Palaeogeography, Palaeoclimatology, Palaeoecology xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

# Dinoflagellate cyst assemblages, biostratigraphy and paleoenvironment of a Paleocene-Early Eocene sedimentary succession in the northern Niger Delta Basin: Comparison with low, mid and high latitude regions

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ARTICLE INFO

*Article history:*
Received 26 December 2016
Received in revised form 11 May 2017
Accepted 12 May 2017
Available online xxxx

*Keywords:*
Alo-1 Well
Imo Formation
Nsukka Formation
Paleocene-Early Eocene
Dinoflagellate cysts
Nigeria

ABSTRACT

This study represents a contribution to the Late Paleocene-Early Eocene biostratigraphy in a low latitude stratigraphic setting where, published studies are few in comparison with mid- and high latitude regions. We generated data for 62 dinoflagellate cysts from a comprehensive analysis of 33 samples covering a 713-m interval in the Alo-1 Well in the northern Niger Delta (Anambra) Basin, Nigeria. Dinoflagellate cyst recovery in the samples varies from very good to poor, and the specimens are commonly well preserved. We calibrate the dinoflagellate cyst data with recent biozonation schemes for ODP Hole 959D, Côte d'Ivoire-Ghana Transform Margin in the eastern Equatorial Atlantic, which allowed for a valid comparison with published studies in well-dated rock sections in northwestern Europe, the Mediterranean region, New Zealand, and Tasmania. Our observations show that there is better correlation between tropical and mid latitude dinoflagellate cyst assemblages compared to those in high latitude regions.

We use the last occurrence and/or last abundance events of dinoflagellate cysts to identify four biostratigraphic zones (zone E to zone H) in the Alo-1 Well. Lithostratigraphic and biostratigraphic analyses suggest a late Selandian age for the contact between the Imo and Nsukka formations. Abundant thermophilic taxa that include the *Cordosphaeridium* group and *Apectodinuim* dominate the assemblage recovered in the depositional succession. The late Selandian to early Thanetian sediments are dominated by the *Cordosphaeridium* group, and are succeeded by abundant to superabundant marker species of *Apectodinium* in the late Thanetian to Ypresian. The superabundance of *Apectodinium* is significant because it is indicative of the global intense climatic warming that characterized the late Thanetian to early Ypresian. The Alo-1 Well dinoflagellate cyst data also suggest deposition under proximal, inner neritic conditions that preserved an assemblage dominated by species of *Cordosphaeridium*, *Damassadinium*, *Ifecysta* and *Polysphaeridium*.

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## 1. Introduction

The Early Paleogene represents a highly dynamic period in Earth's history that was associated with globally elevated temperatures, significant evolutionary turnovers, and extinctions in the marine and terrestrial biota (Crouch, 2001; Zachos et al., 2008; Sluijs et al., 2006; McInerney and Wing, 2011). The sea surface temperatures (SST) of mid and high latitudes during the Paleocene-Eocene Thermal Maximum (PETM) were almost equivalent to the modern tropical values (24–29 °C), while the equatorial regions were extremely warm (>35 °C; Frieling et al., 2017). The presence of warm-water pelagic marine organisms, as well as vegetation and soil types suggest that the high latitudes in both hemispheres were warm (Wing and Greenwood, 1993; Sluijs and Brinkhuis, 2009).

Palynology is an important branch of paleontological sciences that studies the organic microfossils preserved in sedimentary rocks such as pollen, spores, dinoflagellate cysts and acritarchs. Some of the important applications for this science are determining relative ages, reconstructing paleoenvironmental and paleoclimatic conditions, and identifying and correlating rock sequences. Palynological studies of the Early Paleogene in tropical regions are not as substantial as those from mid- to high latitudes. Lack of information on palynological studies from tropical regions is due to poorly preserved environmental settings (e.g., stratifiled lakes, good outcrop exposures) and the confidentiality associated with acquiring data from the petroleum companies exploring in the such regions, including the Niger Delta.

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http://dx.doi.org/10.1016/j.palaeo.2017.05.020
0031-0182/Published by Elsevier B.V.

Tropical palynological studies have focused mainly on the analyses of pollen and spores (sporomorphs) for relative dating and reconstructing paleoenvironmental, paleogeography, paleoclimatology conditions, and floral evolution (e.g., Germeraad et al., 1968). In spite of the attributes noted above, pollen and spores are not commonly used for defining or constraining the standard geologic timescale for the Paleogene (Gradstein et al., 2012). The timescale is defined mainly by calcareous marine microfossils such as planktonic foraminifera and coccolithophorids. Organic-walled dinoflagellate cysts are preserved in nearshore sediments and they are incorporated into the more recent timescale (Gradstein et al., 2012). Applications of dinoflagellate cysts have been successful in the Paleogene biostratigraphic and paleoecologic studies of mostly mid and high latitudes (e.g., Crouch, 2001; Sluijs et al., 2005; Sluijs and Brinkhuis, 2009; Crouch et al., 2014) because they provide paleoecological information about relative variations in salinity, productivity (nutrient enrichment), and relative sea-surface temperatures in coastal and neritic settings (Dale et al., 2002) Furthermore, they are often preserved alongside spores and pollen, thereby providing a tool for correlating sediments from near-shore to slope depositional settings (Traverse, 2007).

It is clear that there is an apparent scientific research gap for further palynological study in tropical regions. Dinoflagellate cyst data offer the opportunity for biostratigraphic dating as well as the interpretation on the extraneous drivers controlling their distributions. Therefore, the availability of ditch cutting samples from a nearly continuous succession in Alo-1 Well in the northern Niger Delta (Anambra Basin), Southeast Nigeria provides the opportunity to study the following objectives: (1) to establish the biostratigraphic zonations in the well and calibrate them with the ODP Hole 959D; (2) to interpret the paleoenvironmental settings of the studied interval and relate the zonations to the depositional environment; and (3) to compare the dinoflagellate cyst composition with those from other low latitude regions and mid and high latitude areas.

## 2. Geologic setting

The Southern Nigeria sedimentary basin comprises the southern Benue Trough, Niger Delta (which now includes the Anambra Basin; Nwajide, 2013), Benin Embayment, Abakaliki Fold Belt, Afikpo Syncline, and the Calabar Flank (Fig. 1). The depositional and tectonic histories of the basin are related to the tectonic stages and epeirogenic movements

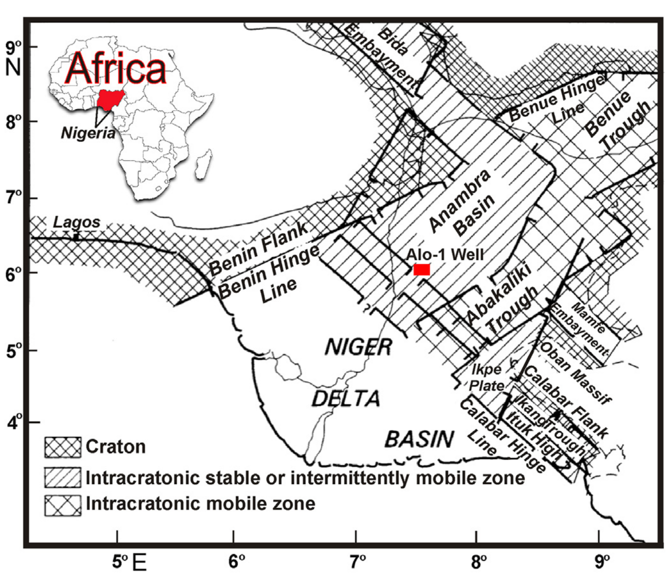


**Fig. 1.** Map of Southern Nigeria showing the location of Alo-1 Well in the Anambra Basin and megatectonic frame of southern Nigeria sedimentary basin (modified from Reijers et al., 1997). Inset shows the location of Nigeria in West Africa.

associated with the separation of the African and South American continents during the Early Cretaceous (Murat, 1972; Burke, 1996).

### 2.1. Tectonics

The tectonic and structural framework of the northern Niger Basin (Anambra Basin) is controlled by a much larger and older tectonic feature, the Benue Trough (Late Jurassic to Early Cretaceous), which is a northeast-southwest folded rift basin (Fig. 1) representing the failed arm of an aulacogen that runs diagonally across Nigeria. The Benue Trough formed simultaneously with the opening of the Gulf of Guinea and the Equatorial Atlantic in Aptian-Albian times, when the equatorial part of Africa and South America began to separate (Reijers et al., 1997). Taphrogenic subsidence along fundamental transform faults cut through the lithosphere and are the landward continuations of the Chain and Charcot oceanic fracture zones initiated the Benue Trough (Emery et al., 1975). These faults subsequently controlled the location of the main axis of subsidence of the resultant basins (Reijers et al., 1997). The Chain Fracture Zone coincides with the Benin Hinge Line of the western Benue Trough, whereas the eastern portion of the trough, which is referred to as the Calabar Flank (Reijers, 2011), is more complicated. The Calabar Flank comprises northwest-southeast tending structures known as the Ikang Trough, Ituk High, and Calabar Hinge Line (Fig. 1). Sinistral transcurrent shearing along the fracture zones caused deformation in the Benue Trough and modified the Gulf of Guinea continental margin from the simple pull-apart basement structures with half-grabens underlying the West African continental margins north and south of the Gulf of Guinea (Reijers et al., 1997; Reijers, 2011).

Murat (1972) proposed three tectonic phases in the stratigraphic evolution of the region during which the axis of the main basin shifted and gave rise to three successive basins. These three phases were: (1) the Abakaliki-Benue phase (Aptian-Santonian), (2) the Anambra-Benin phase (Campanian-mid Eocene), and (3) the southern Niger Delta phase (Late Eocene-Pliocene).

Phase 1 (Abakaliki-Benue) commenced during the middle Albian after major northeast-southwest movements caused the faulting that resulted in the rift-like Abakaliki-Benue Trough. Shelf deposits were laid down on the Anambra Platform between the Calabar and Benin hinge lines and the trough.

Phase 2 (Anambra-Benin) was characterized by compressional movements along the established northeast-southwest trend, which resulted in the folding and uplifting of the Abakaliki-Benue Trough during the late Santonian to early Campanian, and in the formation of the Anambra Basin. The adjoining Benin Flank basement underwent a transgression that lasted until the Early Eocene.

Phase 3 (southern Niger Delta) was initiated by a regression during the Middle and Late Eocene. Vertical movements of blocks bounded by northeast-southwest and northwest-southeast trending faults resulted in the deposition of a large deltaic complex in the down-dip Anambra Basin. This, however, preceded the subsidence of the Oligocene to Recent Niger Delta Basin along the northwest-southeast fault trend.

### 2.2. Stratigraphy and sedimentology

The Paleogene time in southeastern Nigeria is represented by a sedimentary succession that is thicker than 3500 m (Fig. 2). These deposits are divided into the Nsukka Formation (~350 m), Imo Formation (~1000 m), Ameki Group (~1900 m), and Ogwashi-Asaba Formation (~250 m) (Oboh-Ikuenobe et al., 2005). The Imo, Ameki and Ogwashi-Asaba, which were previously considered outcrop equivalents of the subsurface units of the Niger Delta, have now been formally assigned to the Niger Delta territory (Nwajide, 2013).

The Nsukka Formation overlies the Ajali Sandstone. The lowermost part of the Nsukka Formation comprises coarse to medium grained sandstones, which change upward into well-bedded blue clays, fine-grained sandstones, and carbonaceous shales with thin bands of