Holocene land-sea interactions and landform changes in the coastal lands of Vembanad lagoon, Kerala, SW India

D. Padmalal*, K. Maya, S. Vishnu Mohan & B. Baburaj
National Centre for Earth Science Studies, Thiruvananthapuram, Kerala, India-695 031
* [E-mail: drdpadmalal@gmail.com]

Received 9 August 2013; revised 23 October 2013

The sedimentological, palynological, geomorphological and stable isotope (δ¹³C and δ¹⁵N) studies of six borehole cores retrieved from the Vembanad basin together with sedimentological studies of 14 surface sediment samples collected from the barrier beach separating the lagoon from nearby sea were analysed for decoding signatures of land–sea interactions in the sedimentary archives of the area. The radiocarbon age of the subsurface sediments varied from 10620±160 yrs BP to 3990±150 yrs BP. Stable isotope studies reveal indications of the dominance of marine components in the basal portions of the borehole sediments of southern sector. Presence of higher order riparian vegetation is noticed in central and northern sectors of the basin before the region being occupied by lagoon waters of the Holocene transgressive phase. The northward drift of sediments was well represented in the mineralogical diversities of the heavy mineral residue, in addition to the northerly deflections of the distributary channels, especially in the northern part of the basin. The lagoon entrances also showed significant changes during the Holocene epoch. The prominent entrance of the lagoon till Late Holocene was at Andhakaranazhi which was indicated by the anomalous presence of pyriboles (pyroxenes + amphiboles) within the sillimanite dominant domain of the sub-surface sedimentary archive. This entrance became inactive during the latter half of the Late Holocene because of sediment build up and subsequent landform changes. Simultaneously, the entrance at Fort Kochi was developed for the exchange of water between the lagoon and the sea.

[Keywords: Holocene land-sea interactions, Landform changes, Vembanad lagoon South west coast of India]

Introduction

The coastal areas are one of the most dynamic and strategic regions of the world where sea water is in constant interaction with land¹. The area is known for outstanding natural beauty, economic prosperity and also human stress. Therefore, any significant change in the level of sea water or land will have direct effect on the life/economic security of the people in the area.

Vembanad lagoon is the largest back water system in the southwestern coast of India which receives the status of an area of outstanding natural beauty in the tourist map of the world. The lagoon and its river catchments cover about 15000 km² area of the Kerala and play a key role in the socio-economic and geo-environmental scenarios of the state. The coastal lands of the Vembanad basin are influenced by both natural processes and man-made interferences. Reports reveal that a substantial part of this wetland has been reclaimed for various developmental purposes during the period 1839-2004². As most of the developmental initiatives and economic activities of the state are centered on the banks of the Vembanad lagoon, especially around Kochi (otherwise called the Queen of Arabian Sea), a better understanding of the millenial scale changes of land-sea interactions, coastal dynamics and landform changes will be very essential for designing sustainable development strategies in this strategic coastal strip in south western India. In addition to this, we believe that the information will be useful for chalking out strategies for the conservation and management of this unique backwater system which is declared recently as a Ramsar wetland of international importance.

Geo-environmental setting

Vembanad lagoon has a length of 113 km and water spread area of 230 km². The coastal plains of the lagoon has extremely low relief, except at certain stretches near Cherthala (southern arm) and Paravur (northern arm) where the terrain is dissected by a series of dunes with a maximum height of about 8 m. The width of the lagoon³ varies from a few hundred meters to about 4.5 km. An estuarine condition prevails in the lagoon during most part of
the year, except during monsoon season. The lagoon receives freshwater discharges from 7 small rivers with catchment area 14494 km². Geologically, the basin area of the lagoon and its river catchments are composed of four major rock units- i) Pre-Cambrian crystallines, ii) Neogene sedimentary rocks, iii) Laterites and iv) Quaternary sediments. The major landform features noticed in the area include bars or barriers, lagoons, ridge-runnel systems and dunes. The area enjoys a tropical humid climate with an annual average rainfall of about 3000 mm.

Materials and Methods
A systematic fieldwork was carried out to collect primary and secondary data on various landform features of the study area. A total of 14 surface sediment (beach sands) and 6 borehole cores were collected from the area (Fig. 1) for detailed laboratory studies. Sub-samples were subjected to textural analysis following Lewis. Organic matter rich sub-samples from selected depths were subjected to radiocarbon dating at Birbal Sahni Institute of Palaeobotany, Lucknow (India) for establishing the chronological bearing of sediment deposition. Heavy mineralogical analysis of the fine sand fractions of surface and borehole samples was carried out following Mange and Maurer. A few selected sub-samples were subjected to stable isotope estimations for carbon (δ¹³Corg) and nitrogen (δ¹⁵N) at Centre for Tropical Marine Ecology (ZMT), Bremen (Germany) following standard procedures.

Results and Discussion
Fig. 2 shows the lithological characteristics of the borehole cores collected from the coastal lands of the Vembanad basin. The granulometric data and statistical parameters worked out for the beach samples are given in Table 1. Table 2 gives the heavy mineral contents in the surface sediments samples collected from the barrier beach separating the lagoon from the sea together with that of the borehole cores. The beach sands are generally dominated by fine and medium sands which together cover about 70% of the size population. Except the two samples at Mararikulam (Sample Number 9) and Kanjiramchira (Sample Number 10), which are dominated by medium sand, the rest of the samples are dominated by fine sand. The sands are moderately well to moderately sorted (0.55φ to 0.91φ), coarse to...
The lithological characteristics of the borehole core (Fig. 2) reveal that except the Ernakulam borehole core, all the other cores are characterised by a sand apron which is often intervened by silt/clay dominated sediments whose age varies from 5390±140 yrs BP (Pattanam) to 6800±180 yrs BP (Muhamma). The Panavally (5810±100 yrs BP), Ernakulam (5680±170 yrs BP) and Pattanam (5390±140 yrs BP) borehole cores recorded almost similar age at the base of the sand apron. This clearly indicates that the upper part of the sand unit at Muhamma and Kalarkod in the southern sector as well as the entire sand unit of Panavally, Ernakulam and Pattanam have been deposited during Middle Holocene when the sea level reached its maximum land-ward limit. At the same time, the lower part of the sand unit in the southern part of the lagoon might have been deposited during Early Holocene.

The total heavy mineral content gives markedly higher values in the borehole core at Pattanam and minimum at Thannirmukkam (Table 2). The major heavy mineral species identified in the fine skewed and platy to leptokurtic (Table 2).
borehole cores are opaques (represented by ilmenite and magnetite) and sillimanite in the borehole core sands of the southern sector (south of Panavally) with an anomalous increase of pyribole contents (pyroxenes and amphiboles) in the Thannirmukkam borehole core. The borehole cores north of the Panavally is characterised by marked depletion of sillimanite with a concomitant increase in the content of pyriboles.

In an earlier study, Padmalal et al.\(^9\) revealed that the long shore drift of sediments, originally derived from the garnet-sillimanite gneissic (khondalite suite of rocks) provenance, was detected up to 6-7 km north of Panavally station. Nabila\(^10\) also detected sillimanite rich surface sands in a location ~7 km north of Panavally. The sea level rise coupled with the northward drift of littoral currents Early-Middle Holocene was responsible for the progradation and development of sand barriers separating the lagoon from the sea. Abundant supply of sediments in the Early Holocene was responsible for the build up of barrier system while short supply caused its breaching into barrier islands\(^11,12\).

Although the sillimanite/pyribole boundary is located 7 km north of Panavally (Fig. 3), the corresponding line in the present beach is noticed about 10 km south west of Panavally, near Andhakaranazhi (Fig. 4). This together with the anomalous occurrence of pyriboles in the Thannirmukkam borehole core as well as the observed geomorphic expressions points to the existence of an outlet system in this sector linking the lagoon with the nearby sea.

This outlet that has migrated northwards and reached Andhakaranazhi becomes inactive during the latter half of Late Holocene. The closure/near closure...
of the Andhakaranazhi outlet was followed by the development of the outlet near Fort Kochi through which the rivers empty its water and sediments into the Arabian Sea.

The stable isotope data also exhibited marked difference, especially in the basal portion of the borehole cores of the southern (Panavally: $\delta^{13}C$ - 24.33‰; $\delta^{13}N$ 8.22‰) and, central (Ernakulam: $\delta^{13}C$ - 27.17‰; $\delta^{13}N$ 5.80‰) and northern (Pattanam: $\delta^{13}C$ - 27.47‰; $\delta^{13}N$ 5.54‰) sectors of the lagoon. The stable isotope data indicates the presence of marine elements in the south (also confirmed from the abundance of non-pollen palynomorphs of marine affinity in the samples) whereas higher order, treed coastal vegetations in the central and northern sectors before the area being occupied by lagoonal waters of the Holocene transgressive phase. To conclude, the study discloses the fact that the Vembanad lagoon attained its present geomorphic configuration during Holocene epoch- the time span in the earth history known globally for marked land-sea interactions and climate changes. We believe that, information on the Holocene coastal evolution and the stratigraphic architecture deduced from the study will be useful to those who are interested in environment – friendly developments in the coastal lands of Central Kerala, including the fast developing urban – cum – industrial centre, the Kochi city.

Acknowledgements

The authors thank Dr. N. P. Kurian, Director Centre for Earth Science Studies (CESS), Thiruvananthapuram for encouragements and support. Thanks are also due to Dr. K. P. N. Kumaran, Emeritus Scientist, (CSIR), Dr. Ruta B. Limaye, SRA (CSIR), Agharkar Research Institute, Pune for palynological studies. We acknowledge Dr. K. M. Nair, Director, Sredha Scientific Charitable Society (SSCS), Thiruvananthapuram for fruitful discussions. Dr. C. M. Nautiyal, Senior Scientist, BSIP, Lucknow is acknowledged for C14 dates. We thank Professor (Dr.) Tim Jennerjahn, ZMT, Bremen, (Germany) and Dr. K. Soman, Former Head Resource Analysis Division, CESS for stable isotope estimations. VMS acknowledges Council of Scientific and Industrial Research (CSIR), New Delhi for financial assistance through SRF Grant [09/909(0005)/2012-EMR –I].

References