Western Nigerian continental shelf, morphology, sediment pattern and Holocene transgressional phases of the coastline

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Abstract: The Western Nigerian continental shelf lies approximately between longitudes 2°42'–5°00'E. It is a relatively gently sloping shelf incised by two Canyons, Avon and Mahin. The shelf is narrow and varies in width from about 24 km in the west to about 30 km in the east. The beaches between longitudes 2°42'E and 4°30'E are sandy while between longitudes 4°30'–5°00'E, they have a muddy consistency. This is referred to as the "Mahin Mud Beach". The sand deposits between 2°42'–4°30'E extend about 12 kilometers offshore and is separated into two coast parallel sand bodies by a narrow dark grey silty mud facies, 1–2 km wide. East of longitude 4°30'E, the sand facies is replaced by the Mahin Mud Beach. Results of analysis of echograms show that the Pleistocene/Early Holocene transgression of the coastline occurred in a rising sea level curve punctuated by about four sea-level stillstands.

INTRODUCTION

The Pleistocene Epoch immediately antidates the Holocene Epoch which began about 10,000 years B.P. (Before Present). The Pleistocene Epoch was a time during which extensive ice sheets and glaciers formed repeatedly on land and this period is frequently referred to as the glacial age. The spreading of glacials was an obvious result of climatic fluctuations which was accompanied by fluctuation in the level of ocean. During glacial age, sea level were lower than today's level and estimates during the last glacial period give a sea level drop of about 100 m below that of today.

During the late Pleistocene/Early Holocene, deglaciation began as a result of warmer temperatures. The meltwaters poured into the Oceans. This occurred from about 16,000–6,000 years B.P. Curves of time versus depth agree broadly with each other where they pertain to coast believed to be stable (Fig. 1). The rise of sea level was rapid initially, then gradually slowed with time (Shepard, 1961). It is generally favoured that the rising sea level reached its present position during the last 6,000–7,000, years ago (Smart, 1977).

DEVELOPMENT OF THE CONTINENTAL SHELF

Genetically, the development of the continental shelf began about the Wurm (Weichselian) Ice Age when global sea-level fell to more than 100 m under the present level. Transgression following the deglacial meltwaters resulted in subsequent flooding of the surrounding lowlying coastline leading to the formation of the continental shelf (Schmidt, 1974). Worldwide, it differs considerably in width but generally ranges from 20–200 km. Since the end of the last glacial age, sea level has risen 100–120 m in about 12,000 years and over the last 5,000, sea level has fluctuated slightly around its present stand. Growth and development of the shelf was irregular and periods of stagnation or temporary reversal occurred (Curray, 1975).

The evolution of the present day physiography of the western Nigerian shelf can best be understood in the context of the history of the Gulf of Guinea continental margin which began with the separation of South American from the African plate during

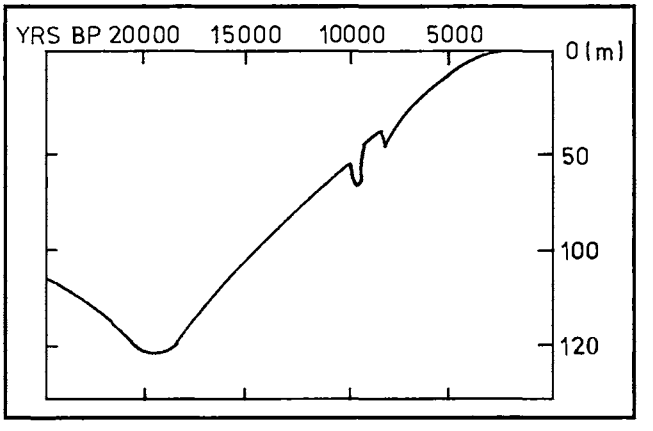

Figure 1. Generalised curve of sea level rise versus depth (after Curray, 1975).

the Jurassic. Continued separation of the two continental land masses resulted in the creation of deep ocean basins and continental margins which is marked by numerous fracture zones. These fracture zones emanate from the mid-Atlantic ridge and abolt on the continental slope and coastal zones.

Various authors among them Allen (1964, 1965), Stonely (1966), Murat (1970), Hospers (1971) and Burke (1972) have treated extensively the geology of the Nigerian coastline and more specifically, the Niger delta. It is not very clear whether the post-Pleistocene sea level reached the present datum in a regularly rising curve or arrived the present nivean at about 6,000 years ago via punctuations by some sea level stillstands of the coast of Lagos. Among the works reported here is an attempt to elucidate the history of late Pleistocene transgression in a section of the western Nigerian continental shelf using ecological methods (coral reefs). A description of the shelf morphology and sediment distribution pattern is also discussed.

The western section of the western Nigerian continental shelf may be regarded to be favourable for the study of Post-Pleistocene transgressional changes. Tectonic movements in the coastal region involving repeated changes from uplift to submergence can be excluded with high probability. Also geologic considerations may indicate that this section of the coastline could be tectonically (?) stable in comparison with young uplifts (?) in tectonically active areas like the Cameroun. Therefore evidences of transgressional stillwater stands, if any, may reflect punctuation in shelf development rather than tectonic movements.

The data used in this study was collected during a series of sea cruises on the Western Nigerian shelf using the Research vessels R.V. Okion and R.V. Sarkim Baka of Nigerian Institute for Oceanography and Marine Research, Lagos, Nigeria between 1985–1989. Survey vessels were positioned using satellite navigational system type Foruno Marine radar model FR/1012 (95% accuracy). Echo sounder type 3FF-620 was used for depth collection in combination with colour echo sounder.

SHELF MORPHOLOGY

The western Nigerian continental shelf lies approximately between longitudes 2°42'E and 5°00'E (Fig. 2). It is a relatively gently sloping shelf and is incised by two canyons Avon and Mahin canyons. Avon lies approximately between longitudes 03°50'E and 3°55'E and is V-shaped with the head only a few kilometers from the coastline. The Mahin canyon lies further eastwards and approximates longitude 4°20'E and 4°25'E. It is oriented in a north-east-southwest direction and is U-shaped (Ibe *et al.*, 1985). In deeper offshore the Avon and Mahin merge into one channel and Mahin canyon forms a tributary of Avon (Peters, 1984). The shelf is narrow and varies in width from 24 kilometer in the west to 30 kilometer in the east. It is divided into inner shelf (0–40 m), middle shelf (40–80 m) and outer shelf (80–120 m).

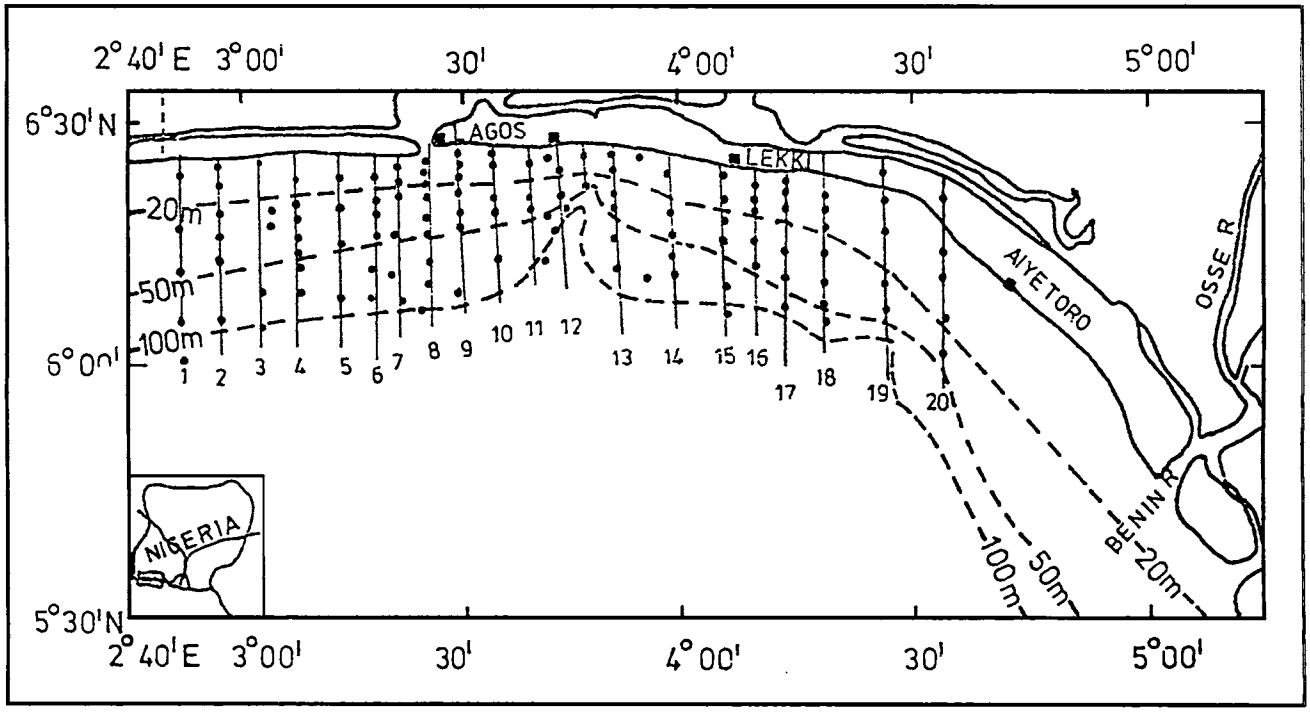

Figure 2. Map of western Nigeria showing shelf bathymetry, profile line and sample locations.

Figures 3 and 4 show profiles across the continental shelf and the upper third of the slope west of Avon canyon. They represent the general shelf morphology east and west of the city of Lagos. The shelf has a general gradient of 1:150 and 1:165 respectively and are comparable to values reported by Allen (1964). It breaks consistently at 110–120 m depth. The continental slope between Lome and Lagos is as wide as the shelf, the toe lying about 1,500 meter (Allen, 1964). Only the upper third of this provide to a limit of 400 meters is considered in this study (Figs. 3 and 4). In this section, the slope gradient varies from 1:2.6 in the West to 1:5 m in the east. There is a general region of slump debris on a small topographic terrace in Figure 4 in the depths between 310–370 meters, recognised from colour echo sounder and Hydrosweep (Courtesy of F.S. Meteor, of the German Hydrographic Institute, Hamburg).

The analysis of echograms sounded along the 100 m isobath between longitudes 2°45'E and 3°45'E showed the existence of two gullies along the shelf break located between (1) 3°15.71–3°16.80E which is double-limbed, and (2) 3°18.71–3°20.05E (Fig. 5).

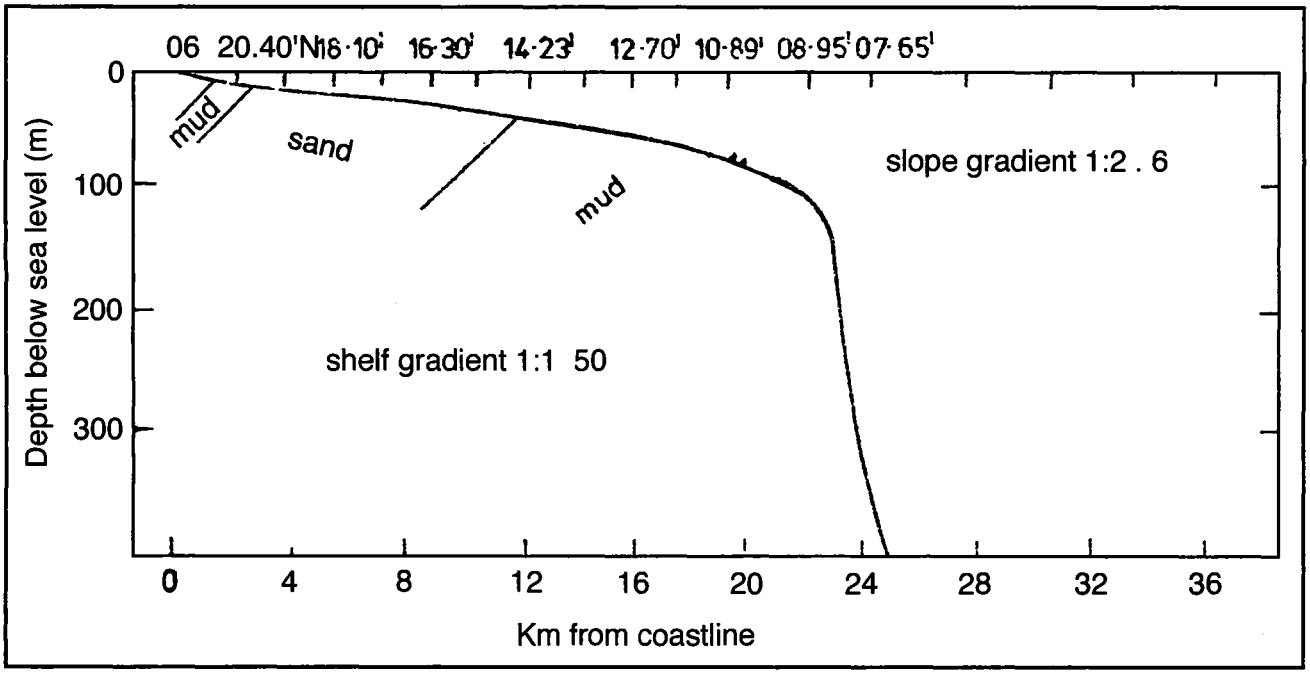

Figure 3. Echo sounder profile near Badagry (long 03°02'04"E) showing shelf morphology and sediment outcrops.

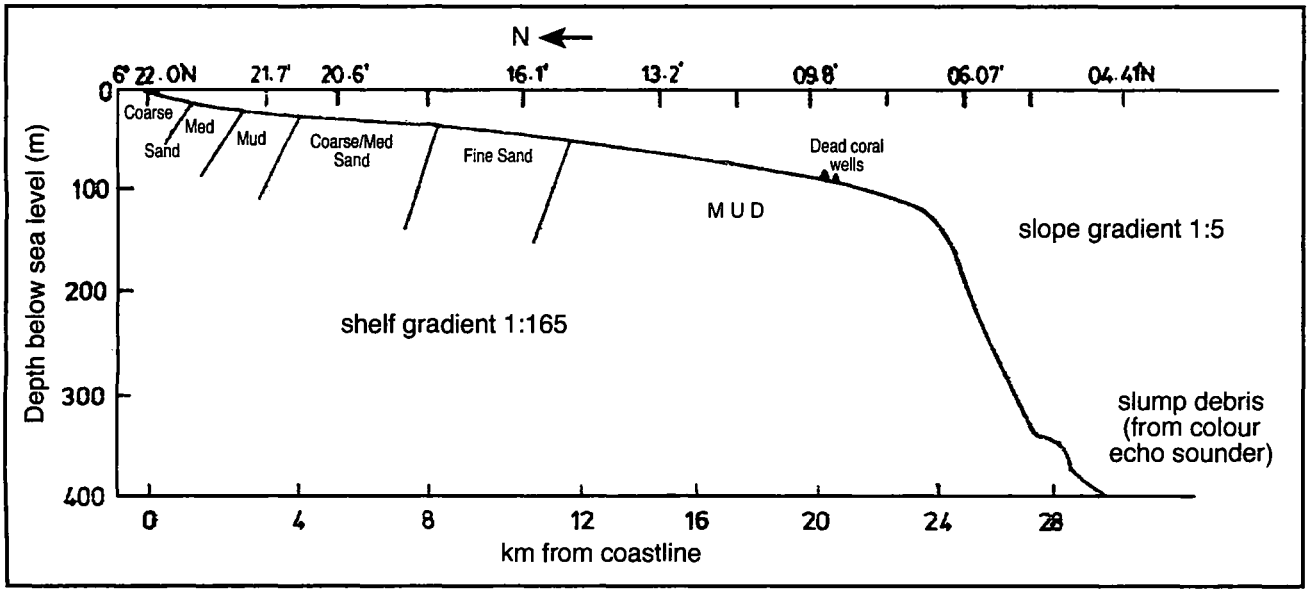

Figure 4. Echo sounder profile off Lagos (long 03°35'0"E) showing shelf morphology and sediment outcrops.

The gullies reach depths of 250 m and widths vary from 1,000–1,200 m in a general bathmetry of 100 m. These gullies were not encountered along the 50 m isobath. They are probably comparable to valleys reported by Curray (1960) from the sandy shelf of the Gulf of Mexico and may represent pathways of shelf break-debris flow to the deep sea.

Water transpiracy over the study area generally increases with increasing distance from the coastline. Records of Sechi disc diappearance depth are: 3–4 m in 10 m water depth, 14–15 m in 50 m water depth, 19–20.8 m in 50 m and 20–20.8 m in 100 m water depth.

SEDIMENTOLOGY

Analysis of 124 grab samples between longitudes 2°42'–4°32'E along 20 profile lines shows that shelf sediments include a wide range of sediment types from shelly and gravelly sand to mud (Ihenyen, 1992, 1994). Between longitudes 2°42'E and 3°50'E there exists two bands of sand deposits which are parallel to coastline and are separated by a dark grey coarse silty mud (Fig. 6). The first sand deposit is a continuation of the beach and extends generally to a distance of about 2 kilometers offshore. It is generally coarse to medium sand (0.80–1.06 ø and 1.41–1.98 ø respectively) and

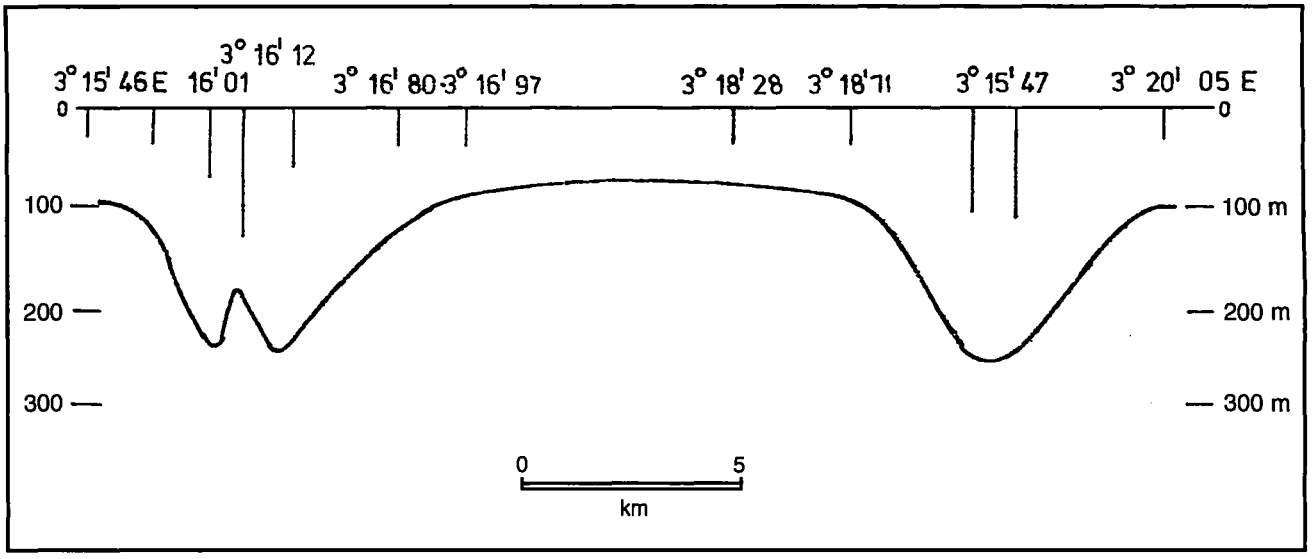

Figure 5. Profile along the 100 m isobath between long 03°15'–03°20'05"E.

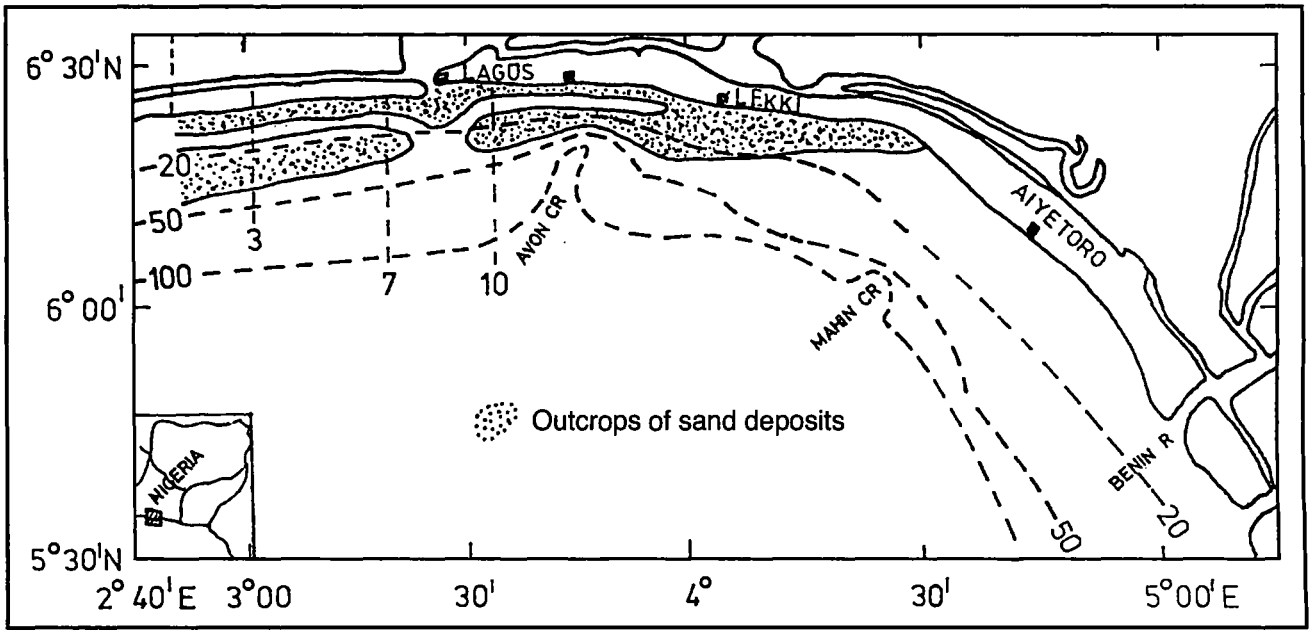

Figure 6. Map showing sediment distribution pattern and profile lines 3, 7 and 10.

well sorted. Between longitudes 3°50'E and 4°32'E, however the sand deposit is dominantly medium sand, moderately well to very well sorted, and fine to very fine skewed. Seawards in this region this coastal medium sand deposit grades into fine sand finally ending up as very fine sand.

The dark grey silty mud facies appears to be restricted to the western section between longitudes 2°42'–3°50'E. It varies in width from 1.5–2.0 km and sediments are poorly sorted, fine skewed and generally platykurtic. The second sand deposit lies seawards of the silty mud facies. It is about 9 kilometer wide in the west and about 5 kilometer wide in the east around longitude 3°40'E. Its lateral continuity is broken between longitudes 3°18'E and 3°25'E off the entrance to Lagos harbour. It is mainly coarse sand at its proximal (shoreward) limit and fine sand at its distal end. Sediments are moderately to well sorted. Like noted in the first sand deposit between longitudes 3°50'–4°32'E, the seaward limit of this sand deposit grades into a region of coarse-medium silty mud (5.10–5.67 ø). This coarse silty mud extends from about 12 kilometer offshore down to the continental slope. Sediments are calcareous at the shelf break. The first sand deposits seems to belong to beach sedimentations continuing at present in this area, while the second deposit probably relates to the "Older Sands" of Allen (1964). The Old sands represents shallow and onshore deposits and its present position many kilometers offshore arose following the Holocene transgression of the sea across the shelf. Eastwards of longitude 4°30'E up to the coastline west of Benin River, the beach has a muddy consistency (Mahin Mud Beach). Burke (1972) reasoned that Avon and Mahin canyons acts as chutes down which sediments that would have reached the Mahin beach are lost to the deep sea.

A generalised surface sediment distribution pattern is illustrated in Figure 3 along with outcrops of coral reefs.

HOLOCENE TRANSGRESSIONAL PHASES

Corals

Corals belong to the order Scleractina in the class Anthozoa of Phylum Chidaria. They consist of solitary or colonial polyps that build a calcareous skeleton into which the polyps can withdraw. Reef-building corals occur only in shallow tropical waters that are highly illuminated and whose temperature does not fall below 18°C. The waters should also be free from large amounts of suspended silicate debritus and not have excessive freshwater runoffs. They donot trive at depths below 20 m sea level (Sellwood, 1981).

They are three types: fringing reefs, barrier reefs and atoll. Fringing reefs develop in shallow water along the coast while barrier reefs form an offshore breakwater parallel to the coasts of continents, or isolated islands. Atolls are circular to semicircular reefs surrounding small ring-shaped volcanic islands and protecting them from ocean waves.

Analysis of shelf echograms particularly off Lagos revealed the existence of both some isolated and continuous bands of dead coral reefs from the middle to the outer continental shelf (40–100 m). Three echograms along longitudes 3°02'E (Profile 3), 3°20'E (Profile 7) and 3°32'E (Profile 10) were most revealing and are represented in Figure 7.

Two coral banks are most prominent and occur in water depth between 85–98 m. They form continuous bands and are aligned almost parallel to the coastline. The outermost coral band occurs in 96–98 m depth and consist of two coral reefs which are separated from each other by about 350 meters. On profile line 10, the coralbanks now rake between 3 and 5 m above sea bottom while on line 7, the echogram reveal that this band has been buried by sediments with their heads just descernable above the ocean bottom. The second coral band is located about 1.10 km north of the proceeding coral band. It consists of two coral walls also and are 4–7 m high above sea floor. Distance between each coral wall is about 430 m. On profile line 7, they are almost similarly buried with sediment.

Two other single coral banks were also recorded on Profile 10. One coral wall is found in 85 m of water and is about 4 m high. This coral bank was not recorded in profile 7. It probably lies buried under thick sediments from the nearby outlet of Lagoon. The outer coral bank representing the 4th series was recorded in Profile line 3 west of Lagos on longitude 3°2'00"E in 46 m of water. It is about 4 m high above ocean bottom.

The growth of corals and continued existence is predicated on optimum water temperature and depth, absence of sediment supply and stable coastline (Tucker, 1981). Sea bed reached its present level about 6,000–7,000 years ago, so that all modern coral reefs became established since that time. Some 16,000 years ago during the Pleistocene Ice Age, sea level was at least 100 m below its present stand. Corals developed before 7,000 years ago should now be well below the depth of active coral formation as a result of the Holocene transgression of the coastline. The absence of similar shallow coral banks today off the coast of Lagos could be linked to the Holocene climatic phase, an epoch representing high sediment discharges to the shelf,

due to a higher wetness.

From this study a series of coast-parallel coral banks are mapped off Lagos on the Western Nigerian continental shelf. Their serial development is correlated to the Post-Pleistocene when sea level fell to about 100 m of its present level. Subsequent transgression of the shelf as a result of higher wetness resulted in submergence of the coral banks. About four separate coast-parallel coral banks are recorded and are separated from each other by an average distance of 1–2 km. Each group of coral banks marks a period of stillstand of sea level during Basin development. Continued sea level rise consequently on deglacial meltwaters resulted in the removal or destruction of optimum growth environment and not until the sea level became stabilized were the reef building corals once more able to establish a wave resistant framework. The new zone of unfavourable condition prevailing over the old habitat resulted in the death of the coral colonies. Their occurrence today several tens of meters below present sea level seem to confirm that the Post Pleistocene sea level reached its present datum via a series of stillstands.

CONCLUSION

The results obtained from this study show that the western Nigerian continental shelf is a relatively gently sloping shelf and incised by two canyons, Avon and Mahin, Avon is V-shaped while Mahin is U-shaped. The general shelf gradient off Lagos is 1:165 and it breaks consistently at 110–120 m depth. Two gullies 1,000–1,200 m wide and about 250 m depth occur between longitudes 3°15'71"–3°16'80"E and 3°18'71"–3°20'05"E on the 100 m isobath.

Sand deposits extend about 12 km offshore in the Lagos area while east of Lekki village, the deposit tapers to an end terminating the sand facies. Thereafter and to the coastline west of Benin River, the beach is muddy. The sand deposits situated off Lagos area occurs in two coat-parallel bands separated by a dark grey silty mud facies. These coastal sand deposits unite to form a single sand body east of Lagos. Further east it fissles out into the Mahin Mud Beach a few kilometers after Lekki.

Evidence adduced from analysis of echograms tend to confirm that the Post-Pleistocene sea level

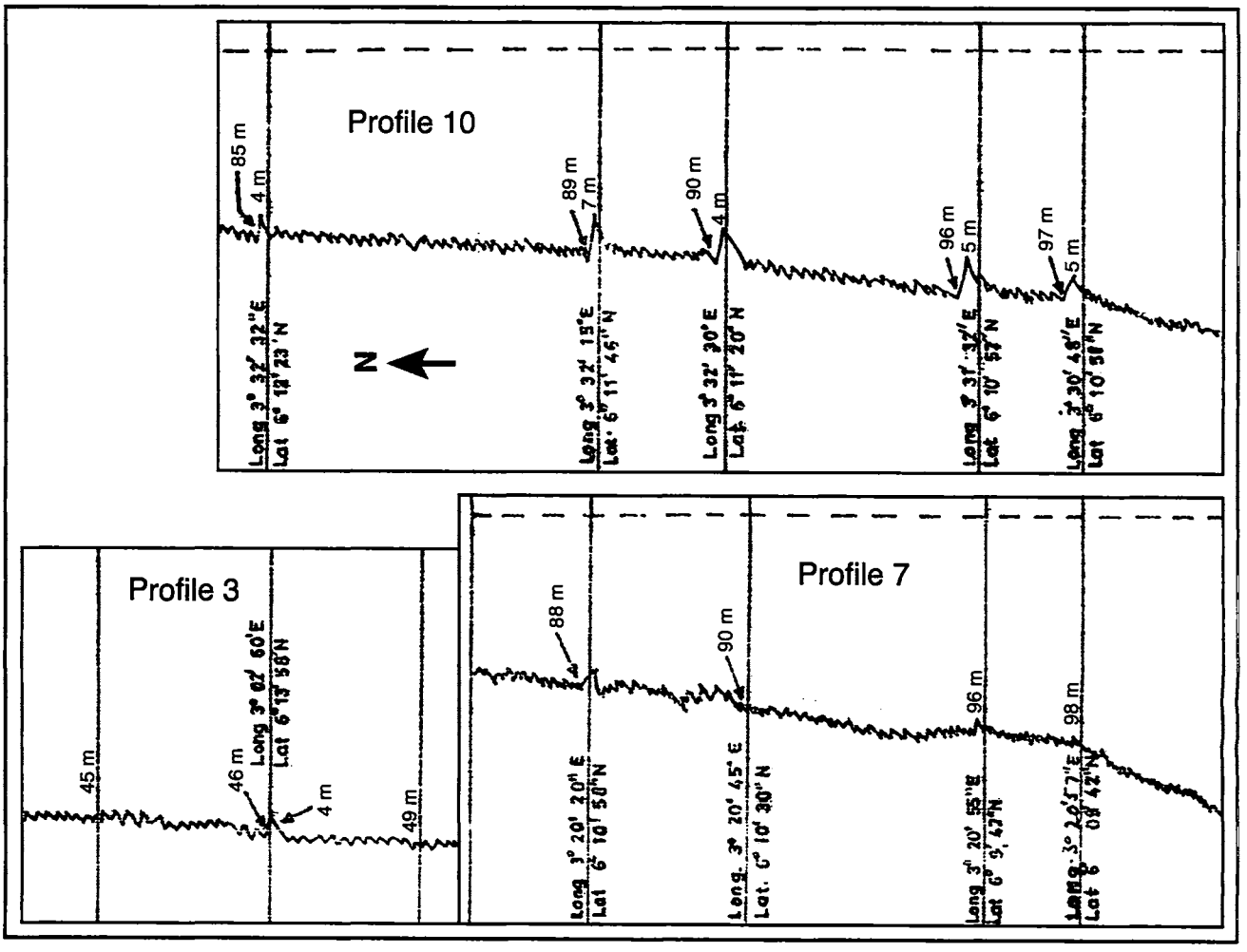

Figure 7. Echo profiles along lines 3, 7 and 10 showing positions of coral banks (modified after Awosika, 1990).

reached its present datum off the coastline of Lagos in a rising curve punctuated by sea level stillstands. Occurrence of dead coral banks which now lye submerged in tens of meters of water show that about four sea level stillstands occurred during the Pleistocene/Holocene transgression of the sea across the coastland.

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Manuscript received 24 April 1997