Dynamic Evolutionary Model of the Late Quaternary Depositional Sequences from the Niger Delta

The Nigerian Government Petroleum Technology Development Fund Scholarship

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1. Introduction

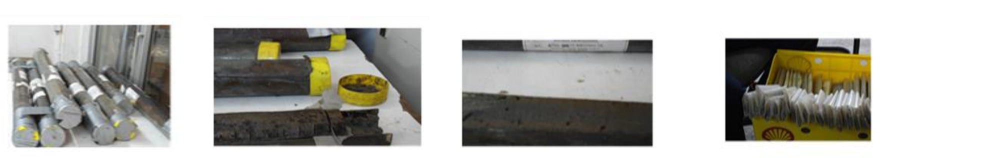
- The evolutionary history of the Niger Delta over the last 20 ka. based on the timing of the land-sea interaction has been a thing of debate due to poor understanding on the influence of West African Monsoon (WAM) circulation.
- The aim of this study is to understand the impact of the factors driving (control) changes in environment through detailed reconstruction of vegetation and sediment supply with respect to the timing of WAM and ITCZ migration during the Late Pleistocene–mid-Holocene in the area of the coastal offshore region of the Niger Delta, Gulf of Guinea (Fig. 1).
- The consequence of this interaction in the North Atlantic causes an increase in the average temperature of the surface waters of the North or South Atlantic Ocean. This effect may coincide with a south/northward shift of the Intertropical Convergence Zone (ITCZ) (EPICA members, 2006; Dupont *et al*., 2008; Collins *et al*., 2010)
- The results permit a re-evaluation of the controls of climate, sea level and sediment supply contributing to the understanding of the two stages evolution of the Niger Delta for the future exploration, exploitation and sustainability of the region (Fig. 6).

2. Objectives

- To determine the controls and compare the timing of West African Monsoon (WAM) and migration of intertropical convergent zone (ITCZ) in relation to the stratigraphic evolution of the Niger Delta (Fig. 2).
- To probe further and reconstruct the evolution of the Niger Delta environments and to present a model that explains the interplay between the driving mechanisms, palaeoenvironments, sea-level and climate change based upon biotic and abiotic evidence (Fig. 6).

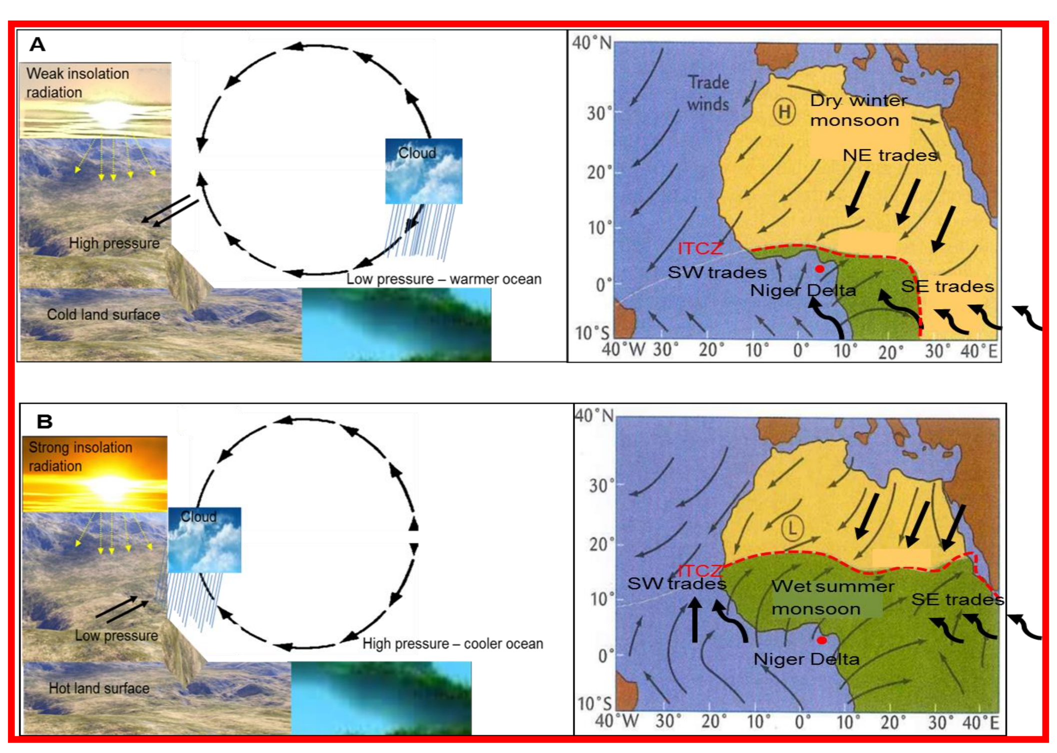
3. Methodology

- This research involves a multi-proxy study based upon three gravity cores of just under 3 metres length each (Fig. 3).
- **Nannofossils**, **Sedimentology and Grain Size Analysis and Geochemistry** techniques were applied (Fig. 3).



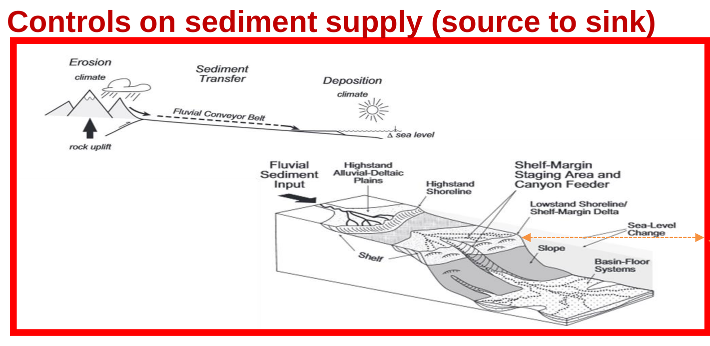
a) Original Gravity Core b) Core sampling at 2 cm c) Slabbed Core d) Collected core samples in bags

5. ITZC & WAM Shift N-S (Fig. 2)



Positions of the Intertropical Convergence Zone (ITCZ) and West African Monsoon System (WAM) during the boreal winter (A), and summer (B). ITCZ is indicated by red dotted lines. Figure modified from Griffiths (1972) and after Leroux (1993).

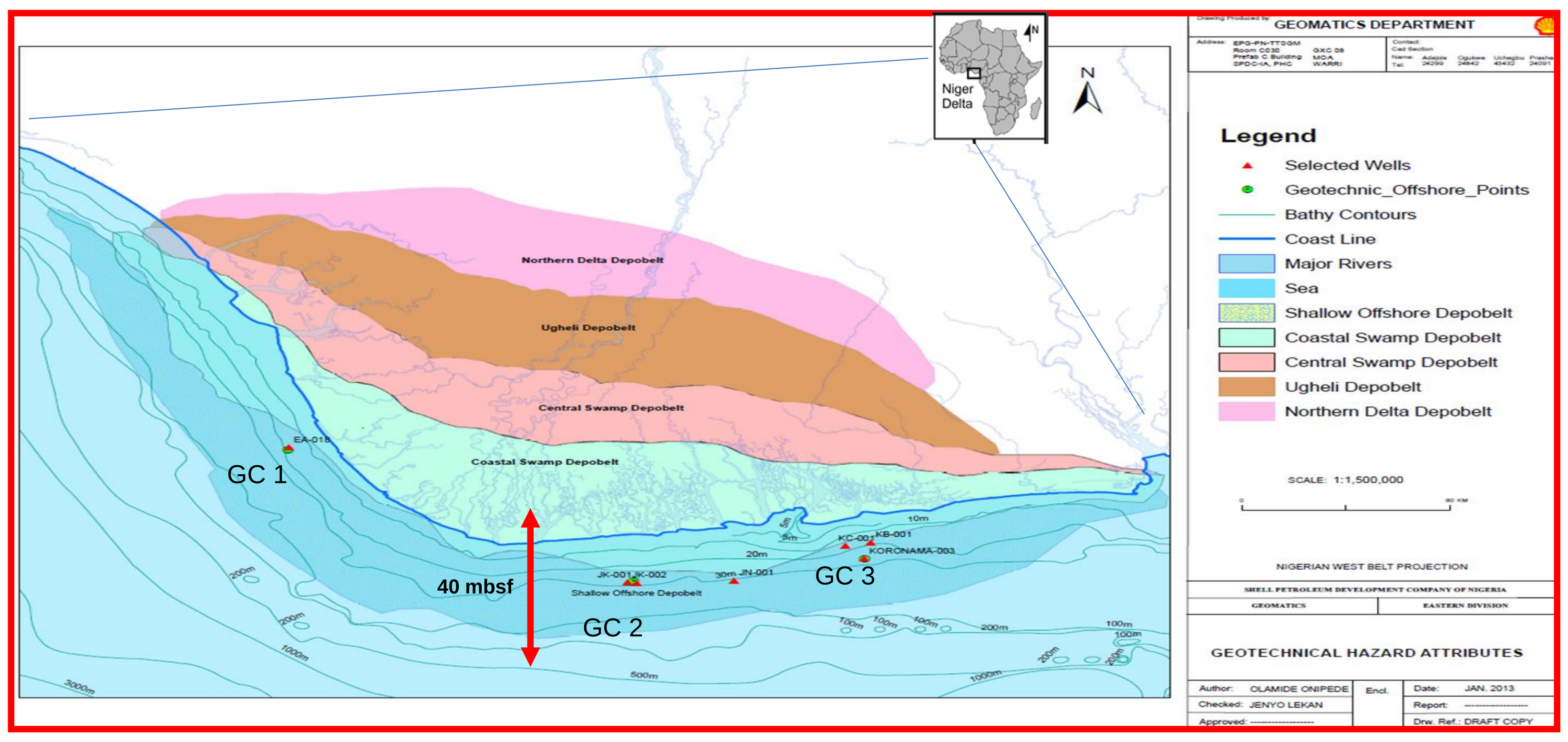
Controls on sediment supply (source to sink)



Sediment output

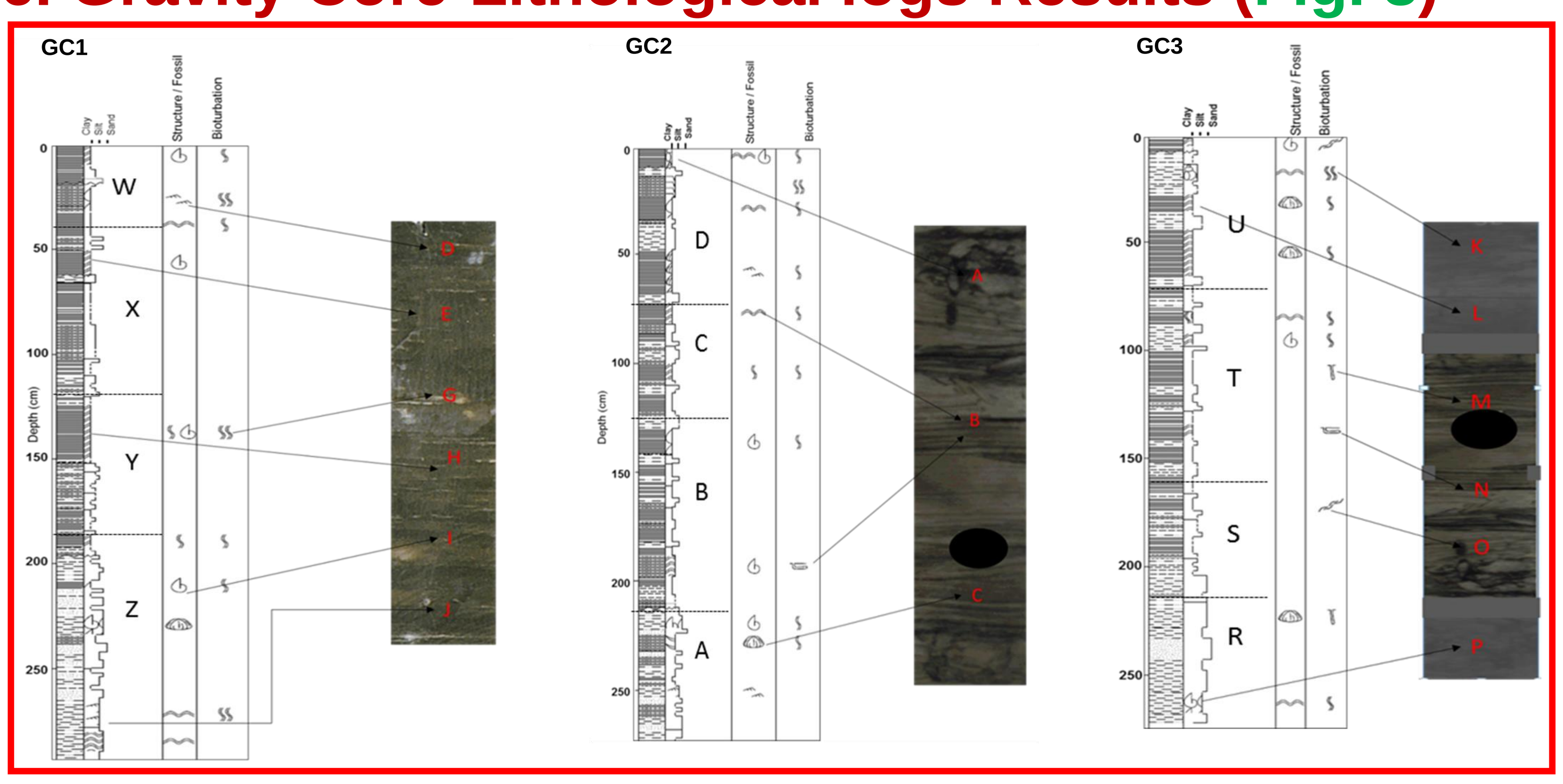
Sediment input

4. The Niger Delta (Fig. 1)



- The Niger Delta is located in southern Nigeria building out roughly southwards into the Gulf of Guinea (Kulke et al., 1995). Divided into 5 structural / depositional units (Depobelts - in colours).
- Consists of 3 Formations namely the Akata, Agbada and Benin Formations that are roughly dated diachronously between the Eocene and Recent.
- GC1= East, GC2=Central, GC3=West geotechnical positions along the Shallow offshore (Fig. 1).

6. Gravity Core-Lithological logs Results (Fig. 3)

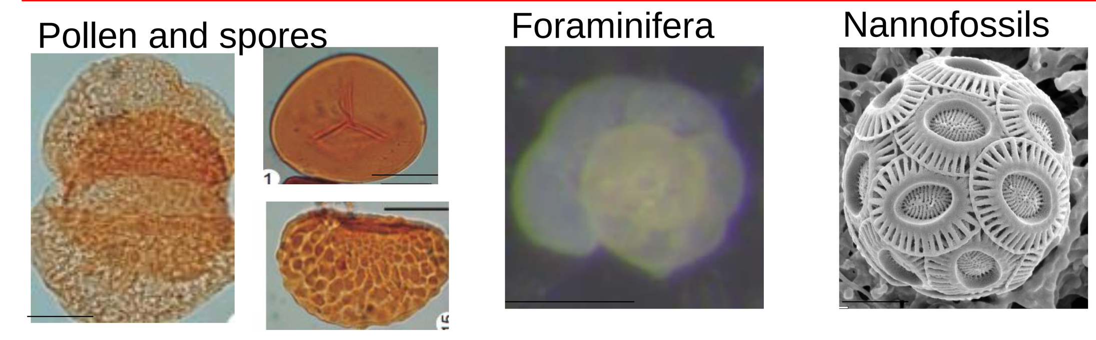


9. Discussions

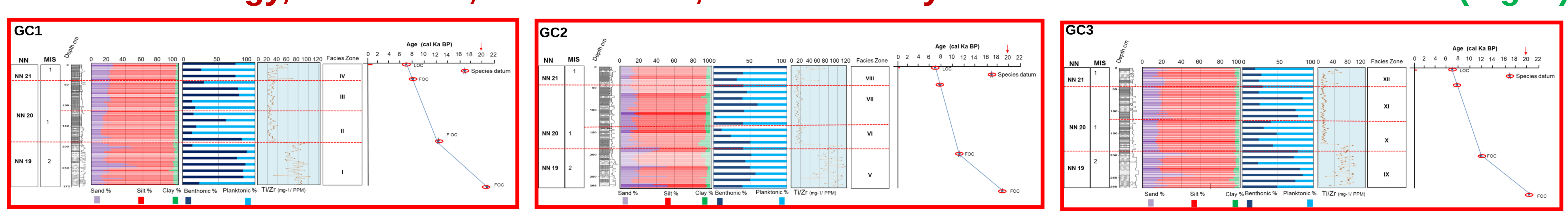
- **A multi-proxy investigation** in relation to the stratigraphic evolution has resulted in the reconstructions of two regional coastal delta shoreface Stages namely: Delta advancing (Stage 1) and retreat (Stage 2) (Figs. 3, 4, 5 & 6).
- During the Late Pleistocene regression, the bottom of the GC sequences shows a contrasting facies variations during the dry climate and low sea level in the glacial period (MIS2) supporting the assumption of a weakened WAM, linked to the episode of "palaeodischarge and delta progradation" (Fig. 6)
- Conversely, in the mid to Early-Holocene transgression could have triggered the dominant facies change during the warm climate and sea level rise in the interglacial period (MIS1), supporting the assumption of a strengthened WAM, "subsequent delta retrogradation and sea level retreat" (Fig. 6).
- Given this, there is a clear regional temporal pattern of the Late Quaternary palaeoenvironmental change either side of the Niger Delta (East to West) (Fig. 1). This shows the importance of key driving mechanisms of deltaic landform evolution.
- In a nutshell, the outcome of this study indicates that the records link well in time to the known hypotheses of the land-ocean interactions providing the main drivers for study of the climate and sea level change in relation to the sedimentary and vegetation evolution of the Niger Delta compared with previous studies from West Equatorial Africa (Fig. 6).

"How have interactions between the position of the ITCZ and the strength of WAM migrated over the Quaternary period, aided in the understanding of both global and local control on the palynomorph records and delta evolution during the late Quaternary"?

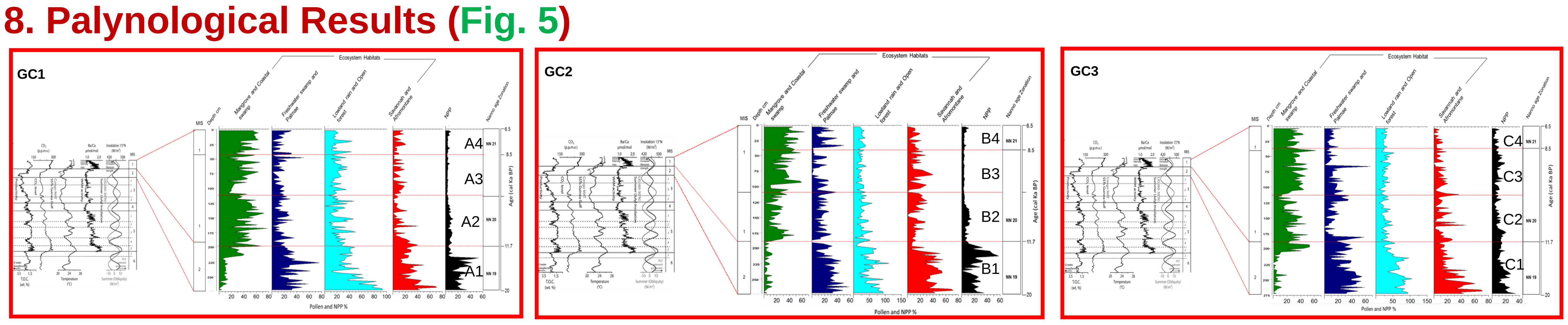
Pollen and spores Foraminifera Nannofossils



7. Sedimentology, Grain Size, Foraminifera, Geochemistry & Sedimentation Rates Results (Fig. 4)



8. Palynological Results (Fig. 5)

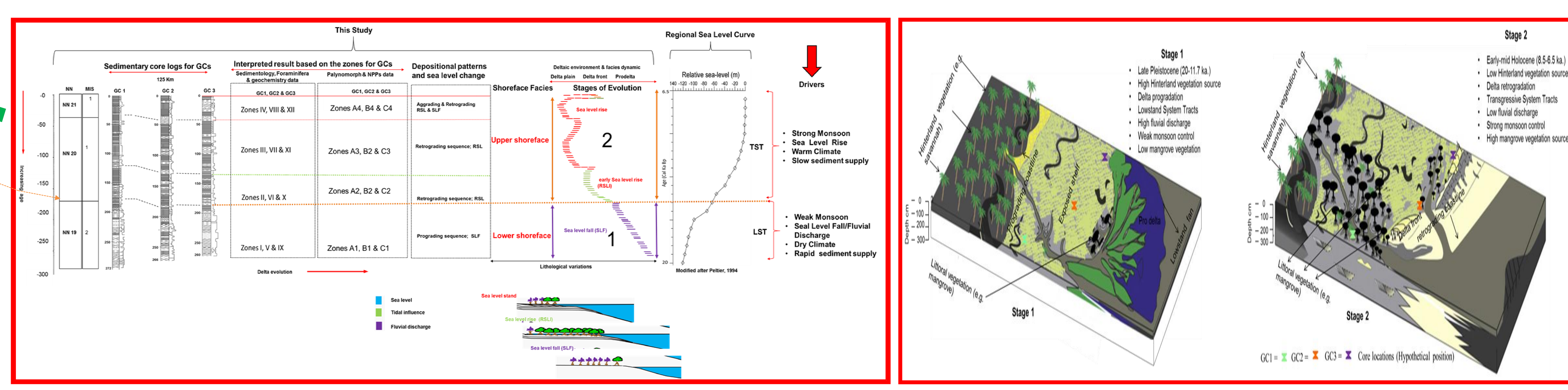


Note: All the relative changes interpreted from the results were inserted into the Fig. 6 based on the observable zones of the GCs data.

Zones: I, V, IX, A1, B1 &C1 consists of high abundant of medium sand, Ti/Zr elements, Benthic foraminifera, hinterland pollen and spores source influenced by dry climate and low sea level in relation to weak monsoon / southern migration of the ITCZ (Figs. 4 & 5).

Zones: II-IV, VI-VIII, X-XII, A2-A4, B2-B4 & C2-C4 comprises of high abundance of silty-fine sand, Plantonic foraminifera, Mangrove pollen and spores source influenced by warm climate and sea level rise in relation to strong monsoon / northern migration of the ITCZ (Figs. 4 & 5).

10. Conceptual model integrating all results in relation to the driving mechanisms (Fig. 6)



11. Conclusions and Implications of the coastal evolutionary stages of Late Quaternary Niger Delta

In addition to the past studies, the current study proposes two regional Stages driving the evolution of the Niger Delta. These are:

A) Regional climate-driven fluvial variations for the initial progradation (e.g. the cooling of the North Atlantic and the weak WAM), and sedimentary supply to the Niger Delta which lasted until 11.7ka (Stage 1) (Figs. 2 & 6).

B) Global sea level rise (e.g. the warming of the South Atlantic and the intensification of WAM) preceding retrogradation period until 6.5ka. (Punctuated by a pulse of the sedimentary supply starvation across the Niger Delta reaffirming the ongoing sea level rise) (Stage 2) (Figs. 2 & 6).

- Drawing on the conclusions above, the wider consequences of these findings based on sediment supply are considered here. The main contribution is related to the improved understanding of transgressive shoreface interactions observed between the evoked climate-sea levels driving or controlling the littoral-coastal sediments and vegetation of the Niger Delta, with variable facies (GCs) changes in relation to the strength of West African Monsoon system.
- Inputs (Stage 1) and outputs (Stage 2) of sediments often reflect the amounts of erosion or accretion affecting the coastal morphology. This relationship is a prerequisite for the reconstructions of sedimentary budgets, coastal management, and for the understanding of the potential variability of ancient deltaic sequences where there is no potential control prominent in the Quaternary could help in decoding the past signals more thoroughly for the sustainable initiatives of the region.

12. References

Collins, J. A., Schefusz, E., Heslop, D., Mulitza, S., Prange, M., Zabel, M., Tjallingii, R., Dokken, T. M., Huang, E., Mackensen, A., Schulz, M., Tian, J., Zarriess, M., and Wefer, G., 2010. Interhemispheric symmetry of the tropical African rainbelt over the past 23,000 years. Nature Geosciences, **4**, 42-45.

Dupont, L. M., Behling, H. and Kim, J. H., 2008. Thirty thousand years of vegetation development and climate change in Angola (Ocean Drilling Program Site 1078). Climate of the Past, **4**, 107–124.

EPICA Community Members, 2006. Eight glacial cycles from an Antarctic ice core.Nature, **429**, 623-628.

Griffiths, J. F., 1972. Climate of Africa: Seasonal changes cause a moist inflow of monsoonal air towards the low-pressure center over North Africa in summer: (In) Earth's climate - past and future. Amsterdam – Elsevier, **9**, 195.

Jermannauda, P., Roubya, D., Robina, C., Nalpasa, T., Guillocheaua, F. and Raillard, S., 2010. Plio-Pleistocene sequence stratigraphic architecture of the eastern Niger Delta: A record of eustasy and aridification of Africa. Marine and Petroleum Geology, **27**, 810-821.

Kulke, H., 1995. Nigeria: (In) Kulke, H., ed. Regional petroleum geology of the World part 11: African, America, Australia and Antarctica: Berlin, Gebruder Bornbraeger, 143-172.

Leroux, M., 1993. The mobile polar high: A new concept explaining present mechanisms of meridional airmass and energy exchanges and global propagation of palaeoclimatic changes. Global and Planetary Change, **7**, 69–93.