Late Weichselian to Holocene Evolution of the Maputo Bay, Mozambique

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ABSTRACT

During the Quaternary the volume of the world's oceans fluctuated, with sea level falls as the water has been incorporated into polar and high latitude ice sheets, and sea level rise as these have subsequently melted. Sea-level lowstands were therefore related to the Pleistocene glaciations, while high-stands correlate with interglacials. In general the climate variations in Africa shows a simple relation: Cold or cool climates are associated with dry episodes and warm climates are associated with wet episodes. This applies to the major Milankovich driven glacials and interglacials, as well as to short-lived intervals related to sun spot activities. The reconstruction of palaeo-shorelines in the Maputo Bay, and the climate around the Maputo Bay is based on bathymetric maps. At about 18,000 yr BP (-130 meters sea level) the Maputo Bay was located in an inland position. As the sea level rose to about 20 m below present around 9000 - 10000 years BP, a barrier island complex developed in the northern coast, which is well defined by 20 m contour palaeoshoreline. The Maputo Bay is only formed around 8000 – 9000 years BP (when the sea level was 10 to 12 m below the present, and it was a long lasting still stand sea level. A huge island was protecting the bay from the sea. Tidal inlet and its associated ebb delta were separating the island from the peninsula in the south and were connecting the lagoon into the sea. The complete picture of Maputo Bay patterns with its modern sedimentary environments including Inhaca Island may have evolved when the sea level has stood close to its present level around 7000 – 5000 years BP, after which the Maputo Bay became more or less stable. Coral reefs may have also developed during this period. Submarine modifications of the topography during and after the sea-level rise make it difficult to make safe interpretations of the coastal palaeomorphology. However, we believe that many of the present major submarine bottom forms, which are seen on the maps today, are related to coastal processes during the sea-level rise, and were preserved when they were flooded during the Holocene transgression.

RESUMO

Durante o Quaternário, o volume da água dos oceanos fluctuou, com a relativa descida do nível do mar, uma vez que a água esteve incorporada nos massa de gelo das grandes latitudes, e subida do nível do mar em consequência do degelo. Baixo nível do mar está portanto, relacionado com as glaciações do Pleistoceno enquando o alto nível correlaciona-se com as interglaciações. No geral as variações climáticas em África mostram uma simples relação: climas frios são associados a episódios secos e

climas quentes à episódios húmidos. Isto deve-se as glaciações e interglaciações motivadas pelo ciclo de Milankovich, bem como pelas actividades de insolação. A reconstução da antiga linha de costa e do clima na Baía do Maputo e arredores, é baseada em mapas batimétricos. Há cerca de 18.000 anos antes do presente (AP) (nível do mar – 130 metros), a posição da Baía do Maputo encontrava-se no interior. Uma vez que o mar subiu até cerca de 20 m abaixo do presente nível, há cerca de 9.000 – 10.000 anos AP, desenvolveu-se um complexo de ilhas barreiras na parte sententrional da costa, bem definido nas linhas batimétricas de 20 m. A Baía do Maputo formou-se apenas por volta de há 8.000 – 9000 anos AP quando o nível do mar esteve 10 a 12 metros abaixo do presente nível, e permaneceu estável por longo período. Durante este período, a baía esteve protegida por uma enorme ilha. O canal de marés com os respectivos deltas de marés enchente e vasante, separava a ilha da peninsula e ligava a laguna ao mar. A completa configuração da Baía de Maputo com os seus respectivos ambientes deposicionais modernos incluindo a Ilha da Inhaca deve ter-se atingido quando o nível esteve próximo do presente nível do mar por volta de há 5.000 – 7000 anos AP, altura em que a Baía de Maputo se tornou mais ou menos estável. Os recifes de corais deve ter-se desenvolvido durante este período. Com as modificações da topografia submarina durante e depois da subida do nível do mar, torna-se defícil fazer interpretações seguras da paleomorfologia costeira. Contudo, acreditamos que a maioria das formas do fundo do mar que se verificam hoje, estão relacionadas com os processos costeiros durante a subida do nível do mar e foram preservadas quando foram inundadas durante a transgressão Holocénica.

1 Setting

The Maputo Bay is located in the Southeast of Mozambique (Fig. 1) about 100 Km North of South Africa. It is one of the most important shipping harbours in the country.

2 The global sea level fluctuations 18,000 BP - present

During the Last Termination (Last Glacial Maximum), the sea level was at least 130 m lower than today (Lambeck and Chappell, 2001; Ramsey, 1997; Ramsey, 2001).

The transgression was fast during from 18,000 BP until 9,000 BP, when the main part of the large, continental ice sheets melted. This first and very fast transgression after the last glaciation was mainly related to the melting of ice, while the thermal expansion of the seawater must have been of lesser importance.

From 9,000 BP to 6,500 BP the sea-level rise was slower, and the present global sea level was reached at the end of this time interval.

Whether or not the global sea level was higher at any time in the Holocene than it is today is a question that is still under debate. However, Ramsey (1995) found from datings of beachrocks that the sea level along the southeast coast of Africa was around 3 m higher than today around 5 – 4,000 BP, during the Holocene climatic optimum. He argued that this high sea level, which is above the generally accepted global sea level for this time interval, was the result of a thermal expansion, due to the very warm Agulhas Current that flows towards SW along the southeast coast of Africa.

One factor that Ramsey (1995) did not use as an argument is the orbital constellation. At 5,000 BP the precession resulted in a change to a higher summer insolation in the southern hemisphere than in the northern. We also know from the studies of corals in Mozambican Channel (Bard et al. 1997; Gasse, 2000) that the sea surface temperature was at its highest around 5,000 BP, and around 6 °C higher than it was during the LGM. It was at that time also higher than it is today.

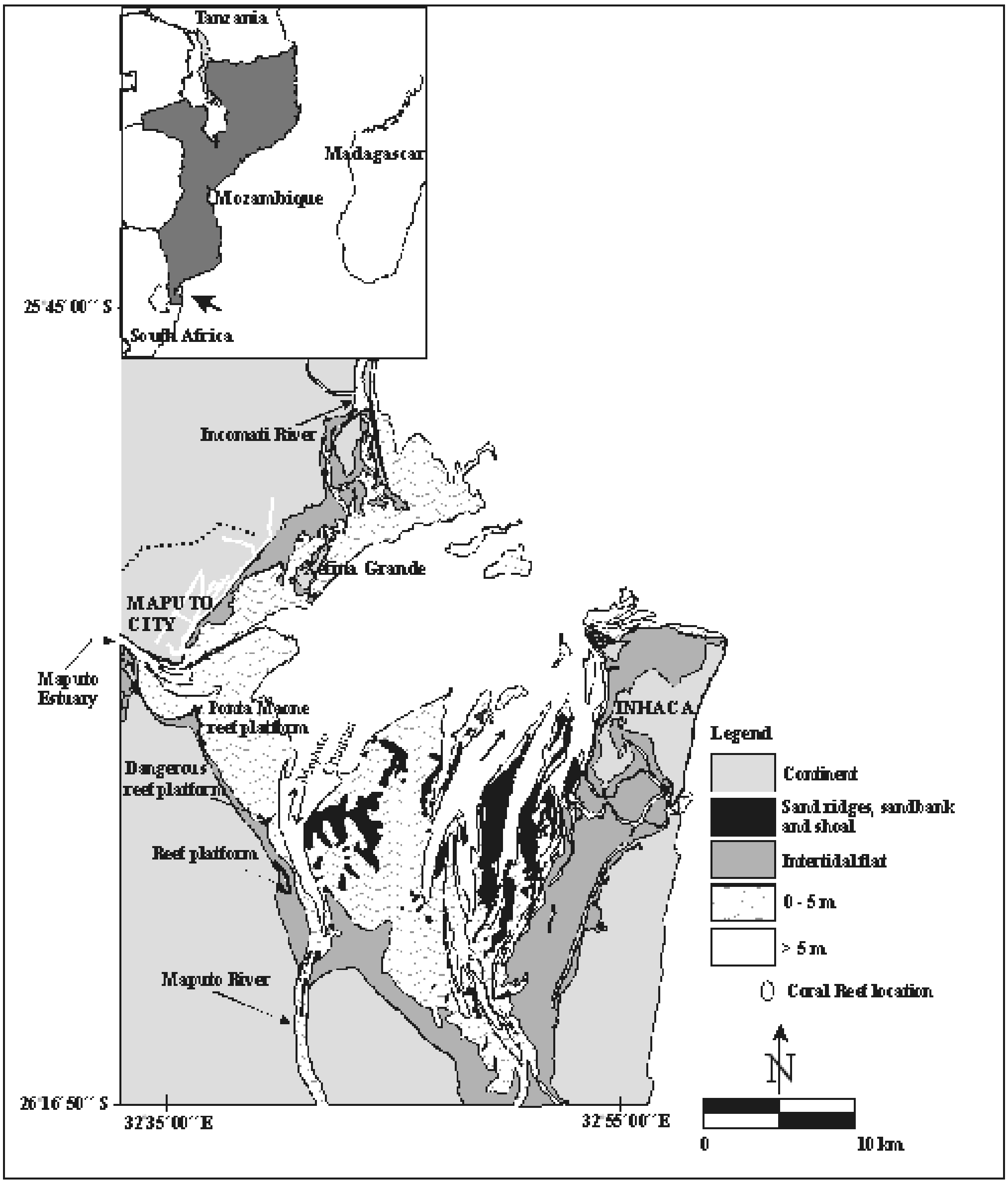

Figure 1. Geographic positioning of the Maputo Bay and details on recent sedimentary environments (After Achimo 2002).

3 Climate and vegetation in southeast Africa 18,000 BP - present

In general the climate variations in Africa shows a simple relation: Cold or cool climates are associated with dry episodes and warm climates are associated with wet episodes. This applies to the major Milankovich-driven glacials and interglacials, as well as to short-lived intervals related to sun spot activities.

The Last Glacial Maximum was genereally cold all over the world. In Africa it was a Glacial Aridity Maximum/Maxima 22-13,000 ^{14}C y.a. (about 23,000-14,500 'real' years ago) (Adams, 1998). Partridge (1997) reconstructed LGM rainfall for southern Africa for the LGM, on the basis of various data sources. He suggested that the southeast part of the region had a rainfall, which was about 60-70% of present-day.

Generally, it is assumed a lowering of the temperature over the African continent during the LGM of 5-8 ^{o}C compared to the present. However, from the fossil pollen records it is often difficult to decide what was the result of a dryer and what was the result of a cooler climate.

It is shown that the African climate responds well to the precession cycles of 21,000 years (Gasse, 2000; Partridge, 1997). The climate in northeast and southwest Africa is mirrored. A well documented humid and warm period occurred in northeast Africa with a culmination 8,000 years ago, when the Earth was closest to the Sun during the northern hemisphere summer (deMenocal, 2000). Southeast Africa at that time still experienced a dry climate and cooler climate (Adams, 1998). Around 5000 BP the climate in southeast Africa became more humid, when the Earth became closer to the Sun in the southern hemisphere summer. Today the Earth is closest to the Sun in January.

During the past few years it has been shown that the non-orbital climate variations like the Medieval Warm Epoch and the Little Ice Age may be global, and not only restricted to the northern hemisphere (Bradley, 2000; Broecker, 2001 Crowley, 2000 Kerr, 1999). Although still debated, it seems possible to explain these climatic episodes by the sun spot activity (Beer *et al.*, 2000). Tyson (1993) and Tyson *et al.* (2000) found from speleotheme studies that there had been several distinct climatic cycles in southeast Africa during the past 2000 years, and that both the Medieval Warmth and the Little Ice Age are distinct. The former was warm and wet, while the latter was cool and dry.

4 The reconstruction of palaeo-shorelines in the Maputo Bay, and the climate around the Maputo Bay

This reconstruction is based on bathymetric maps. Submarine modifications of the topography during and after the sea-level rise, makes it difficult to make safe interpretations of the coastal palaeomorphology. However, we believe that many of the present major submarine bottom forms, which are seen on the maps today, are related to coastal processes during the sea-level rise, and were preserved when they were flooded during the Holocene transgression.

The reconstruction of the former shorelines from the bathymetric chart shows that the shoreline over the broad Maputo Bay has undergone lateral translation with rising sea level. This paper gives the first and a general overview of Late Weichselian to Holocene evolution of Maputo Bay. The former shoreline is preserved as barrier islands complex, platforms, river outlets, and information on the palaeoclimate and sea level curves are here used to build up this study. In this study we have applied the relation between the sea levels and the ages by Ramsey (1995; 1997).

During the Last Glacial Maximum (Fig. 2) at about 18,000 yr BP (-130 meters sea level) the Maputo Bay was located in an inland position. Most of its continental shelf

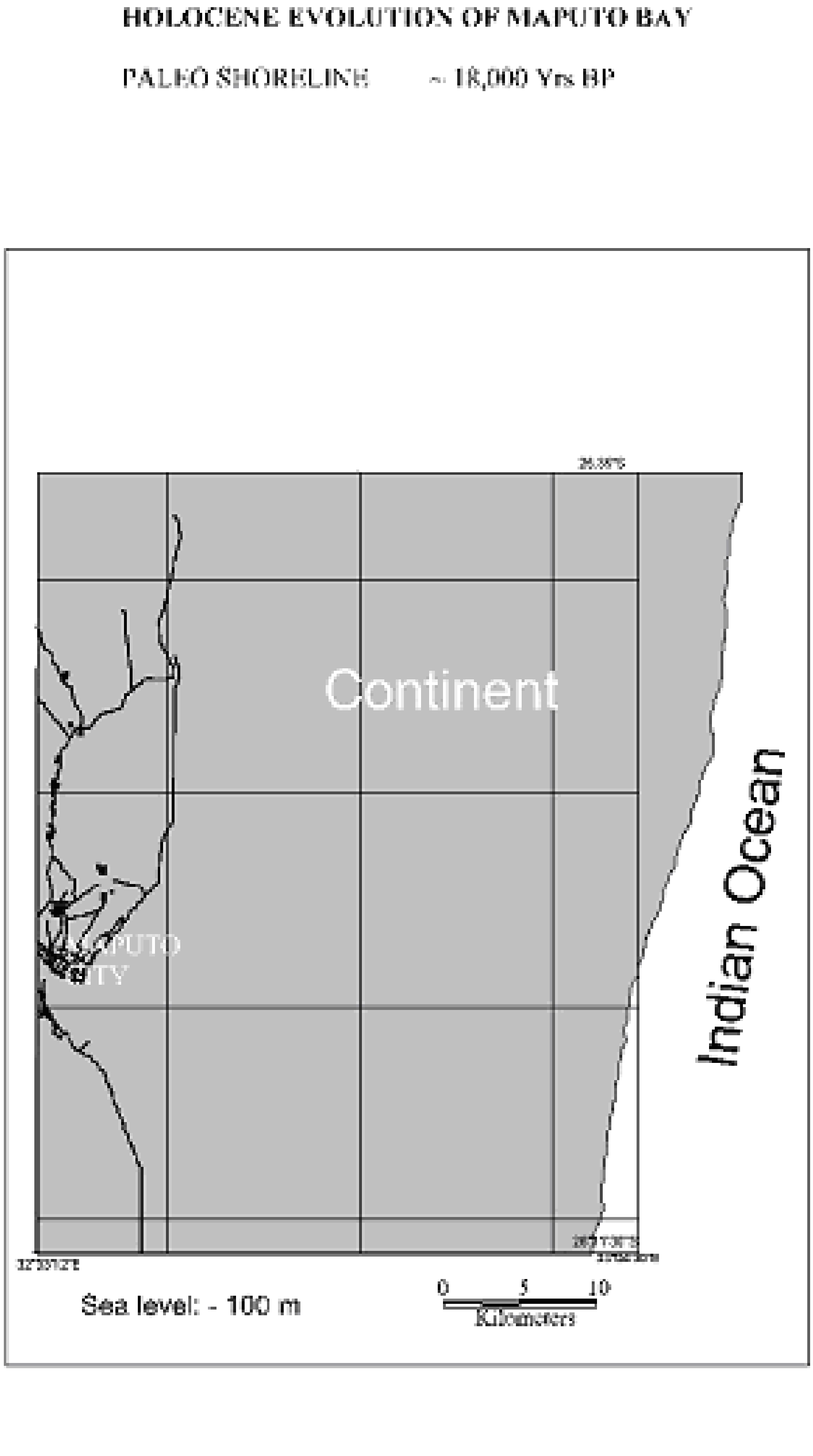

Figure 2. Palaeoshoreline of the Maputo region 18,000 Yrs BP. The present Maputo Bay was located approximately 70 Km away of the NNE –SSW straight coastline.

was a dry land within an extensive low gradient coastal plain. The coastline was straight, like it is along the Maputaland coast to the south today. The site of the

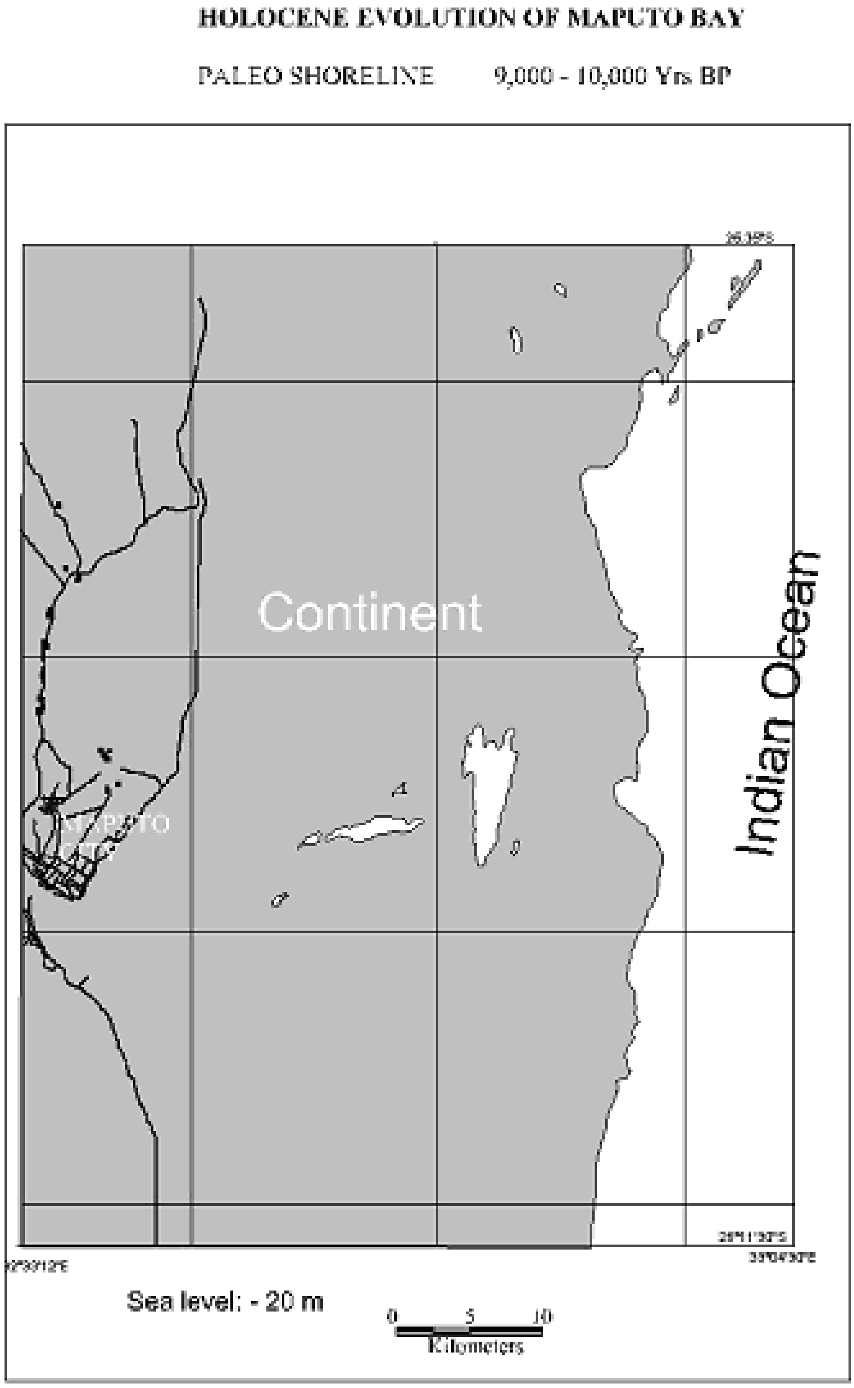

Figure 3. The shoreline was oriented approximately N – S and had retreated few Km westward. At the northern part, a chain of small islands oriented NE - SW were formed close to the shoreline. Behind this island complex there was a small lagoon and, eventually, tidal flats.

present Maputo City was positioned around 70 km from the coastline. The sea surface temperature was probably around 5 ^{o} C lower than today (in Gasse, 2000). The coast was exposed to long-shore currents.

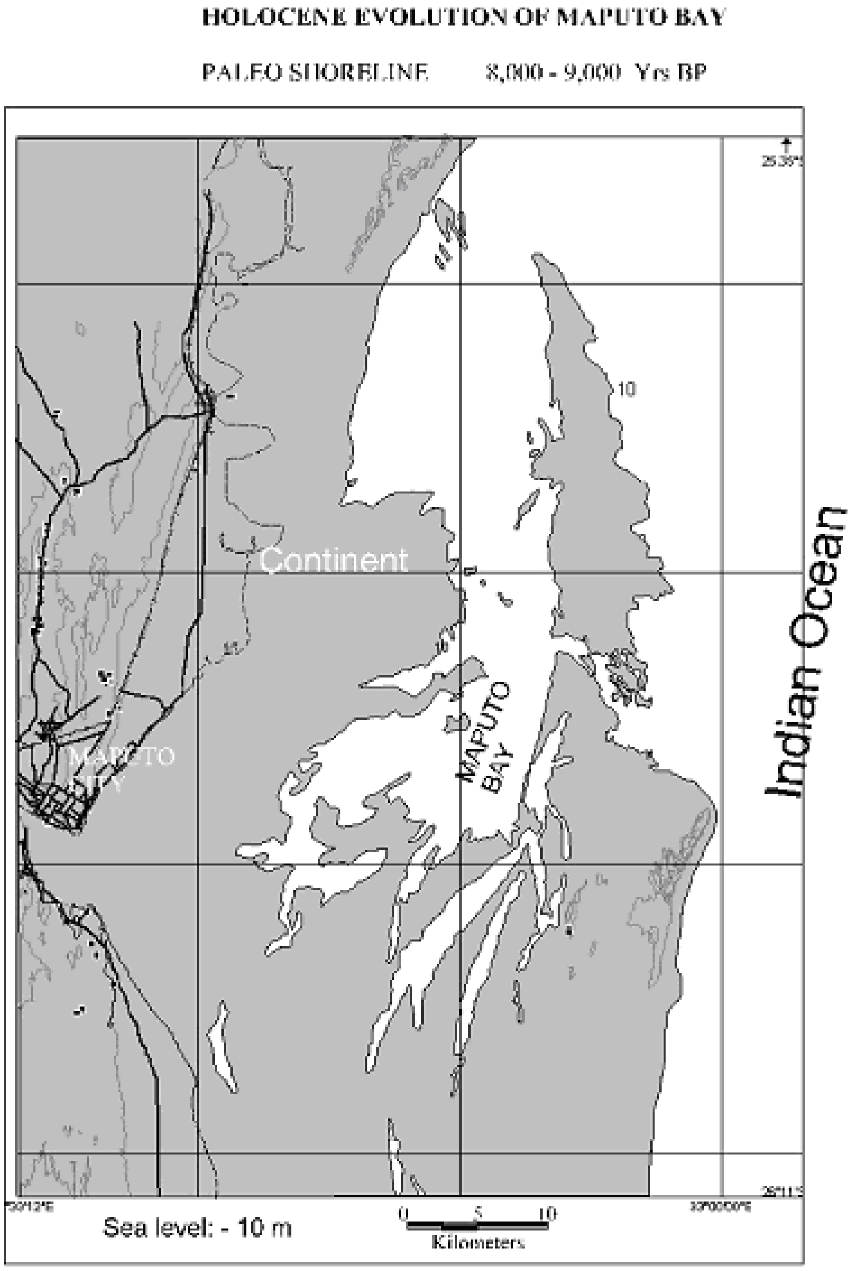

Figure 4. ***Maputo bay*** *started to be formed. A huge barrier island was protecting the bay from the sea.Tidal inlet and its associated ebb delta separated the island from the peninsula in South, and connected the lagoon to the sea. The Maputo River outlet is clearly shaped and elongated lakes also are formed probably from the marine flooding and/or water table rising.*

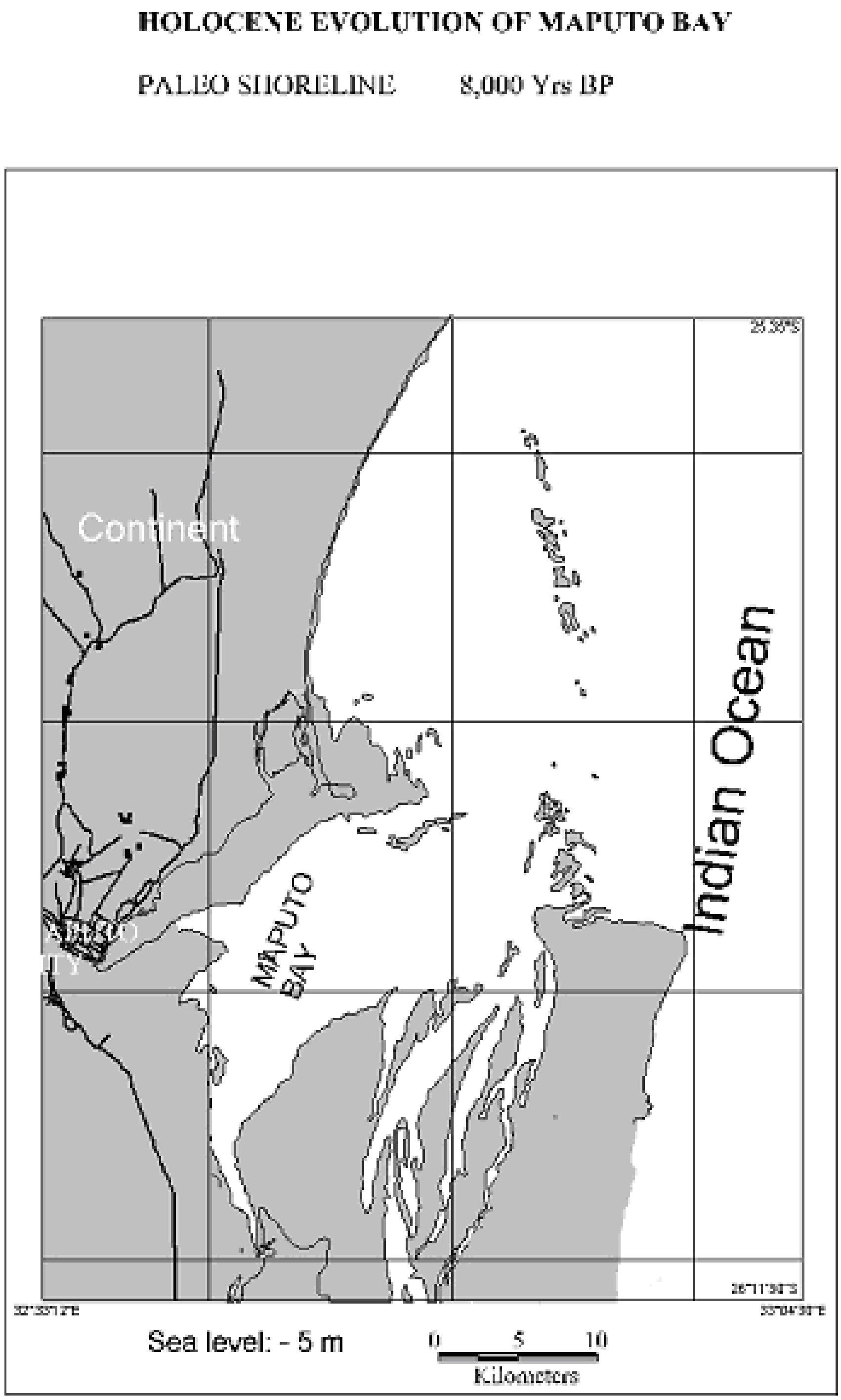

Figure 5. The huge barrier Island was drowned and only the elevated patches were left behind as remnants. New barrier complex has developed at the expense of the remains of the old ebb delta due to further marine flooding.

In general the precipitation was everywhere lower during the LGM than today (see general presentation above). However, in addition to this, a higher relative aridity is also to have been expected with the translation of the present coastline over 50 km to the East. If we compare with the present, there is today a significant rainfall gradient over such a distance inland from the Indian Ocean Coast. If we apply the general data from Partridge (1997) with an air temperature 5^o C less than today, and a precipitation about 40 % lesser, the coastal plain east of the present Maputo probably belonged to a Dry Tropical Climate Zone. Another effect of the climate is that the LGM conditions are likely to have led to a decrease in river discharge and sediment load reaching the sea.

The Holocene epoch was characterised by dramatic rise in sea level, increased precipitation compared to the LGM, marine inundation of coastal areas and regional rise in the coastal groundwater table. As the sea level rose to about 20 m below present around 9000 - 10000 years BP, a barrier island complex developed in the northern coast, which is well defined by 20 m contour palaeoshoreline (Fig. 3).

Behind this island complex there was a small lagoon and, eventually, tidal flats, in which fine silt and clays may have settled out of suspension. Inland fresh water lakes also developed in the north and central regions due to increased coastal precipitation and rise of the groundwater table. The steady supply of sediments, wave action and long shore currents were the most important factors that favoured the development of the barrier island complex in the northern coast.

The Maputo Bay is only formed around 8000 – 9000 years BP (when the sea level was 10 to 12 m below the present (Fig. 4), and it was a long lasting still stand sea level. A huge island was protecting the bay from the sea. Tidal inlet and its associated ebb delta were separating the island from the peninsula in the south and were connecting the lagoon into the sea. The Maputo River outlet is clearly shaped and elongated lakes also are formed probably from the marine flooding and/or water table rising. Some wetlands and peat deposits could also be formed during this time and, better conditions for the development of mangroves may have existed around the river outlet surroundings.

The continued sea level rise to about 5 m below the present (Fig.5) drowned some of the island and, only elevated patches were left behind as barrier island complex and a new barrier island complex developed at the expenses of further marine flooding and remains of the ebb delta. The position of Maputo River and Maputo Estuary is well established side by side with “Machangulo Estuary”, the later is discerned by it funnel shape. Elongated sand ridges in the “Machangulo Estuary” forms the foundations of the present sand shoals and sandbanks in the bay. The conditions for the development of the mangroves may have bloomed by this time. The complete picture of Maputo Bay patterns with its modern sedimentary environments including Inhaca Island may have evolved when the sea level has stood close to its present level around 7000 – 5000 years BP, after which the Maputo Bay became more or less stable. Coral reefs may have also developed during this period.

During the late phase of the sea level rise -5 m - present sea level (Fig. 6), southeastern Africa experienced a very warm and wet period around 5000 BP. At that time the sea level might have been somewhat higher than today (Ramsey, 1995). The lowest areas around the present Maputo Bay would then have been flooded. It would

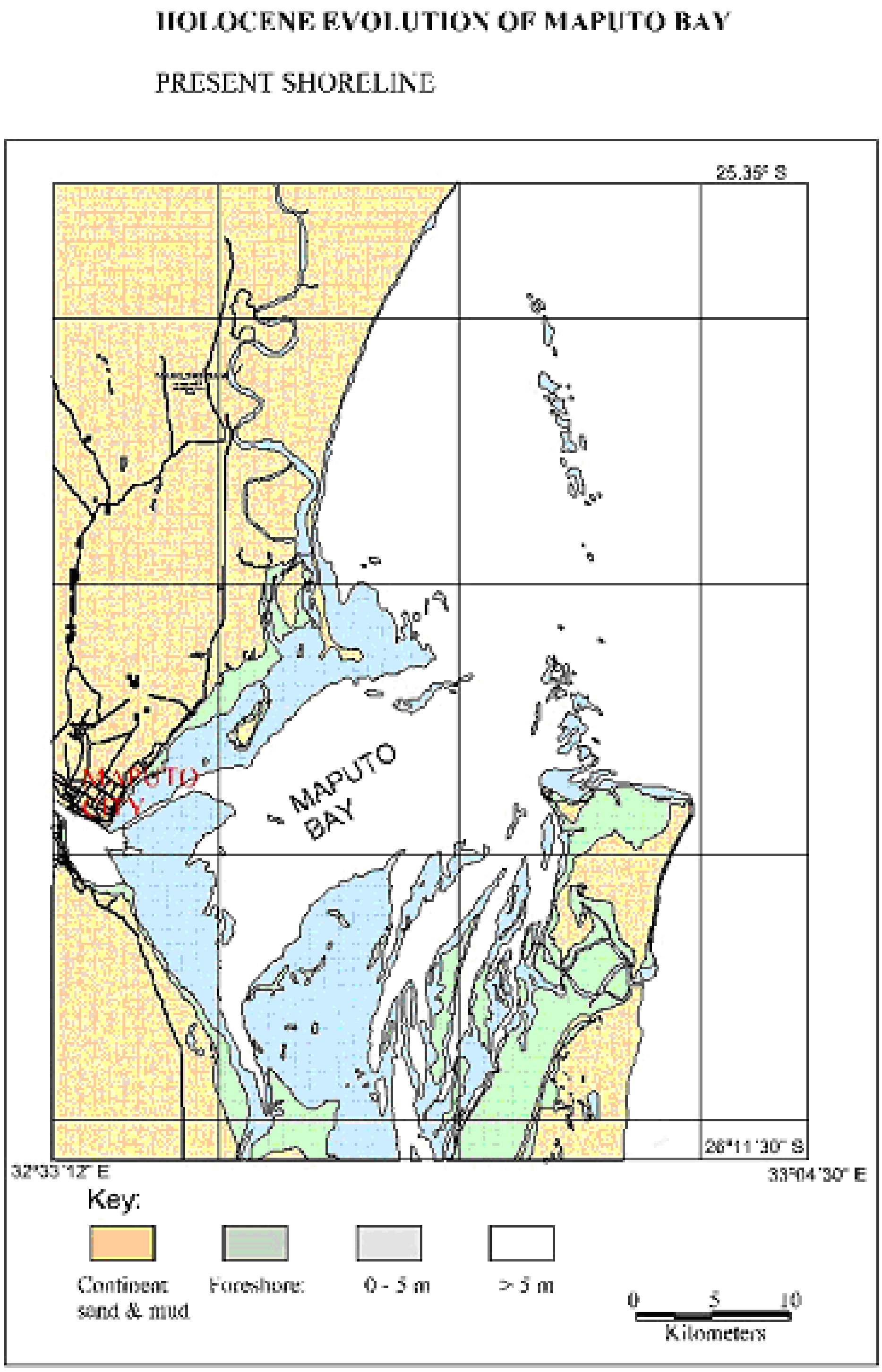

Figure 6. Complete picture of the Maputo Bay patterns with its modern sedimentary environments including Inhaca Island.

be an interesting future study to see if there are evidences of such a high marine level around the Bay. A sea temperature being a couple of degrees higher than today

(Gasse, 2000) would have resulted in a very moist and warm climate around the bay, and probably dense mixed mangrove forests in the estuaries. This period was also very moist in the inland, and there might have been frequent major flood events.

This last period also includes the Medieval Warm Epoch and the Little Ice Age. During the former, the temperature was probably at least as high as today, and the precipitation was high. One can expect rather frequent floods to have occurred. During the latter the coastal area must have been drier than today. Floods were probably less frequent. At the end of the 19th century and the beginning of the 20th century the climate again became warmer and this period was in particular wet (Huffman, 1997). Maize was exported from Maputo into Natal, which is one indication of a wetter climate in the close inland areas.

5. Conclusions

The predicted sea-level rise related to the global warming (UNEP, 2001) may again result in a flooding of the lowest lying areas around the Maputo Bay, including parts of the heavily populated Maputo City. We believe that studies of the past may contribute to an understanding of the future climate, and that palaeomaps may be a useful tool to evaluate the risk areas during possible future sea-level fluctuations.

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