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Evolution of the siliciclastic-carbonate shelf system of the northern Kenyan coastal belt in response to Late Pleistocene-Holocene relative sea level changes

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A B S T R A C T

A classification of depositional environments of the Lamu Archipelago is proposed based on a sedimentary facies analysis of unconsolidated and hard bottoms of the study area. The genesis of the siliciclastic-carbonate depositional pattern, typical of this East African region, is closely related both to the presence of a quartz-dominate Pleistocene riverine net—flooded during the Holocene sea level rise—and to the coeval development on the shallow shelf of a coral ecosystem producing vast skeletal sediments. The present facies pattern originates from the variable contribution in time and space of three sediment types: skeletal carbonate, quartz and palimpsest debris. The facies analysis allowed to distinguish 10 depositional facies and to differentiate them into three main types of substratum: soft bottom, reefal hard bottom and non-reefal hard bottom. These three types define both the loose facies typical of the channelized coastal belt and several facies of the shallow shelf. In the first, the amounts and textures of the stored sediment are strictly related to three major geomorphic types of substratum: sheltered mangal flat, shallow channel and deep channel. In the second and the third, a wide range of textures is related to coastal flats, benches, islets and emerging rocks. This modern facies pattern is implemented through a series of evolutionary phases: i—during the Last Interglacial Period, since isotope substage 5b, the shallow shelf—above −20 m—is permanently exposed for about 80 ka, with erosion, karstification and cuts of river channels through the shelf; ii—after the Last Glacial Maximum, when the sea level fell to about 110–115 m b.p.s.l. (below present sea level) at 18–17 ka BP, the sea level rose at −20 m for about 9 ka, flooding the shallow shelf area and gradually drowning the riverine net; iii—the maximum flooding of the coastal belt was reached at about 4.5 ka BP, when a gradual moisture reduction caused a decrease of siliciclastic sediment supply; iv—a fairly rapid fall of sea levels since about 4.5 ka BP was probably accompanied by a decline in drought, producing relatively high siliciclastic loose sediment remobilization that carved the morphological steps of the coastal flat, leading to the regression of the coral reef community, and the formation of rhodolith beds. The investigated depositional system is then correlated with the model of a distally steepened ramp with mixed carbonate-siliciclastic sedimentation, suitable for the present setting of the Kenyan coast.

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1. Introduction

The surveyed Kenyan coastal belt is located between approximately 2°00'S and 2°30'S, where the Lamu Archipelago faces the coast. Its three largest islands are Lamu, Manda and Pate (Fig. 1). These islands, along with many smaller ones, are separated from the coastline by a drowned anastomosed fluvial net, passing landward to a wide endorheic basin that extends along the Somali border. To a large extent, this drowned fluvial system is associated with depositional environments, which are valuable repositories of climate and sea level histories, as sea level oscillates and reefs grow and wane in shallow areas along the continental shelf.

The unifying feature of the southern Somali and north Kenyan coastline is the presence of uplifted reef complexes cut by marine terraces at different elevations above the present sea level, bordered by wave-cut notches and tidal-dominated channel nets, which discharge fresh water only during the wet seasons. The processes of fluvial sediment contribution, shoreline accretion, coastal cementation and coastal erosion—coupled with inherited landform architecture, such as residual barrier islands—have produced the complex coastal system, whose present facies pattern developed since the Holocene flooding of the continental shelf. As a result, the coast is dominated by active beach/dune shores, wave cut platforms into Pleistocene coral limestone, barrier islands mainly formed by eolianites, fringing reefs and patch reefs growing in shallow shelf areas. The morphological characters, the distribution and variety of surficial sediments and the processes associated with their origin are documented in this study, which aims to deepen knowledge of the recent evolution of the northern Kenyan coast and its response to Quaternary sea level changes.

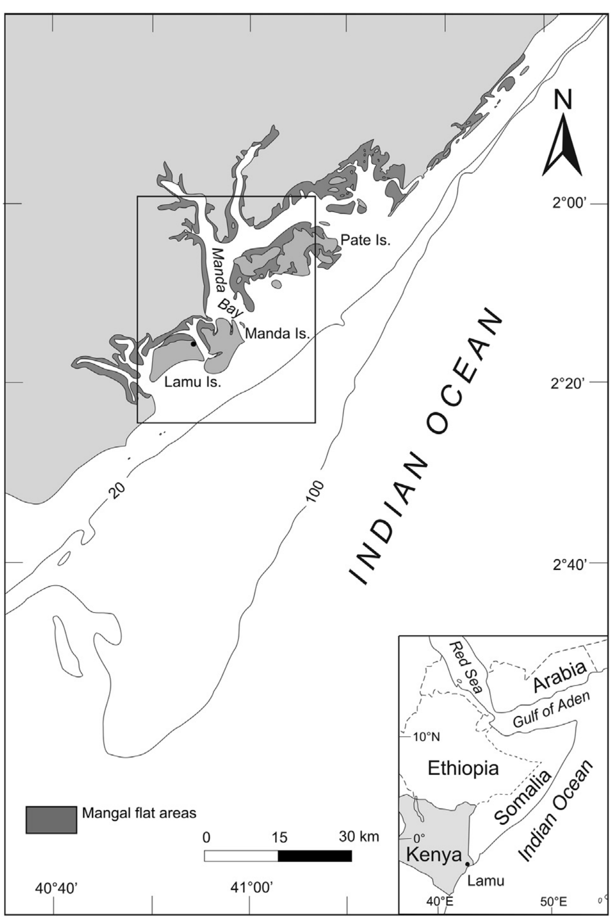

Fig. 1. Location of the study area on the northeast coast of Kenya.

The present day sedimentary pattern has been primarily influenced by changes in the sedimentary supply in response to sea level oscillations within a siliciclastic-carbonate system, where the siliciclastic sediment drift off by rivers and the carbonate sediment production in shallow marine water dominate the depositional environments. As on many tropical continental margins worldwide (Testa and Bosence, 1999; Purdy and Gischler, 2003; Page, 2006; Ryan-Mishkin et al., 2009; Gischler et al., 2010), also this part of the African coast of the Indian Ocean has received substantial siliciclastic and biogenic carbonate sediments during the Late Pleistocene and Holocene. The siliciclastic sediment supply to the Lamu shelf should have been greater during the Last Glacial Period (LGP), which coincided with a sea level lowstand, when the rivers incised the exposed shelf to equilibrate the lowering of base levels. Conversely, the siliciclastic supply should have been minimal during the late Holocene, due to continental shelf flooding: from about 9 to 10 ka BP (Achimo et al., 2004; Camoin et al., 2004) the rising sea level forced rivers to retreat landward. In contrast, the indigenous carbonate sedimentation should have decreased during the sea level drops, as the exposure of the shelf reduced the shallow marine sea floor areas where the accommodation space was compatible with the skeletal carbonate production rate. Furthermore, the carbonate sediment production should have increased when the sea level rose above the shelf edge, with a subsequent expansion of shallow water environments. Then, the skeletal carbonate storage on the shelf reached its maximum 5 to 4 ka BP (Ramsay, 1995) during a highstand about 3.5 m above the present sea level, when shallow marine accommodation space was greater than at present. Few reliable data exist on the timing of the last flooding of the African continental shelf of the Indian Ocean and on the maximum highstand reached by sea level. Useful information can, however, be deduced by some works on several islands in the western Indian Ocean (Colonna et al., 1996; Camoin et al., 1997; Montaggioni and Faure, 1997; Zinke et al., 2003; Van Der Plas et al., 2012). Here we