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Biostratigraphy and Paleoenvironment of *Bolivina* Fauna from the Niger Delta, Nigeria

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Abstract

A rich *Bolivina* assemblage occurs in the onshore Tonjor-1 well of Niger Delta; eighteen species are reported for the first time. Some index planktonic foraminifera allowed a late Early Eocene age assignation, in addition to some *Bolivina* species that are known to be restricted to samples from the studied intervals. The *Bolivina* species recovered permits the subdivision of the succession into one taxon and interval range zones respectively and two concurrent subzones. The interval zone is *Bolivina ottaensis* Reyment; while the taxon zone is *Bolivina attenuata* Cushman. The concurrent sub-zones are *Bolivina foliacea* Sellier de Civrieux and *Bolivina jacksonensis* Cushman and Applin. The planktonic foraminifers associated with the bolivinids are namely, *Acarinina pentacamerata* (subbotina), *A. psuedotopilensis* (Subbotina), *Pseudohastigerina wilcoxensis* (Cushman and Ponton) and *Globigerina officinalis* Subbotina which permits the late Early Eocene dating of these zones. Stratigraphic diversity variation of the bolivinds allowed the recognition of late Early Eocene marine transgression which correlates with the global timing of Early Eocene transgression. The presence of strong costae, and larger test suggests a deposition in a well oxygenated slope to bathyal environment.

Keywords: Bolivinids, Niger Delta, Agbada, Gulf of Guinea, planktonic foraminifera, first occurrence datum (FAD), last occurrence datum (LAD)

1. Introduction

The Niger Delta basin is situated in the Gulf of Guinea, Central West Africa, into which it progrades (Figure 1). The delta is considered one of the most prolific hydrocarbon provinces in the world hosting giant oil fields both onshore and offshore. Hydrocarbon exploration in the Niger Delta dated back to 1950's. This exploration and other investigation have contributed to documented stratigraphic and micropaleontologic data base for the region. Researches in micropaleontology has gained importance owing to increase in exploration for hydrocarbons. The petroleum industry in Nigeria have described and adopted informal zonation which is largely unpublished (Evamy et al., 1978). Benthonic foraminiferal assemblages of the Niger have been extensively published, however, the documentation of *Bolivina* has remain unsatisfactory. Petters (1982) reported 5 *Bolivina* species; Brun et al. (1984) reported less than ten. Subsequently, the oil industry identified about fifteen bolivinids to generic level.

The aim of this paper is to present a glimpse of the rich *Bolivina* assemblage by establishing biostratigraphic zonation and assess their palaeoenvironmental significance.

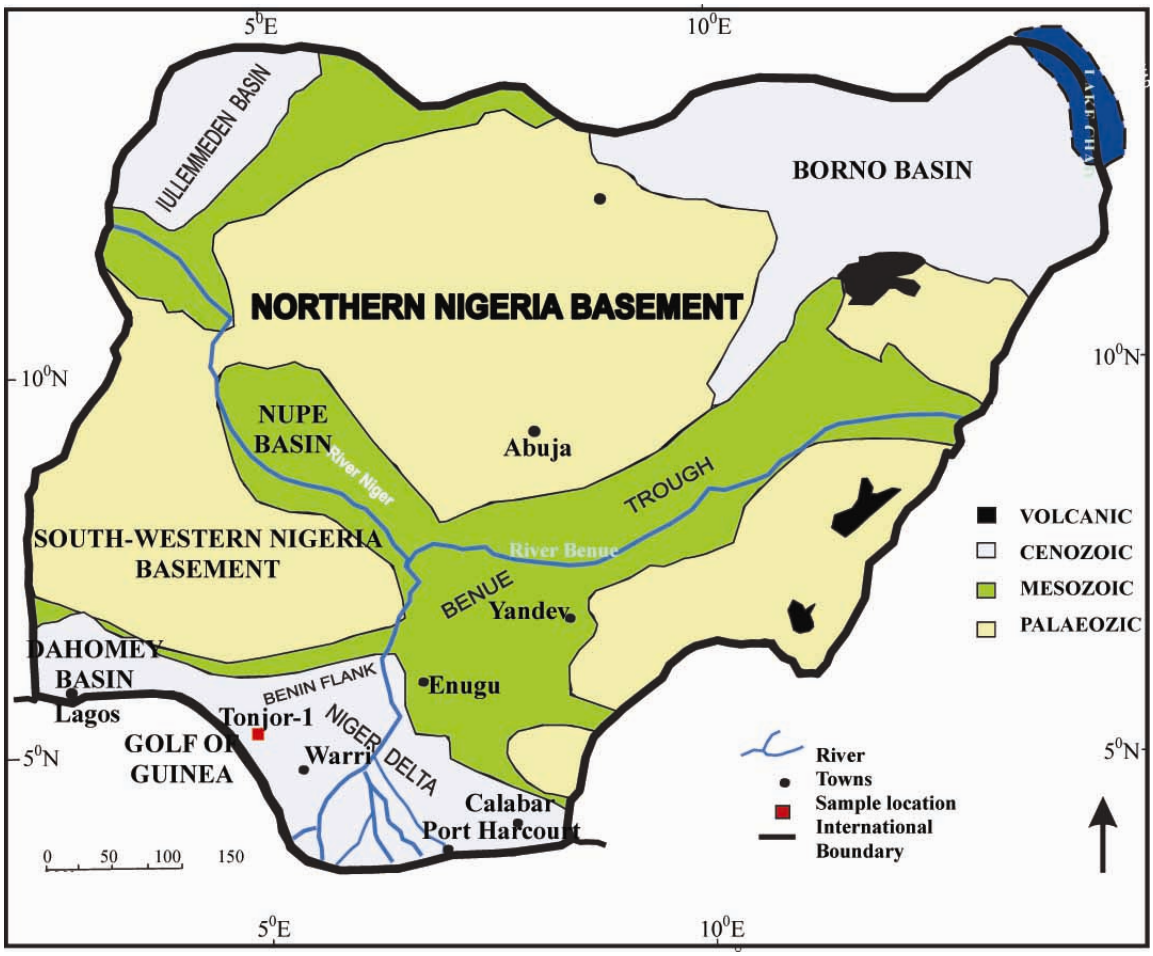

Figure 1. Geological map of Nigeria showing sample locations (Modified from Geological Survey of Nigeria, 1974)

2. Geological Setting

The geometry of the Niger Delta is controlled by the Chain and Charcot Fracture Zones of the Equatorial Atlantic Ocean (Emery et al., 1975). These zones confined clastic fill reaching some 12,000 m in thickness, the break-up of the central African – South American part of Gondwana took place along rift zones that met in a triple junction in the area of the Gulf of Guinea now occupied by the Niger Delta (Burke et al., 1971; Weber & Daukoru, 1975; Whiteman, 1982). The area which followed the Equatorial and South Atlantic Ocean margins developed into the oceans, whereas the third, failed arm is represented by the Benue Trough.

During the rift phase the first sediments of the Cretaceous to Tertiary cycle accumulated. The oldest of these has been dated as Albian (Doust & Omatsola, 1989). Thick successions of marine and marginal marine clastics and carbonates were deposited in a series of transgressive and regressive phases from Cretaceous to Tertiary (Murat, 1972; Weber & Daukoru, 1975; Stoneley, 1966, Short & Stauble, 1967). Vertical sections through the Niger Delta shows three units that are regarded as successive, diachronous prograding depositional facies namely the Akata, Agbada and Benin formations (Avbobvo, 1978; Evamy et al., 1987; Doust & Omatsola, 1989; Kulke, 1995; Figure 2). The Akata Formation is composed of thick shale sequences and may contain south turbidite sands. The Agbada Formation consists of paralic siliclastics. The Benin Formation is composed of continental deposits.

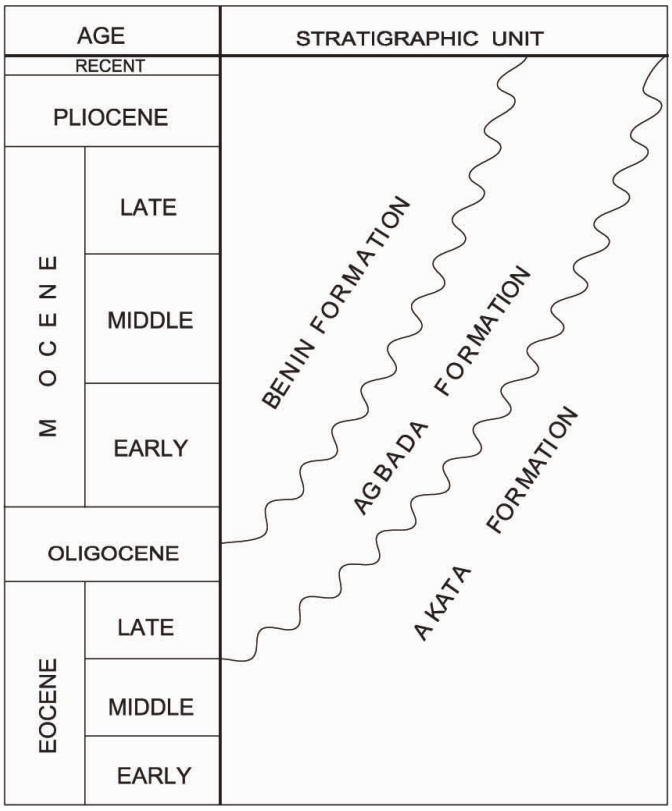

Figure 2. Stratigraphic units in the Niger Delta and their ages
(Modified from Short & Staube, 1967; Schumberger, 1985)

3. Materials and Methods

Ditch cuttings for the study were available from 2385 to 2535 m from Tonjor-1 well drilled by Phillips Oil Company of Nigeria. Seventeen ditch cutting samples were processed for their foraminiferal content, using standard micropaleontological techniques (Pessagno, 1967; Zingula, 1968; Brasier, 1980). Samples were disaggregated by heating in a solution of sodium carbonate and distilled water, then were wet-sieved through a 63-micron (230-mesh) sieve, to retain foraminifera. Sieved samples were dried in an oven set at 60°C. Samples were examined on a micropaleontological picking tray with a Fisher Scientific binocular microscopic. Digital photomicrographs were taken with a Nikon SMZ 1500 binocular stereomicroscope.

The bolivinids were mounted on microfossils slides and sorted into recognizable species. The quality of preservation of the specimens is good which made it possible to determine species ranges. Loeblich and Tappan (1987) generic classification was followed for generic assignment. Identification at the species level are based on Sellier de Civrieux (1976), Petters (1982), Bolli et al. (1994), Jones (1994) and Ellis and Messina Catalogue (Online version; http://www.micropress.org). Taxonomic descriptions of the bolivinids mentioned in this article are not presented here. All original species descriptions have been checked in the Ellis and Messina catalogue.

4. Lithostratigraphy

The section from Tonjor-1 well contains a single lithostratigraphic unit, the Agbada Formation. The available thickness of sediments belonging to the formation is 180m. The formation is characterized by a grey shale with sandy levels (Figure 3).

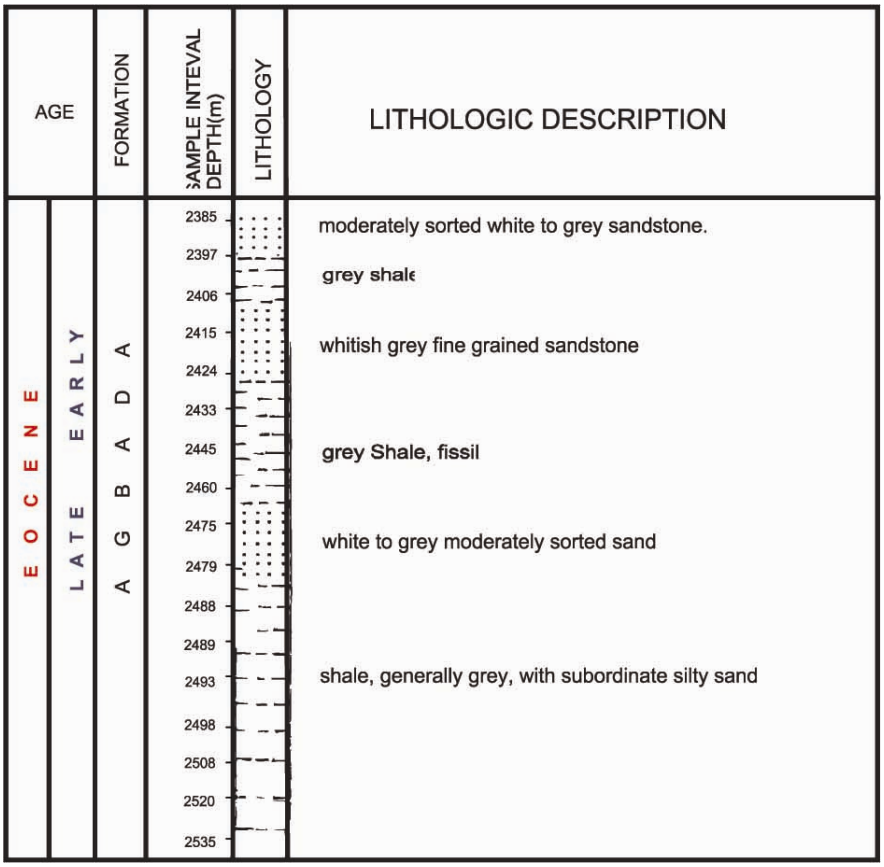

Figure 3. Lithostraigraphy of Tonjor-1 well

5. Bolivina Fauna

The microfaunal character of forms is indicated by a fairly abundant bolivinids and sparse planktonic foraminifera. Planktonic foraminifera were used as controls in constraining the stratigraphic ranges of the bolivinids. A total of twenty-three species of *Bolivina* were identified, out of which eighteen are reported for the first time. Species reported for the first in the Niger Delta are: *Bolivina midwayensis* Cushman, *B. striatella* Cushman, *B. jacksonensis* Cushman and Applin, *B. inflata* Heron-Allen and Farland, *B. paralica* Perconig, *B. foliacea* Sellier de Civrieux, *B. britannica* MacFadyen, *B. beyrichi – carinata* Hantken, *B. sulphurensis* Cushman and Adams, *B. attenuata* Cushman, *B. bituminosa* Spandel, *B. crenulata* Cushman, *B. ignara* Cushman and Stone, *B. danvillensis* Howe and Wallace, *B. simplex* Cushman and Renz, *B. aenariensis* (Costa), *B. caudriae* Cushman and Renz, *B. imperatrix* Graham de Klasz and Rerat. Stratigraphic distribution chart of these bolivinid species is presented in Figure 4 and steromicrographs of bolivinids and planktonic species are presented in Figures 6-8.

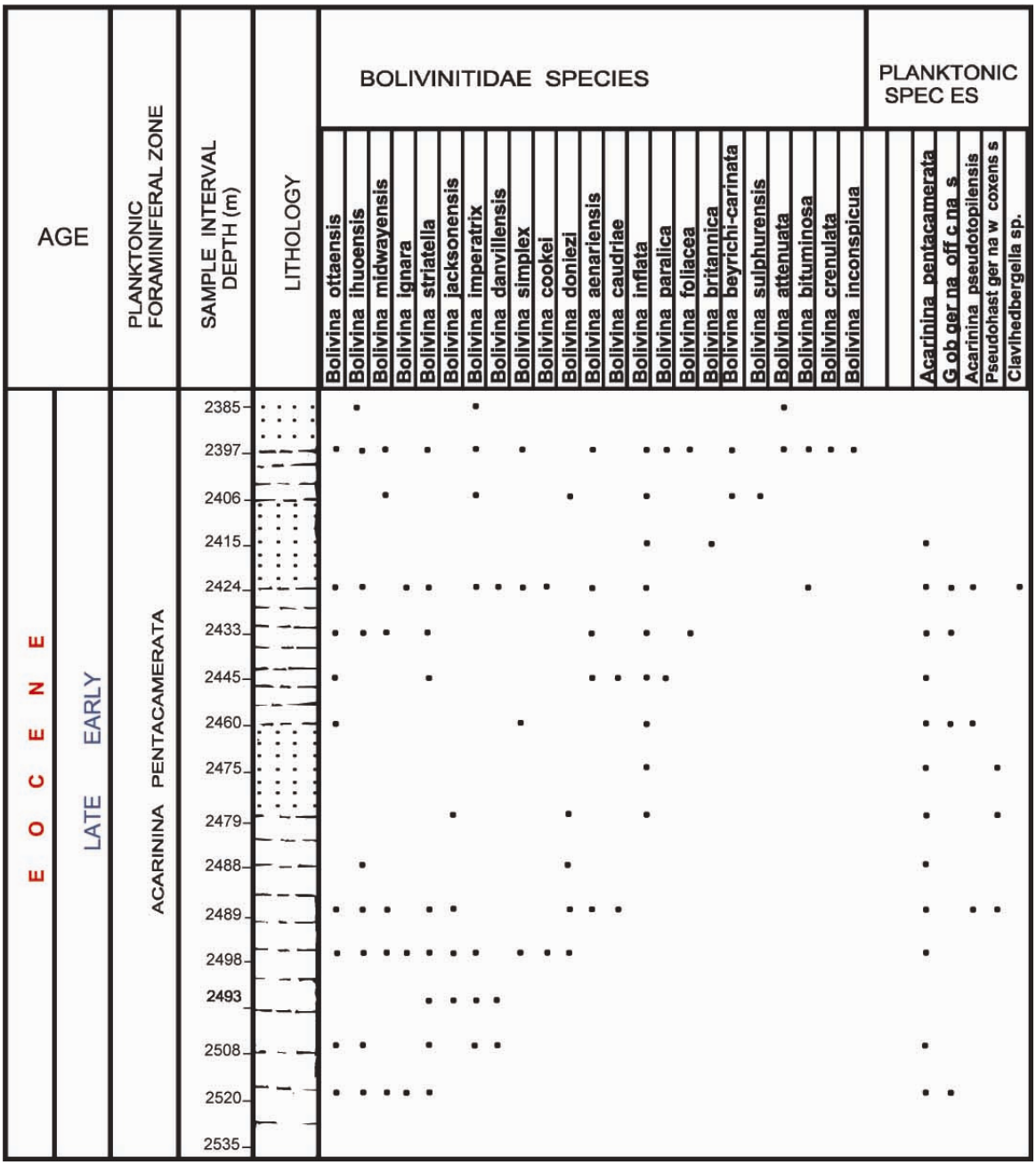

Figure 4. Stratigraphic distribution chart of Bolivina and planktonic foraminiferal species

6. Biostratigraphy

Benthonic foraminifera, which the *Bolivina* belong to are generally long-ranged. However, some of the bolivinid species recovered from Tonjor-1 well are stratigraphically restricted. Those planktonic foraminiferal species that are age diagnostic were used for stratigraphical controls.

The analysis of the bolivinids was carried out using standard biostratigraphic methods and biozones distinguished according to the International Stratigraphic Guide (Hedberg, 1976; Murphy & Salvador, 1999). The stratigraphic range of the species are illustrated in Figure 5. The following biozones are proposed for the Tonjor-1 well.

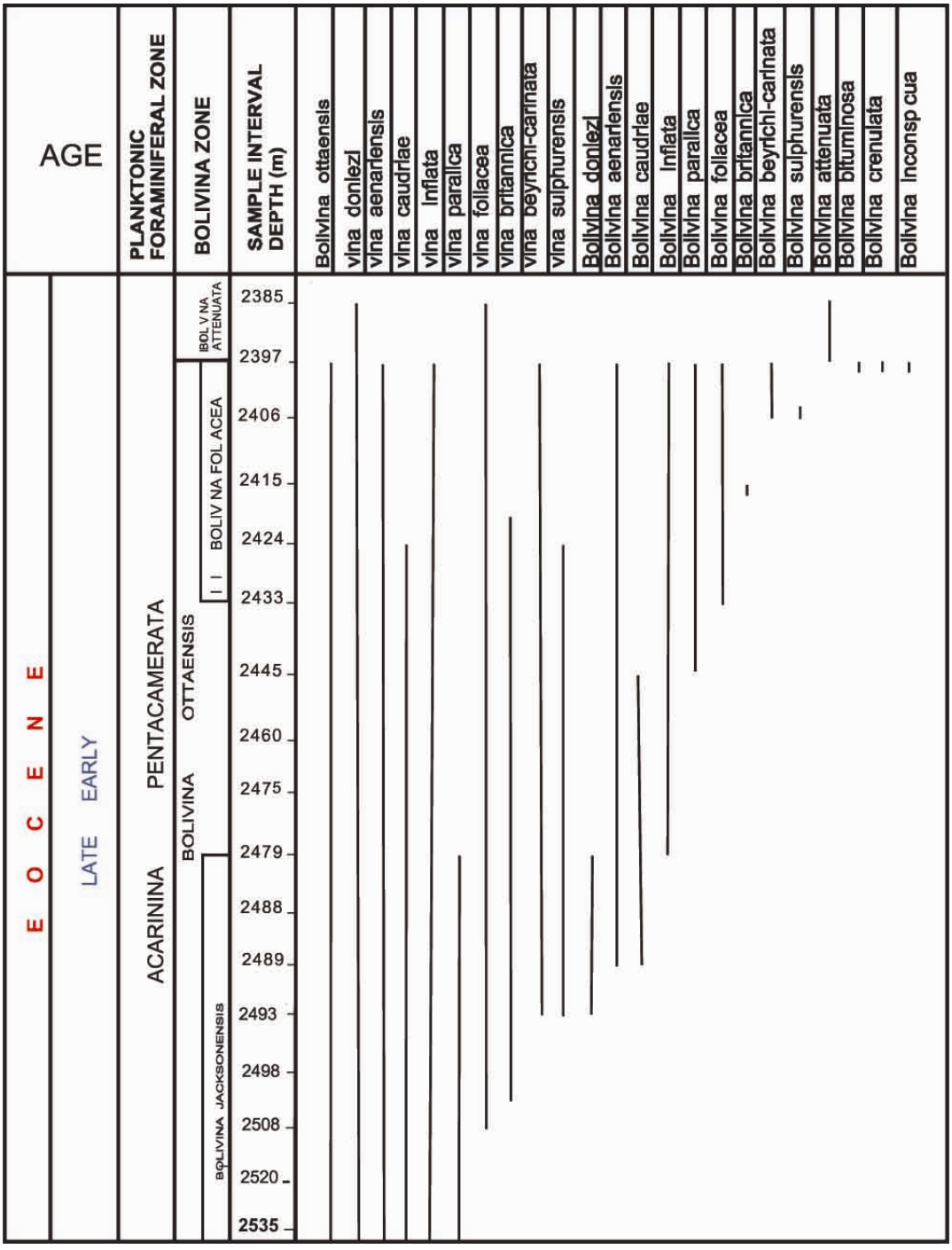

Figure 5. Range chart of Bolivina species in Tonjor-1 well

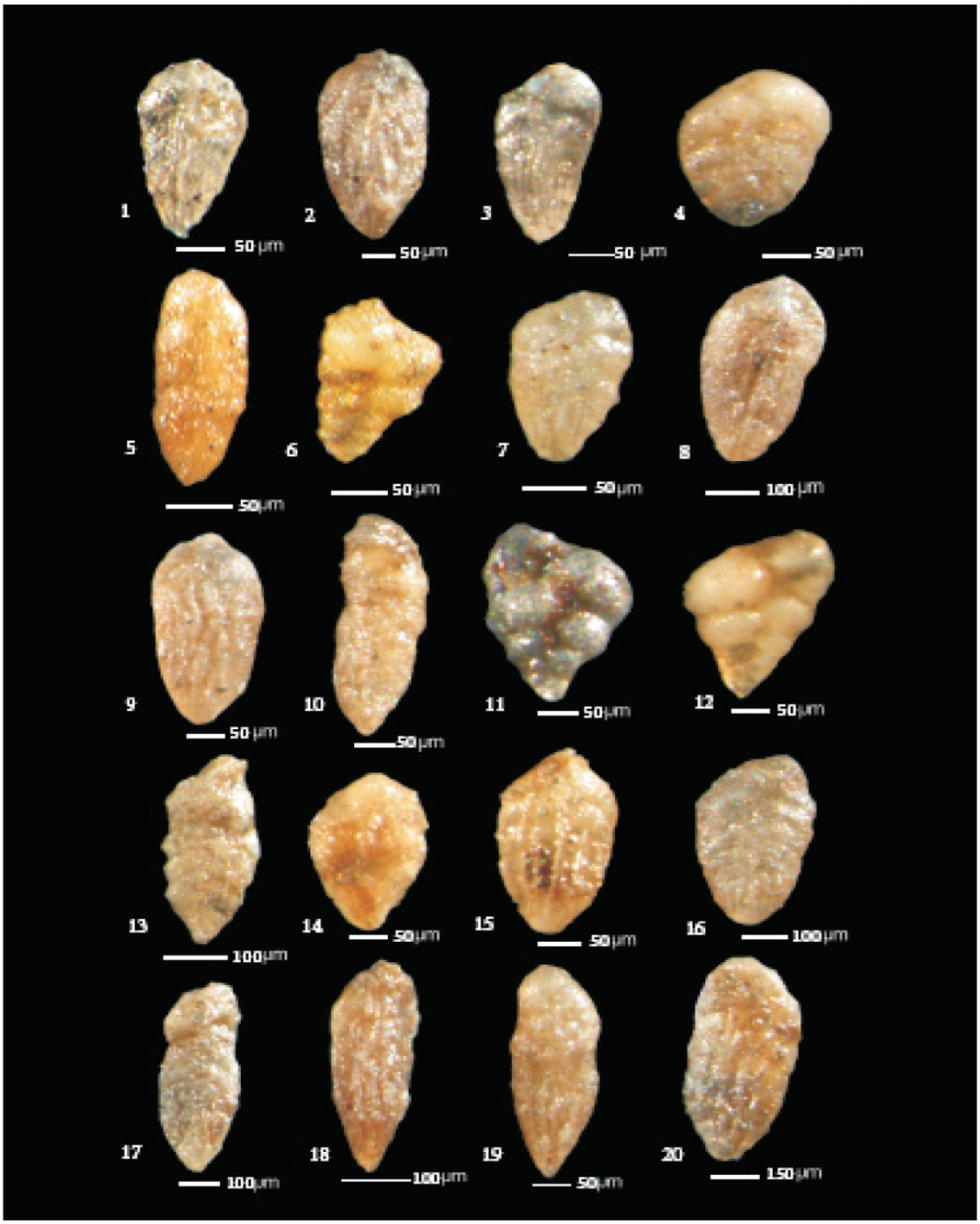

Figure 6. **1**) *Bolivina crenulata*; **2, 19**) *Bolivina ottaensis*; **3**) *Bolivina bituminosa*; **4**) *Bolivina attenuata*; **5**) *Bolivina sulphurensis*; **6**) *Bolivina britannica*; **7**) *Bolivina jacksonensis*; **8**) *Bolivina caudriae*; **9**) *Bolivina danvillensis*; **10**) *Bolivina striatella*; **11 & 12**) *Bolivina inflata*; **13**) *Bolivina paralica*; **14**) *Bolivina doniezi*; **15**) *Bolivina inconspicua*; **16**) *Bolivina simplex*; **17**) *Bolivina midwayensis*; **18**) *Bolivina beyrichi carinata*; **20**) *Bolivina cookie*

Figure 7. **1, 5, 6**) *Bolivina ottaensis*; **2**) *Bolivina foliacea*; **3**) *Bolivina aenariensis*; **4**) *Bolivina imperatrix*

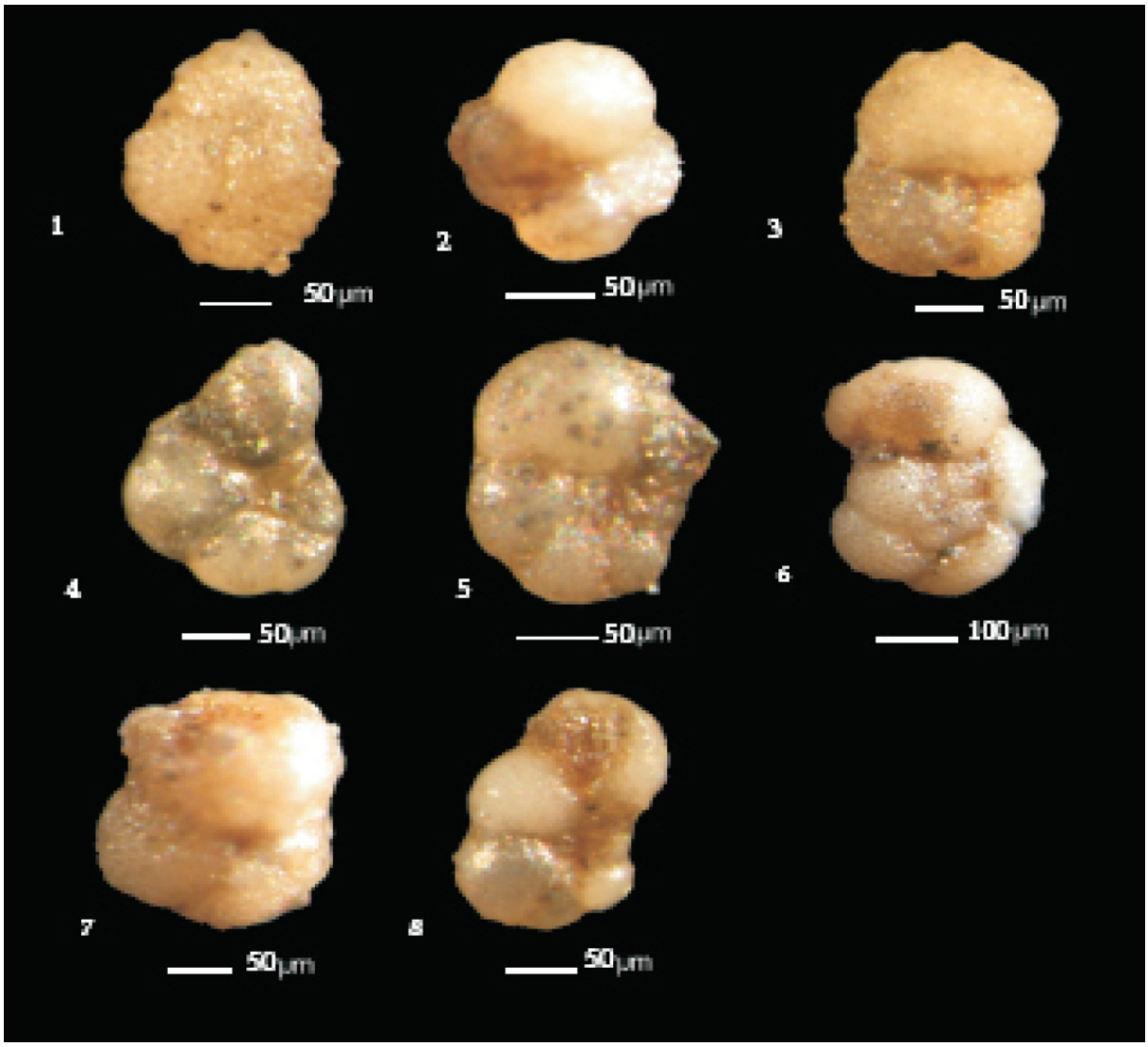

Figure 8. **1 & 2**) *Acarinina pentacamerata*; **3**) *Globigerina officinalis*; **4**) *Clavihedbergella* sp.; **5 & 6**) *Acarinina pseudotopilensis*; **7**) *Pseudohastigerina wilcoxensis*; **8**) *Pseudohastigerina wilcoxensis*

i) *Bolivina ottaensis* Interval zone
   a) *Bolivina foliacea* Concurrent-range-subzone
   b) *Bolivina jacksonensis* Concurrent-range-subzone

ii) *Bolivina attenuata* Taxon range zone

1) ***Bolivina ottaensis*** Interval-Zone

The base of this zone is defined by the first appearance datum (FAD) of *Bolivina ottaensis* (Figure 5). The top is marked by the first appearance of *Bolivina attenuata*, which also coincides with the bioevent (appearance and disappearance) of *Bolivina bituminosa, Bolivina crenulata* and *Bolivina inconspicua*, an event that may be due ecologic factors. Species restricted to this zone are: *Bolivina ottaensis, B. midwayensis, B. ignara, B. striatella, B. jacksonensis, B. doniezi, B. foliacea, B. britannica, B. beyrichi-carinata, B. sulphurensis, B. bituminosa, B. crenulata* and *B. inconspicua*. The following species appear in this zone but range upward into the next zone: *Bolivina ihuoensis, B. imperatrix, B. danvillensis, B. simplex, B. cookie, B. aenariensis, B. caudriae, B. inflata,* and *B. paralica*. The association of these bolivinids with *Acarinina pentacamerata, A. pseudotopilensis* and *Pseudohastigerina wilcoxensis* suggests a late Early Eocene age for this zone and correlates with the *Acarinina*

pentacamerata zone (Blow 1969; Stainforth et al., 1975; Petters, 1983). *A. pseudotopilensis* has received a widespread recognition as a zonal index for Early Eocene (Subbotina, 1947; Loeblich & Tappan, 1957; Jenkins, 1971). The appearance of *Pseudohastigerina wilcoxensis* was used to define the base of Eocene (Berggren, 1971). *Globigerina officinalis* has a known range of Eocene to Oligocene (Subbotina, 1953). This zone is represented in the Agbada Formation penetrated by the Tonjor-1 well at depths between 2397 and 2535 m.

2) ***Bolivina jacksonensis*** Concurrent Sub-Zone

The FAD of *Bolivina jacksonensis* marks the base of this zone. The top is coincident with the LADs of two species which are restricted to the sub-zone, namely the

concurrent part of the ranges of *Bolivina doniezi* and *Bolivina jacksonensis* (Figure 5). This sub-zone embraces the Agbada Formation between depths of 2479 and 2535m in the Tonjor–1 well. The sub-zone is dated late Early Eocene based on the presence of the planktonic foraminifer, *Acarinina pentacamerata*.

3) ***Bolivina foliacea*** Concurrent Sub-Zone

The base of the sub-zone is recognized by the FAD of *Bolivina foliacea*. The top is coincident with the LADs of several species which are restricted to this zone, namely the concurrent part of the ranges of *Bolivina foliacea, B. bituminosa, B. crenulata, B. sulphurensis, B. inconspicua, B. britannica* and *B. beyrichi-carinata* (Figure 5). This sub-zone occurs within the Agbada Formation between depths of 2397 and 2433 m in the Tonjor-1 well and is of late Early Eocene based on the associated planktonic foraminifer, *Acarinina pentacamerata*.

4) ***Bolivina attenuata*** Taxon Range-Zone

The zone is marked by the entire occurrence of *Bolivina attenuata*; base of this zone is marked by the FAD of *Bolivina attenuata* which coincides with the top of the *Bolivina ottaensis* interval-zone and with the bioevent (sudden appearance and disappearance) of *Bolivina bitumunosa, Bolivina crenulata* and *B. inconspicua*. The top of the zone is marked by the lowest occurrence of the species. Species restricted to this zone is *Bolivina attenuata*. This zone has a probable range within limits of late Early Eocene. The *Bolivina attenuata* Taxon - zone embraces the Agbada Formation between depths of 2385 to 2397 m.

7. Paleoenvironment

Bolivinid assemblages from Tonjor-1 well were examined to determine the depositional environment. Paleoenvironmental interpretations, mainly bathymetric and oxygenation levels determined in this study are based upon comparison of morphological features with recent analogues. Bolivinid species diversity is qualitatively applied to interpret changes in sea level.

7.1 Bathymetry

Morphological comparisons of forms have allowed a broad categorization of bathymetry in the studied well. Smith (1963) noted that bolivinid faunas found in slope environments generally show larger test sizes compared to those of the inner neritic zone. Bandy (1960) also reported that costate bolivinids become dominant in the outer shelf and upper bathyal zones. Other characters exhibited by bathyal species are coarse perforations, strong striae and heavy limbation. Costae paralleling the longitudinal axis occur in forms occupying the outer neritic and much of the bathyal zone.

Bolivinid species from the Eocene in the studied well (Tonjor-1) consist of forms that have dominantly large tests adorned with costae. Bolivinids in this category are *Bolivina ottaensis, Bolivina ihuoensis, Bolivina imperatrix, Bolivina simplex, Bolivina striatella, Bolivina ignara, Bolivina foliacea, Bolivina inconspicua,*. These species probably habited slope to bathyal water.

7.2 Oxygen

Lutze (1962; 1964) studied *Bolivina spissa* Cushman, *Bolivina pseudobeyrichi* Cushman and *Bolivina argentea* Cushman, all benthic foraminiferal species living off the coast of southern California. He demonstrated that within one species there may be great variation in width/length ratios, in the development of costae, in the length of an apical spine, in the amount of sutural limbation, in the proportion of pore free areas on chambers, in imbrications of chambers and in the development of keeled edges. He considered one of the primary controlling factors to be the level of oxygen concentration in the bottom water of basins. High oxygen levels were associated with the secretion of more surface sculpture, such as more spines, more costae or larger keels, whereas very low oxygen concentrations resulted in the marked reduction or absence of many kinds of surface sculpture.

The Eocene specimens from the studied intervals have well developed costae, limbation, keels and carinae which suggest that the environment was well oxygenated.

7.3 Sea Level

Stratigraphical variation in foraminiferal species diversity was considered to indicate changes in sea level by Walton (1964). Petters (1983) recognized that major transgressive peak occurred in Early Eocene of the Gulf of Guinea based on planktonic foraminifera fauna. The occurrence of planktonic foraminiferal species associated with bolivinids of Tonjor-1 in this study correlate the influence of Early Eocene transgression in the Niger Delta region. A bolivinid major diversity peak (Figure 9) correlate the timing for the transgressive phase in the Niger Delta with the global Early Eocene transgression.

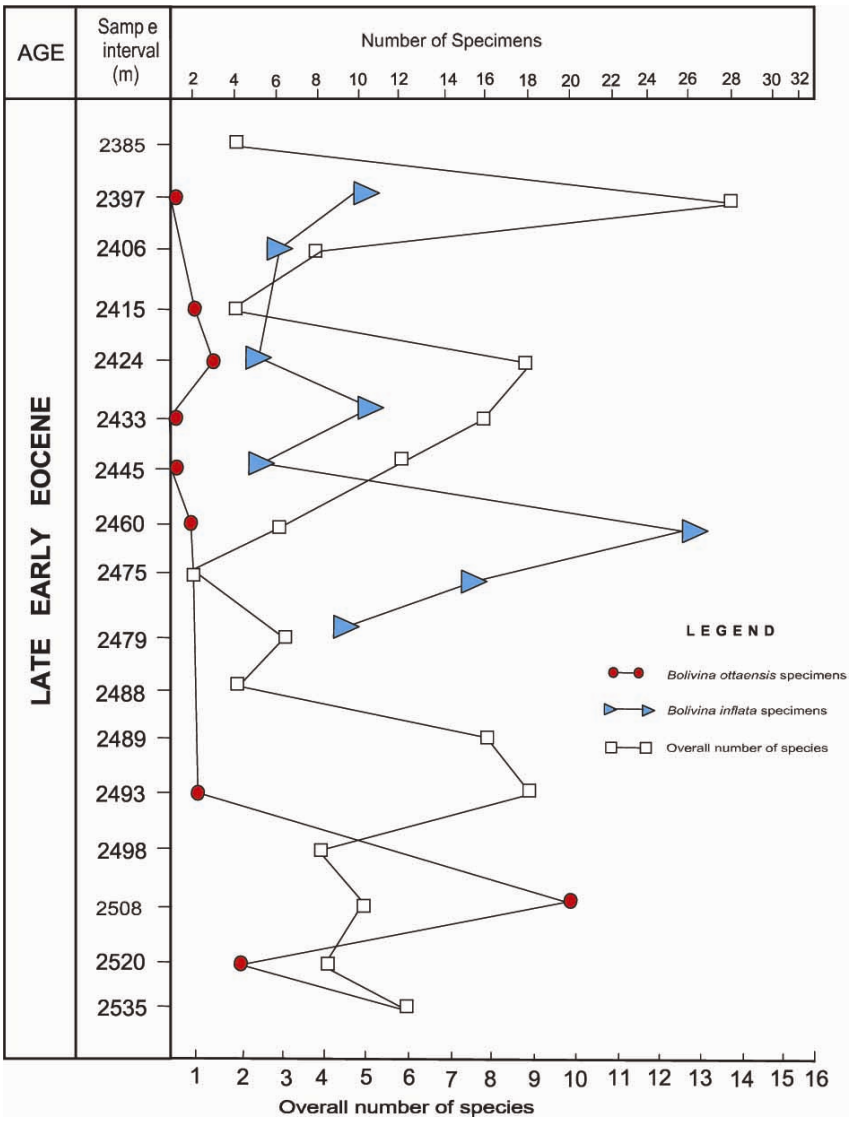

Figure 9. Abundance of Bolivina Species in Tonjor-1 well

8. Conclusion

Foraminifers belonging to the family Bolivinitidae in the Niger Delta basin, Nigeria have allowed the subdivision of late Early Eocene succession into interval range zone, *Bolivina ottaensis*; taxon zone, *Bolivina attenuata*, and 2 concurrent sub-zones, *Bolivina foliacea* and *Bolivina jacksonensis*. Eighteen species of *Bolivina* are reported for the first time in the Niger Delta basin.

Heavily costate ornamentations on the test of the bolivinids suggest deposition in water depth ranging between slope to bathyal under a well oxygenated condition. Bolivinid species diversity permits the recognition of regional Early Eocene transgression.

Acknowledgement

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