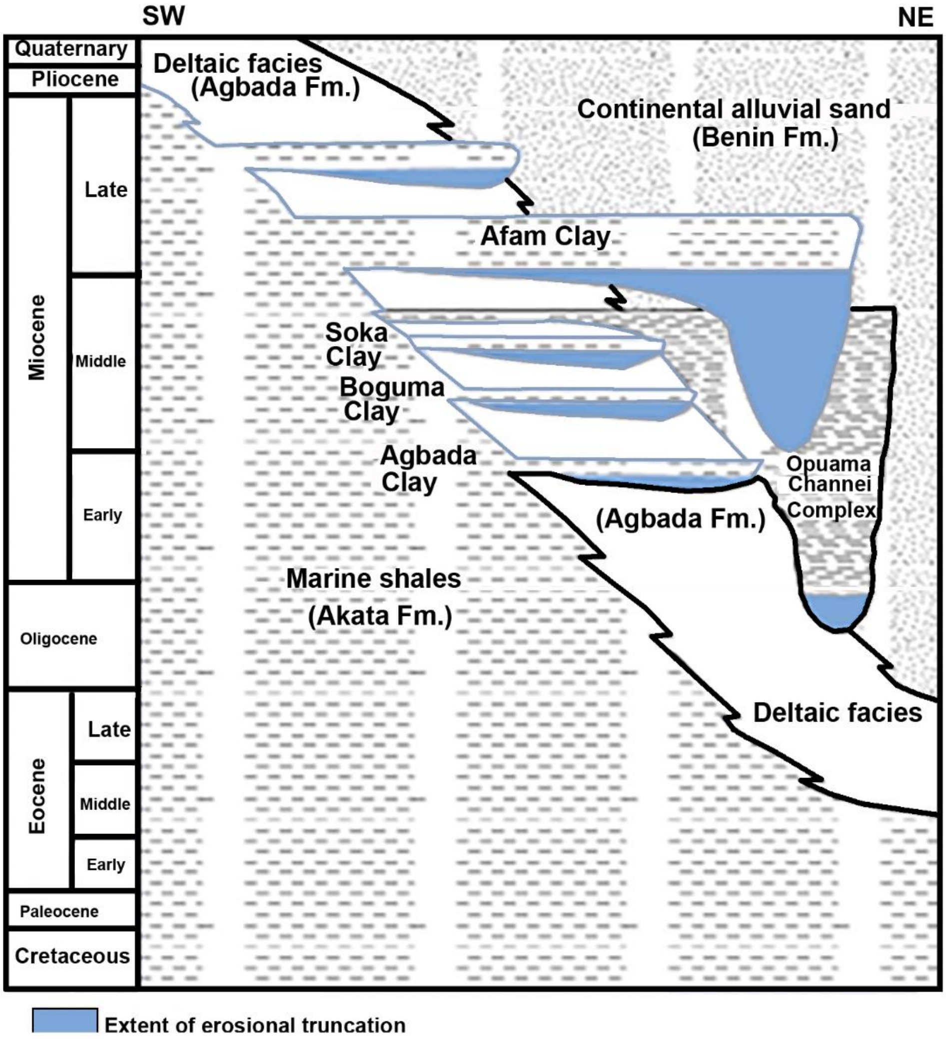

Fig. 2 Stratigraphy and paleoenvironment of the Eocene-Pliocene interval of the Niger Delta (modified from Doust & Omatsola, 1990)

The three major lithostratigraphic units defined in the subsurface of the Niger Delta (Akata, Agbada and Benin formations) decrease in age basinward, reflecting the overall regression of the depositional environments with in the Niger Delta clastic wedge. Stratigraphic equivalent units to these three formations are exposed in Southern Nigeria. The formations reflect a gross coarsening-upward progradational clastic wedge (Short & Stauble, 1967), deposited in marine, deltaic, and fluvial environments (Weber & Daukoru, 1975).

Ogbe (1982) studied the biostratigraphy and palynology of the Niger Delta, identifying three main marine transgressions during the Pleistocene. Stradner (1959) first reported the presence of the calcareous nannofossil genus *Discoaster* in the Tertiary rocks in Austria. Recently, Ojo et al. (2009) studied nannofossils encountered from two deep offshore wells and identified eight biozones. The Tertiary biostratigraphy of most part of the Tertiary deposits of the Niger Delta wells has been achieved by using the globally recognized zones of Martini & Bramlette (1963), Martini & Worsely (1970), Martini (1971) and Berggren et al. (1985).

MATERIALS AND METHOD

A total of 98 ditch cuttings from two wells in the Niger Delta region of Nigeria were made available for this study. The wells are code-named MAY-01 and MAY-02.

Well MAY-01 comprises of 52 ditch cutting samples, collected at interval of 40ft. (12.19m) to 120ft. (36.58m) from depth of 4050ft. (1234.44m) to 11700ft. (3566.16m) while MAY-02 comprises of 46 ditch cutting samples, collected at 30ft. (9.14m) intervals from the depth of 7200ft. (2194.56m) to 9850ft. (3002.28m).

These wells were logged and processed for nannofossils analysis; smear-slides were prepared by following standard procedures. The calcareous nannofossils were studied under a transmitting light of a binocular microscope in immersion, at ×1250 magnification. Standard counts of 12 transverses were carried out, followed by an extensive search of the slide for rare marker fossils. This method was standardized for each slide and the nannofossils observed where recorded in the analysis sheet with specific and generic determinations and abundance by using the Stratabug biostratigraphic software.

Taxonomy of the calcareous nannofossils follows Perch-Nielsen (1985) and Young (1998).

RESULTS AND INTERPRETATION

Biostratigraphic interpretation of the studied sections was attempted based on the calcareous nannoplankton zonations and age estimation of: Martini and Bramlette (1963), Martini and Worsely (1970), Martini (1971), Young (1998), Beggren et al. (1985) and Raffi et al. (2006). The results concerning the diversity and abundance of the identified calcareous nannofossil assemblages is also presented below.

CALCAREOUS NANNOFOSSIL ASSEMBLAGES AND ABUNDANCE

In all, twenty calcareous nannofossil taxa were identified (Fig. 3) ranging from the Cretaceous up to the Neogene. The dating of the studied deposits has been made based on calcareous nannofossils events recorded by the significant biostratigraphic species, such as: *Ceratolithus cristatus, Ceratolithus armatus, Helicosphaera sellii, Discoaster quinqueramus, Discoaster berggrenii* and *Discoaster hamatus.*
Nannofossil zones and age interpretations are presented in the distribution charts and biostratigraphy summary in Figs. 4 and 5. The results are summarized below for each of the wells in Table 1. The events which were considered are the FDO (first downhole occurrence) and LDO (last downhole occurrence).

CALCAREOUS NANNOFOSSILS BIOSTRATIGRAPHY

The first and last appearances data of the calcareous nannofossils identified in the two wells, their abundance, stratigraphic age and biozones are described below (Table 1, 2 and 3).

Biostratigraphic Intervals of MAY-01 Well
Zone: NN11
Age: Late Messinian
Interval: 4020ft. (1225.30m) – 8070ft. (2459.74m)
Diagnosis: This interval is fairly rich in calcareous nannofossils. The First Downhole Occurrence (FDO) of *Discoaster berggrenii* and *Discoaster quinqueramus* at 4860ft. (1481.33m) confirms the top of this zone. The HO (highest occurrence) of *Discoaster quinqueramus* marks the 5.8 Ma MFS (Haq et al. 1987) condensed section and its age ranges from Tortonian to Messinian. The Last Downhole Occurrence (LDO) of *Discoaster berggreni* at 7950ft. (2423.16m) marks the base of this NN 11 zone of Martini (1971) and it dates back to the Late Messinian at 8.4 Ma. This also corresponds to the middle and upper part of the subzones NN11a of Martini (1971). The LDO of Discoaster quinqueramus at 6390ft. (1947.67m) is dated 7.0 Ma MFS (Haq et al. 1987).

Zone: NN 10
Age: Late Miocene
Interval: 8070ft. (2459.74m) – 10120ft. (3084.58m)

Table 1 Depth of occurrence of some calcareous nannofossils.

S/N	**Calcareous Nannofossil Taxa**	**Depth of occurrence of Calcareous Nannofossils in May-01 Well**	**Depth of occurrence of Calcareous Nannofossils in May-02 Well**
1.	*Discoaster hamatus*	10330ft. (3148.54 m) - FDO 10900ft. (3379 m) - LDO	9600ft. (2926.08 m) (present)
2.	*Discoaster berggrenii*	4860ft. (1481.33m) - FDO 7950ft. (2423.16m) - LDO	7890ft. (2404.87m)-FDO 8940ft. (2771.4 m)-LDO
3.	*Discoaster quinqueramus*	4860ft. (1481.33m) - FDO 6290ft. (1949.9m) - LDO	7710ft. (2350.01 m)-FDO 8880ft. (2752.8 m)-LDO
4.	*Ceratolithus armatus*	-	7470ft. (2276.86 m)-FDO 7650ft. (2331.72 m)-LDO
5.	*Helicosphaera sellii*	-	7170ft. (2222.7 m)-FDO 7470ft. (2276.86 m)-LDO
6.	*Ceratolithus cristatus*	-	7170ft. (2222.7m)-FDO 7500ft. (2286m)-LDO
7.	Barren Zone	8070ft. (2459.74m) to 10120ft. (3084.58m)	9000ft.(2743.2m) to 9540ft. (2907.79m)
8.	*Discoaster pentaradiatus*	6390ft. (1,980m)- FDO 6540ft. (2027.4m)- LDO	9260ft. (2870m)-FDO 9550ft. (2960.5m)- LDO
9.	*Discoaster brouweri*	4140ft. (1283.4m)-FDO 11710ft. (3630.1m)- LDO	7170ft. (2222.7m)- FDO 9600ft. (2976m)- LDO
10.	*Reticulofenestra pseudoumbilicus* >7 microns	9130ft. (2830.3m)- FDO 11020ft. (3416.2m)-LDO	7320ft. (2269.2m)- FDO 9750ft. (3022.5m)- LDO
11.	*Calcidiscus macintyrei*	11230ft. (3481.3m)-Present	7260ft. (2250.6m)-FDO 8250ft. (2557.5m)- LDO

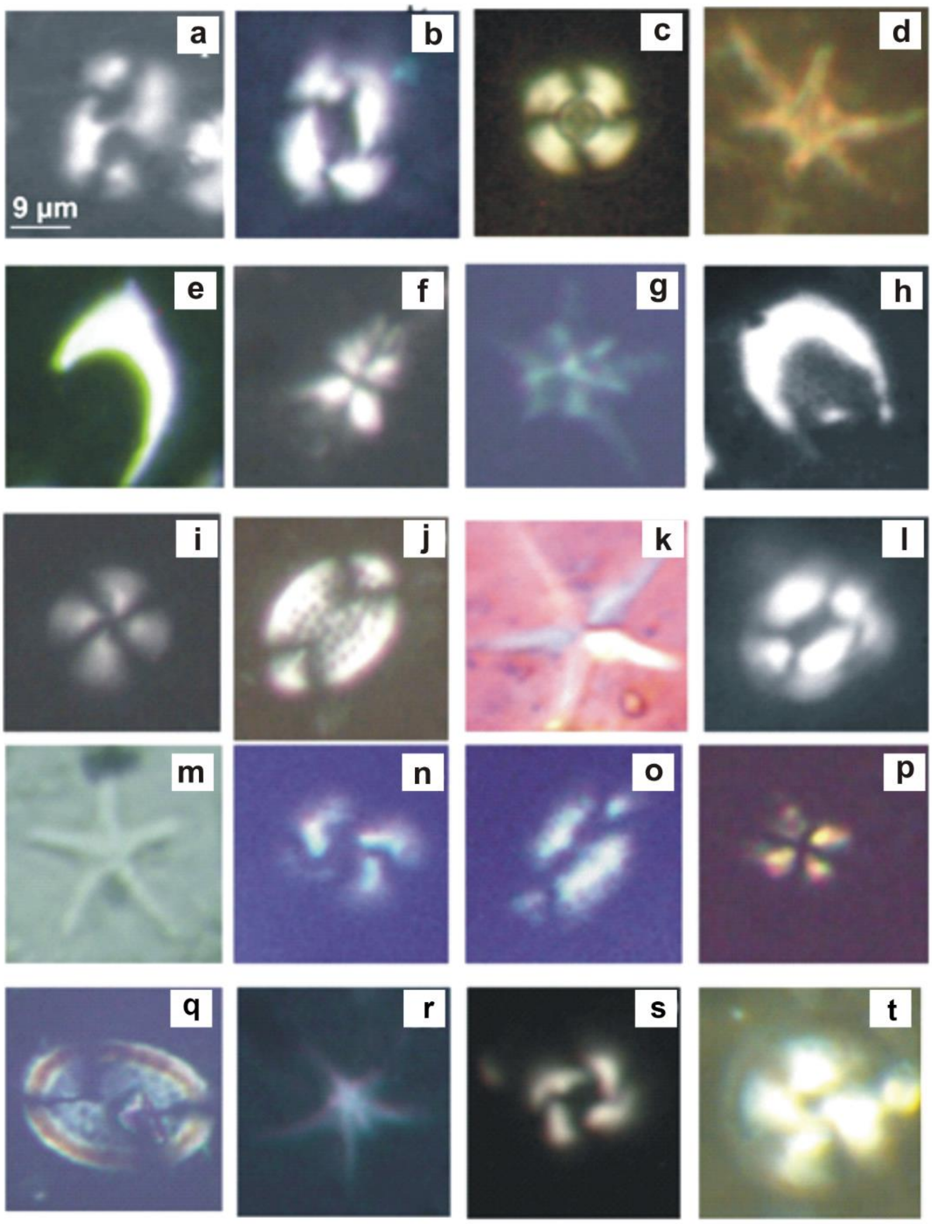

Fig. 3. Microphotographs at LM (light microscope) of the calcareous nannofossils identified in the two studied wells; scale bar 9 microns. **a** *Helicosphaerea sellii* Bukry and Bramlette; **b** *Reticulofenestra pseudoumbilicus* > 7 microns (Gartner) Gartner; **c** *Calcidiscus tropicus* (Kamptner) Gartner; **d** *Discoaster brouweri* (Roth and Hay in Hay et al.) Bukry; **e** *Ceratolithus armatus* (Muller, 1974); **f** *Sphenolithus abies* Deflandre in Deflandre and Fert; **g** *Discoaster berggrenii* Bukry; **h** *Ceratolithus cristatus* (Young, 1998); **i** *Calcidiscus leptoporus* (Murray and Blackman) Loeblich and Tappan; **j** *Pontosphaera multipora* (Kamptner ex Deflandre in Deflandre and Fert) Roth, 1970); **k** *Discoaster pentaradiatus* Tan; **l** *Coccolithus pelagicus* (Wallich) Schiller; **m** *Discoaster hamatus* Martini and Bramlette; **n** *Cyclicargolithus floridanus* (Tan) Bramlette and Riedel; **o** *Helicosphaera carteri* (Wallich) Kamptner; **p** *Sphenolithus moriformis* (Brönnimann and Stradner) Bramlette and Wilcoxon; **q** *Pontosphaera discopora* Schiller; **r** *Discoaster quinqueramus* Gartner; **s** *Reticulofenestra haqii* Backman; **t** *Calcidiscus macintyrei* (Bukry and Bramlette) Loeblich and Tappan.

Diagnosis: This interval is virtually barren of calcareous nannofossil abundance and is considered to represent the NN 10 of Martini 1971 based on the geometrical position.

Zone: NN9
Age: Tortonian
Interval: 10120ft. (3084.58m) – 11710ft. (3569.21m)
Diagnosis: the well-developed nannofossil assemblages, with high abundance and diversity within this interval is considered to represent the 9.2 Ma MFS (Haq et al. 1987) condensed section. This interval is dated based on the First Downhole Occurrence (FDO) of *Discoaster hamatus* at 10330ft. (3148.58m) and the LDO at 10900ft. (3379m).

Biostratigraphic intervals of MAY-02 well
Zone: NN 12
Age: Early Zanclean (Early Pliocene)
Interval: 7170 ft. **(**2185.42 m) -7650ft. (2331.72 m)
Diagnosis: This interval is characterized by well-developed nannofossil abundance and diversity. The most abundant interval is situated at 7470ft. (2276.86m). This represents the 5.0 Ma MFS (Haq et al. 1987) and 5.59 Ma

Table 2 Calcareous nannofossils recognized in MAY-01 WELL at different depths and their corresponding biozones.

Depth (feet)	Epoch	Age (Ma)	Zones (Martini, 1971)
4020ft.(1225.30m)	LATE MIOCENE	5.8 Ma	NN 11 *Discoaster berggrenii* and *Discoaster quinqueramus* (FDO)
5450ft.(1661.16m		7.0 Ma	NN 11- *Discoaster quinqueramus* and *Discoaster berggrenii* (LDO)
8070ft.(2459.74m)		Indeterminate	NN10 Barren zone
10120ft.(3084.58m) 11710ft.(3569.21m)		9.2 Ma	NN9 – *Discoaster hamatus* (FDO)

Table 3 Calcareous nannofossils recognized in MAY-02 WELL at different depths and their corresponding biozones.

Depth (feet)	**Epoch**	**Age (Ma)**	**Zones (Martini 1971)**
7200ft.(2194.56m)	LATE MIOCENE	Indeterminate	NN13 and Younger
7470ft.(2276.86m)		5.0 Ma	NN 12 *Ceratolithus Amatus, Helicosphaera sellii, Ceratolithus cristatus* (LDO)
7650ft.(2331.72m)		5.8 Ma	NN 11 *Discoaster quinqueramus* and *Discoaster berggrenii* (FDO)
7710ft.(2350.01m)		7.0 Ma	NN 10 Discoaster *quinqueramus* and *Discoaster berggrenii* (LDO)
9000ft.(2743.2m)	LATE MIOCENE		BARREN ZONE
9540ft.(2907.79m) 9870ft.(3008.38m)	LATE MIOCENE	9.2 Ma	NN9 *Discoaster hamatus*

MFS (Young, 1998) Late Miocene Zone. This is confirmed by the FDO of *Ceratolithus armatus* and the LDO of *Helicosphera sellii* at the depth of 7470ft. (2276.86 m). The LDO of *Ceratolithus cristatus* at 7650ft (2331.72 m) further confirmed the age assigned to this horizon.

Zone: NN11
Age: Late Messinian
Interval: 7650ft. **(**2331.72 m) – 9000ft. (2743.20 m)
Diagnosis: This interval is very rich in calcareous nannofossils. The FDO of *Discoaster quiqueramus* at 7719ft. (2350.01 m) and FDO of *Discoaster berggrenii* at 7890ft. (2404.87 m) confirms this zone, while this interval shows a peak of abundance; it correlates with the 5.8 Ma MFS (Haq et.al. 1987) condensed section. The LDO of *Discoaster quinqueramus* and *Discoaster berggrenii* mark the base of th NN11 zone of Martini (1971). The 7.0Ma MFS is at 8850 ft. (2697.48 m).

Zone: NN10
Age: Late Miocene
Interval: 9000 ft. **(**2743.20 m) – 9540ft. (2907.79 m)
Diagnosis: This interval is virtually barren of calcareous nannofossils and is considered to represent the NN10 zone of Martini 1971, based on the stratigraphic position.

Zone: NN9
Age: Tortonian
Interval: 9540ft. **(**2907.79m) – 9870ft. (3008.38m)
Diagnosis: This interval contains only a few nannofossils. The presence of *Discoaster hamatus* at 9600 ft. (2926.08 m) confirms the presence of 9.2 Ma MFS (Haq et al. 1987) condensed section.

CALCAREOUS NANNOFOSSIL ABUNDANCE IN THE SRATIGRAPHIC UNITS OF THE TWO WELLS

MAY-01 Well

4020ft. (1225.30m) – 8070ft. (2459.74m)
This sequence is defined by an alternation of shale/mudstone with argillaceous sandstone as shown in Fig. 4. The unit is characterized by the short stratigraphic range of discoasterids, such as *Discoaster berggrenii* and *Discoaster quinqueramus* and the presence of *Ceratolithus armatus*, all of them showing high abundance.
8070ft. (2459.74m) – 10120ft. (3084.58m)
This is a sequence of alternation of argillaceous sandstone with interbedded sandy mudstone. The unit is characterized by a sharp disappearance of the calcareous nannofossils.
10120ft. (3084.58m) –11700ft. (3566.16m)
The unit is characterized by a massive grey to black, hard and clastic argillaceous sandstone overlain by mudstone

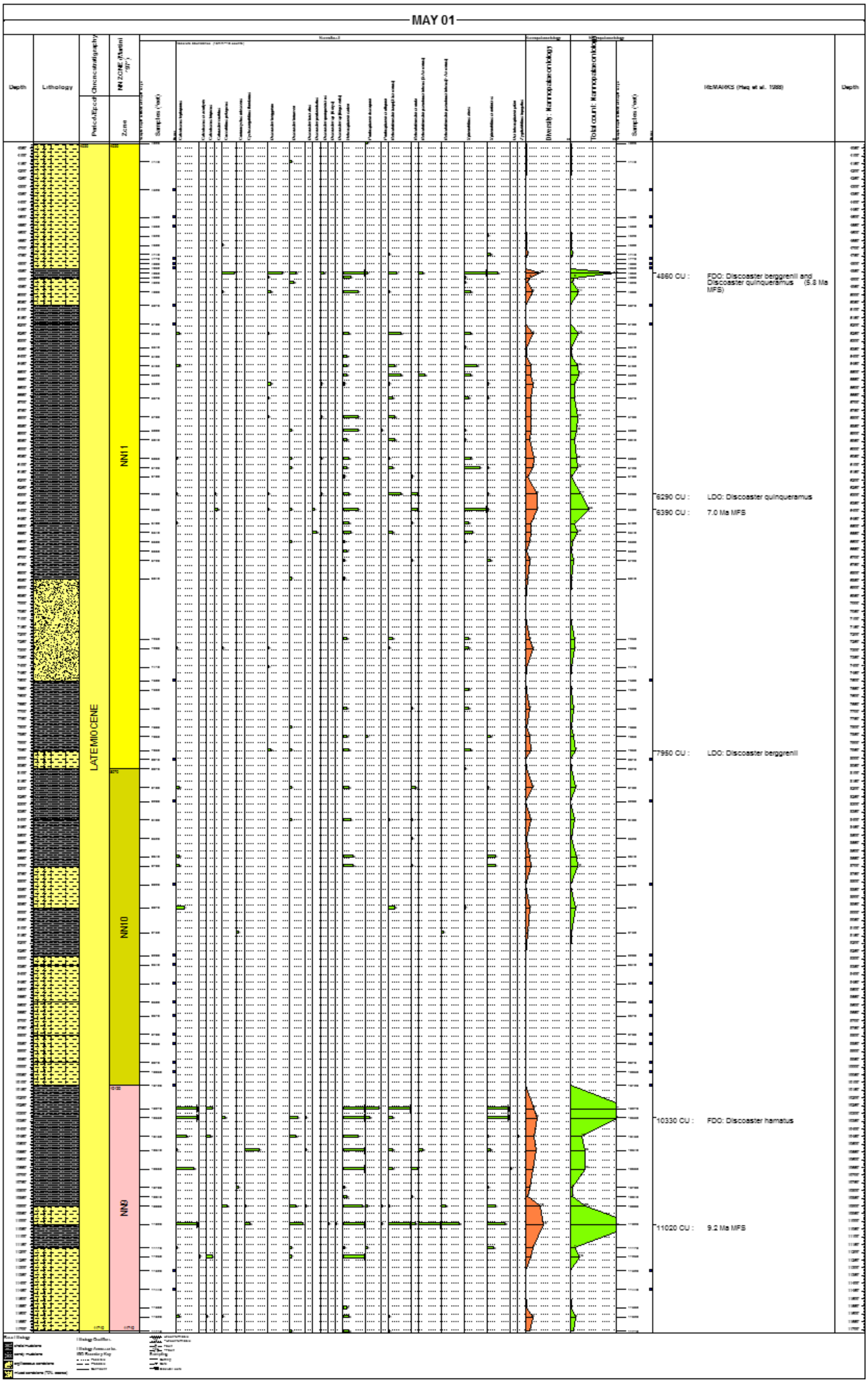

Fig. 4 Calcareous nannofossil stratigraphic chart of MAY-01 well.

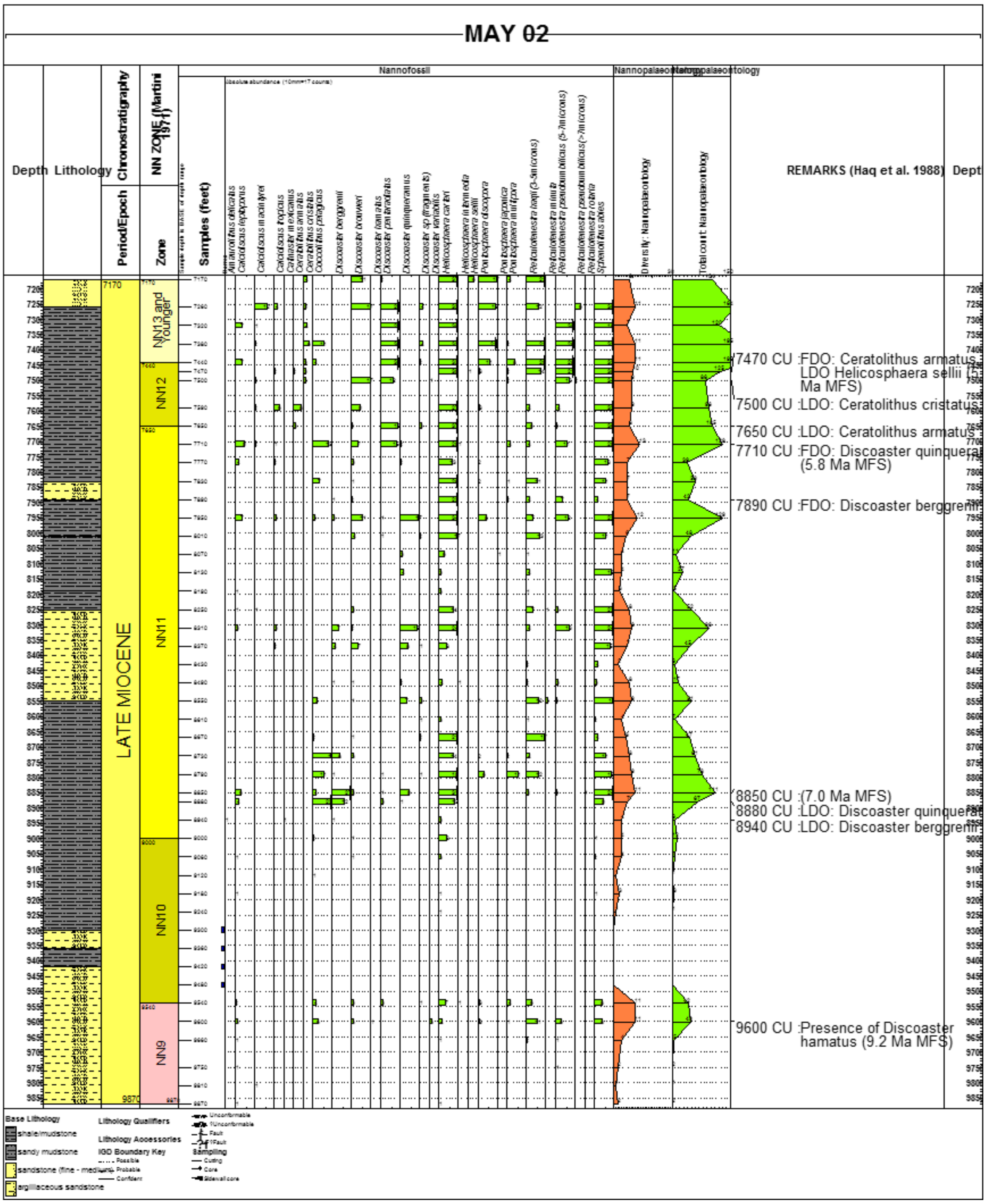

Fig. 5 Calcareous nannofossil stratigraphic chart of MAY-02 well.

and sandy mudstone. This lithology is associated with high abundance of *Discoaster pentaradiatus* and *Discoaster hamatus*.

MAY-02 Well

7170ft. (2185.42m) – 7650ft. (2331.72m)

This unit is made by fine to medium-grained sandstone and light to dark grey moderately soft, fissile shale (Fig. 5). The unit marks the first appearance and gradual abundance increasing of *Ceratolithus armatus*, along with the first and last downhole occurrence of *Helicosphaera sellii* in the well.

7650ft. (2331.72m) – 9000ft. (2743.2m)

The upper part and the lower part of the unit are dominated by nannoliths including *Discoaster quinqueramus* and *Discoaster breggrenii*.. There is a gradual appearance and disappearance in the diversity of the aforementioned discoasterids within this unit.

9000ft. (2743.2m) – 9540ft. (2907.79m)

This is a sequence of grey to dark, platy, soft shale/ mudstone, sandy mudstone, argillaceous sandstone. The unit is characterized by a sharp disappearance of the calcareous nannofossils.

9540ft. (2907.79m) – 9870ft. (3008.38m)

The unit is characterized by a massive sequence of grey to black argillaceous sandstone with great abundance and diversity of *Discoaster brouweri* and *Discoaster hamatus*.

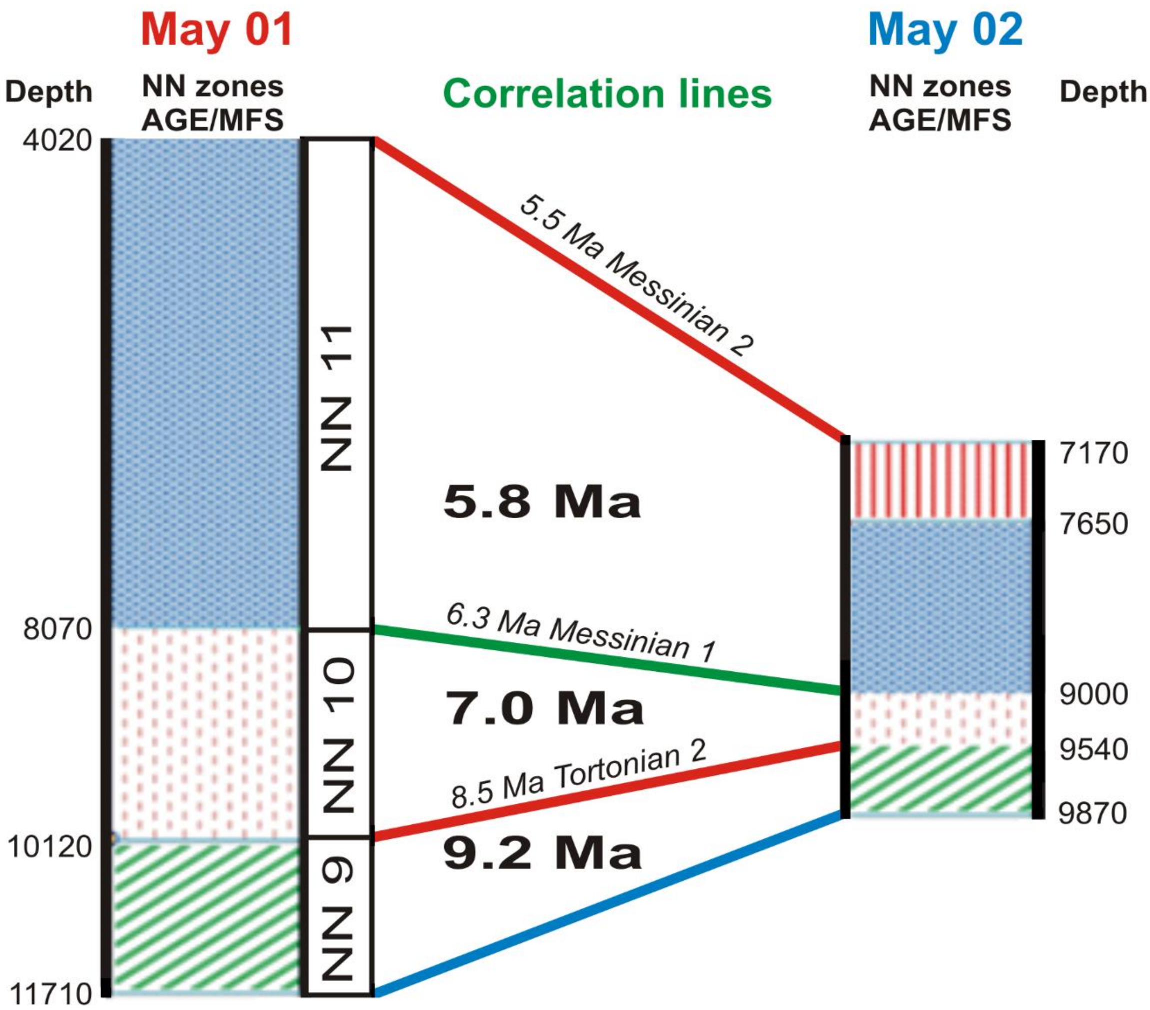

Fig. 6 Correlation of the MAY-01 and MAY-02 wells based on calcareous nannofossil zones, MFS and SB.

There is an observed bloom in the nannoliths and they became important constituents of the nannofossil assemblages within this unit.

Correlation of MAY-01 and MAY-02 wells

The MAY-01 Well recorded three broad zones namely: NN11, NN10 and NN9 zone of Martini (1971), while the MAY-02 Well recorded four zones namely: NN12, NN11, NN10 and NN9 zones. The correlation of the three zones recognized in the two wells and the correlation of the dated ages, the Maximum Flooding Surface (MFS) with their corresponding Sequence boundary (SB) within the studied intervals are shown in Fig. 6.

Four biozones, namely *Discoaster hamatus* (NN9), a barren zone (NN10) and *Discoaster quinqueramus* and *Discoaster berggrenii* (Zone NN 11) were identified and correlated in MAY-01 and MAY-02 wells, respectively. *Discoaster hamatus* (Zone NN9) was found between intervals of 10120ft. (3084.58m) to 11700ft. (3566.16m) in MAY-01 and intervals of 9540ft. (2907.79m) to 9870ft. (3008.38m) in MAY-02 as shown in Table 2 and Table 3. A barren zone of NN 10 was identified between intervals of 8070ft. (2459.74m) to 10120ft. (3084.58m) in MAY-01well and intervals 9000ft. (2743.2m) to 9540ft. (2907.79m) in MAY-02 well. *Discoaster quinqueramus* and *Discoaster berggrenii* (Zone NN 11) were found between intervals 4020ft. (1225.30m) and 8070ft. (2459.74m) in MAY-01well and between intervals 7650ft. (2331.72m) and 9000ft. (2743.2m) in MAY-02 well.

From the above mentioned correlation, it is noted that MAY-01 and MAY-02 have a complete succession of the biozones as shown in Fig. 6. The same figure shows the stratigraphic distribution of the recorded species along with the significant datum, suggesting the Maximum Flooding Surfaces.

CONCLUSION

Ditch cuttings samples from MAY-01 and May-02 wells were studied based on the calcareous nannofossils present to detect the biostratigraphy, ages and to perform correlation between the units of the two wells.

A total of 20 calcareous nannofossils were identified in the two wells. The calcareous nannofossil assemblages of the two wells are moderately rich and diversified. The middle part of MAY-01 well, representing 6290ft. (1917.19m) to 7950ft (2423.16m) is highly fossiliferous than the upper part, section while the upper part of the MAY-02 well is richer in calcareous nannofossil in the interval 7470ft. 2276.86m) to 7890ft. (2404.87m), but its lower part is virtually barren.

The highest nannofossils abundance is shown by Upper Miocene-Lower Pliocene index species, such as *Ceratolithus cristatus*, *Ceratolithus armatus*, *Helicosphaera sellii*, *Discoaster quiqueramus*, *Discoaster berggrenii* and *Discoaster hamatus*.

The biozones recognized in the two wells following the zonation of Martini (1971) are NN9, NN10, NN11, NN12 and NN13. The NN9 is the oldest biozone occurring 9.2 Ma. This is followed by a barren zone, in the interval of NN10; the NN11 biozone extends between 7.0 Ma and 5.8 Ma and it is followed by the NN12 with stratigraphic age of 5.0 Ma; the youngest identified biozone is NN13, from which the top has not been observed.

The correlation of the two wells based on the calcareous nannofossils present and their short stratigraphic age shows that the two wells have threesimilar biozones namely NN9 and NN11 belonging of Late Miocene age, associated with 9.2 Ma and 7.0Ma to 5.8 Ma respectively, including the interval covered by NN10, for which typical calcareous nannofossil have not been observed.

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