Marine Geology 319–322 (2012) 1–20

Contents lists available at SciVerse ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

# Geometry and chronology of late Quaternary depositional sequences in the Eastern Niger Submarine Delta

V. Riboulot [a,b,*], A. Cattaneo [a], S. Berné [b], R.R. Schneider [c], M. Voisset [a], P. Imbert [d], S. Grimaud [d]

[a] Ifremer, GM-LES, Brest, France
[b] Université de Perpignan Via Domitia, Perpignan, France
[c] Christian-Albrechts University Kiel, Germany
[d] TOTAL, Pau, France

ARTICLE INFO

*Article history:*
Received 14 February 2011
Received in revised form 6 March 2012
Accepted 8 March 2012
Available online 28 March 2012

Communicated by D.J.W. Piper

*Keywords:*
Niger Delta
Late Quaternary
3D seismic data
Sequence stratigraphy
Growth fault
Oxygen isotope stratigraphy
Subsidence

ABSTRACT

On seismic profiles, the Eastern Niger Submarine Delta displays spectacular prograding wedges separated by discontinuities on the continental shelf and correlative conformities seawards. In spite of the numerous studies focused on deep oil reservoirs in this area, and because of the presence of pronounced syndepositional deformation, the detailed geometry and chronology of the Quaternary succession has been neglected, while it contains relevant information about sedimentary processes and the factors controlling sediment depocenters, presence of fluids and sediment deformation.

This study provides the first comprehensive view of the Late Quaternary stratigraphic architecture of the Eastern Submarine Niger Delta. The stratigraphic interpretation is based on: (1) a seismic dataset composed of 2D seismic profiles with variable resolution (Sparker, Chirp) and four 3D seismic blocks (short offset processing); and (2) *in situ* measurements and samples (3 Calypso and 2 Stacor long piston cores). The correlation of seismic reflectors with chronological information from long piston cores ($\delta^{18}O$ values and XRF-derived Ca profiles), shows that the upper-most 5 depositional sequences formed during the last ca. 500 kyr BP, in response to glacial/interglacial fluctuations driven by 100-kyr Milankovitch cycles and the subsidence rate for the late Quaternary period are around 300 m/Myr. The prograding wedges at the shelf break have distinct seismic facies with high-angle clinoforms building regional scale depositional sequences locally disrupted by growth faults. Although highly influenced by syndepositional deformation with thick accumulation in the hanging walls of growth faults, the main depositional sequence pattern is tuned with glacio-eustatic oscillations and the high-angle clinoforms near the shelf edge correspond to upper shorefaces/delta fronts or subaqueous deltas formed during glacial lowstand periods. The largest Mass Transport Complex in this zone is interpreted as resulting from oversteepening of the shelf edge during MIS 10.



## 1. Introduction

The study of continental margins with sequence stratigraphy greatly gained from the enhanced geophysical techniques deployed during the past two decades in response to intense offshore oil exploration. The introduction of systematic 3D and 4D surveys by oil companies (Hart, 1999) gave access to several academic institutions with high-quality datasets and new approaches such as seismic geomorphology (Posamentier et al., 2007). However, the subsequent studies have generally focussed on the entire sedimentary cover with a long time-scale approach, or on selected buried intervals (e.g., Bertoni and Cartwright, 2005; Ryan et al., 2009). The chronological significance of the imaged morphologies is often depicted within broad age ranges, hampering the possibility of tuning the very high frequency fluctuation of paleoenvironmental parameters visible in sediment cores with the structure of continental margins.

Recent studies about continental margin chronostratigraphy of Quaternary depositional sequences show how the imprint of global factors such as glacio-eustasy has been particularly marked in shaping continental margins (e.g., Berné et al., 2004; Rabineau et al., 2006; Ridente et al., 2008). However, relatively few studies integrate regional geomorphological study of the last quaternary sequences based on 3D seismic data with proxy analyzed of many cores in order to show impact of global factors (glacio-eustasy and syn-sedimentary deformation).

The continental margin offshore the Niger Delta deserves attention because it is one of the largest oil-bearing offshore provinces, it is a margin facing one of the largest river deltas of Africa and worldwide, active since the Eocene and contributing an impressive amount of sediment (Goudie, 2005) where the siliciclastic sedimentary units pile up with impressive thickness (up to 12 km, Doust and Omatsola, 1990) and are controlled by the interplay between sediment supply and syntectonic deformation (Corredor et al., 2005). The margin offshore Niger Delta, including the

* Corresponding author at: Ifremer GM-LES, BP70, 29280 Plouzané, France. Tel.: +33 298 224226; fax: +33 298 224570.
*E-mail address:* vincent.riboulot@ifremer.fr (V. Riboulot).

0025-3227/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.margeo.2012.03.002

subaqueous part of the delta, the continental slope and rise down to the abyssal plain, is named 'Niger Delta' by oil companies (e.g., Damuth, 1994; Corredor et al., 2005 among others), 'Niger Delta complex' (Oomkens, 1974) and 'Greater Niger Delta area' (Morley et al., 2011). In this paper, we use the term "Eastern Niger Submarine Delta" (ENSD) to describe the subaqueous sediment bulge situated at present in the prolongation of the modern delta plain.

The late Quaternary (term used for the interval between 0.781 Myr and present) sedimentary deposits architecture, in the ENSD has remained poorly known. In industry seismic records (Jermannaud et al., 2010), Quaternary units display cyclic patterns, suggesting a link with sea-level changes as observed in other continental margins, but their architecture is complicated by the presence of widespread sediment instabilities (e.g., Garziglia et al., 2010), syn-depositional growth faults (e.g., Hooper et al., 2002) and fluid escape features (e.g., Bayon et al., 2007; Sultan et al., 2007).

This study establishes a sound high-resolution chronostratigraphic framework for the Eastern Niger Submarine Delta (ENSD) allowing the reconstruction of sedimentary processes responsible for the observed geometries. The combination of conventional 3D seismics (in particular if re-processed for geohazard assessment of the uppermost 100–150 m below the seafloor) and scattered VHR 2D seismic lines allows to interpret the along-strike variability of depositional sequences in particular in areas affected by pronounced syndepositional deformation. The integration of morphological seafloor analysis with sedimentological and paleo-environmental data from piston cores,

**Table 1**
Source of Ifremer geophysical data used in this study. The campaigns Guiness1 and 2 were conducted in collaboration with Elf, the campaign Erig3D with TOTAL.

| Campaign | R/V | Year | Data used here | Tools |
|---|---|---|---|---|
| Guiness 1 | Atalante | 1992 | Swath bathymetry | Simrad EM12, frequency ≈ 13 kHz |
| Guiness 2 | Atalante | 1993 | 2D seismic profiles | Sparker source 250–1000 Hz |
| Erig 3D | Pourquoi pas? | 2008 | 2D seismic profiles | Sysif, deep-towed CHIRP source 650–2000 Hz |

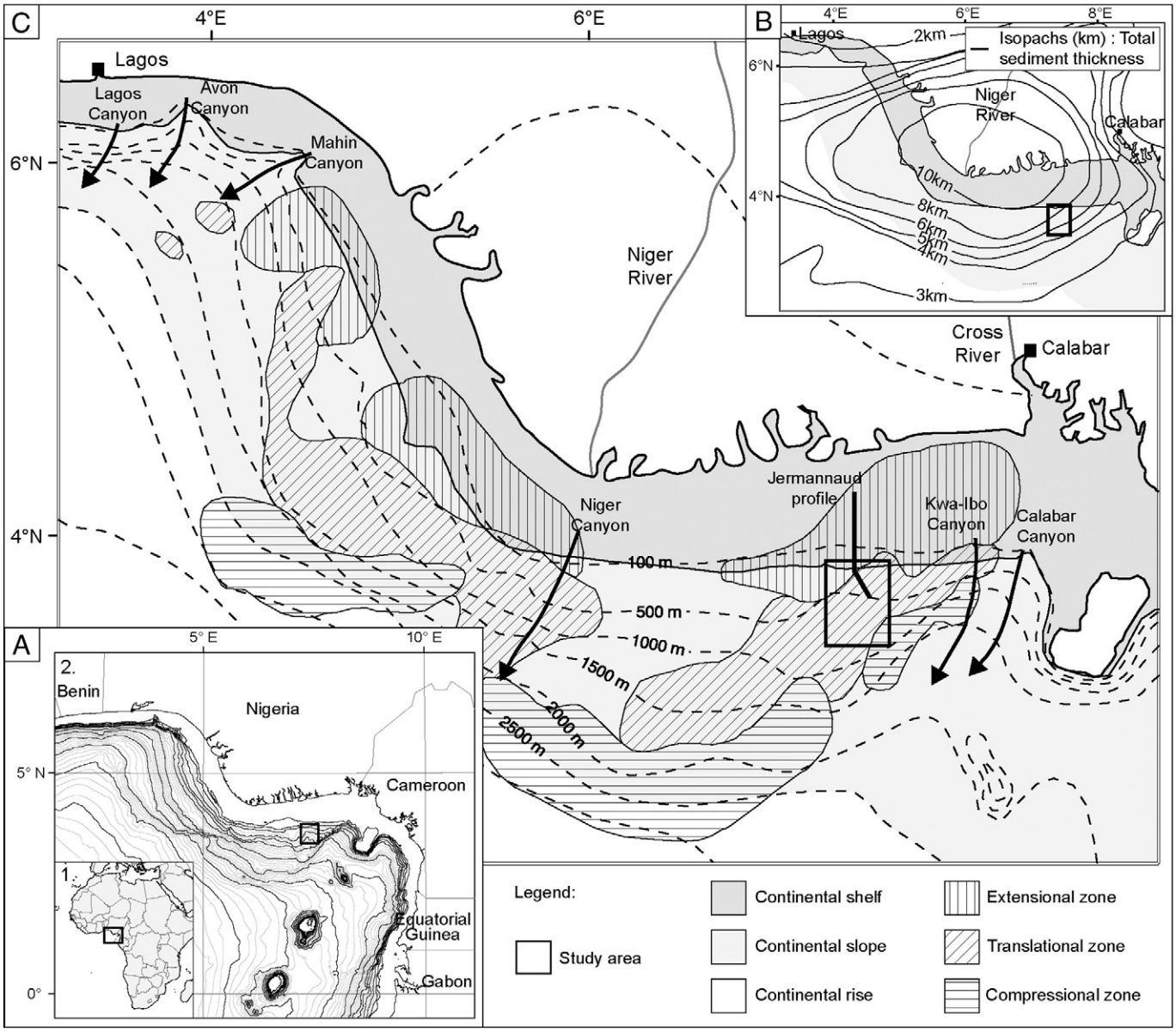


**Fig. 1.** A.1. Geographic location of the Gulf of Guinea. A.2. Gulf of Guinea general bathymetry map showing the location of the study area (bathymetric contours spacing is 100 m). B. Map of the total sediment filling in the "Niger Delta" (Kaplan et al., 1994). C. Regional distribution of structural styles created by gravity tectonics with regional location of physiographic domains (modified from Damuth, 1994) superposed on the bathymetric contours from Gebco data.