Earth Science Research; Vol. 3, No. 1; 2014
ISSN 1927-0542 E-ISSN 1927-0550
Published by Canadian Center of Science and Education

Calcareous Nannofossil Biostratigraphy of A, B, C, D Wells, Offshore Niger Delta, Nigeria

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Received: November 19, 2013 Accepted: December 2, 2013 Online Published: January 24, 2014
doi:10.5539/esr.v3n1p108 URL: http://dx.doi.org/10.5539/esr.v3n1p108

Abstract

The calcareous nannofossil biostratigraphy of four deep water wells, A, B, C, D, offshore Niger delta has been studied in order to document their biostratigraphic distribution, establish biozonation and stratigraphic correlation. Ditch cutting samples were collected at 30 ft intervals. They were processed according to the standard calcareous nannofossil sample preparation technique. A total of forty-two nannofossil species were identified in the four wells. Most parts of the wells are characterized by abundant and diverse nannofossil assemblages which permitted the subdivision of the sections into zones. A total of five zones and two subzones were identified from this study based on diagnostic marker species and notable nannofossil events. The zones are *Catinaster coalitus* zone (NN8), *Discoaster hamatus* (NN9), *Discoaster loeblichi* which occupy the base of *Discoaster berggrenii* and the top of *Discoaster bollii* was used to identify the NN10 zone. The main marker for this zone which is *Discoaster calcaris* is missing in the study wells; this may be due to dissolution of the calcitic wall during sedimentation process. Other zones encountered in this study are *Discoaster berggrenii* subzone (NN11a), *Discoaster quinqueramus* subzone (NN11b), *Amaurolithus tricorniculatus* zone (NN12) and *Ceratolithus rugosus* zone (NN13). The age of the strata ranges from the middle Miocene to the early Pliocene. The zones were based on the first and last appearances of maker species as well as their relative abundances. The occurrence of *Amaurolithus delicatus* in wells C and B implies that the well intervals containing the species cannot be younger than early Pliocene age. The four wells show good correlation with each other based on the identified zones. The biozones identified in this study will be useful for subdivision and correlation work in the deep offshore Niger delta Neogene sequence.

Keywords: biostratigraphy, calcareous nannofosils, biozones, Neogene sequence, well correlation, relative abundances, characterization, stratigraphy

1. Introduction

As the world class hydrocarbon matures, most of its subsurface uncertainties lay at reservoir scale. The need for well site biostratigrapher to monitor the drilling and correlate the strata is essential to avoid abortive and unprofitable exercise. Calcareous Nannofossil therefore is a major tool used by the biostratigrapher in the characterization of the reservoir strata and correlation in the well site operation. The importance of biostratigraphic correlation is critical in the construction of accurate time slice and play fairway analysis in Petroleum exploration. The aim of this study is to document the distribution of calcareous nannofossils, determine their Biostratigraphy and delineate biozones, correlate the wells and interpret their geological history.

2. Location of Study Area and Geology

The wells are located in the offshore Niger Delta, Nigeria, which is situated in the Gulf of Guinea. (Figure 1) Wells D and C are located in the western arm of the Charcot fracture zone, while Wells B and A are located in the eastern section of the Charcot fracture zone. The materials used for this study were obtained from deep offshore field owned by Shell Nigeria Exploration Petroleum Company (SNEPCo), Lagos.

The Niger Delta is subdivided into three diachronous lithostratigraphic units. These are the Benin Formation. (mostly continental sands), the Agbada Formation (alternation of sands and shales) and the Akata Formation. While the Akata Formation is the basal unit composed mainly of marine shales believed to be the main source rock within the basin. The Agbada Formation is made up of alternating sandstone, siltstone, and shale sequences that constitute the petroleum reservoirs of the basin. The Agbada Formation was penetrated in the middle Miocene to late Pliocene sequences of the four wells studied, piercing through the mobile shale, mud diapir and channelized turbidites.

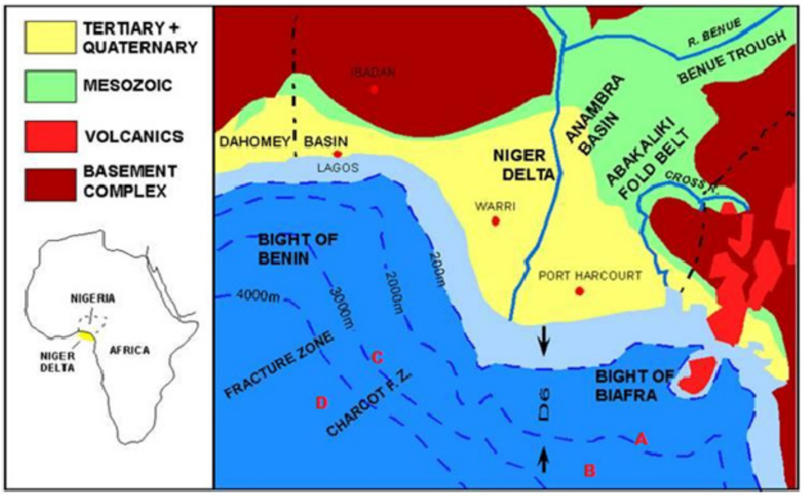

Figure 1. Simplified geological map of the study area in the Niger Delta (KEY: **A** – Well A; **B** – Well B; **C** – Well C; **D** – Well D

3. Methodology

The materials include soft and paper copies of seismic sections and base map, ditch cutting samples from four wells A, B, C and D and digital well log data. A total of 453 ditch cuttings were analysed for wells A, B, C and D. Eighty-five and 164 ditch cutting samples from the intervals of 4900–9920 ft. and 4530–14600 ft. of wells A and well B respectively, while 92 and 112 samples from the intervals of 5760–11400 ft. and 6000–12750 ft. were analysed for wells C and D respectively. These wells were logged and sampled at 30 ft. intervals and processed for nannofossil analysis using the standard smear slide preparation method. The prepared slides were examined under transmitted light microscope. Detailed identifications (to species level where possible) were made. Fossils were recorded in the analysis sheet with other relevant information. The species name and abundance of each species with depths were used as input data into the Stratabug biostratigraphic software. The data were utilized and integrated in the age dating of critical horizons. From this data set, plots of population abundance and species diversity were made using the prepared checklists. The coincidence of these peaks guided the selection of the candidate maximum flooding surfaces, the positions of which were subsequently confirmed on the log.

4. Discussion of Results

Calcareous nannofossils species and abundance have been analysed and interpreted based on the assemblages of diagnostic species and notable biostratigraphic events in the A, B, C and D wells. (Figures 10–13) A total of five zones and two subzones were identified from this study based on the assemblages of diagnostic species and notable nannofossil events namely: *Ceratolithus rugosus* zone (NN13) (CN10c), *Amaurolithus tricorniculatus* zone (NN12) (CN10a-CN10b) (duly represented by *Amaurolithus delicatus)*, *Discoaster quinqueramus* subzone (NN11a) (CN 9b), *Discoaster berggrenii* subzone (NN11b) (CN 9a) *Discoaster calcaris* zone (the missing marker species represented by *Discoaster loeblichii*) (NN10) (CN 8a-8b), *Discoaster hamatus* zone (NN9) (CN7a-7b), and *Catinaster coalitus* zone (NN8) (CN6), (Tables 1–4). The missing marker species might be as a result of dissolution of the skeletal calcite or sedimentation processes. The four wells correlate reasonably, as they show similarities in their nannofossil species (Figures 6–9). It was observed in the correlation of the biozones in the well sections that the wells on the eastern wing of the Charcot fracture zone are down thrown with a drop of about 2,490 ft to 4,350 ft. (830 to 1318 meters) relative to the wells on the western wing of the fractured zone (Figure 9). The biozonation and correlation of the wells A, B, C, and D have helped to subdivide the deep offshore Niger delta Neogene sequence into easily recognizable biostratigraphic units that will enhance prospectively of hydrocarbons.

Table 1. Nannofossils biozonation of Well D

Depth (feet)	Age	Nanno Zone Martini (1971)	Okada & Bukry (1980)	This Study	Zonal Characteristics / Bioevent
7000 7260 7440 8000	Early Pliocene	NN13	CN10a- CN10b	*Ceratolithus rugosus*	→ 7250 *Helicosphaera selli* → 7260 *Ceratolithus rugosus*
		NN 12		*Amaurolithus tricorniculatus*	→ Top *Discoaster quinqueramus*
9000	Late Miocene	NN11	CN9a – CN9b	*Discoaster quinqueramus, Spenolithus* abies	→ 9000 *Catinaster mexicanus* → 9090 *Spenolithus abies* (7.4 Ma MFS)
9600		NN10	CN8a – CN8b	*Discoaster calcaris*	→ 9600 HO of *Discoaster bolli*
10000 12000		NN9	CN 7a- CN7b	*Discoaster hamatus*	→ 9720 *Discoaster hamatus* (9.2Ma MFS)

Table 2. Nannofossils biozonation of Well B

Depth (feet)	Age	Nanno Zone Martini (1971)	Okada & Bukry (1980)	This Study	Zonal Characteristics / Bioevent
4500 4530 5600 6600	Early Pliocene	NN 12 - NN 13	CN10a - CN10c	*Amaurolithus tricorniculatus*	Presence of *Amaurolithus delicatus* at 4530ft suggest that the well is not younger than NN12
8600 9090 9600 13350	Late Miocene	NN 11	CN9a – CN9b	Discoaster quinqueramus Top at 12,390ft.Discoaster berggrenii	Top; *Discoaster quinqueramus* the co-occurrence of *Amaurolithus, Discoaster quinqueramus* and *Discoster berggrenii* with the dominance of *D. quinqueramus* over *D. berggrenii*. This relationship has being tied to the 6.0 Ma(MFS) Base *Discoaster berggrenii* (8.6 Ma) at 13350 ft
		NN 10	CN8a – CN8b	*Discoaster loeblichii*	*Discoaster. loeblichii (8.7 Ma)*
13400 14600		NN9		*Discoaster hamatus*	*Discoaster neohamatus* at 13,410

Table 3. Nannofossils biozonation of Well A

Depth (feet)	Age	Nanno Zone Martini (1971)	Okada & Bukry (1980)	This Study	Zonal Characteristics / Bioevent
5020 6040	Late Miocene	NN 11	CN9a – CN9b	*Discoaster quinqueramus*	→ 5020 Presence of *D. quinqueramus* confirms the assigned zone. → 6040 Base *D. quinqueramus* (8.6Ma)

Table 4. Nannofossils biozonation of Well C

Depth (feet)	Age	Nanno Zone Martini (1971)	Okada & Bukry (1980)	This Study	Zonal Characteristics /Bioevent
5000 5880	Early Pliocene	NN13	CN10c	*Ceratholithus. acutus*	→ 5880 Presence of *S. heteromophus, H. ampliaperta, D. adamanteus* indicate Faunal mixing.
6000 6420 6600		NN12	CN10a - CN10b	*Amaurolithus delicatus*	→ 6420 Base *C. acutus* (5.2Ma) *Amaurolithus delicates* → 6600 Top *D. quinqueramus* (5.6Ma)
6840 7000 7740 8000 8520		NN11	CN9a – CN9b	*Discoaster. quinqueramus* *Discoaster. berggrenii*	→ 6840 Top *A. amplificus* (5.9Ma) → 7740 Base *A. amplificus* (6.6Ma) → 8520 Top *Ct. Mexicana*
9000	Late Miocene	NN10	CN8a – CN8b	*Discoaster. loeblichii*	→ 9000 Base *D. berggrenii* (8.6Ma) 9120 Top *D. bolli* (9.1Ma)
		NN9	CN7a – CN7b	*D. hamatus*	→ 9780 Top *D. hamatus* (9.4Ma) → 9900 Base *D. hamatus* (10.7Ma)
10000 10020 10500 11000	Middle Miocene	NN8	CN6a – CN6b	*Catinaster coalitus*	→ Top *Catinaster coalitus*

The relative abundance and short stratigraphic ranges of nannofossils make them an excellent group for the biostratigraphic subdivision of the Mesozoic and Cenozoic strata (Figures 2–6). Their planktic habit and thus relatively rapid dispersal over large areas enhance their usefulness as tools for regional and inter-regional correlations. Zoning and correlation were established in A, B, C, and D wells. The wells were zoned using the standard nannofossil zonation schemes. These are the NN (Neogene Nannofossils) zones of Martini (1971) and the CN (Calcareous Nannofossil) zones of Okada and Bukry (1980). Based on the work of Berggren et al. (1995), absolute ages have been assigned to important bioevents. The zones encountered in this study ranged from the Middle Miocene to the Early Pliocene. Well A lies within the Late Miocene while Wells B, C, and D penetrated strata from Middle Miocene to Early Pliocene age. *Catinaster coalitus* zone of Middle Miocene represents the NN8 (CN6) zone of Martini (1971), it occurs only in Well C. The *Discoaster hamatus* zone NN9 (CN7a–7b) occurs across the studied wells representing the Middle/Late Miocene. The occurrence of *Discoaster leoblichii* and the top occurrence of *Discoaster bollii* were used to mark the NN10 (CN 8a–8b) zone in place of the zonal marker species, *Discoaster calcaris* which was missing. *Discoaster berggrenii,* NN11a (CN9a) subzone and *Discoaster quinqueramus* NN11b (CN9b) sub zone are the marker species for the Late Miocene. All the above named zones fall within the Middle Miocene to Late Miocene. The last zones encountered in this study are the *Amaurolithus tricorniculatus* zone, which has been represented by *Amaurolithus delicatus* in Wells B and C. *Ceratolithus rugosus* zone was identified in Well C where it has been represented by *Ceratolithus acutus*. These zones collectively fall within the NN12 and NN13 (CN10c) representing the Early Pliocene.

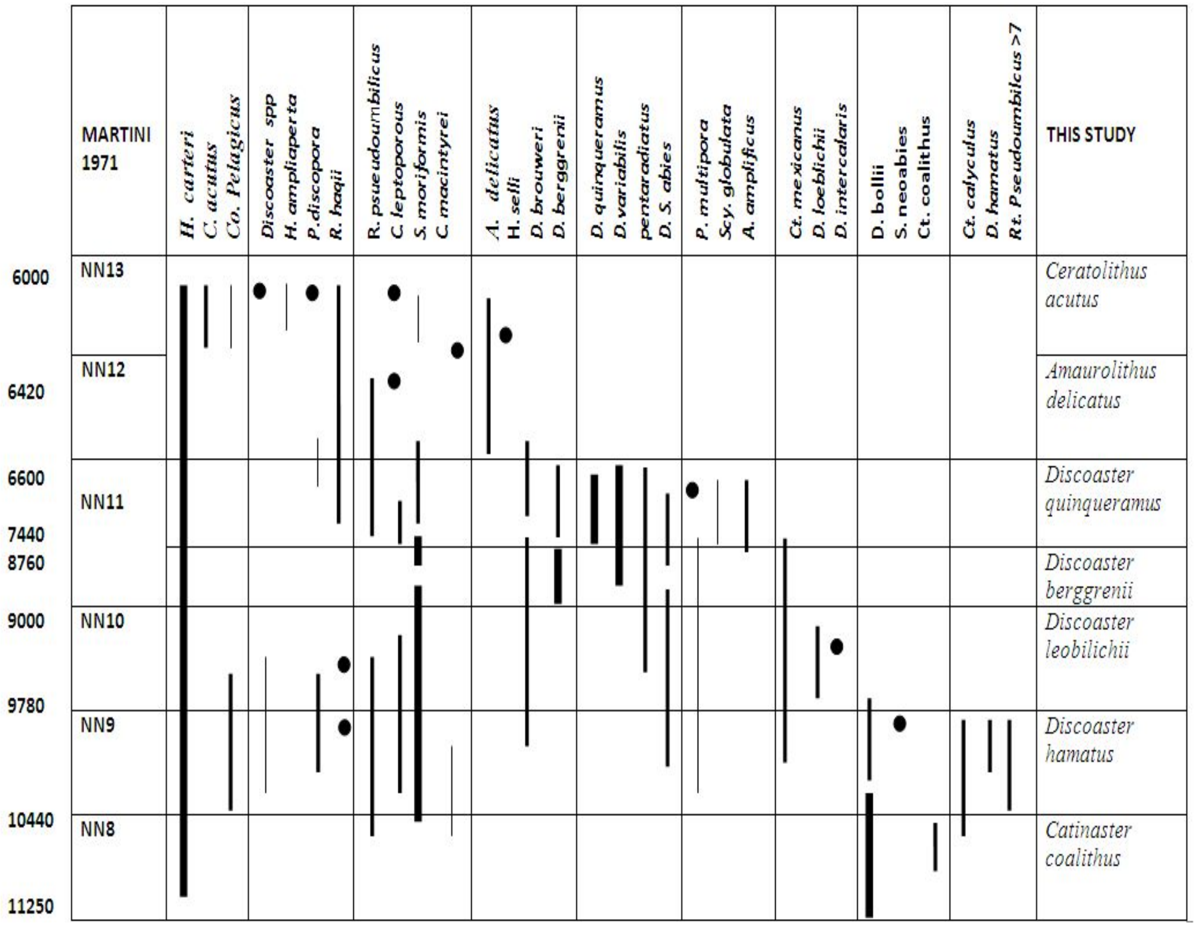

Figure 2. Calcareous nannofossil range chart of Well C

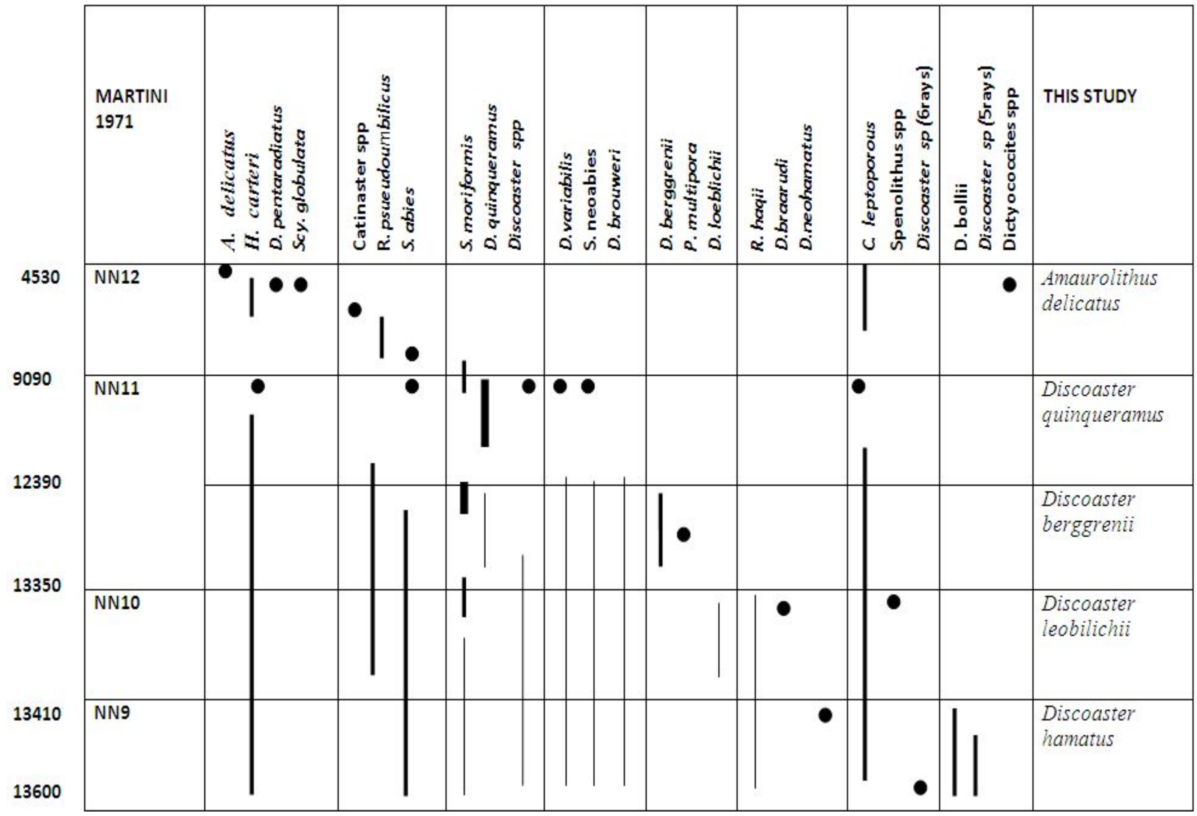

Figure 3. Calcareous nannofossil range chart of Well B

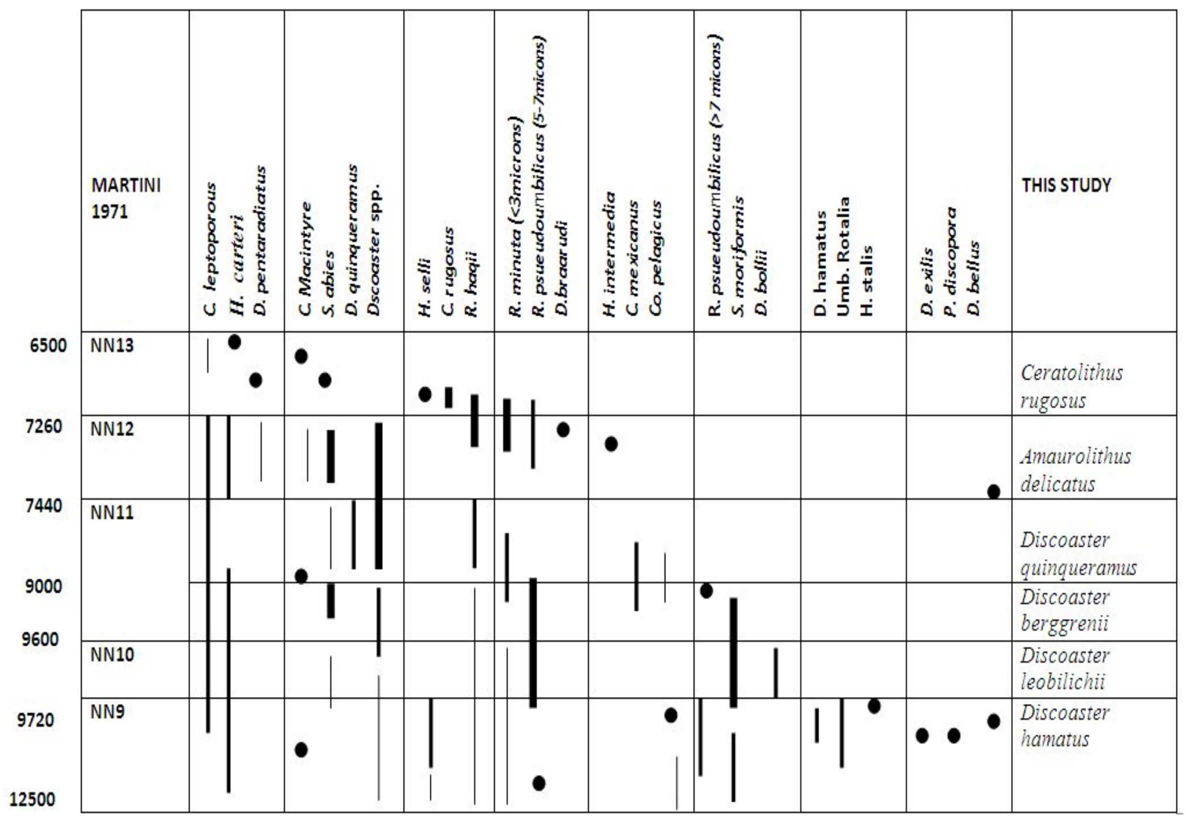

Figure 4. Calcareous nannofossil range chart of Well D

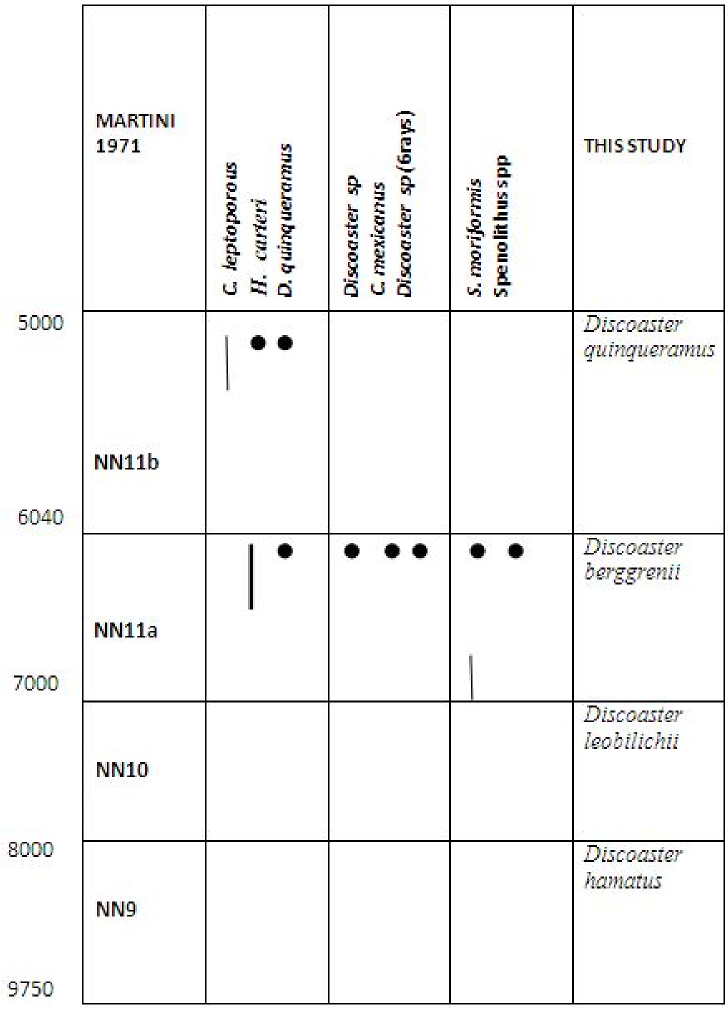

Figure 5. Calcareous nannofossil range chart of Well A

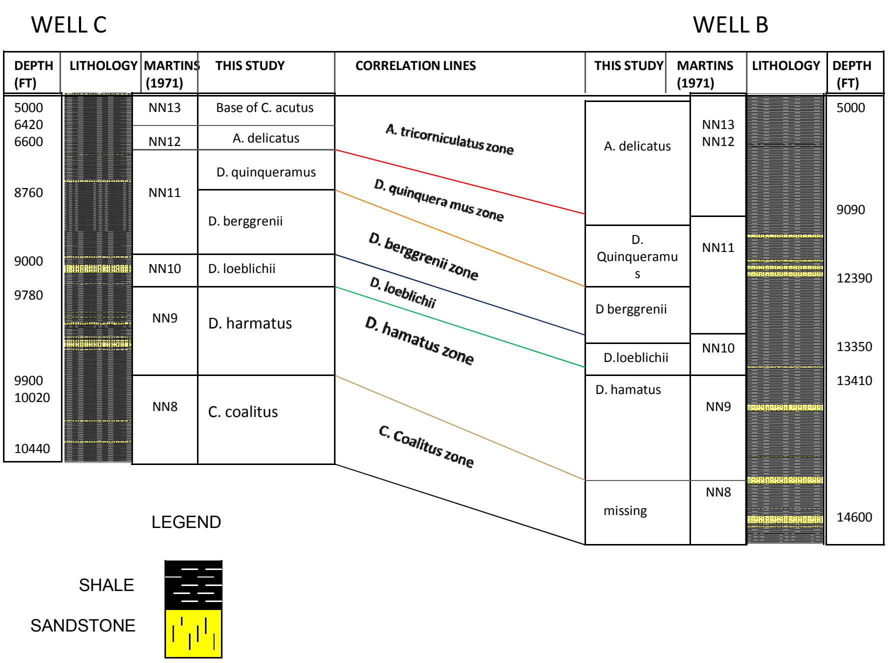

Figure 6. Correlation of nannofossil zones in C and B wells

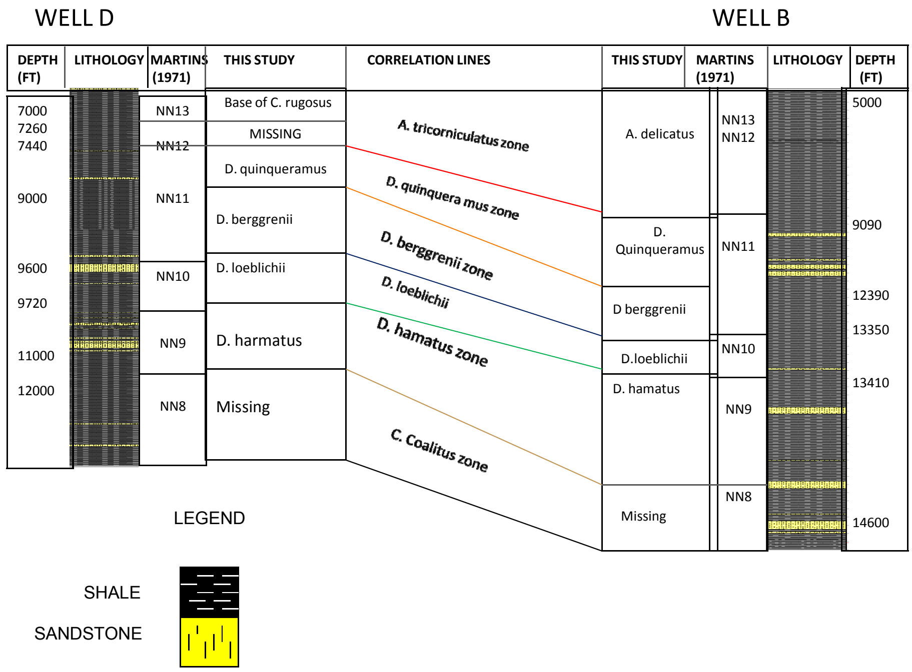

Figure 7. Correlation of nannofossil zones in D and B wells

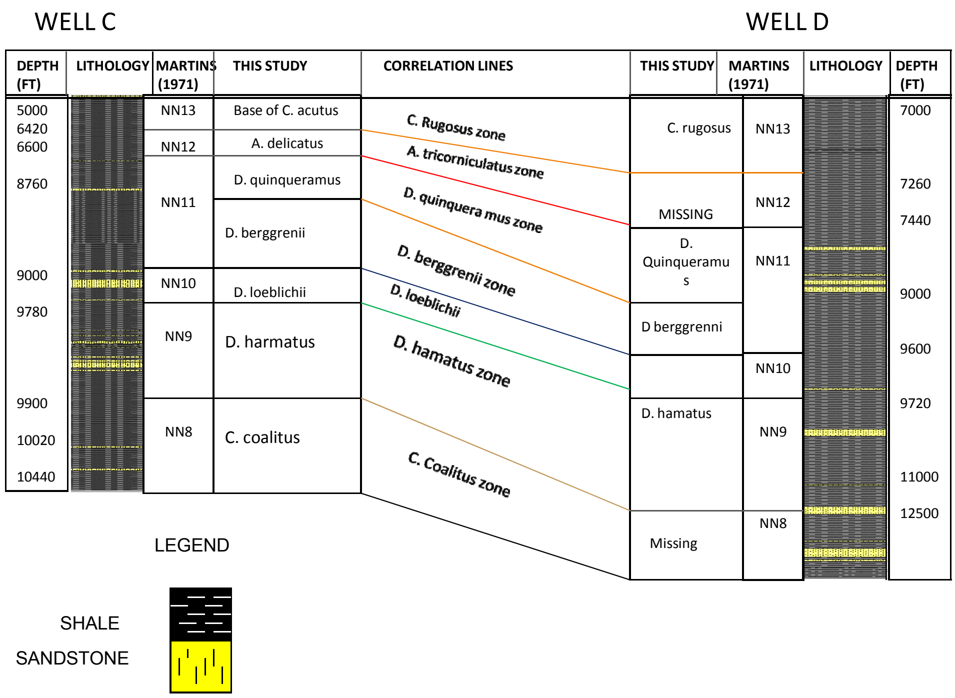

Figure 8. Correlation of nannofossil zones in C and D wells

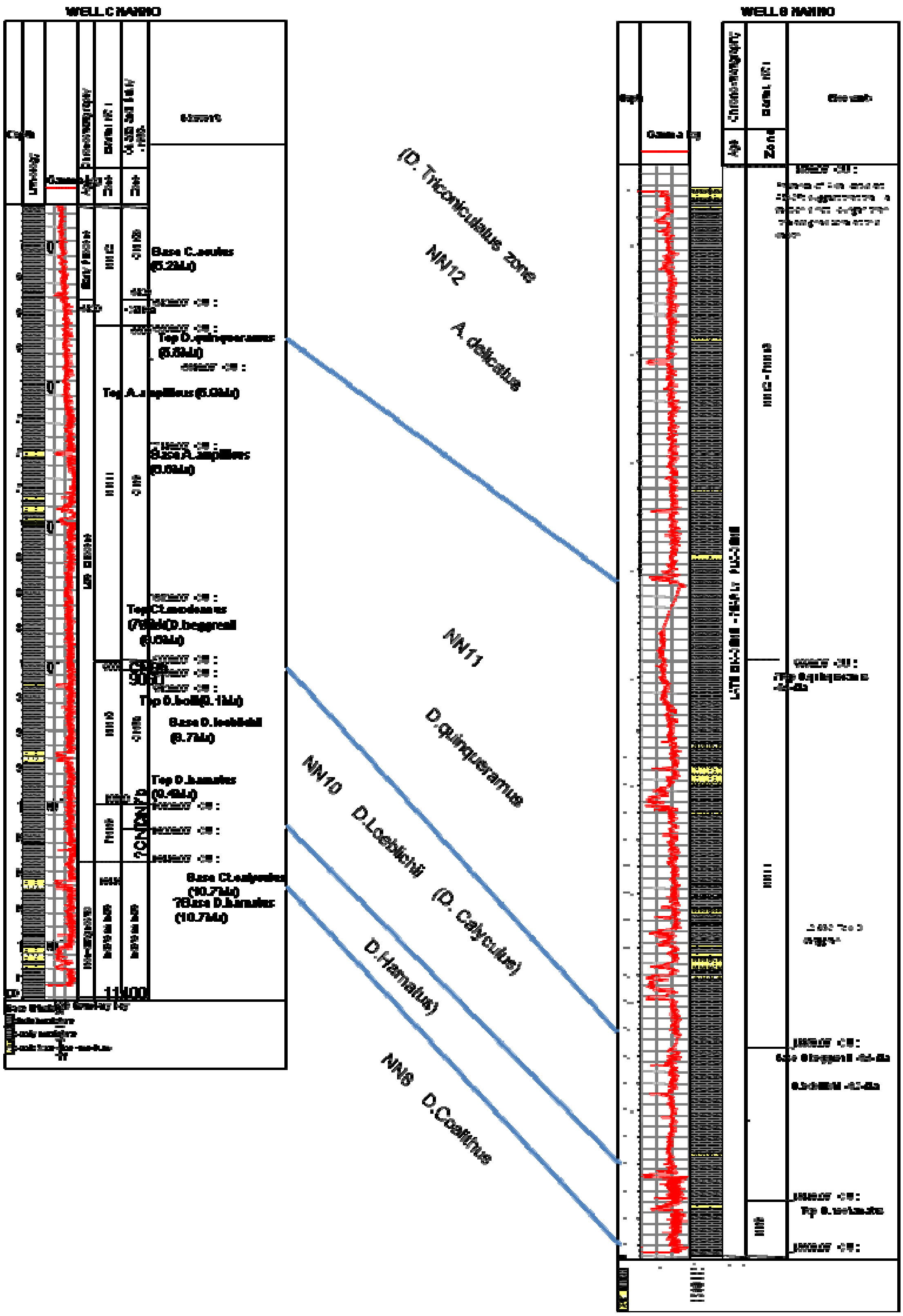

Figure 9. Correlation of nannofossil zones in C and B wells (Detailed)

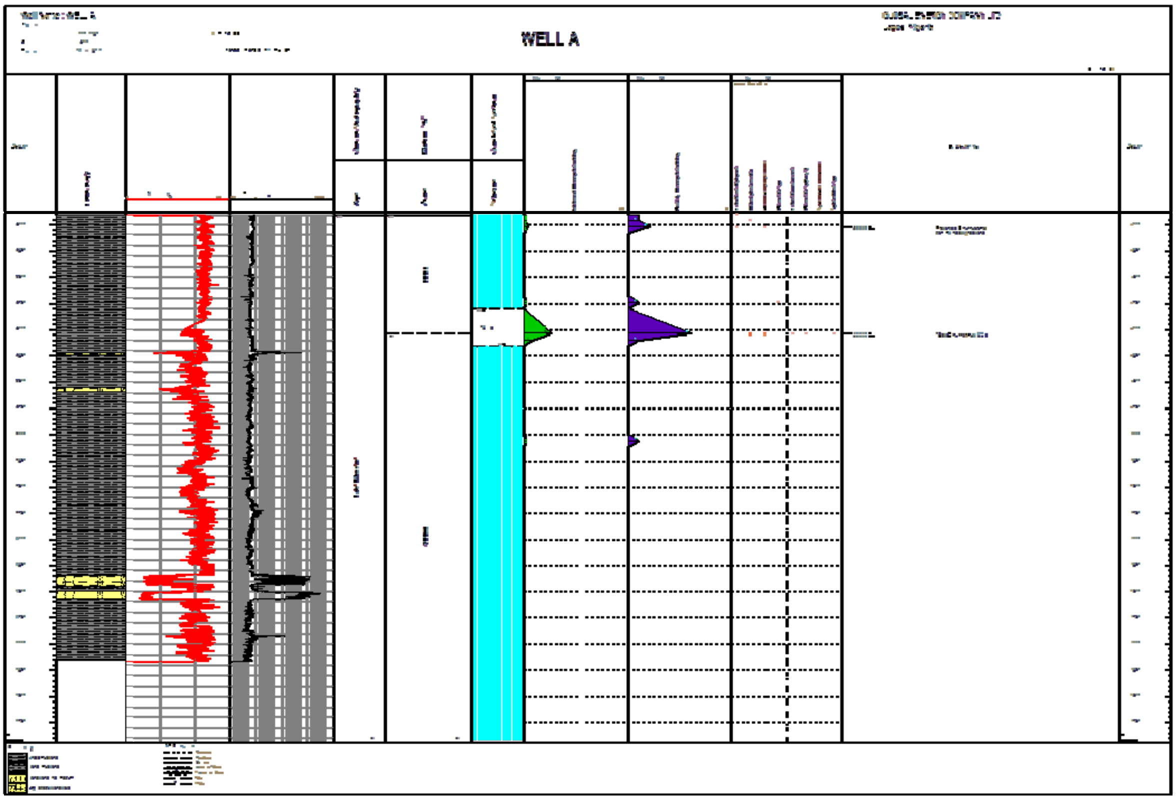

Figure 10. Nannofossil distribution chart of Well A

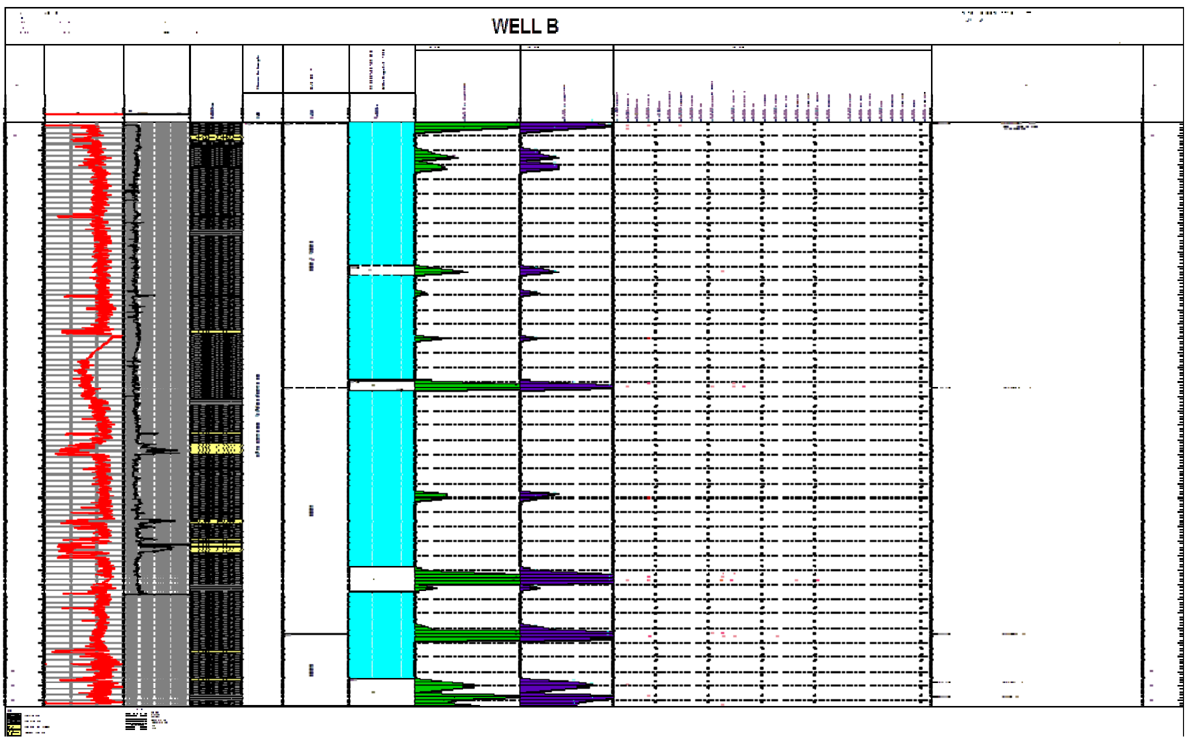

Figure 11. Nannofossil distribution chart of Well B

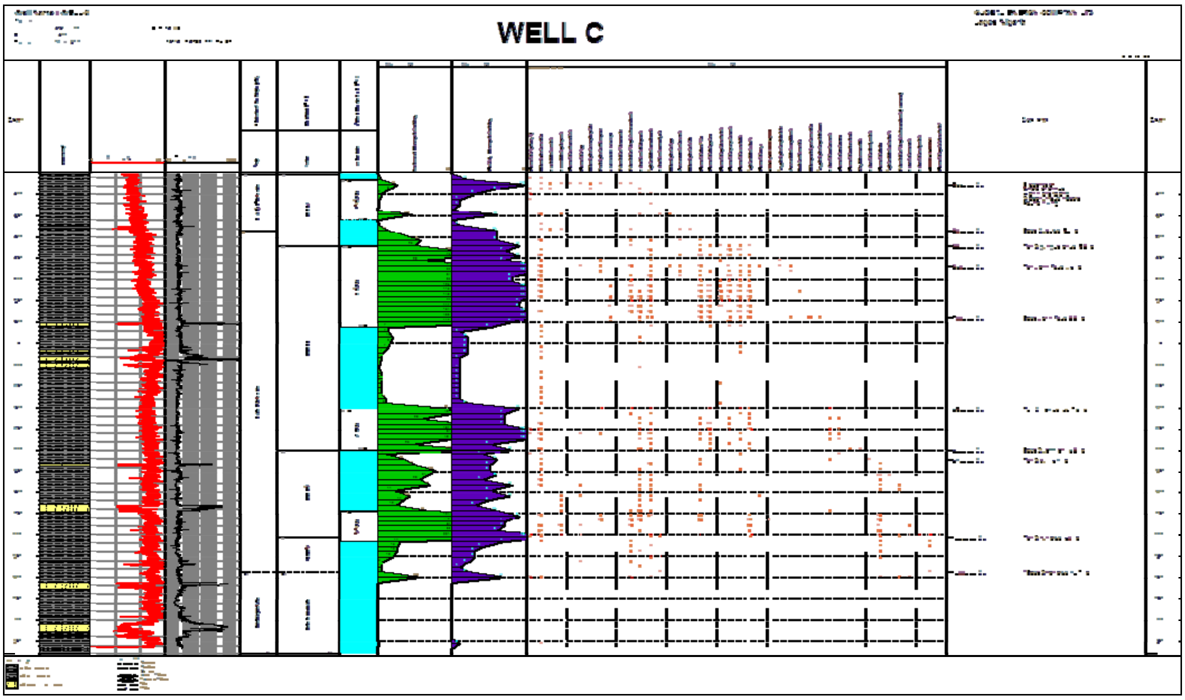

Figure 12. Nannofossil distribution chart of well C

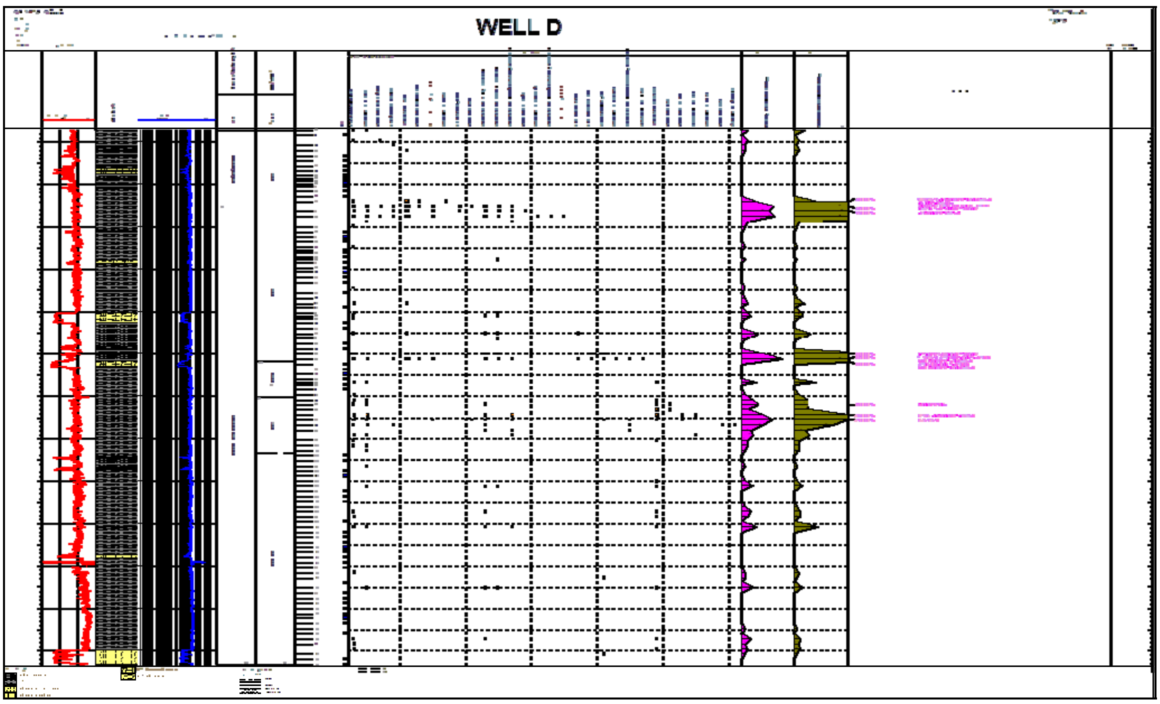

Figure13. Nannofossil distribution chart of Well D

5. Summary and Conclusions

The nannofosil species and biozones identified in this study correspond to an almost complete Upper Cenozoic Nannofossil zonation scheme of Martini (1971) and Okada and Bukry (1980). The absence of the marker species (*Discoaster calcaris*) in the four wells is in agreement with what exists in other previously studied wells in the Niger Delta (Ehinola et al., 2009). In addition, biostratigraphic work from the Gulf of Guinea around the coastal region of the Cote d'Ivoire - Ghana margin shows similar reports (Shafik et al., 1998). These workers adopted proxies for the original marker species at the intervals where marker species had rare or sporadic occurrences. A total of Five nannofossil zones (NN13, NN12, NN10, NN9, NN8) and two Nannofossil subzones (NN11a, NN11b) belonging to Middle Miocene to Early Pliocene age were identified from this study based on diagnostic marker species and notable nannofossil events. The zones are *Catinaster coalitus* zone (NN8), *Discoaster hamatus* (NN9), *Discoaster loeblichi* which occupy the base of *Discoaster berggrenii* and the top of *Discoaster bollii* was used to identify the NN10 zone, (The main marker for this zone which is *Discoaster calcaris*). Other zones encountered in this study are *Discoaster berggrenii* subzone (NN11a), *Discoaster quinqueramus* subzone (NN11b), *Amaurolithus tricorniculatus* zone (NN12) and *Ceratolithus rugosus* zone (NN13).

Nannofossil abundance/diversity patterns calibrated with recorded chronostratigraphically important bioevents and correlation with the Global Sea Level Chart of Haq et al. (1987) and Global Cycle Chart of Hardenbol et al. (1998) facilitated the recognition of five Maximum Flooding Surfaces (MFS's) dated 5.0 Ma, 6.0 Ma, 7.4 Ma, 9.5 Ma, and 11.6 Ma, and five Sequence Boundaries (SB's) dated 4.2 Ma, 5.6 Ma, 6.7 Ma, 8.5 Ma and 10.5 Ma. The analyzed sections of the wells are composed of deepwater sediments which were deposited in upper to lower bathyal environments.

Acknowledgements

Global Energy Limited is acknowledged for the provision of laboratory facilities and the stratabugs software. The studied materials were provided by Shell Nigeria Petroleum Exploration Company (SNEPCo).

References

Berggren, W. A., Kent, D. V., Flynn, J. J., & Van Couvering, J. J. (1995). Cenozoic Geochronology. *Geological Society of American Bulletin, U.S.A., 96*, 1406-1418.

Haq, B. U., Hardenbol, J., & Vail, P. R. (1987). Chronology of fluctuating sea levels since the Triassic. *Science, 235*(4793), 1156-1167. http://dx.doi.org/10.1126/science.235.4793.1156

Hardenbol, J., Thierry, J., Farley, N. B., Jacquin, T., De Graciansky, P. C., & Vail, P. R. (1998). Mesozoic and Cenozoic Sequence Chronosstratigraphic Framework of European Basins. In P, C. De Graciansky, J. Hardenbol, T. Jacquin, & P. R. Vail (Eds.), *Mesozoic and Cenozoic Sequence stratigraphy of European Basins*, SEPM Publication 60.

Martini, E. (1971). Standard Tertiary and Quarternary calcareous nannoplankton zonation. In A. Farinacci (Ed.), *Proceedings of second Planktonic Conference, Roma* (1970, Vol, 2, pp. 739-765).

Ojo, E. A., Fadiya, L. S., & Ehinola, O. A. (2009). Biozonation and Correlation of BDX-1 and BDX-2 Wells of Deep Offshore Niger Delta Using Calcareous Nannofossils. *Search and Discovery Article (AAPG),* (50194), 8.

Okada, H., & Bukry, D. (1980). Supplementary modification and introduction of code numbers to the low latitude coccolith biostratigraphic zonation. *Marine Micropaleontology, 5*(2), 321-325. http://dx.doi.org/10.1016/0377-8398(80)90016-X

Shafik, S., Watkins, D. K., & Shin, I. C. (1998). Upper Cenozoic Calcareous Nannofossil Biostratigraphy Côte d'Ivoire-Ghana Margin, Eastern Equatorial Atlantic.

PLATE 1

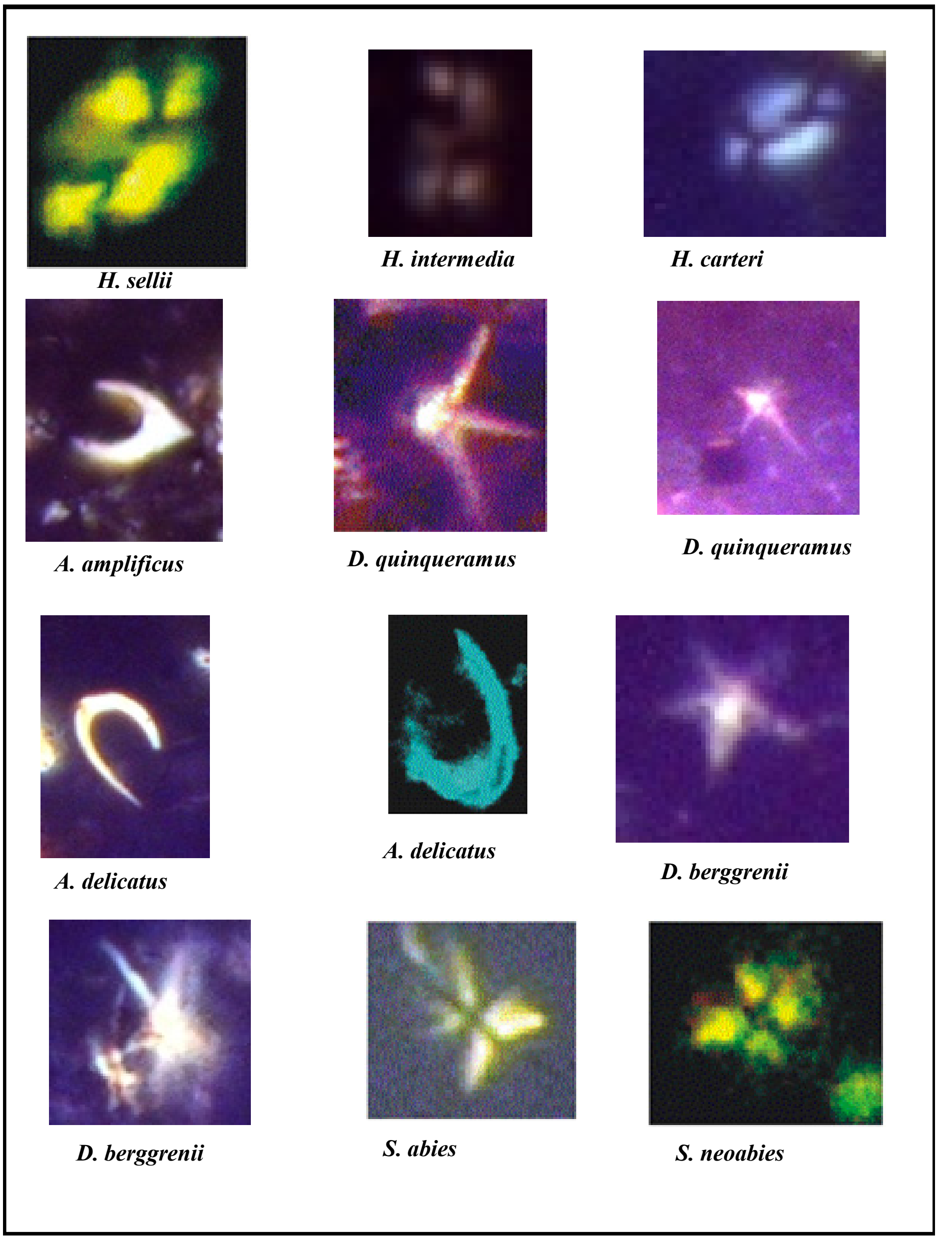

PLATE I

Figure

1. *Helicosphaera sellii,* Jafar and Martini, 1975: Distal side; X2400

2. *Helicosphaera intermedia,* Martini, 1965: Distal side; X2400

3. *Helicosphaera carteri,* Theodoridis, 1984: Distal side X2000

4. *Amaurolithus amplificus,* Gartner and Bukry, 1975: Distal side X2800

5–6. *Discoaster. Quinqueramus,* Gartner, 1969: Distal side X2800

7–8. *Amaurolithus delicatus,* Gartner and Bukry, 1975; Distal side X2800

9–10. *Ceratolithus rugosus,* Gartner, 1969: Distal side X2500

11. *Sphenolithus abies,* Deflandre and Fert, 1954: Distal side X2000

12. *Sphenolithus neoabies,* Deflandre and Fert, 1954; Distal side X1800

PLATE 2

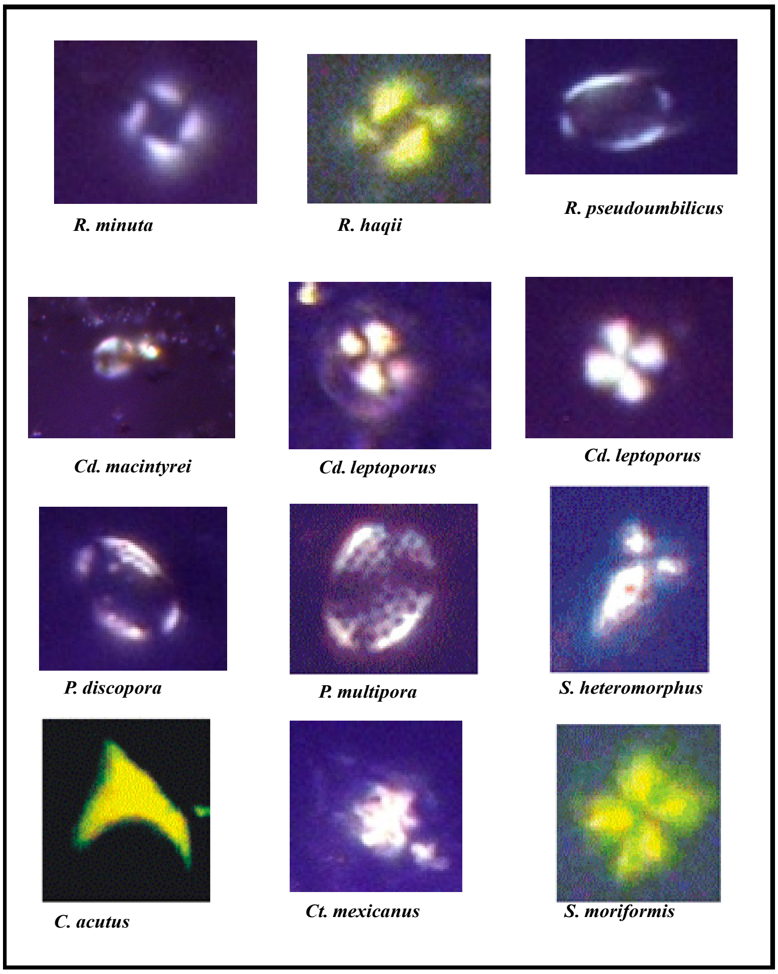

Plate II

Figure

1. Reticulofenestra minuta Roth, 1970; Distal side X1800

2. Reticulofenestra haqii Backman, 1978; Distal side: X2400

3. Reticulofenestra pseudoumbilicus, Gartner, 1969; Distal side X2500

4. Calcidiscus macintyrei, Bukry and Bramlette, 1969: Distal side X2000

5–6. Calcidiscus. Leptoporus, Murray and Blackman, 1898; Distal side X2550

7. Pontosphaera discopora, Schiller, 1925: Distal side X2800

8. Pontosphaera multipora (Kamptner. 1948) Roth. 1970; Distal side X2800

9. Sphenolithus heteromorphus, Deflandre, 1953; Distal side X1800

10. Ceratolithus acutus, Jordan and Young, 1990; Distal side X2400

11. Catinaster mexicanus, Bukry, 1971b; Distal side X2000

12. Sphenolithus moriformis Bronnimann and Stradner, 1960; Distal side X2200

PLATE 3

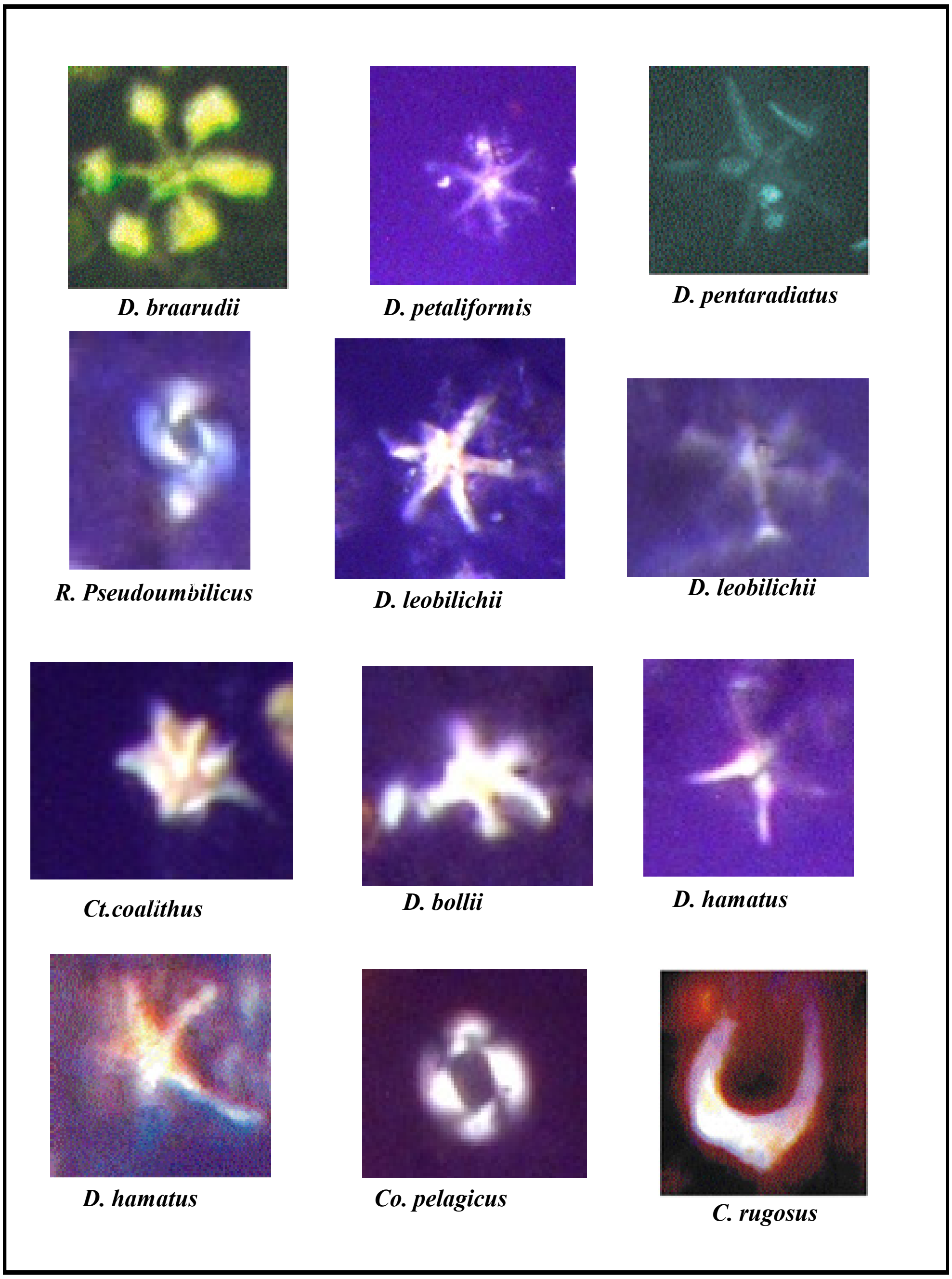

Plate III

Figure

1. Discoaster braarudii, Bukry, 1971: Distal side X2600

2. *Discoaster petaliformis*, Moshkovitz and Ehrlich, 1980; Distal side X2400

3. *Discoaster pentaradiatus*, Tan, 1927; Distal side X2500

4. *Reticulofenestra pseudoumbilicus*, Gartner, 1969; Distal side X2550

5–6. *Discoaster leobilichii,* Bukry, 1971a; Distal side X2000

7. Catinaster coalithus, Tan 1927 ; Distal side X 2000

8. *Discoaster bollii,* Martini and Bramlette, 1963; Distal side X2800

9–10. *Discoaster hamatus,* Martini and Bramlette, 1963; Distal side X2550

11. *Coccolithus pelagicus,* Schiller,1930; Distal side X2200

12. *Discoaster hamatus,* Martini and Bramlette, 1963; Distal side X255