

Middle Miocene Carbonate Crash in the Niger Delta: Evidence from Calcareous Nannofossils

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Abstract Analysis of the Serravallian calcareous nannofossils from eight Niger Delta deep offshore wells shows, for the first time, evidence of the Middle Miocene carbonate crash from the Gulf of Guinea. These nannofossil-poor sediments provide very low biostratigraphic resolution and preclude a refined biozonation for the interval in this region. Evidence of such poor preservation of calcium carbonate microfossils (mainly foraminifera and nannofossils) in the Middle Miocene is widespread in the eastern equatorial Pacific Ocean, where the term ‘carbonate crash’ was first used. The carbonate crash has also been identified from the Caribbean, Atlantic and Indian oceans. With the recognition of the event in the Gulf of Guinea, it could be said to be a global phenomenon. The carbonate crash, as observed in the studied Niger Delta wells, spans the interval of nannofossil zones NN5 to NN8. The event has been documented between zones NN5 and NN10 in other regions of the world. The overlap in time and the nature of the crash in the Gulf of Guinea is comparable with reports from other parts of the world, suggesting a common cause as responsible for the crash.

Keywords Middle Miocene, carbonate crash, Niger Delta, calcareous nannofossils

1. Introduction

Records of poor preservation of calcareous microfossils, a sharp reduction in calcium carbonate weight-percent and lower calcium carbonate mass accumulation rates (MARs) are well documented from many oceans around the world. These phenomena, spanning the Middle to Late Miocene, are more pronounced in the eastern and central equatorial Pacific, Indian, Caribbean and Atlantic Oceans (Lyle *et al.*, 1995; Peterson *et al.*, 1992; Sigurdsson *et al.*, 2000 and King *et al.*, 1997, respectively). Vincent (1981) showed unusually low carbonate weight-percent at Deep Sea Drilling Project Site 310 on the Hess Rise (north central Pacific). He referred to the interval as the mid-Eocene 10 event, which was correlated with the Chron 4a interval spanning 9.6 to 9.2 Ma, using the geomagnetic polarity time-scale of Cande and Kent (1992). The term ‘carbonate crash’ was employed by Lyle *et al.* (1995) to represent the interval between 11.2 and 8.6 Ma in Ocean Drilling Program (ODP) Leg 138 and other sites in the eastern equatorial Pacific, characterised by lower calcium carbonate MARs. Identification of a Caribbean carbonate crash was a significant finding at ODP Leg 165 in the Caribbean Sea (Sigurdsson *et al.*, 2000). They reported a reduction of calcium carbonate weight-percent, lower calcium carbonate MARs and poorer preservation of calcium carbonate microfossils in the Middle to Late Miocene (12 – 10 Ma) in the Caribbean. This was noticeable at three sites: in the Yucatan Basin, the Colombian Basin and the Pedro Channel. Roth *et al.* (2000) further investigated the Caribbean carbonate crash of Sigurdsson *et al.* (2000). They studied the nature, extent and timing of intense fluctuations in the burial of carbonate sediments, to gain a better understanding of the changes in global thermohaline circulation and the establishment of the modern global ocean conveyor belt. They concluded that tectonic activity on the northern Nicaraguan Rise in the early Middle Miocene led to the establishment of a connection between the southern and northern Caribbean basins, by opening two

main new seaways: the Pedro Channel and the Walton Basin. Muza (2000) studied nannofossils from ODP Leg 170 sites, collected from a transect across the Middle American Trench off the Nicoya Peninsula, eastern equatorial Pacific Ocean. He observed that, within the Miocene, at Sites 1039 and 1040, nannofossil zones NN10–NN6 of Martini (1971) were difficult to differentiate due to low sedimentation rates, thus providing only a low-resolution biostratigraphy.

Difficulties are often encountered in the biostratigraphic interpretation of the Middle Miocene using nannofossils in the Niger Delta. These difficulties have, however, not been viewed to have a basin-wide or regional significance, as oil wells are often studied individually, with little effort applied to correlating across or between fields. The findings presented in this paper emanate from a work primarily designed to refine the biozonation schemes of Martini (1971) and Okada and Bukry (1980), which are the basis for the calcareous nannofossil biostratigraphic work in the region. There occurs a consistent impoverishment of assemblages to outright barrenness of samples from the basal part of NN9 to the lower part of NN5 in all the wells studied in the offshore Niger Delta basin. Sometimes, the top of *Sphenolithus heteromorphus* (NN5 zonal marker) is not seen while the NN7 zonal marker, *Discoaster kugleri* is not seen at all in most wells. *Discoaster exilis* distribution in the studied wells is such that it occurs below zone CN5 (NN6 & NN7), where it can be used as zonal marker in the Okada and Bukry (1980) zonation scheme. These observations aroused our curiosity to examine this interval in other parts of the world. Comparison has revealed that the interval is a known problem in most oceans, where it has been documented from the evidence of poor preservation of carbonate microfossils, reduction in calcium carbonate weight-percent and lower calcium carbonate MARs (Vincent 1981; Lyle *et al.*, 1995; Sigurdsson *et al.*, 1997; Roth *et al.*, 2000; Diester-Haass *et al.*, 2004; Krammer *et al.*, 2006; Jiang *et al.*, 2007). Here, we

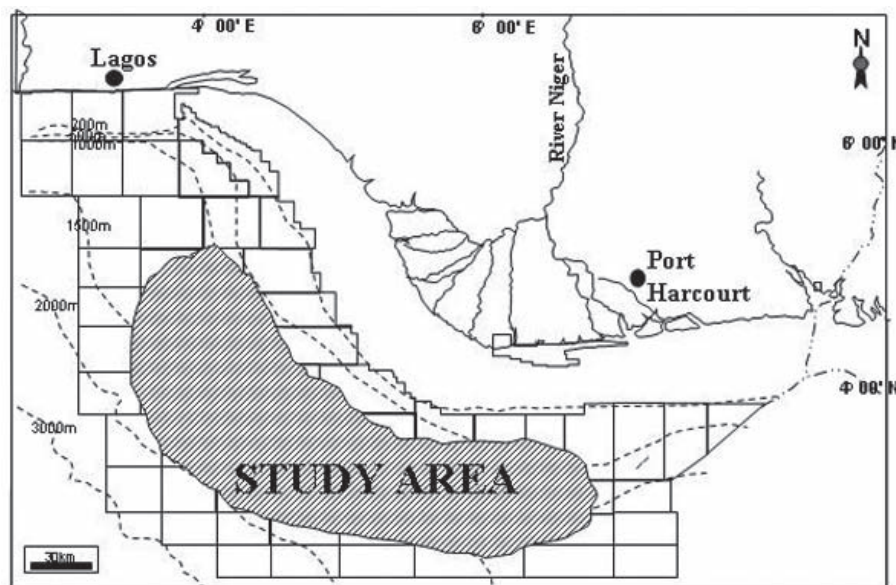


Figure 1: Niger Delta Map showing the approximate location of the study area

present our observations of poor nannofossil preservation in the offshore Niger Delta and relate this to the carbonate crash reported from other basins around the world.

2. Materials and Methods

Over 1300 ditch-cuttings samples from eight wells from the offshore deep-water Niger Delta were investigated. The eight wells represent a transect through the marked area in Figure 1 and are code-named DPW-1 to DPW-8 for proprietary reasons. The samples are predominantly shale, with occasional sands. Suspension slides were prepared for all samples, using standard preparation methods. About 5 grams of sample was cleaned with detergent and dispersed in distilled water and the suspension flooded onto a 22 x 40mm glass cover slip and dried on a hot-plate at about 50 – 60°C. The coverslip was then mounted on a labelled glass slide using Norland optical adhesive mounting medium. Slides were examined with an Olympus Photomicroscope at 1000x and 1500x magnifications under cross-polarised and bright field illumination.

For each slide, all nannofossils encountered in eight long traverses were identified, to species level, where possible. The relative abundance and species richness of the assemblages, along with a description of preservation, degree of dissolution and sample appearance in the light microscope, were recorded on an analysis (logging) sheet for each sample.

3. Results

The nannofossil distribution in the eight wells is shown in Figures 2 – 9. The studied samples are characterised, in most parts, by abundant and diverse nannofossil assemblages permitting easy application of the Martini (1971) and Okada and Bukry (1980) biozonation schemes. The Middle Miocene section of the studied wells, however, was found to be poor in nannofossils.

Significant nannofossil datums have been assigned absolute ages as summarized in Gradstein *et al.* (2004).

The nannofossil biozones encountered in this study ranged from the Lower Miocene NN1 (CN1a) to Lower Pliocene NN13 (CN10c). Four wells (DPW-2, DPW-4, DPW-5, DPW-6) extend up to the Lower Pliocene, while wells DPW-1, DPW-3, DPW-7 and DPW-8 are restricted to the Miocene. Seven of the wells studied span the area of interest (zones NN5 – NN9). Only DPW-2 range from NN7 – NN12.

3.1. DPW-1

This well penetrated sequences from the Lower (NN2) to Upper Miocene (NN11). Fairly abundant and diverse nannofossils were recorded in NN2 through NN4. Nannofossil abundance gradually reduces from NN5 to the basal part of NN7, and then pick up from NN10, where a highly abundant and diverse nannofossil assemblage was recorded through NN11. A sample mix-up attributed to caving was noticed below NN11. The biostratigraphy is therefore based on nannofossil datum tops only and abundances recorded below this interval are believed to be higher than the in situ abundances, thereby making the expected impoverished nannofossil assemblages less obvious. NN7, NN8, NN9 and NN10 cannot be differentiated due to the absence of the characteristic zonal markers – *Discoaster kugleri*, *Catinaster coalitus* and *Discoaster hamatus*. The interval below NN7 cannot be subdivided due to poor nannofossil distribution and this is labelled as 'indeterminate' down to the observed top of *Sphenolithus heteromorphus* marking the top of NN5. Even though NN5 was interpreted, fossil abundance and species richness remain low within the interval.

3.2. DPW-2

Well DPW-2 ranges from the Middle Miocene (NN7) to Lower Pliocene (NN14). Fossil preservation in the basal part of the well, below NN8 (Middle Miocene) and abundances are consequently low. A gradual increase in abundance was recorded from NN8 through NN10, while high abundance and diversity nannofloras prevail from NN11 through NN14. A sharp decrease in abundance and diversity and barrenness was recorded in many samples in the upper part of the analysed section of the well (Figure 3).

3.3. DPW-3

Well DPW-3 ranges from the Lower Miocene (NN4) to Upper Miocene (NN11). Zone NN4 is characterised by common occurrences of nannofossils, which then sharply reduces at the lowest part of NN5 through NN7. However, a slight abundance increase, dominated by some species of *Reticulofenestra*, was observed just within the interval of low nannofossil abundance (Figure 4). The assemblages contain no index species to allow biozones to be

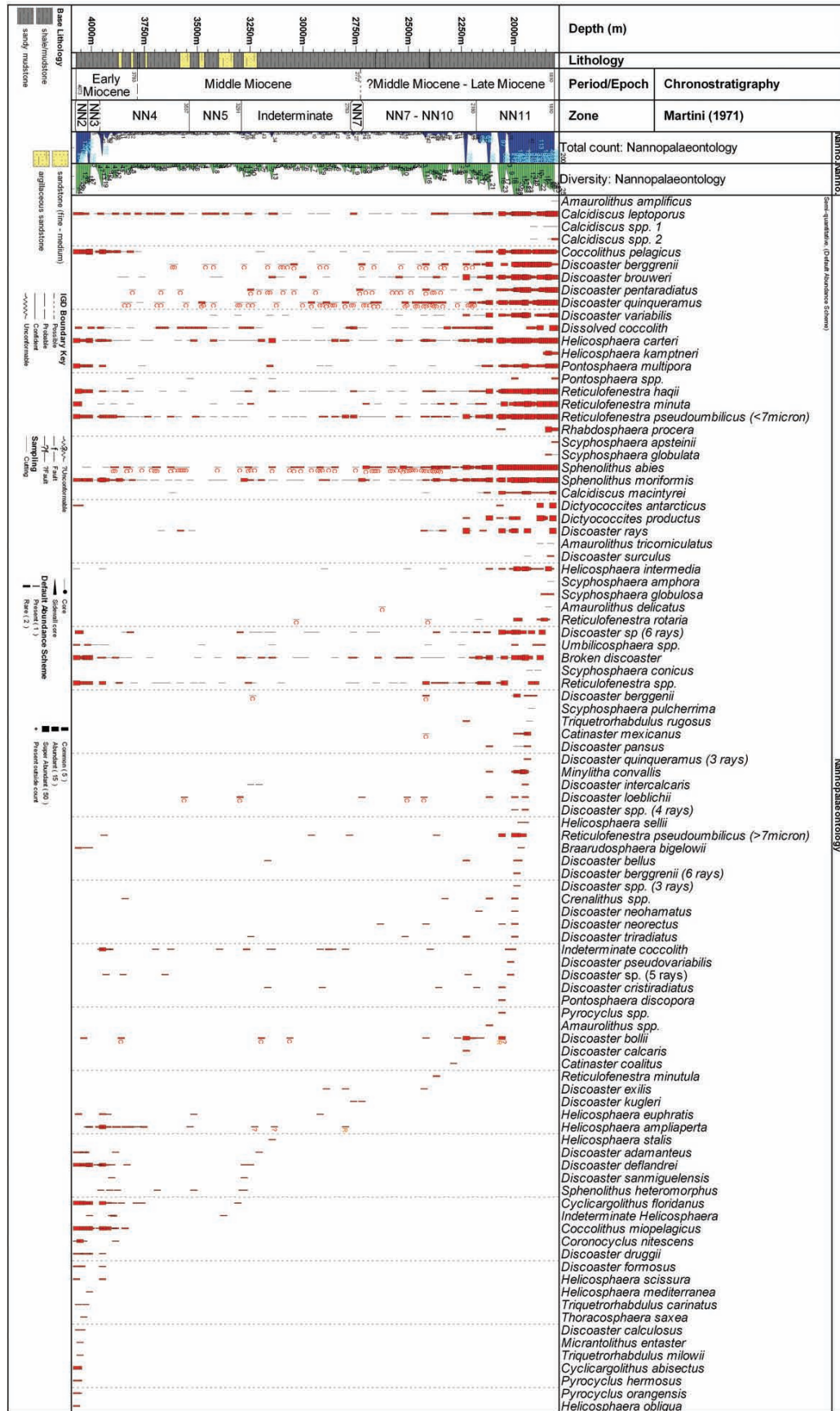


Figure 2: Calcareous nannofossil distribution in DPW-1 well

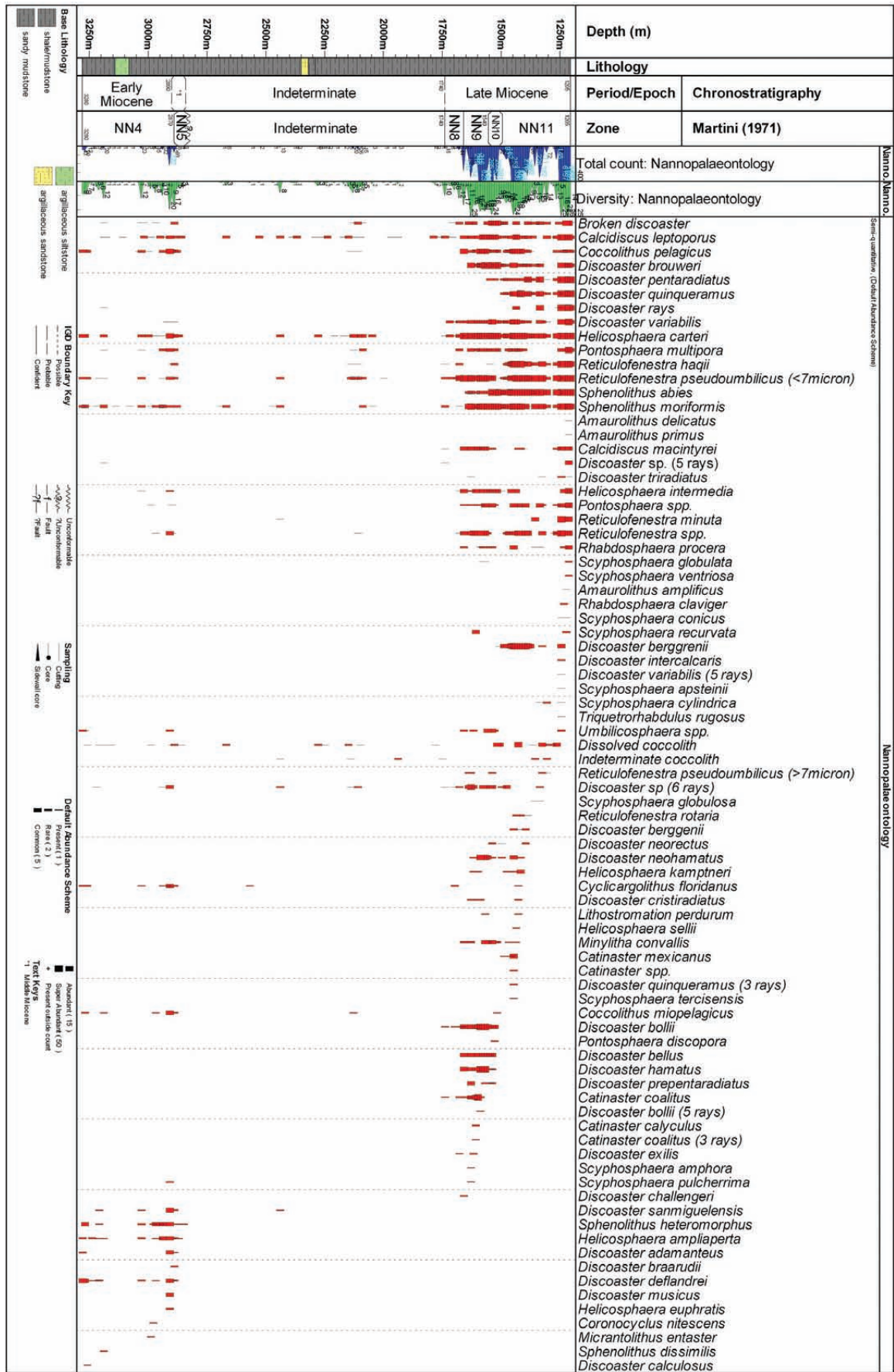


Figure 4: Calcareous nannofossil distribution in DPW-3 well

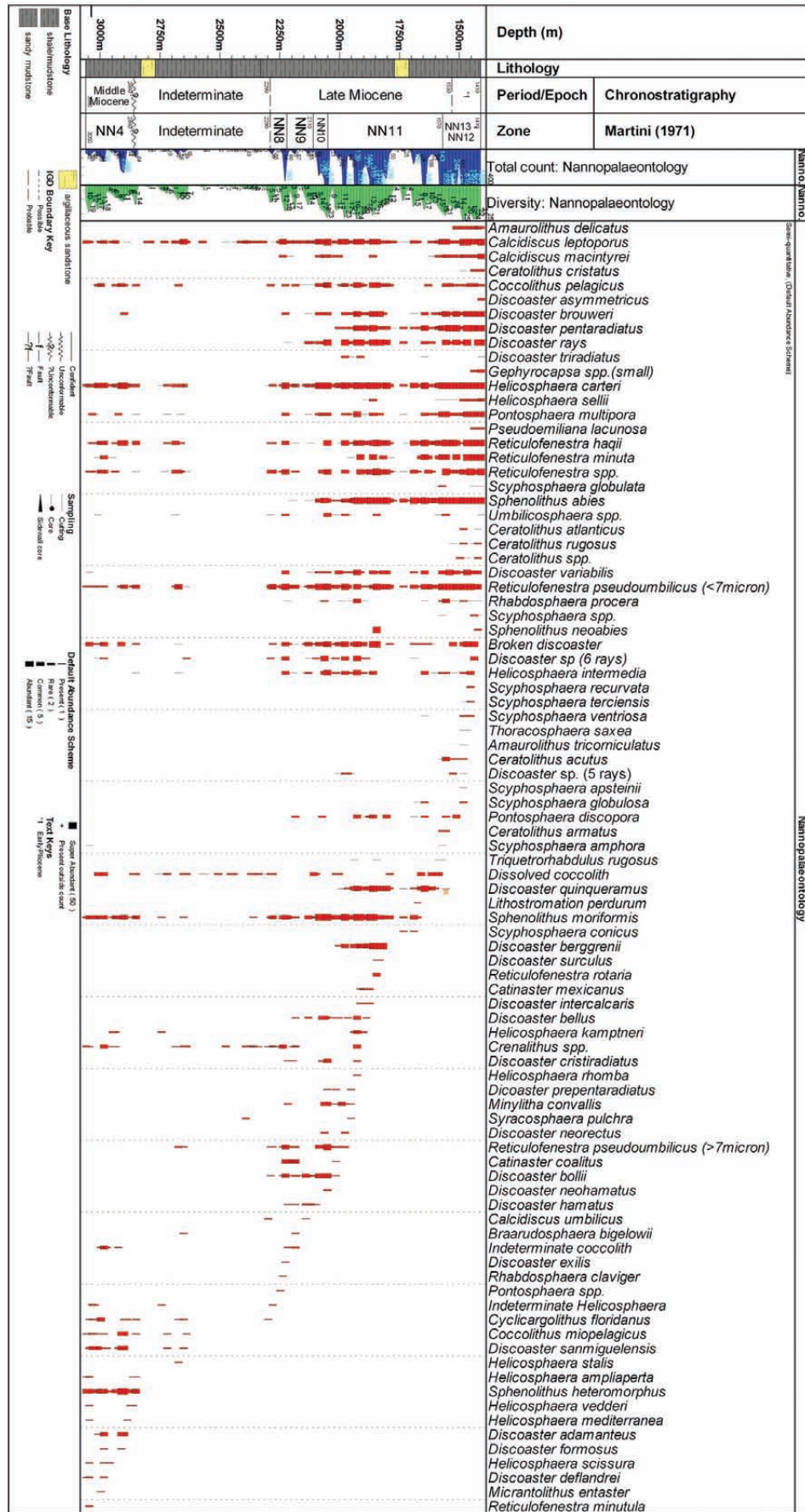


Figure 5: Calcareous nannofossil distribution in DPW-4 well

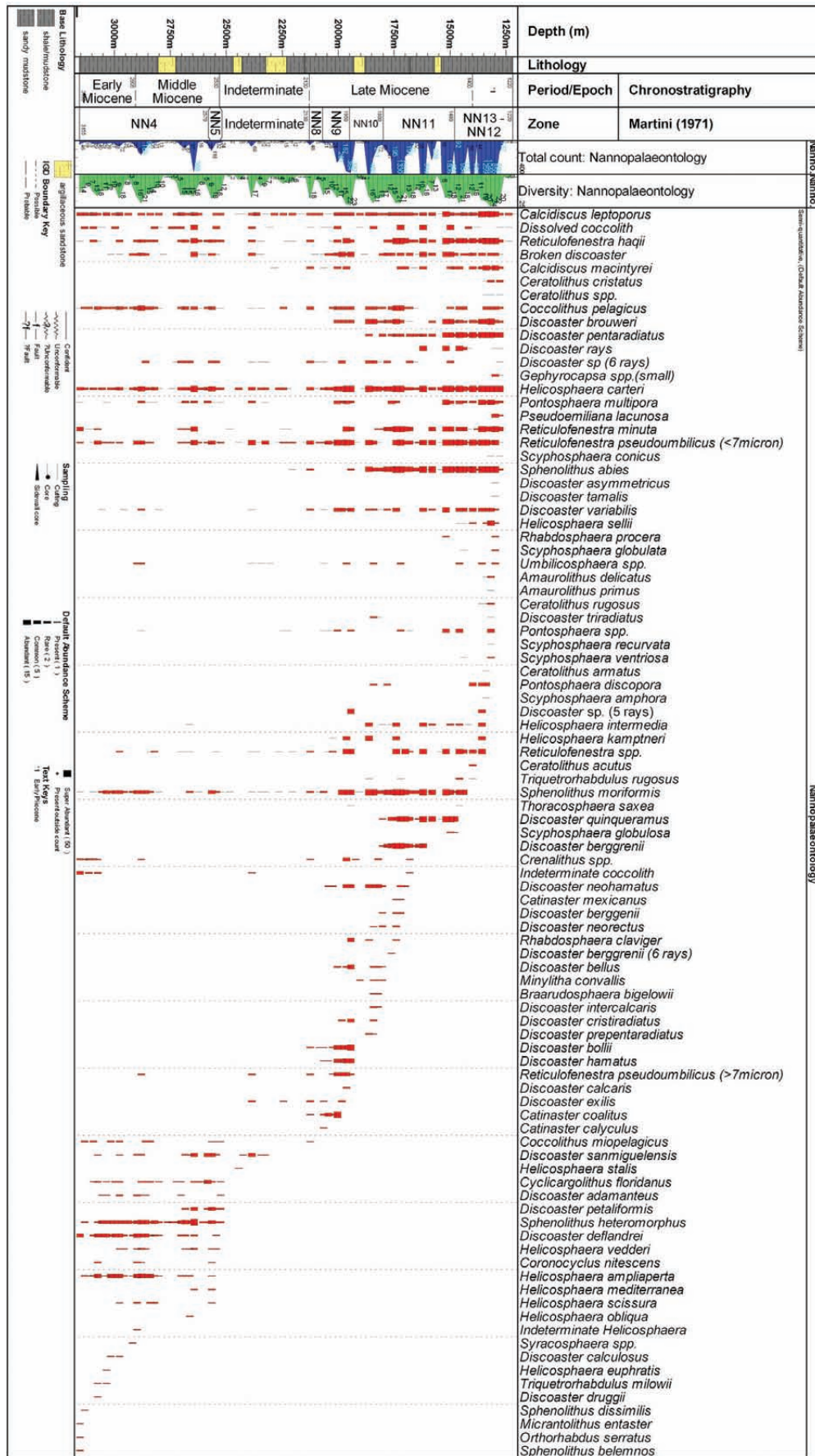


Figure 6: Calcareous nannofossil distribution in DPW-5 well

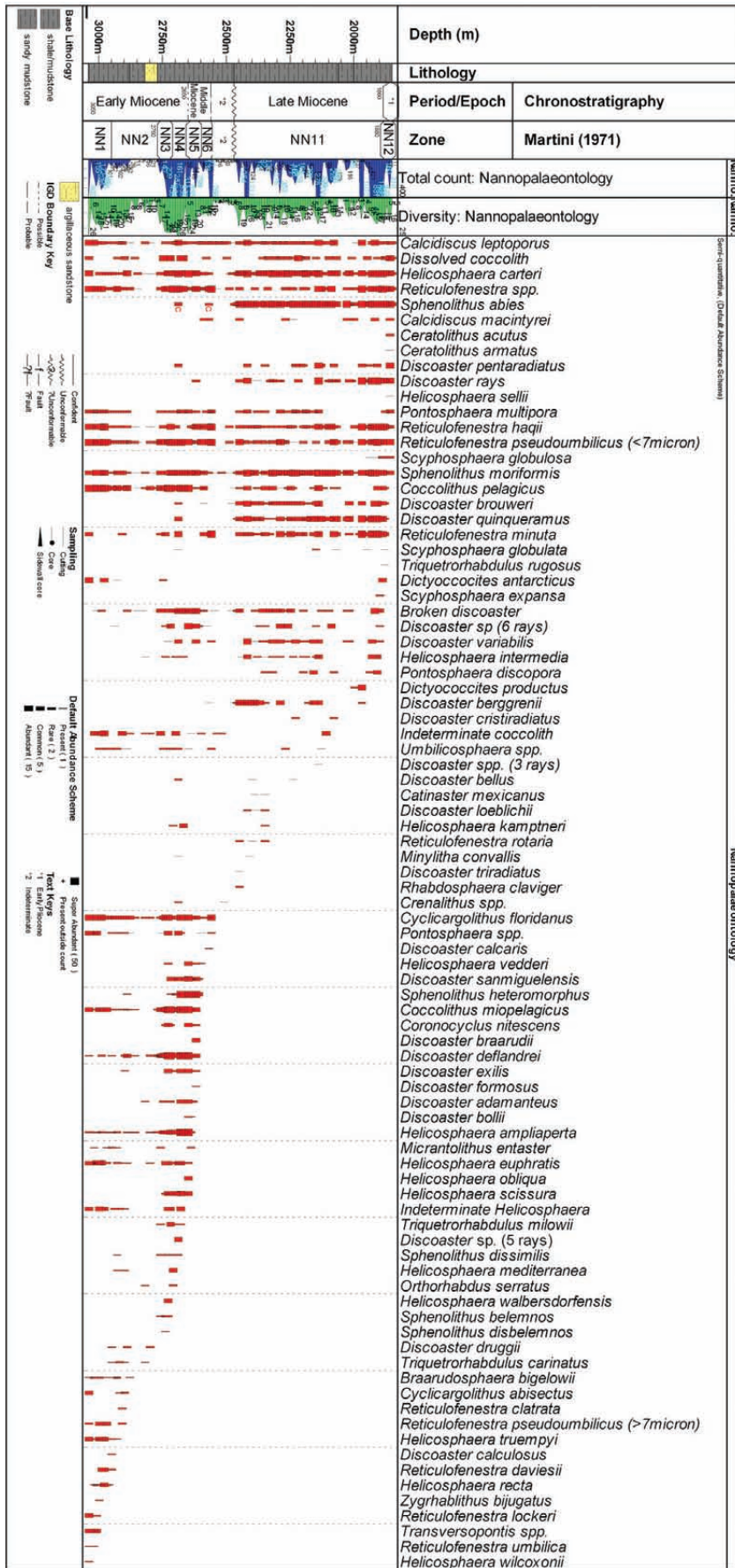


Figure 7: Calcareous nannofossil distribution in DPW-6 well

well. However, NN7 – NN10 were not distinguishable in the well. This is believed to be the result of an unconformity or the presence of a diapiric structure that resulted in the condensation of zones NN3 - NN6. The usual paucity of nannofossils characterising NN7 and NN8 is visible above NN6 in the well section (Figure 7).

3.7. DPW-7 and DPW-8

Wells DPW-7 and DPW-8 both penetrated the Lower to Upper Miocene, with moderate nannofossil distribution only in the Lower to Middle Miocene (NN4 to NN5) and the Upper Miocene (NN11). The poor nannofossil abundances above NN4 allow the determination of NN5 and NN8, while NN6 and NN7 were not distinguishable, due to the interval of poor nannofossil recovery (Figures 8 and 9).

4. Discussion

Integration of the results from the eight wells studied (Figure 10) reveals a sharp decrease in nannofossil abundance and diversity from the basal part of NN9 downwards, such that the NN9/NN8 zonal boundary becomes difficult to determine. From the base occurrence of *Discoaster hamatus* (10.55 Ma: Gradstein *et al.*, 2004) in NN9, discoasters are very rare or not represented at all, in the assemblages, until the basal part of NN5 (DPW-4, DPW-6 and DPW-8) or topmost part of NN4 (DPW-1, DPW-3, and DPW-7) where a few occurrences of *Discoaster deflandrei* were recorded. Well DPW-2 did not penetrate below NN7, while a few occurrences of *Discoaster sanmiguelensis* were observed in NN6 in DPW-5. In general, discoasters are abundant in NN1 to NN4 and dwindled rapidly in abundance and diversity in NN5, with a near-absence in NN6 to NN8, and a gradual reappearance in the basal part of NN9. They then increase rapidly in abundance and diversity from the upper part of NN9 through NN13 in the wells studied. The sparse nannofloras from the base occurrence of *Discoaster hamatus* to the top occurrence of *Helicosphaera ampliaptera* are dominated by *Reticulofe-*

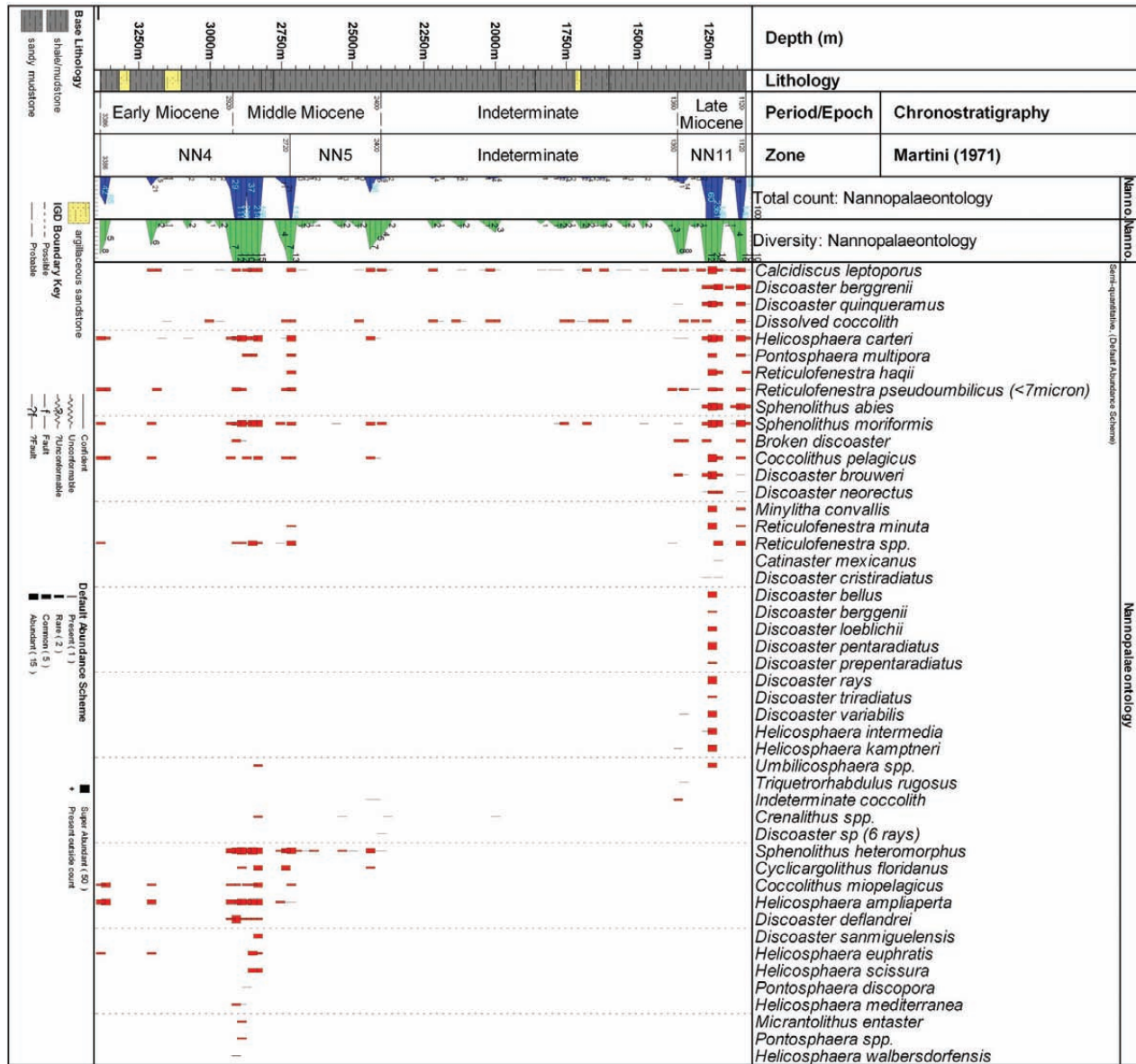


Figure 8: Calcareous nannofossil distribution in DPW-7 well

nestra spp., *Coccolithus pelagicus*, *Helicosphaera carteri* and *Calcidiscus leptoporus*. NN6 and NN7 cannot be differentiated in seven of the wells studied, due to the absence of the zonal marker – *Discoaster kugleri*, and the generally low abundance nannofloras within this interval. The reticulofenestrids, represented by *Reticulofenestra pseudumbilicus*, *R. haqii*, *R. minutula* and *R. minuta*, dominate assemblages in some horizons within the interval covered by the crash, and account for about 80% of the total nannofossil species richness.

The decrease in calcareous nannofossil abundance and species richness in the Middle Miocene, as observed in this study, has been reported from several oceans. This has been referred to as the ‘carbonate crash’ by Lyle *et al.* (1995) and the term has been used by other authors who have made similar observations of Middle Miocene nannofloras (Peterson *et al.*, 1992; King *et al.*, 1997; Sigurdsson *et al.*, 2000 and Muza, 2000). It is clear that paucity of nannofloras commenced about the same time (~8.6 Ma)

and ended at the same time (~15.4Ma) in the eight wells studied strongly suggesting a carbonate crash affecting the entire Niger Delta. This constitutes the first report of the crash in the Gulf of Guinea region. Nannofossil data from the studied wells show relatively high nannofloral abundance and diversity between zones NN1 and NN4 and NN9 to NN13 while relatively low abundance and diversity or barrenness is observed between zones NN5 and NN8. Muza (2000) reported difficulties in assigning zones NN6 to NN10 (13.2 – 8.6 Ma) due to low nannofossil abundances in the Middle American Trench, Nicoya Peninsula, Costa Rica. The unresolved zonal range indicate a duration of up to 4.6 Myr. Vincent (1981) reported the crash from the north central Pacific which he claimed, lasted between 9.6 – 9.2 Ma (upper NN9, ~0.4 Myr). In the eastern equatorial Pacific, the crash was observed between 11.2 – 8.6 Ma (NN8 – NN11) indicating the duration of 2.6 Myr as reported by Lyle *et al.* (1995). Sigurdsson *et al.* (2000) reported that the crash lasted 2 Myr

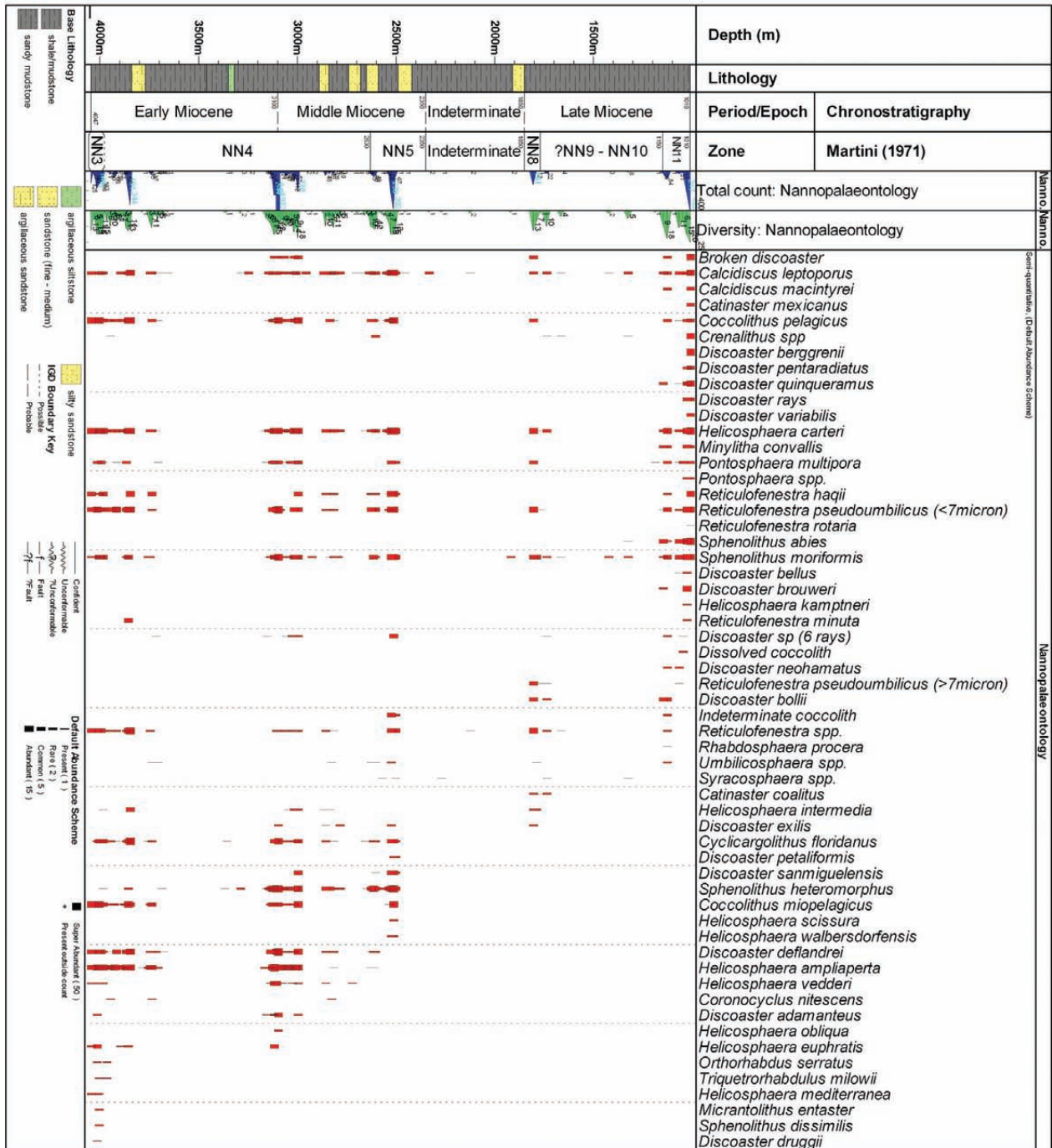


Figure 9: Calcareous nannofossil distribution in DPW-8 well

in the Caribbean between 12 – 10Ma (NN7 – NN9). The interval lasted 3.5 million years in the western equatorial Atlantic between 14.0 – 11.5 Ma as reported by King *et al.*, (1997). No age constraint can be applied to this work based on the scope of our study, but we can extrapolate that the poor nannofossil distribution observed in the Middle Miocene NN5 – NN8 zones in the Niger Delta wells of the Gulf of Guinea areas has a link with the ‘carbonate crash’ recorded about the same age in different parts of the world. Although, we have different lengths of time from the different oceanic locations, this is believed to be due to several factors operating in these areas. Putting an age

constraint and making a comparison will mean that the same relative time scale was used by all the authors which probably is not the case. The nannofossil datum preceding the event, in the earliest Middle Miocene (Langhian) is the top of *Helicosphaera ampliaperta* (14.91 Ma) while the datum postdating it is the base of *Discoaster hamatus* (10.55 Ma – ages based on Grandstein *et al.*, 2004). This shows that the upper Langhian and the entire Serravalian age were encompassed by the crash and that the age is between 14.91 and 10.55 Ma and the extent of the crash is 4.36 Myr. There exists a slight variance with the observation of Muza (2000) from the Middle American Trench,

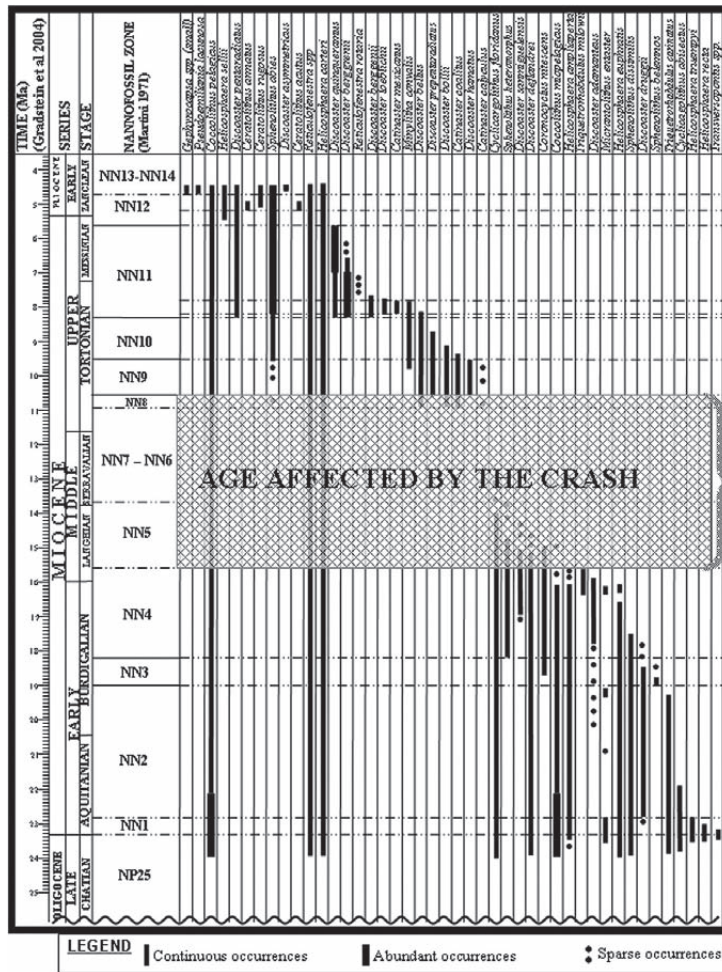


Figure 10: Stratigraphic distribution of nannofossils showing the areas covered by the crash (synthesized from DPW-1 to DPW8 wells).

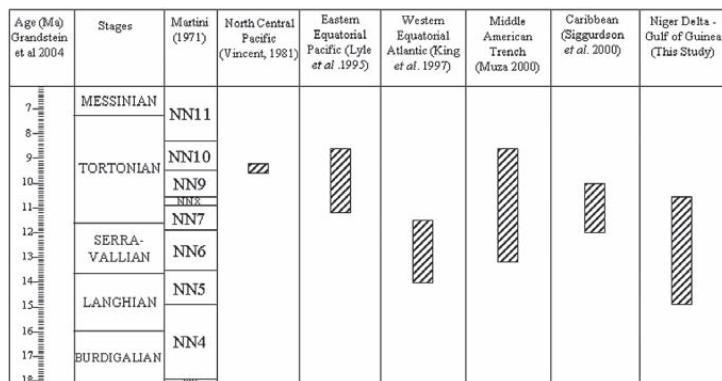


Figure 11: Duration of the carbonate crash in different regions

as zones NN10 and NN9 are well represented in almost all the wells studied in the Niger Delta, indicating that a return to 'normal' conditions in the Gulf of Guinea occurred earlier than in the Middle American trench. From the foregoing, it can be concluded that, whatever cause was responsible for the crash it started earlier, lasted a longer period and stopped earlier in the Gulf of Guinea than in most other places (Figure 11).

With the recognition of the crash in the Gulf of Guinea, in addition to the reports from other oceanic locations,

the 'carbonate crash' could be concluded to be a global phenomenon. Several possible causes have been investigated and suggested as responsible for the crash in the different regions. This interval has been related to various palaeogeographic and palaeoceanographic events, which were controlled by factors such as tectonism, oceanic currents, changing sea level, water chemical composition, shoaling of the lysocline and climatic conditions in the regions where the 'crash' has been reported. Lyle *et al.* (1995) ascribed the major changes in carbonate sedimentation the Middle - Late Miocene boundary in the eastern Equatorial Pacific to dissolution. The interval was interpreted by the authors as a 1200m shoaling of the lysocline. King *et al.* (1997) ascribed the carbonate crash of the western tropical Atlantic to a long term shoaling of the lysocline between 14.0 and 11.5 Ma, followed by a lysocline deepening at 10.5 Ma. Roth *et al.* (2000) corroborated the idea of dissolution in their work on the Caribbean carbonate crash. However, Diester-Haas *et al.* (2004) suggested an increase in the delivery of lithogenic matter from the Oranje River as principal cause of the 'carbonate crash' off southwest Africa, since no clear evidence for carbonate dissolution was found. Jiang *et al.* (2007), from their analysis of carbon and oxygen isotopes of marine sediment cores from Oceanic Drilling Program Site 1256 during (Leg 206) in the Guatemala Basin, suggested that surface-circulation-induced infertility was the cause of the late/middle Miocene 'carbonate crash'. Krammer *et al.* (2006) also ascribed the diminished numbers of calcareous nannofossils between 9.6 to 9.0 Ma at ODP site 1085 (eastern South Atlantic, off Namibia) to weakened nannofossil productivity.

As observed earlier by Roth *et al.* (2000), the comparable nature and partially overlapping timing of the carbonate reductions in the Pacific, Caribbean and Atlantic suggest a common cause associated with changing oceanic circulation. It is therefore assumed that, whatever cause has been responsible for the crash in these regions, it is most likely to extend to the Gulf of Guinea region. The actual cause in this region being beyond the scope of this research has been left for detailed study in a future research project.

5. Conclusions

A dearth of calcareous nannofossils has been observed in the Middle Miocene Niger Delta deep-water sequences. A comparison of this observation with other regions of the world suggests that the 'carbonate crash' of Lyle *et al.* (1995) is also preserved in the Gulf of Guinea area. The interval spanned by the crash, as observed from the affected nannofossil zones (NN5 – NN8), indicate that the

interval of the crash commenced and ended earlier in the Gulf of Guinea region than in the eastern equatorial Pacific where it was first reported. However, there exists an overlap in the timing and nature of the crash around the world, which suggests a common cause, as initially suggested by Roth *et al.* (2000). Suggested causes for the crash from other regions include, low nannoplankton productivity, thought to be due to changing climatic conditions and nutrient depletion during the Serravallian period, carbonate dissolution and shoaling of the lysocline. Further investigation evidence of potential causes of the crash in the Gulf of Guinea area is reserved for future research and will involve study of agglutinated and calcareous foraminifera in tandem with quantitative nannoplankton data.

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