Vegetation Dynamics vs. Sediment Supply During the Late Quaternary: Paradigm of Sea Level Change and Two Distinct Time-Bound Stages of the Niger Delta Coastal Evolution

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Abstract

This paper examines the impact of climate-sea level controls on the vegetation and evolution of the Niger Delta during the Late Quaternary. The extraneous controls on the environment outlined in this context confirm a direct link between vegetation dynamics (pollen data), sediment supply, and the landscape evolution of the Niger Delta between 20 ka and 6.5 ka. Two phases of sedimentation are recognized based on multiple proxies analyzed in three gravity cores obtained from the shallow offshore at ˜40 m water depth. Phase I records abundant occurrences of Poaceae, Cyperaceae, and Podocarpus pollen from a dry hinterland, charred grass cuticles, nonmarine alga Pediastrum, high Ti/Zr ratio, and lower sedimentation from 20-11.7 ka. Phase II records an expansion of mangrove vegetation, high Fe/S ratio, and increase in planktonic foraminifera between 11.7 ka and 6.5 ka. This second phase is attributed to sea-level rise and higher sedimentation during the development of delta plain and mangrove vegetation on the gently sloping shelf. These sequential records provide a new clue about the link between the evolutionary stages of the Niger Delta landscape and vegetation dynamics during two distinct time-bound intervals, which potentially delineate the boundary between two Marine Isotope Stages: MIS2 (late glacial period) and MIS1 (interglacial period).

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1. Introduction

- This study provides the implications of the factors driving (controls) the environment changes of the coastal offshore of the Niger Delta, West Africa (Fig. 1) through detailed analyses of Nannofossils, Sedimentology, Grain Size Palynology & Geochemistry with respect to the timing of West African Monsoon (WAM) & Intertropical Convergence Zone (ITCZ) migration during the last 20 ka.
- The consequence of this interaction in the North Atlantic causes an increase in the average sea surface water temperature (SSTs) of the North or South Atlantic Ocean. This effect may coincide with a south/northward shift of the 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 & West African regions for the future exploration, exploitation and sustainability of the settings (Fig. 4).

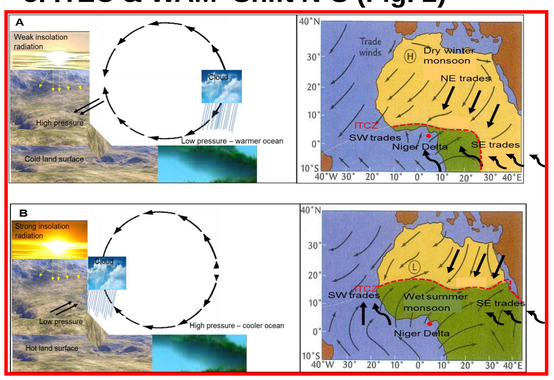
2. Objectives

- 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. 4).

3. Methodology

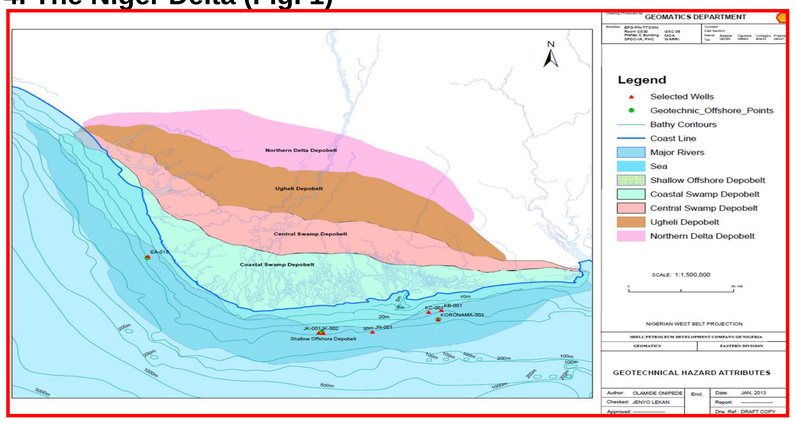
- This research involves a multi-proxy study based upon three gravity cores of just under 3 metres length each (Fig. 3).
- **Nannofossils**, **Sedimentology and Grain Size Analysis Palynology, and Geochemistry** techniques were applied (Fig. 3).

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



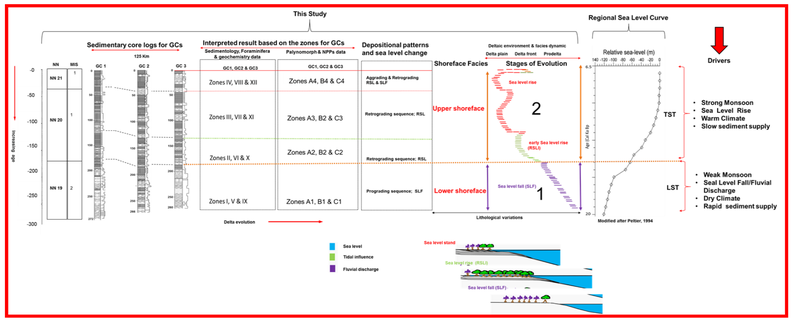
Positions of the Intertropical Convergence Zone (ITCZ) and West African Monsoon System (WAM) during the boreal winter (A), and summer (B). ITCZ is indicated by red dotted lines. Figure modified from Griffiths (1972) and after Leroux (1993).

4. The Niger Delta (Fig. 1)

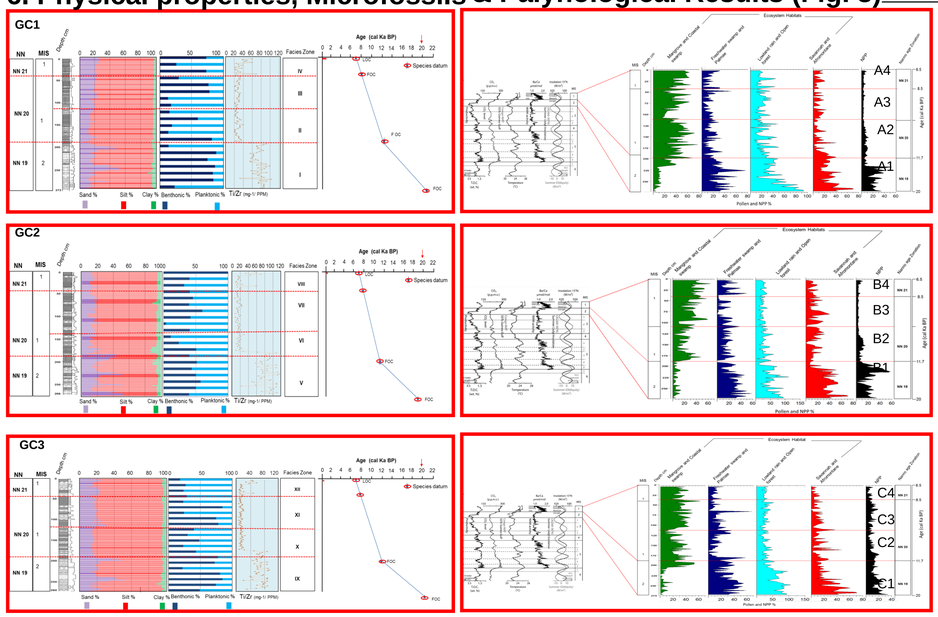


- The Niger Delta is located in southern Nigeria building out roughly southwards into the Gulf of Guinea (Kulke et al., 1995). Divided into 5 structural / depositional units (Depobelts - in colours).
- Consists of 3 Formations namely the Akata, Agbada and Benin Formations that are roughly dated diachronously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

7. Integrated coastal evolutionary stages (Fig. 4)



6. Physical properties, Microfossils & Palynological Results (Fig. 3)

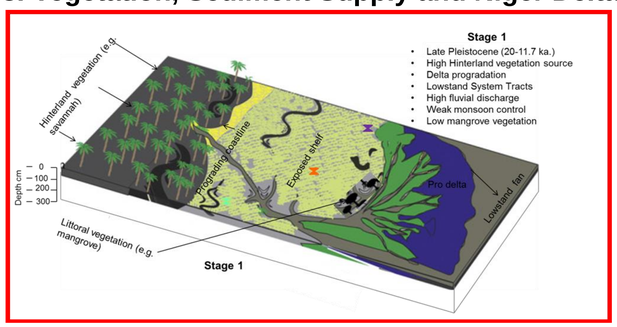


Note:

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. 3).

Zones: II-IV, VI-VIII, X-XII, A2-A4, B2-B4 & C2-C4 comprises of high abundance of silty-fine sand, Planktonic 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. 3).

8. Vegetation, Sediment Supply and Niger Delta Evolution after 20 ka (Fig. 4)



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,).
- During the Late Pleistocene regression, the bottom of the GCs sequences shows a contrasting facies variations indicating a dry climate and low sea level in the glacial period (MIS2) supporting the assumption of a weak WAM, linked to the episode of "palaeodischarge and delta progradation" (Fig. 4)
- Conversely, in the mid to Early-Holocene transgression the dominant facies change could have been triggered during the warm climate and sea level rise in the interglacial period (MIS1), supporting the assumption of a strong WAM, "subsequent delta retrogradation and sea level retreat" (Fig. 4).
- 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. 4).

10. Conclusions and Implications of the coastal evolutionary stages of Late Quaternary Niger Delta, West African margin

In addition to the past studies, the current study proposes two regional Stages driving the evolution of the Niger Delta in the Gulf Guinea, West Africa. 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 (Fig. 4). (Stage 1) (Figs. 2 & 4).

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 &4).

- The main contribution is related to the improved understanding of transgressive shoreface and vegetation 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.
- These relationships could be a prerequisite for the reconstructions of sedimentary budgets, coastal management, and for the understanding of the potential variability of ancient deltaic sequences and vegetation where there is no potential control prominent on the Quaternary sediment could help in decoding the past signals more thoroughly for the sustainable initiatives of the region.

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