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Mid Holocene Palaeoenvironments from Lake Nhlange, Northern Kwazulu-Natal, South Africa

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ABSTRACT

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Palaeoenvironments are described from 5 vibracores taken from within Lake Nhlange, the largest waterbody within the Kosi system which comprises a series of lakes linked to the sea via a large tidal sand-flat. The mid to late Holocene lagoonal palaeoenvironment has undergone minimal sedimentation since the Last Glacial Maximum (18,000 BP, oxygen-isotope stage 2). Shelf-margin gravity slumping has transported typical shallow water, intertidal molluscan assemblages into deeper subtidal environments. The lake bathymetry exhibits a drowned Last Glacial Maximum palaeofluvial channel topography, preserved by the post-Last Glacial Maximum (Flandrian) transgression which formed a large coastal dune barrier, trapping the lakes behind it. The palaeoestuary mouth was located at Bhanga Nek, until approximately 3,000 BP, but has been relocated 13 km north, approximately 1,500 BP, to where it now maintains an open inlet through the coastal barrier. An abundant Holocene molluscan assemblage combined with detailed sedimentological descriptions indicate that the conditions within Nhlange have changed over the last 5,000 years from a deep coastal estuarine/lagoonal system, with free tidal exchange to a predominantly freshwater lake. The molluscan assemblages indicate a subtropical, temperate lagoonal environment similar to Durban Bay (prior to anthropogenic changes) with a number of species including *Paphia textile* indicating a warmer climate. A modern analogy of the palaeoenvironment would be that of the inside edge of Bazaruto Archipelago, Mozambique.

ADDITIONAL INDEX WORDS: *South Africa, molluscan assemblages, coastal evolution, vibracoring, Quaternary sea-levels.*

INTRODUCTION

The Cenozoic evolution of the south-east African coastal plain, including the north KwaZulu-Natal coastal plain, is poorly understood. This is due to a number of factors including the lack of outcrop, paucity of fossil remains and widespread reworking of older sand forming a blanket over most of the area. Historically there have been a few attempts to unravel the stratigraphy including work done by MAUD (1968); KING, (1972); DAVIES (1976) and HOBDAY, (1976) and HOBDAY and ORME (1975). More recent work includes foraminiferal studies by MCMILLAN (1987), Late Pleistocene molluscan assemblage descriptions from Lake Nhlange, Kosi Bay, by COOPER *et al.*, (1989), sedimentological and stratigraphical descriptions from Lake Sibaya, situated 30 km to the south of Kosi, by MILLER (1994, 1996) and a reconnaissance study of the coastal plain dune chronology by WRIGHT, (1995). In most instances the authors indicate that the coastal plain has had a complex geological evolution and unravelling the geological history is made difficult by the lack of suitable dating material. Tectonics have played a small part, with eustatic sea level fluctuations playing the major role in the coastal evolution. COOPER (1994) gives a an account of how segmentation is the dominant morphological process in separating the Kosi system into different waterbodies.

Lake Nhlange forms part of the Kosi system of interlinked coastal lakes (Figure 1) and provides an ideal window into the late Pleistocene and Holocene evolution of not only the north KwaZulu-Natal coastline, but more importantly the whole southeast African coastal plain which stretches from the north of South Africa, through Mozambique and Tanzania, to Kenya. Thus, a vibracoring programme was set up to provide palaeoenvironmental information. The 5 core localities (Figure 1) were chosen to be in relatively close proximity as it was hoped to intersect various shallow seismic reflectors, discussed in detail by WRIGHT (1997).

The aims of this paper are to:

(1) describe the molluscan fauna from the cores taken from Lake Nhlange,
(2) establish an age for the faunal assemblages and finally,
(3) reconstruct the various environments that are represented within the cores using modern day analogies, where applicable.

STUDY AREA

The Kosi system is situated at the northern extremity of the South African east coast (Figure 1), approximately 3 km

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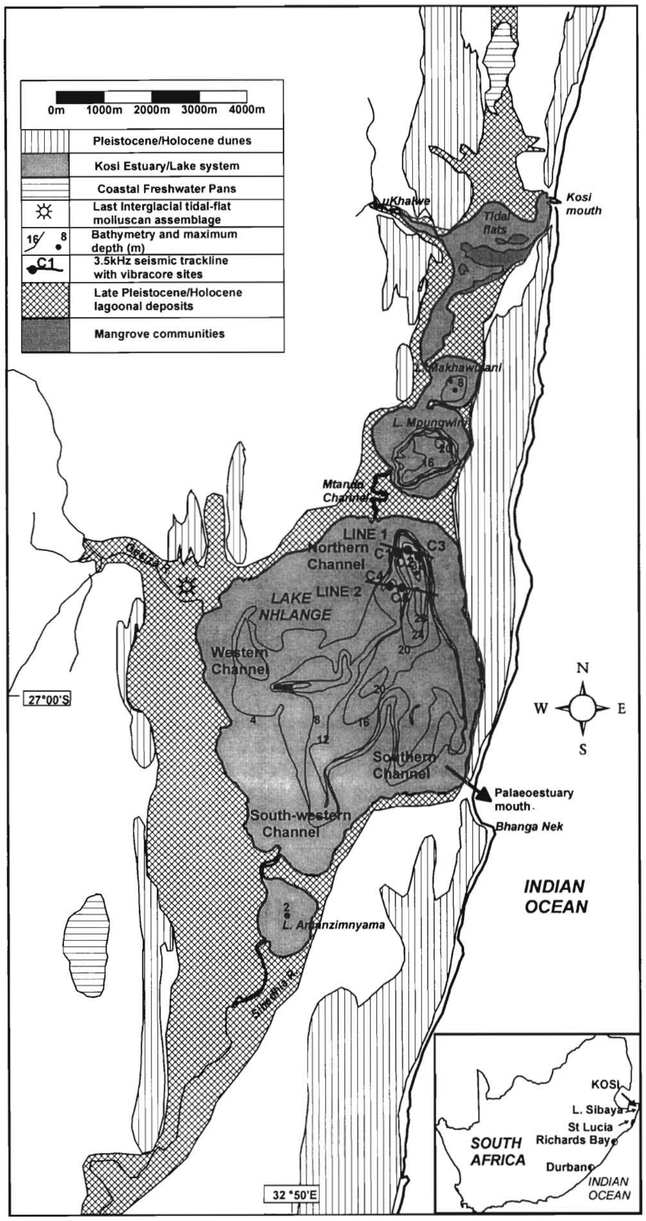

Figure 1. Locality map of the Kosi estuary and lake system showing the bathymetry of Lake Nhlange indicating the drowned Last Glacial Maximum palaeofluvial topography as well as the core sites and seismic lines

south of the Mozambique border. The 5 cores were taken from Lake Nhlange (29° 57′ S, 32° 48′ E), the largest lake in the segmented system. The entire Kosi system is separated from the Indian Ocean by a coastal dune barrier, reaching 130 m in height with low points at the estuary mouth and Bhanga Nek (12 m elevation). The barrier consists of a core of red dune sand thought to be of mid to late Pleistocene age against which yellowish and white Holocene dune sand has accumulated (Cooper, *et al*, 1989). The western banks of the system are composed entirely of red and orange dune sands of mid to late Pleistocene age that frequently form cliffs. Underneath the late Pleistocene and Holocene aeolian sand cover are the argillaceous sediments of Tertiary and Cretaceous age (Wright, 1995).

Late Pleistocene and Holocene climatic changes have not only affected sea-levels (Ramsay, 1995) but also the vegetation cover, enabling prevailing winds to reactivate some of the aeolian sand that formed the palaeodune cordons, further modifying the catchment topography. The sand, thus forms a continuous blanket cover throughout the catchment area. The lack of clay minerals within the quartz rich sand has ensured that there is a high porosity within the cover. The clay-rich sediment from the underlying Cretaceous and thin Tertiary act as an impermeable base to the water table ensuring that the water sits perched within the thin sand cover, close to the surface. In fact, the large coastal lakes such as Sibaya (30 km south of Kosi) and Kosi are merely surface expressions of the watertable (Miller, 1994). Large wetlands have formed within the interdune depressions where the watertable is exposed. Where they have been firmly established, thick peat deposits exist, some forming during the Last Interglacial (Eemian) period approximately 125,000 years before present (BP) according to Orme (1973). Diatomite deposits of late Pleistocene age are often associated with these fresh waterbodies.

The Kosi drainage system is ill-defined because of the pans, swamps and marshes which surround it but its catchment is estimated to be approximately 540 km² in extent. The lake obtains most of its fresh water from the local drainage and the high water table that is characteristic of the coastal plain. Due to the high porosity of the cover sand there is a lack of surface drainage within the system, with just the Sihadhla and Gesiza Rivers being perennial (Begg, 1978). Almost all the freshwater input is from the high surface watertable that fluctuates with the wet and dry cycles that dominate the regional climatology (Wright *et al.*, 1997). Orme (1973) suggests that only 5% of the total annual precipitation is borne by rivers within the Kosi system.

The 4 lakes and tidal flat are separated from each other by low-lying flat areas that comprise either peats or redistributed fine to medium grained well sorted quartz sand (Figure 1). Cooper *et al.* (1989) describes a lagoonal molluscan assemblage from the western side of Lake Nhlange giving it an Eemian age (Last Interglacial, 125,000 BP). These deposits, situated at 7 to 8 m above mean sea-level, were originally described by Orme (1973) and assigned a Holocene age.

The bathymetry within Lake Nhlange indicates a drowned fluvial topography (Hill, 1969; Orme, 1973; Cooper, 1994). Very little sedimentation has taken place to alter the bathymetry since the formation of the barrier lake system (Wright, 1997). Three distinct palaeochannnels flow from the west, southwest and north into the deepest section of the lake. Sand encroaching from the barrier to the west has formed a steep drop-off on the eastern side of the lake.

METHODS

A 5 × 6 m barge was assembled on the shore at Lake Nhlange and comprised 4 polystyrene blocks wrapped in heavy duty industrial plastic and encased in a wooden frame.

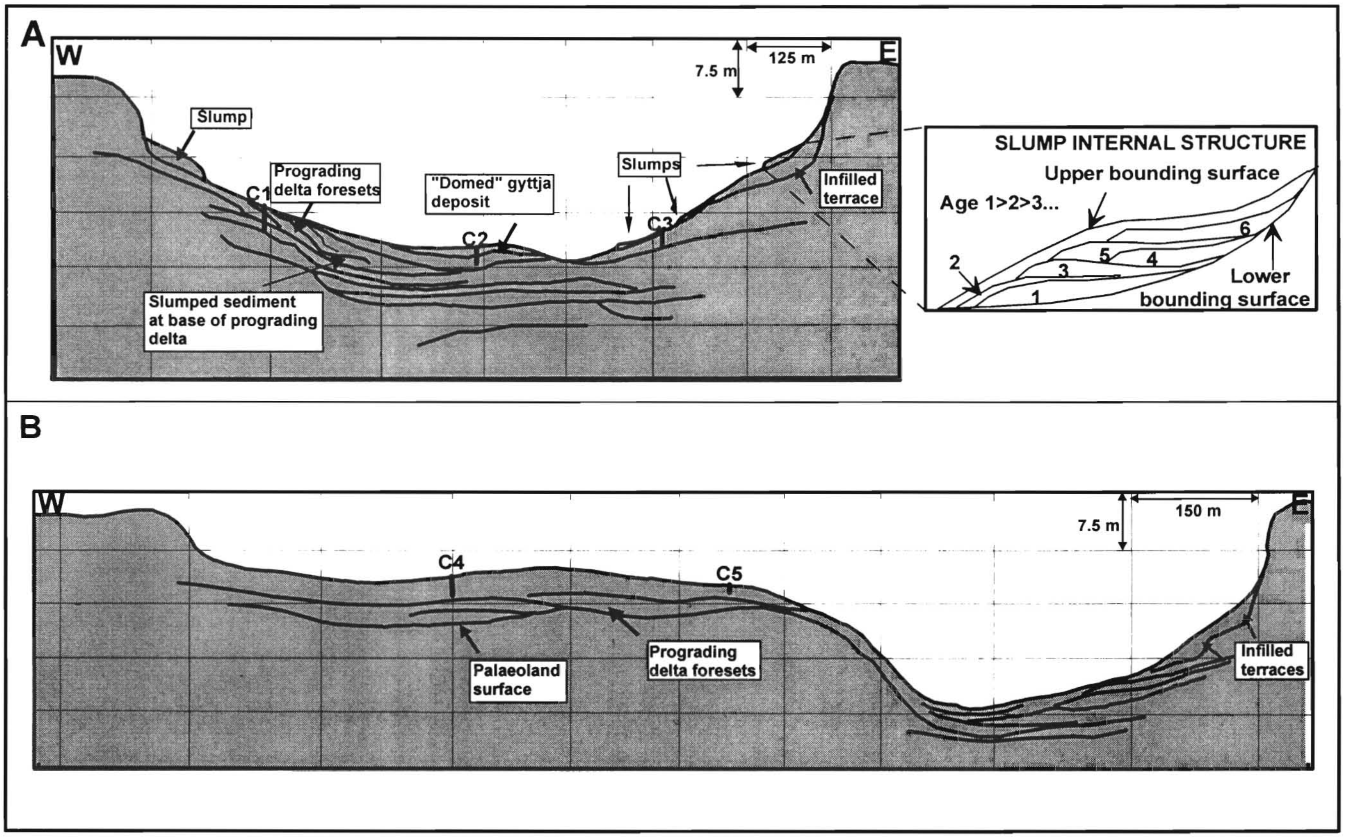

Figure 2a&b. 3.5 Khz shallow penetration seismic profiles, showing the late Pleistocene to recent stratigraphy. The insert within Figure 2a shows the internal structure of the slumps.

Onto the barge was mounted a superstructure from which the vibracoring device was deployed (WRIGHT and BOVA, 1990).

A marine *Kiel* Vibracorer was specially adapted to be deployed from the barge. The vibracore frame was erected within the well of the barge and suspended from the superstructure. Once on site the Vibracorer was lowered to the lake floor using an electronic winch and the vibrahammer triggered remotely, driving the 3 m box-core into the sediment. The vibracore and frame was then winched to the surface where the core was detached, kept vertical and transported to the laboratory. Once in the laboratory the cores were split, photographed, logged and sampled. The sampling included picking out molluscan assemblages (some used for Radiocarbon dating) and sediment grainsize statistics. The core logs were not corrected for shortening as it was not certain whether the shrinkage was due to dewatering or loss of core out the bottom.

Core sites were positioned along seismic lines (Figure 1) that were run using a 3.5 kHz shallow-penetration seismic system using a 125 millisecond sweep rate. The seismic records (Figures 2a and b) show a number of prominent reflectors, the deepest being just below 10 m sediment depth that have been described in detail by WRIGHT (1997).

CORE DESCRIPTIONS

Details of the 5 cores are given as Figures 3 to 5, and describe the major sedimentological units. Each distinct facies unit recognised was described on the basis of sedimentary structure, grainsize characteristics, micro- and macrofaunal content and colour. Each unit within the cores were designated a sedimentary environment from which it was deposited, taking all the facies descriptions into account.

Core 1

Core 1 (Figure 3a) is located at 20 m depth (below mean sea-level) on the eastern sloping margin of the deep northern basin of Lake Nhlange (Figure 1). The core penetrated 2.5 m of sediment, cutting through two reflectors (Figure 2a).

The sedimentary sequence preserved in core 1 represents deposition in several different environments. The lower most unit (Unit 7:Figure 6) with its high proportion of muddy sediment and intense bioturbation and molluscan assemblage suggests a deepwater lagoonal deposit. The molluscan assemblage described from Unit 7 indicate a predominantly microtidal Durban Bay (30°S; 31°E) type lagoonal environment (pre human interference) that experiences a subtropical temperate climate, where conditions found from low intertidal tran-

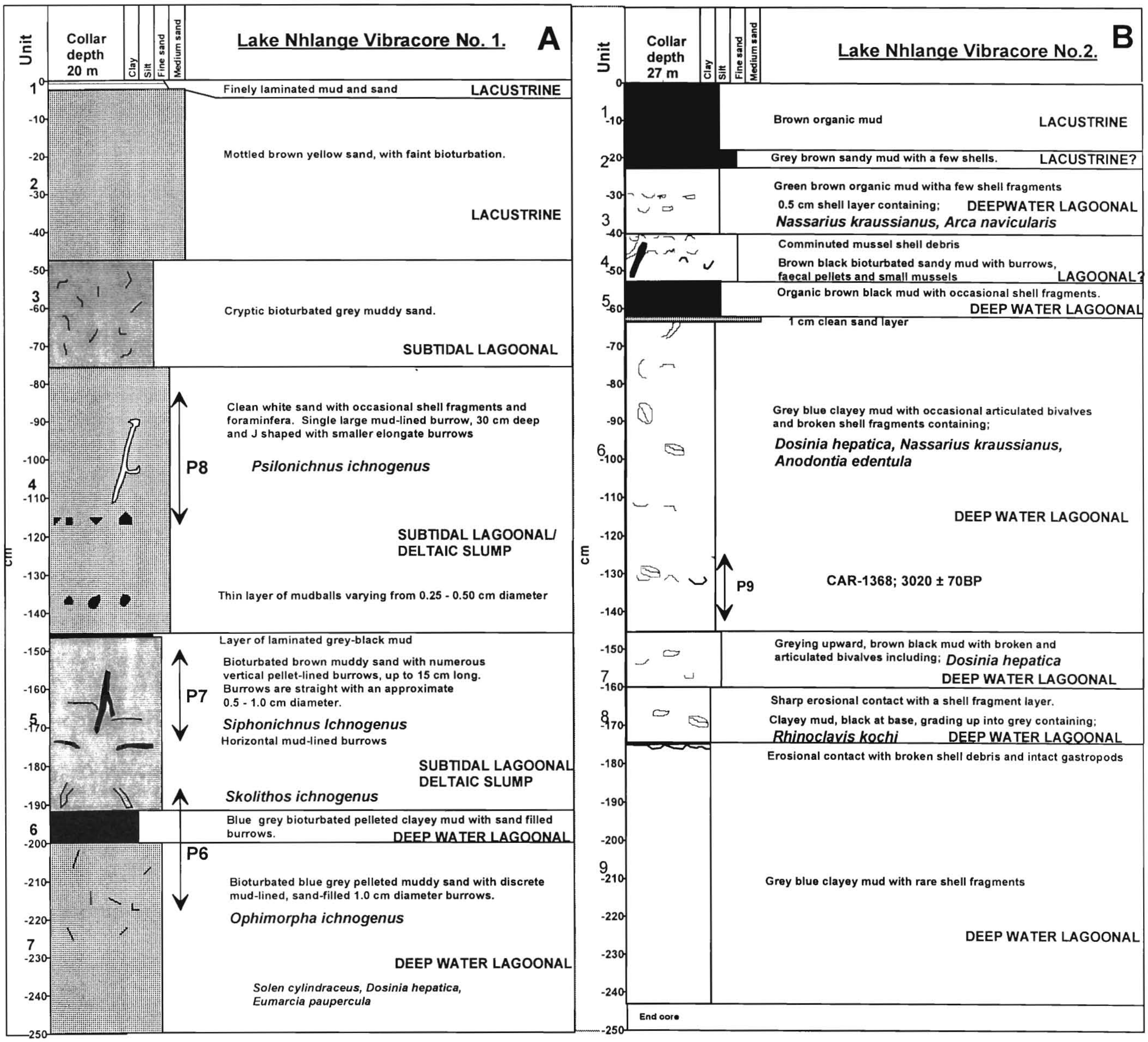

Figure 3. Detailed logs of core 1(a) and core 2 (b) showing their different sedimentary units. Intact molluscan assemblages, dates, photograph localities (P) and ichnofacies are logged together with the sedimentary descriptions to describe a depositional environment for each unit.

quil areas are slightly muddy. The blue pellets in the sediment are probably faecal pellets of the infaunal burrowing organisms. The high mud content within the units indicate a relatively deep part of the deposition basin, in which resuspension by wave action is minimised. Habitation by thin-walled epibenthic foraminifera would then be possible. The lack of large molluscs within this environment could be explained by high turbidity or an unsuitable substrate. Deposition would have been continuous but slow to enable the complete bioturbation. The fine sand fraction may have been carried in by periodic increases in discharge from the feeding rivers.

The accumulation of a pelleted layer (Unit 6, Figure 6) probably represents a period of reduced clastic input and hence higher production of pellets.

Unit 5 (Figure 7), which lacks an appreciable mud content, was still deposited in a lagoonal environment as indicated by the presence of small, thin-walled untransported foraminifera and a few centric diatoms. The lack of mud coupled with the incomplete bioturbation suggests that deposition of sand was too rapid for appreciable mud accumulation, although the presence of mud balls in the middle and top of the unit indicate significant breaks in sand deposition. Unit 5 probably represents a fluvial flood deposit, a suggestion supported

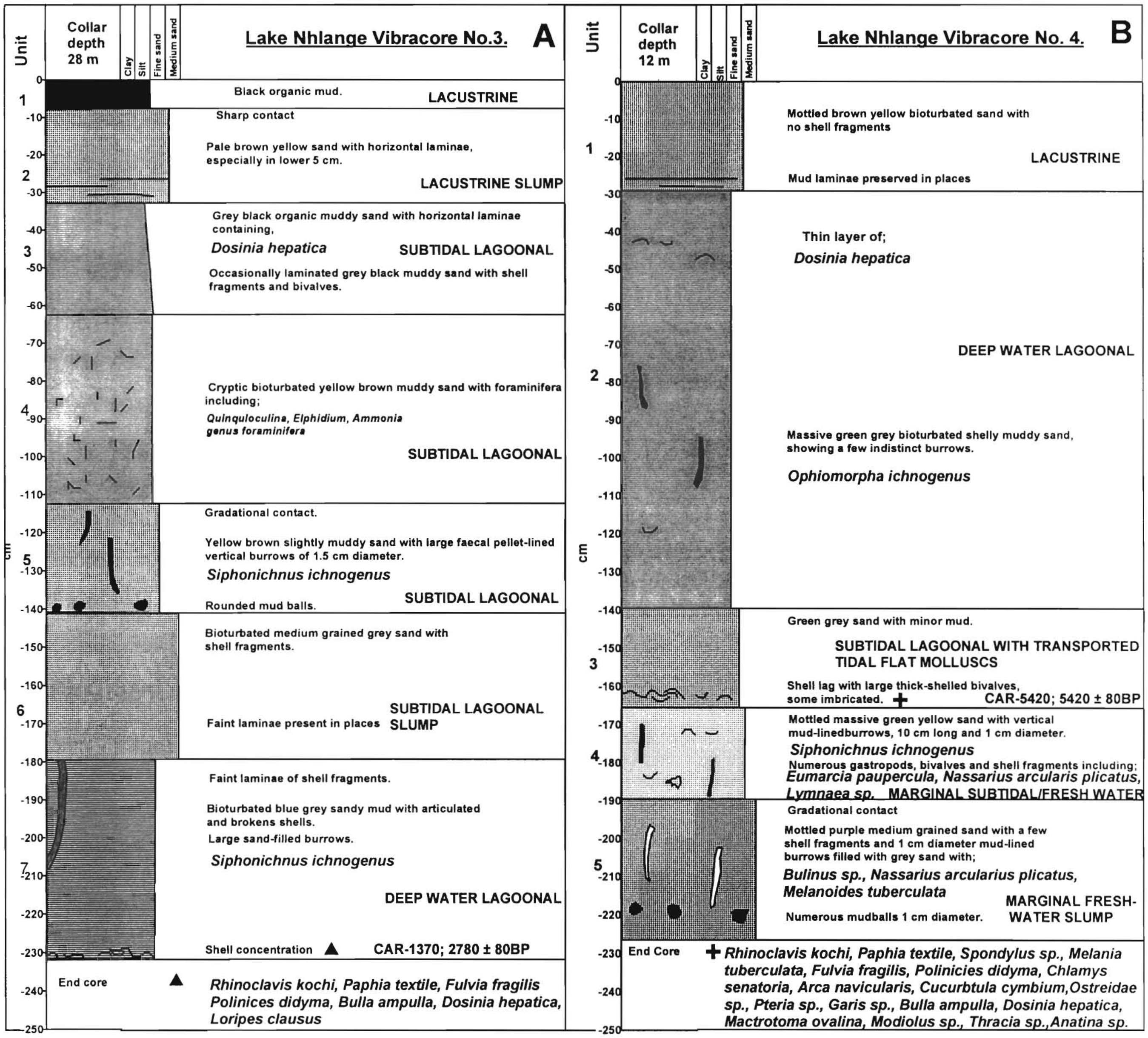

Figure 4. Detailed logs of core 3(a) and core 4(b) showing their different sedimentary units. Intact molluscan assemblages, dates and ichnofacies are logged together with the sedimentary descriptions to describe a depositional environment for each unit.

by the subangular nature of the grains, deposited in a quiet lagoonal environment. The sand remained undisturbed by tractual currents, maintaining its angularity. Foraminifera and diatoms colonised the unit and were carried into the sediment by infaunal burrowers. Straight, vertical, mud-lined burrows, indicating the *Siphonichnus* ichnogenus (Figure 7) were probably formed by the sand crab *Callianassa kraussi*. The layer of grey black mud separating Units 5 and 4 indicate a quiet period during which mud settled out of suspension. Units 5–7 coincide with the near-horizontal layer penetrated by the lower part of the core, as seen on the seismic profile (Figure 2a).

The absence of foraminifera and the presence of mud balls in Unit 4 suggest that it too could be a flood deposit but of greater magnitude than those represented by previous units. The laminated mud layer demarcating Unit 4 from the lower unit indicates that the sand was deposited as a large pulse ensuring that the mud layer was protected from bioturbation. This together with the seismic interpretation suggest that Units 3–4 entered the basin as a slump of fluvial material from the west, possibly as the prograding delta foreset. The elongate burrows which resemble those of *Callianassa kraussi* suggests that the conditions were still brackish. *C. kraussi* is a deep burrower hence the lack of other bioturbation. The

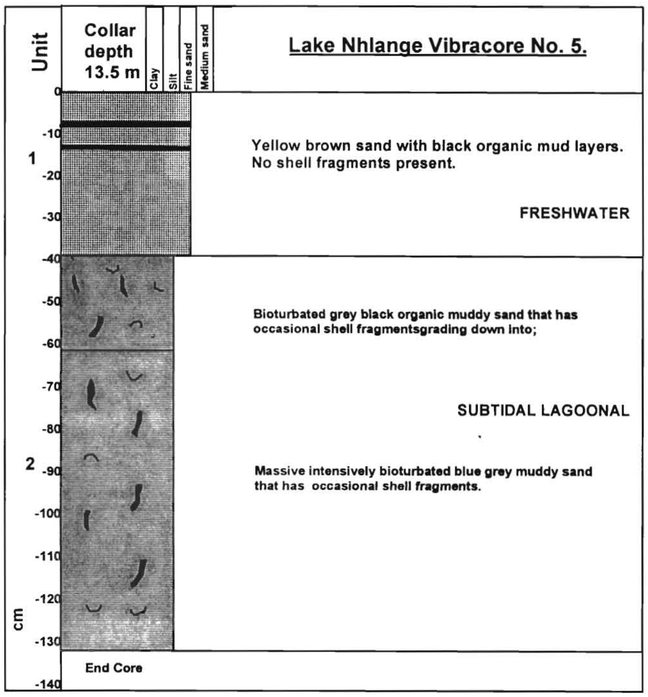

Figure 5. Detailed log of core 5 showing the core split up into different sedimentary units. Sedimentary descriptions are used to depict palaeoenvironment for each unit.

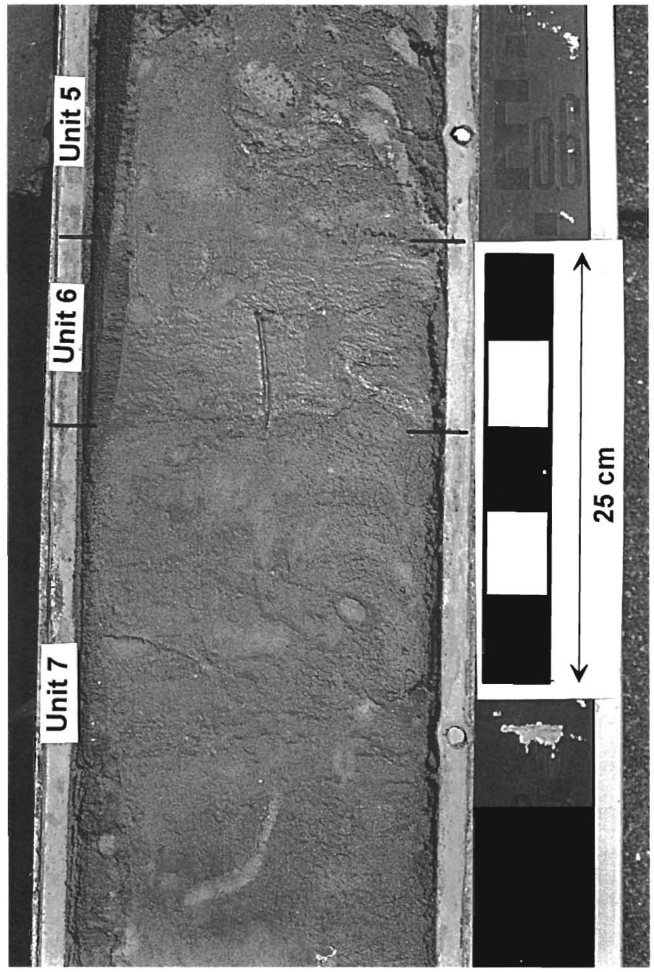

Figure 6. Core 1 showing the base of Unit 5, Unit 6 and the top of Unit 7. Note the sand-filled burrows through Units 5 and 6, indicating the *Skolithos* ichnogenus as well as the faecal pellet-lined burrows in Unit 7 indicating the ichnogenus *Ophiomorpha*. Scale to the right is in cm.

well sorted nature of what is interpreted as a flood deposit must be attributed to the well sorted source material. The presence of the *Psilonichnus* ichnogenus (Figure 8) may represent *Ocypode*, a ghost crab that is found in the intertidal zone, digging burrows down to the watertable (BRANCH and BRANCH, 1983).

The succeeding Unit 3, which is bioturbated, probably indicates alternating sand and mud deposition on the surface of this slump deposit showing more tranquil subtidal conditions after the slump. The presence of a few abraded foraminifera tests suggests an input from littoral sands or even that the unit itself which is supratidal represents a deltaic facies on the lagoon margin on which epifaunal habitation by thin walled foraminifera would have been impossible. Units 3 and 4 probably represent the progradational sequence shown in Figure 2a.

The overlying Units of 2 and 1 are markedly different in colour to the previous units suggesting a change in chemical conditions. The contact between Unit 2 and 3 is sharp, indicating a period of erosion. The units contain organic remains including insect carapaces and appendages. This together with the lack of shelly carbonate material suggests a freshwater depositional environment. Figure 2a shows the core locality to be on the side of a steep slope, where mass gravity flows (slumps) are the main mechanism of transport, thus Unit 2 probably comprises a massive deposit of shelf sand that has slumped into the deeper areas of the lake. The mud deposition in Unit 1 indicates tranquil deep water conditions as are found at present within the lake.

Core 2

Core 2 (Figures 2a and 3b) is located at 27 m depth, within the deepest part of Lake Nhlange. The core penetrated 245 cm of mostly fine grained sediment. The core is differentiated into 9 different units which are summarised as follows.

The depositional sequence from the majority of Core 2 represents a protected backwater lagoonal environment where tranquil conditions allow the fine sediment to settle out. The massive nature of the mud suggests that the sediment was intensely bioturbated indicating a high infaunal activity and low sediment accumulation rate. The increased sand content of the upper units and the presence of *N. kraussianus* and an unidentified mussel shell fragment, indicate a shallower possibly intertidal environment, but still where calm conditions allowed for a large amount of mud to accumulate. Unit 1 and possibly Unit 2, represent the fine detrital sediment similar to that which is presently accumulating in the lake.

N. kraussianus, D. hepatica and *A. edentula* are most char-

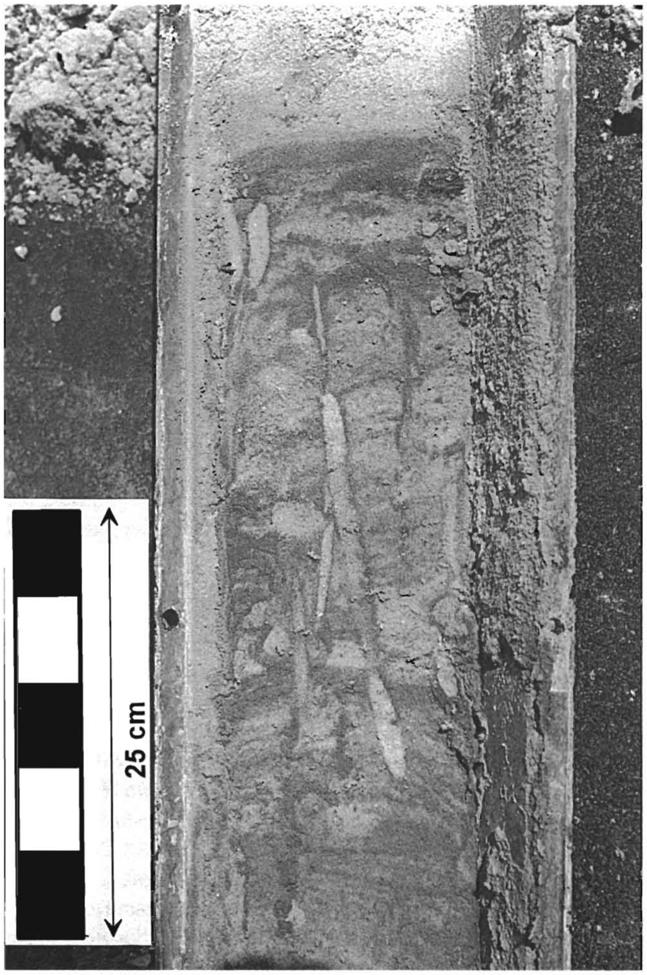

Figure 7. Unit 5 of Core 1, showing a *Siphonichnus* ichnogenus formed by a burrowing invertabrate, probably *Callianassa Kraussi*. Scale is in cm.

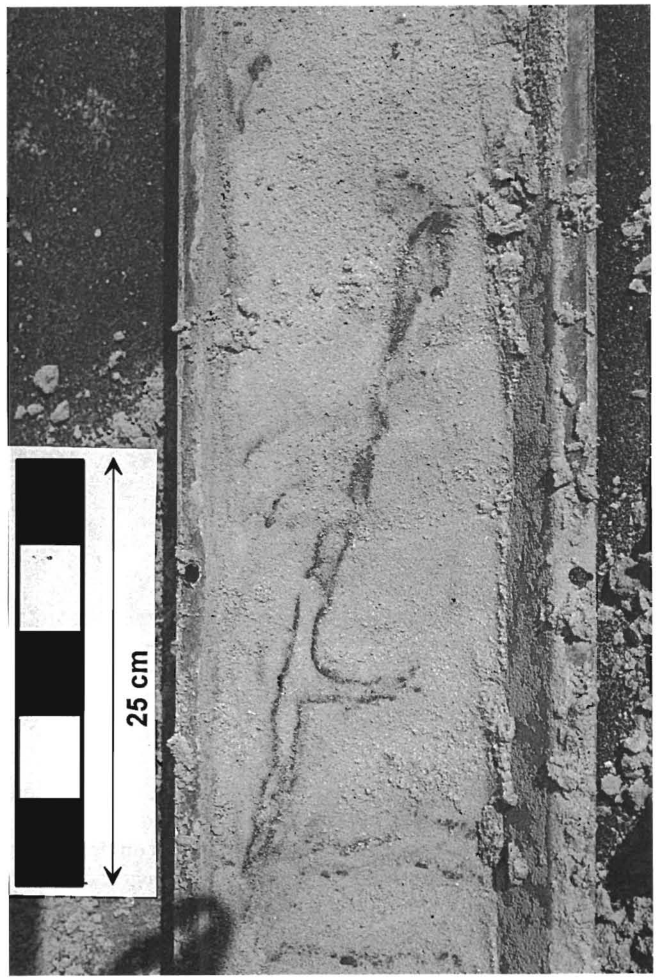

Figure 8. Unit 4 of Core 1, clearly showings a large mud-lined 30 cm long burrow through clean fine grained quartz sand indicating the ichnogenus *Psilonichnus*. Note the thin layer of mudballs at the base of the burrow. Scale is in cm.

acteristic of sheltered, muddy estuarine backwaters. Unfortunately, because of its rounded shape, empty shells of *N. kraussianus* are easily translocated by water movement and are thus poor environmental indicators. Unit 6 (Figure 9) consists entirely of stiff grey to blue mud that has occasional articulated *Dosinia hepatica, Anodontia edentula* and broken shell debris. *A. edentula* is a shallow- to superficially infaunal species, characteristic of soft lagoonal muds; it was abundant in Eemian lagoons along the southern Cape coast. Although a few isolated colonies survived until well into the present century, it may now be extinct within South African limits.

The in situ *Dosinia hepatica* (Figure 9, sample CAR-1368), indicates a ^{14}C age of 3020 ± 70 BP, giving an approximate sediment accumulation rate of 1 mm every 2.2 years for the deep lacustrine/lagoonal areas.

Core 3

Core 3 (Figure 4a) was obtained from 28 m depth, within the deep northern basin of Lake Nhlange and was a total of 232 cm length. The core comprises a mixture of fine grained argillaceous and arenaceous sediment culminating in 7 different units.

Unit 1 and 2 are lacustrine deposits where Unit 2 represents the sandy lake floor environment, comprising slumped shallow shelf material and Unit 1, the deep water deposit. The remaining units molluscan and microfaunal assemblages seem to indicate a typical sandy tidal flat environment. Sample CAR-1370, an intact mollusc has a ^{14}C age of 2780 ± 80 BP giving an approximate sedimentation rate of 1mm every 0.85 years. The fast sedimentation rate of core 2 can be explained by the slumping mechanism providing a greater volume of sediment than the gravity settling of fine material that typifies core 2. Although the shelly layer at the base of Unit 7 was dated at 2780 BP, when sea-level was established at approximately 3 m below present mean sea-level (RAMSAY, 1995), the sample comes from approximately 30 m below mean sea-level, indicating that it was impossible to have an intertidal sand-flat environment at 27 m below mean sea-

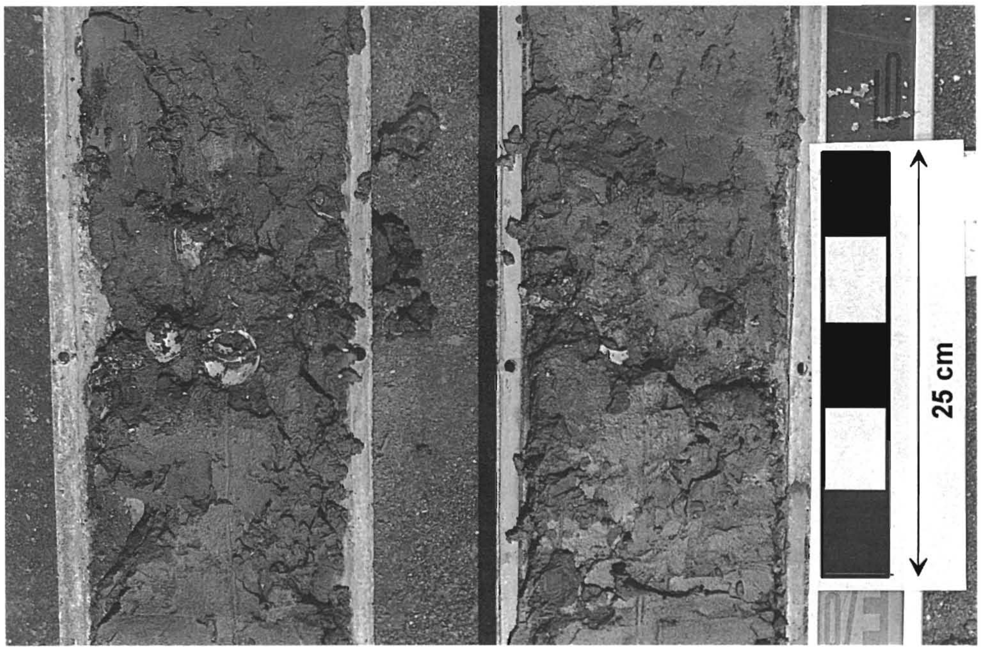

Figure 9. Core 2, Unit 6, showing the blue-grey clayey mud that has a layer of articulated *Dosinia hepatica* that were C^{14} dated at 3020 ± 70 BP, indicating the uppermost lagoonal unit that can be correlated to the final closure of the palaeomouth at Bhanga Nek. Scale in cm.

level for that time. Thus, most of the sand (with associated faunal assemblages) has been transported from a sandy intertidal environment into a deep water lagoonal environment by slumping, probably associated with the progradation of the eastern barrier during the latter stages of the post-Last Glacial Maximum (Flandrian) transgression when sea-level was approximately 2 m below present levels (RAMSAY, 1995). This would explain why a typical sand-flat species such as *Loripes clausus* and *Quinqueloculina* are associated with *Rhinoclavis kochi,* a typical deep water lagoonal species.

The high concentration of *Quinqueloculina* with subordinate *Elphidium* and *Ammonia* species is uncommon (COOPER and MCMILLAN, 1987) since the hypersaline conditions that *Quinqueloculina* thrive in normally deter other species from growing (BRASIER, 1980). Together with *Loripes clausis*, the above foraminiferal assemblage is very similar to the present intertidal sand-flat environment found upstream of the Kosi Mouth. WRIGHT *et al.* (1990) describe a similar estuarine foraminiferal assemblage from the St. Lucia Estuary Mouth, approximately 140 km south of Kosi Bay. The fact that they are found within Unit 4, a subtidal lagoonal back barrier environment adds further evidence for inter tidal sands slumping into deeper areas.

Core 4

Core 4, (Figure 4b), obtained from 12 m depth in the north eastern section of Lake Nhlange consists of 5 sandy units containing a minor mud fraction.

The upper most Unit 1 represents a typical sandy lacustrine environment that represents present mid to shallow water conditions within Lake Nhlange.

Unit 2, with *Dosinia hepatica* and an *Ophiomorpha* ichnofacie, possibly indicating *Callianassa* indicate a shallowwater subtidal lagoonal environment similar to Durban Bay.

The varied shell assemblage from Unit 3 indicates a mixing of sources; *M. tuberculata* is diagnostic of riverine outflow whilst *Spondylus* and *Pteria* species are indicative of subtidal reef. The majority of other species indicate shallow tidal muddy sand-flats, possibly with marine angiosperms. Thus this assemblage indicates tidal movement, even some wave action, with a fluvial sediment supply nearby, rather than a near-life assemblage.

The tidal flat molluscan assemblage (dated at 5420 ± 80 BP) from Unit 4 infers a mean sea-level at that time to be in the order of 14 m below present levels. According to RAMSAY (1995) it is well established that sea-level approximately 5,400 BP for this area was at approximately 1.5 m above mean sea-level, indicating that it was not possible for this molluscan assemblage to be *in situ*. The dates and their relative positions down the cores infer transport from shallow areas (possibly tidal flats) into deeper water. The seismic interpretations (Figures 2a and b) confirm this process of subaqueous slumping which is interpreted as the termination of sediment circulation systems within the lake or lagoon as it must have been then and might suggests a deltaic setting offshore of the little river from which COOPER *et al.* (1989) described the raised Eemian shell fauna, *i.e.* the palaeo Gesiza River.

The diverse molluscan assemblage indicates a dynamic environment similar to Durban Bay before human interference, where a restricted barrier inlet allowed calm, predominantly sandy intertidal molluscan faunas to flourish. The shells may have formed in a back-barrier sand-flat environment similar to that found at present inside of the Bazaruto Archipelago (21°S; 32°E), Mozambique, where tidal currents scour the tidal sand-flats that are dominated by marine angiosperms, carrying some of the shelly debris off into deeper parts of the back-barrier, where the sediment fills the deeper areas by slumping down the face of a prograding flood-tidal delta.

The molluscan assemblages from Units 4 and 5 indicate a brackish to freshwater environment at the base of the core indicated by *Lymnaea* sp., *Bulinus* sp. and *Melanoides tuberculata*. This environment represents similar conditions to those of Unit 3, but more a marginal subtidal lagoonal condition as found at the head of the lagoon where freshwater catchment input has the most influence.

Core 5

Only 132 cm of sediment was extracted from core 5 (Figure 5), taken from 13.5 m depth, on the eastern slope to the northern basin.

The sequence preserved in core 5 includes 2 units that have similar lithologies but different colour. Unit 1, due to its close proximity to the oxygenated surface and small mud fraction, has a yellow brown colour whilst Unit 2 is darker in colour due to their higher mud content. Unit 2 also contains a few shell fragments and is bioturbated.

Unit 1 represents the sand that is presently mantling the shallow lake margins and is made up from redistributed aeolian sand that has been worked by lacustrine near shore wind-induced currents during lower lake levels. The sand may have been introduced to the deeper levels by gravity slumping along the lake margins, filling the fluvial palaeochannels from the west. The 2 organic layers may depict the calm tranquil conditions after the sand has moved as a gravity slump.

The arenaceous sediment has covered the older, deep lacustrine/lagoonal deposits of Unit 2. The lack of estuarine infauna suggest that these 2 deposits were formed in the upper reaches of the palaeobarrier lagoon and had most of its fine grained sediment brought in from a fluvial origin. The lack of marine or estuarine fauna suggest that Unit 2 may have been deposited during the calm tranquil conditions that prevailed in the deeper water of the lagoon prior or during the period when the entrance to the sea was severed.

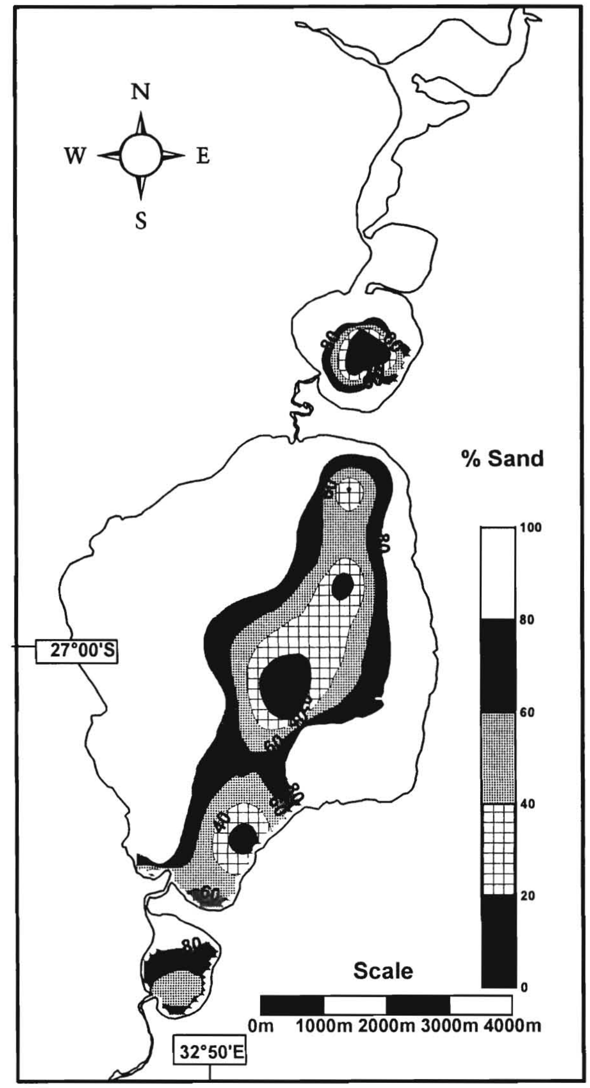

Figure 10. A percent sand distribution map of the Kosi system showing how the shallows are dominated by high sand concentrations and the depths by mud. Sand is transported into the deeper areas by gravity slumping of the unstable shelf margins.

PALAEOENVIRONMENTAL RECONSTRUCTION

Core 1 records a change from a relatively deep water, sheltered lagoon receiving periodic influxes of sediment from flooding rivers, possibly as the prograding delta foreset of the palaeoGesiza River, to a freshwater environment in which sand was initially deposited as slumps from the shallow margins and finally by sedimentation in deeper water. Figure 10 shows the surface sand distribution for Lake Nhlange, indicating how sand dominates the lakes shallow shelf, with the finer detrital muds (gyttja) settling out within the deeper tranquil areas. Figure 2 documents sand movement from the shallow shelf areas into the deeper areas by slumping.

The lower part of core 2 stratigraphy indicates a deepwater subtidal lagoonal environment where calm conditions allow fine sediment to settle out. The high degree of bioturbation and shell fragments indicate an active infauna. This is overlain by muddy layers that have a higher sand content. The molluscan assemblage within the top layers indicate that the sand was introduced as part of the eastern barrier migration and not from the catchment, to the west.

Core 3, except for the top 2 units, represents, at face value, a tidal flat type environment that has a high biogenic component. Correlation of dating with the seismic interpretation and sea-level curves indicate that, the core represents a subtidal lagoonal environment with intertidal sand (and associated tidal flat fauna) being deposited as a series of gravity slumps. Tidal currents would have been moderate to low allowing the mud fraction to settle out after slumping.

Palaeoenvironments from within core 4 indicate marginal freshwater, brackish subtidal conditions at the base, changing upward into deepwater lagoonal conditions in the middle and finally freshwater lacustrine conditions at the top. The thick shell lag found within Unit 3 has a molluscan assemblage characteristic of predevelopment Durban Bay although *Paphia textile* and *Anatina* species indicate a warmer environment, such as Mozambique. The *Spondylus* genus association represents a subtidal rocky/coral environment whilst *Melanoides tuberculata* is diagnostic of freshwater conditions. This association indicates that either; the shells have been transported a long distance or that the subtidal and freshwater environments are in close proximity. *Modiolus philippinarum* live on marine grasses indicating an environment typical of the Mozambique type tidal sand-fiats, as found at Bazaruto Archipelago, where marine angiosperms are common. Many of the species described from Unit 3, Core 4, thrived in the Cape lagoons during the Last Interglacial (Eemian). *C. cymbium* is unique in the family Gastrochaenidae on account of its secreting calcareous, cocoon-shaped protective case, attached to empty bivalve shells. It is found in Mozambique but has not been recorded previously from South Africa. Dating of the top most estuarine shell assemblages from Cores 2 and 3 indicate that Lake Nhlange closed its mouth at Bhanga Nek about 3,000 years BP.

Core 5 stratigraphy shows subtidal marginal lagoonal deposits being overlain by lacustrine deposits indicating the change over when the mouth at Bhanga Nek closed for the last time, approximately 3,000 BP, with the environment becoming lacustrine, as it is at present.

Although all 5 cores were taken within close proximity to each other, except for the top lacustrine units, few stratigraphic units are similar, indicating very limited lateral extent of the palaeoenvironments.

The main value of the dating is to set a maximum age for closure of Bhanga Nek and perhaps the shells setting limits on salinity and hinting at palaeoenvironments. The dates from core 2 (3020 ± 70 BP) and 3 (2780 ± 80 BP) probably represent the same event, the final closure of the tidal inlet at Bhanga Nek, approximately 3000 years ago. WRIGHT *et al.* (1997) indicate that the present estuary mouth, situated 13 km to the north of Bhanga Nek, was established at least 1500 years before present, during the last Holocene high. MILLER (1994) has indicated a permanent separation of Lake Sibaya from the sea about 5030 ± 70 years before present.

LATE PLEISTOCENE TO HOLOCENE COASTAL EVOLUTION

COOPER *et al.*, (1989) indicates that an extensive system of tidal flats existed in and around the area presently occupied by Lake Nhlange, at various times in the past, the oldest being associated with the Last Interglacial (Eemian) approximately 125,000 years before present. The preservation of the 6–8 m terrace in its present position west of the present lake, (Figure 1) indicates that the area around the terrace was not affected by river incision during the Last Glacial Maximum (Wurm Glaciation) when a sea-level drop to −120 m about 18,000 years before present (WILLIAMS *et al.*, 1981; RAMSAY 1995; 1996) caused the incision of most rivers. The Last Interglacial raised terrace also remained unaffected by subsequent Holocene sea-level fluctuations which produced well defined terraces elsewhere in the Kosi system.

Last Interglacial deposits that would have been located in the area of the present Lake Nhlange were scoured out during the regression associated with the Last Glacial Maximum. The bathymetry of Lake Nhlange indicates a relic fluvial valley, similar to that of Lake Sibaya. This suggests that the scour reached at least 35 m below mean sea-level. As sea-level rose during the post-Last Glacial Maximum transgression, the ability of the palaeochannel to remain open diminished with the decreasing gradient, thus forming a lagoonal type environment, which is recorded within the cores. The palaeomouth situated in the Bhanga Nek area closed permanently approximately 3,000 years ago as the tidal scour could not keep up with the longshore drift. The barrier increased in height due to wind blown sand accumulation, ensuring that it never opened again. This forced a new mouth to form further northward, where the present Kosi Mouth was established at least 1,500 years before present, during the 1.5 m last Holocene high. (WRIGHT *et al.*, (1997).

It is interesting to note of the 37 molluscs recorded from the Kosi system in 1949 (BROEKHUYSEN and TAYLOR, 1959) only three species have been recorded since 1965 (BOLTT and ALLENSON, 1975). The presence of *P. textile* within the horizon dated at approximately 5,400 years before present indicates tropical conditions prevailing at that time. Similar samples have been dredged from both Durban and Richards Bay (29°S; 32°E) and have been dated at 4,800 BP indicating that the South African east coast had an extended period of elevated temperatures. These temperatures coincide with the peak of the Holocene transgression 4,000 to 6,000 years BP, where the sea-level was 3.5 m above mean sea-level approximately 4,500 BP (RAMSAY, 1995). THOM (1984) shows a similar Holocene transgression for the Australian coastline, indicating eustatic conditions.

The molluscan assemblages described from the 5 cores, except for the freshwater species, mostly represent a typical pre-development Durban Bay-type habitat (lagoonal, slightly muddy sand, normal salinity, fauna living at low tide to just below), where the temperature was higher than at present. Although the predevelopment Durban Bay analogy is correct, a more accurate modern analogy of a sheltered sand-flat community (as shown in Unit 3, Core 4) would be the more characteristic of Mozambique, as far south as Maputo (50 km north of Kosi) and similar ecosystems can only develop further south as peripheral isolates, in large lagoonal embayments such as at Kosi and Durban Bay.

CONCLUSIONS

Descriptions of molluscan and foraminiferal assemblages performed in isolation indicate that most of the core environments seem to be intertidal sand-flats and shallow subtidal muddy lagoonal deposits, but when specific units are dated and intergrated with seismic data, they show that the infaunal remains have been transported, as part of the sediment, into deeper lagoonal/back barrier areas by gravity slumping mechanisms. This indicates the need for a holistic approach to analysing a core, as sedimentology, palaeontology and seismic interpretation taken in isolation will often lead to spurious environmental reconstruction. Taken at face value the cores record regressive conditions, changing from marine to freshwater, but they actually represent conditions that occurred during the post-Last Glacial Maximum transgression due to constriction of the connection with the sea.

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