

On Some Aspects of Barrier Islands of the West Coast, India

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ABSTRACT

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Three barrier island systems, namely, Maniyet barrier island system, Vypin-Cochin barrier island system, and Alleppey barrier island system situated along the west coast of India are located, mapped and studied using remote sensing data, topographic maps, and naval hydrographic charts. Efforts are made to gather geomorphic evidences which are helpful in understanding possible stages of formation of barrier islands. Based on transgressional and regressional nature of the coast, physiography of barrier islands, and the shoreline changes, it has been concluded that the evolution of the barrier islands has taken place in three prominent stages: (1) Initial emergence of the land during which paleo beach ridges were formed, (regressional phase), (2) subsequent submergence of the land, which is characterized by engulfment of beach ridges (transgressional phase), and (3) emergence of the coast during which breaching (regression phase) of ridges and barrier island formation took place.

ADDITIONAL INDEX WORDS: Remote sensing, coastal geomorphology, coastal erosion, beach sand, island.

INTRODUCTION

Out of various barrier beach forms, spits, bay barrier or bay mouth bars and barrier islands, the latter have been the subject of the most intensive investigations and the most widely reported upon, in recent years (SCHWARTZ, 1990). Historically, debate over the barrier island development started when BEAUMONT (1845) proposed bar emergence as the mechanism responsible for elevation of the coastal feature. Since then, the concept of barrier evolution has been developed over more than a century with an emphasis on the various processes shifting with new knowledge.

SCHWARTZ (1973) in his book *Barrier Islands* has compiled selected literature which covers the historic growth of the subject with claims and counter claims of different authors on the origin of the barrier island. More recently, attention from the research community has turned to the classification and migration aspect of barrier islands (KRAFT, 1982; LEATHERMAN, 1980, 1981). Two fine overviews on barrier islands are presented by NUMMEDAL (1983) and OERTEL and LEATHERMAN (1985). A special issue of *Marine Geology* devoted to barrier islands provides detailed information on the interaction between the six major sedi-

mentary environments associated with barrier islands.

In India, serious efforts to understand the evolution and origin of barrier islands are limited probably due to underestimation of the importance of barrier island study. AHMAD (1972) while describing coastal geomorphology of the Indian coast has mentioned and described several spits and barrier islands along the Indian coast. KUMAR and MURTY (1987) studied responses of barrier beaches along the Kerala coast to monsoonal forces. KUNTE and WAGLE (1991) studied the evolution of spits along the south Karnataka coast. Other scientists (EARATTUPUZZHA and GEORGE, 1980; KUNTE and WAGLE, 1993a, b; KUNTE, in press; MONI, 1980; PREMCHAND and HARISH, 1985; NAIR, 1987; PRAKASH and PRITHVIRAJ, 1988) have dealt with barrier/spits as one of several other geomorphic landforms.

Aims of this study are, first, to locate, map and describe barrier islands of the west coast of India using remotely sensed data, and secondly, to gather geomorphic evidences which are helpful in predicting possible stages of formation of these barrier islands.

Study Area and Environment

The coastal area of Kerala is characterized by a strip of barrier land between Quilon and Can-

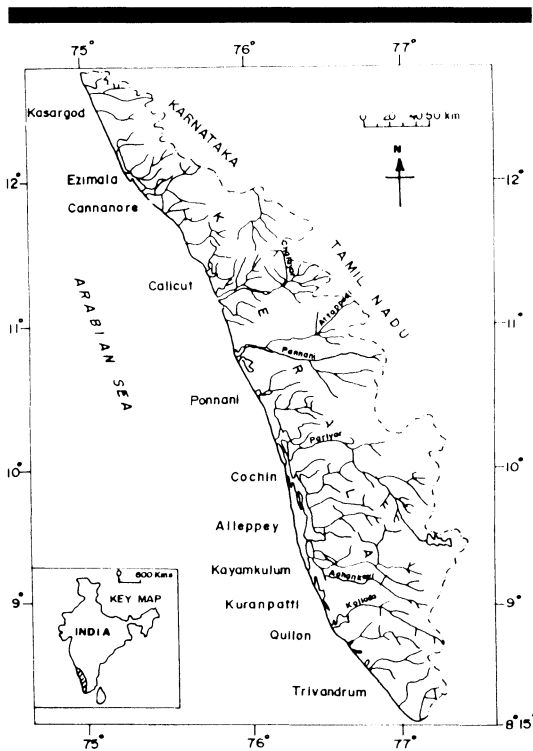


Figure 1. Location map of study area. Numbers 1 to 3 indicate location of the barrier islands.

nanore of the Kerala state, which separates the Arabian Sea from a chain of long irregular lagoons and estuaries. Elsewhere in India, they are practically nonexistent. The location of these barrier islands is shown in Figure 1.

The entire west coast is exposed to seasonally changing winds—the monsoons. The reversal of these winds takes place predominantly from the southwest (during May–September) to northeasterly (during December–March) directions. The study area receives an annual rainfall of about 300 cm. The mean tidal range varies from 0.9 m in the south to 1.8 m in the north. The tides are semi-diurnal. The highest waves average 3.2 m, and a wave period of 9 to 12 seconds is reported (MONI, 1980).

MATERIALS AND METHODS

Landsat black and white images of spectral bands 4, 5 and 7 on a scale of 1:1 million were used for the preliminary study. Enlarged Landsat images were studied to locate and map barrier island systems. Major geomorphic forms observ-

able in the coastal zone were also demarcated. Shoreline changes were detected by comparing satellite images from years 1972–1973 to 1982 images and Naval Hydrographic charts of different years. Topographic maps were used for checking the interpreted results and for comparing shoreline changes.

RESULTS

Shoreline

On satellite imagery, the coastal area of the Kerala is recognized by a barrier strip of land between the Arabian Sea and a chain of backwaters estuaries and river outlets. In synoptic view, the shoreline of Kerala is seen as nearly straight and trending north-northwest to south-southeast. However, it shows, from north to south, a dextral shift. The innermost shoreline is irregular and crenulate with several rias. Barrier islands are recognized as gray to light-toned, elongated, narrow land masses surrounded by dark-toned water and located near the coast on the seaward side. Other coastal features identified include narrow beaches, beach ridges, islands, spits, bars, rivers, estuaries, lagoons, mudflats, tidal flats, deltaic planes, paleo shoreline, and so on. The shoreline is a compound one with a variety of features, some of which have resulted from submergence and others from emergence.

Physiography of Barrier Islands

The descriptive definition of a barrier island usually includes the terms elongate, narrow land formation, composed of unconsolidated materials lying parallel to the shoreline and separated from the mainland by lagoons and/or bays (OERTAL, 1985). Operational definition imposes limitations such as generally being less than 10 meters above sea level, and with a length to width ratio of less than 10:1, commonly being subjected to wave, tidal and wind energies. OERTAL (1985) proposed the concept of the "Barrier Island System". In this, he identified six coastal environments: (1) mainland, (2) back barrier lagoon, (3) inlet and inlet deltas, (4) barrier island, (5) barrier platform, and (6) shore face.

Three barrier island systems of the Kerala coast, namely, (1) Maniyet barrier island system (Figure 2), (2) Vypin-Cochin barrier island system (Figure 3), and (3) Alleppey barrier island system (Figure 4), fit well within the limits of the above definition.

(1) Maniyet barrier island system: This barrier

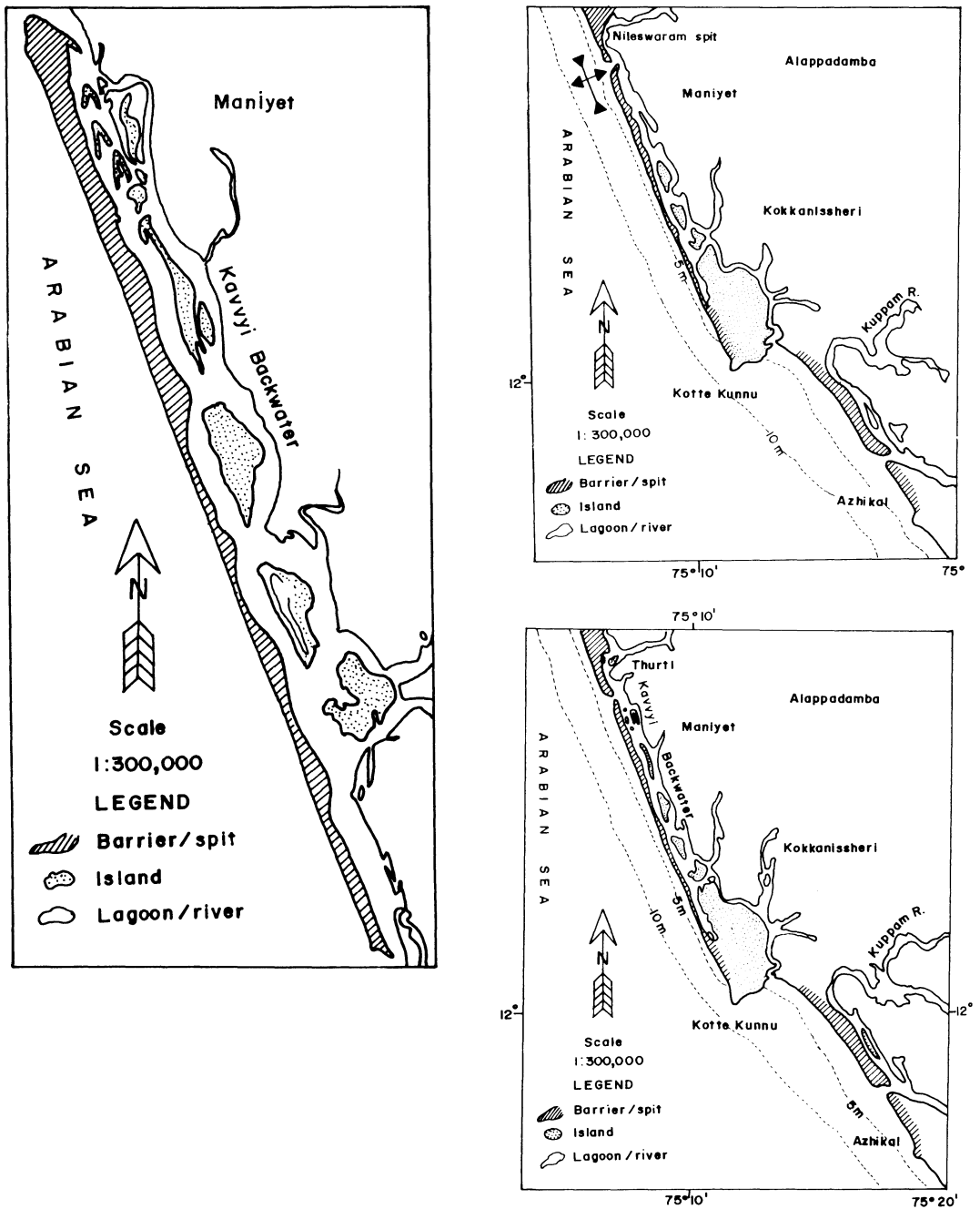


Figure 2. Maniyat barrier island system. Observe shoreline changes in the figures. Source: (2a, left) After AHMAD (1972). (2b, top right) Naval Hydrographic chart No. 259, dated: 31 December 77. In survey: 1851–1937, 1:72,000–1:75,000, Indian charts. (2c, bottom right) Naval Hydrographic chart No. 258, dated: 15 March 79. In survey: 1899–1932, 1:25,000–1:75,000, British Admiralty chart.

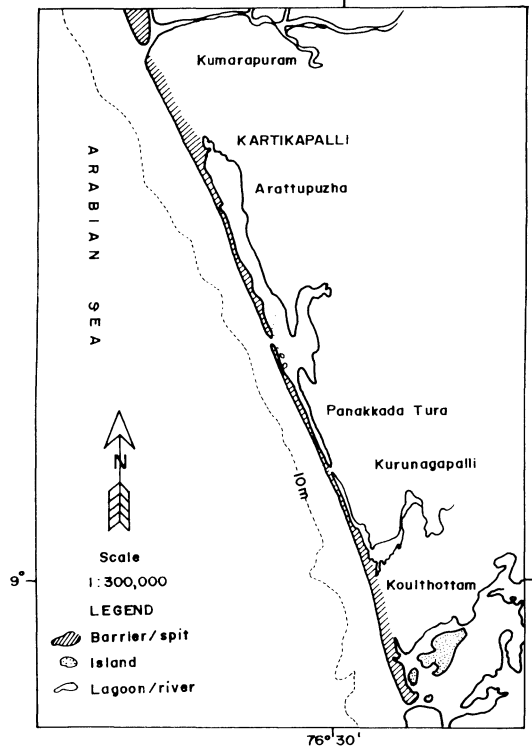
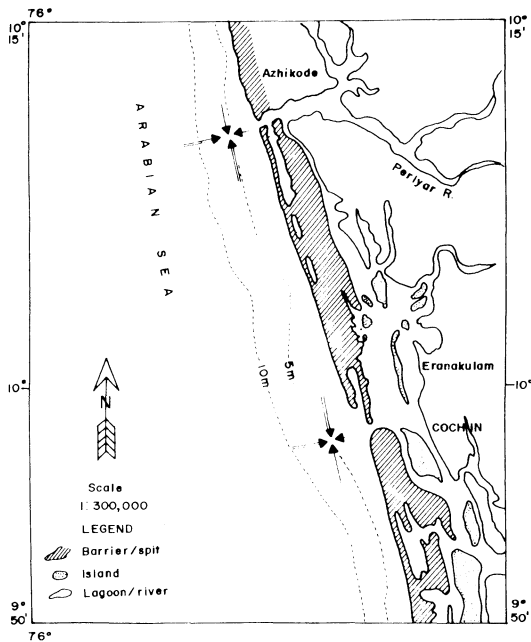


Figure 4. Alleppey barrier island system. Source: Naval Hydrographic chart, No. 260, Dated 15 October 86. In survey: 1851-1852, 1:72,000. East India Company survey.

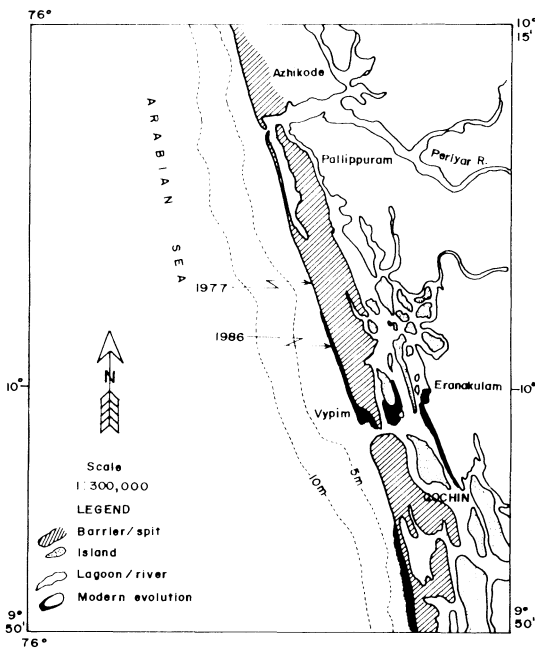


Figure 3. Vypin-Cochin barrier island system. Shaded portion shows accretion of land (3B2) over (3B1) prevailing land. Source: (3A) Survey of India toposheets, year 1963. (3B) 1) Naval Hydrographic chart, No. 259, dated: 31 December 77. In survey: 1851-1937, 1:72,000-1:75,000, Indian charts. 2) Naval Hydrographic chart, No. 260, dated: 15 October 86. In survey: 1958, INS Jammuna survey, 1:25,000.

is located between Thurti and Kotte Kunnu in Cannanore district (Figure 2c). This is about 18 km long and 200-600 m wide. The back barrier lagoon, known as 'Kavvi Backwater', is about 1.5 km wide and is partly occupied with a number of islands oriented parallel to the coast. A backshore sandy beach is confined to the northern and southern extremities. The inner indented shore is remarkably contrasted to the geometrical straightness of the outer shore.

The barrier inlet on the north separates the northern distal end from the southward pointing distal end of Nileswaram spit (Figure 2b). The barrier inlet on the south had separated the southern end from the headland located to the south, and the barrier was entirely isolated from the mainland (Figure 2a). Later, the southern distal end appears to prograde and join to the headland on the south (Figure 2b and c). Both distal ends over the barrier inlets are diverted inwards which

indicates that the prevailing force of the longshore and onshore currents is greater than the offshore force (Figure 2b). The northern islands within the back barrier lagoon are seen merged with the mainland (Figure 2b and c). The barrier island is fully cultivated and densely settled suggesting its stability.

(2) Vypin-Cochin barrier island system: The strip of the coast from Azhikode to Vypin and Cochin to Anthakaranzhi form barrier island systems called here the Vypin-Cochin barrier island systems (Figure 3a and b). Barrier islands are situated on the northern and southern sides of the Cochin harbor entrance channel. The Vypin barrier island is 26.5 km long and 1 to 2.5 km wide. Both ends of this barrier were split. A narrow, feather-edged, northward- and inward-pointing spit is seen attached to the northern end. Whereas a similar southward-pointing spit was attached to the southern end (Figure 3a). Later, the lagoonal portion between the split southern ends was filled by sediments, and the distal ends were clubbed together (Figure 3b). Sand dunes have occupied much of island.

Cochin barrier island (Figure 3), 30 km long and 1–2 km wide, largely consists of belts of sand dunes. A back barrier lagoon approximately 75 km long and 5 to 10 km wide is known as Vembandan lake (Figure 3b). The northern distal end of the barrier is broad and rounded. The southern distal end is merged with the mainland. Several north to south elongated islands are seen concentrated in the northern portion of the back barrier lagoon. The barrier inlet between the islands is the entrance channel to Cochin harbor.

(3) Alleppey barrier island system: Figure 5 shows two sketches of the Kerala coast presented by NIELSON (1920). Figure 5a is dated 1704 and 5b is dated 1670. According to him, there were four barrier islands between Cranganore and Quilon separated by wide inlets. Presently, Alleppey barrier island system (Figure 4) is seen along the coastal stretch between Kumarapuram and Koulthottam in the form of a complex spit, consisting of two long, narrow bar shaped spits. The northern Arattupuzha spit is 12.5 km long with its width ranging from 100 to 500 m, whereas the southern Kurangapalli spit is 14 km long and has an average width of 500 m. Barriers have an almost detached kayamkulam back barrier lagoon from the sea (Figure 4). Small islands are present within the lagoonal area. The entire barrier system is fully cultivated and densely populated.

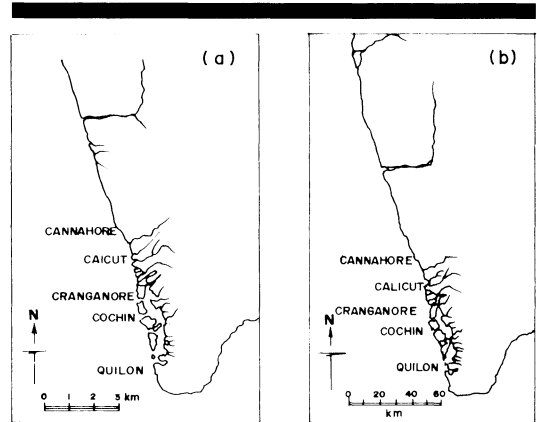


Figure 5. West coast of India at about year 1700 (after Nielson, 1972) (5a) Sketch dated 1704. (5b) Sketch dated 1670.

In addition to these barrier island systems, 28 spits having lengths of more than one km have been identified along the Kerala coast from enlarged satellite images and topographic maps. Most of them are simple, narrow, long and are generally parallel to the present shoreline (KUNTE, in press).

DISCUSSION AND CONCLUSION

Barrier Evolution

Factors responsible for the origin and growth of barrier islands are not clear. Different workers have expressed diversified views. While explaining the evolution of barrier islands of the west coast of India, AHMAD (1972) proposed that predominant monsoonal onshore winds blowing from a direction transverse to the shore are responsible for bringing sediments from the submarine floor near the shoreline to build up ridges or barriers above the sea level. These barriers were further pushed inland that they were converted into spits by their appendages at one end or the other to the "headland". Such a possibility of vertical accretion of sandbars accompanied by landward migration was first put forward by BEAUMONT (1845) and was later reconsidered by OTVOS in 1970 and 1977 for Gulf of Mexico barriers.

Along the high energy coast of Kerala with a gentle offshore slope, landward transport of sediments is possible. The thin, straight and bar type natures of the barrier island and several spits in the study area suggest that the above hypothesis is one way of explaining their origin. But then, these features should have formed a forward shoreline. In fact, the azimuthal straightness of

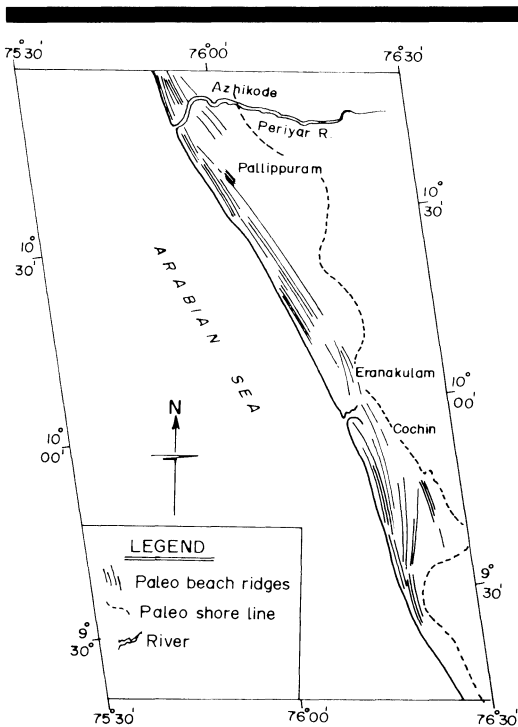


Figure 6. Section of study area showing paleo beach ridges and paleo shoreline (interpreted from satellite image).

the coastal features is noteworthy, and these features are in line with the shoreline of the mainland to the north and south.

Cutting of inlets through spits is considered as another explanation of the formation of barrier islands. FISHER (1967) proposed that the breaching of the spit forms barrier islands and the inlets separate them from their source and each other. Available historic recordings of shoreline development (Figures 2, 3, 4) do not exhibit any evidence of breaching of spits anywhere along the study area, rather they show growth of islands and subsequent joining of barrier islands with each other (Figures 4, 5) and with the mainland (Figure 2).

A third possibility is the emergence of an offshore bar as a barrier during an episode of land uplift or sea lowering. This was suggested by MERRILL in 1890 and has recently been discussed by LEONTYEV and NIKIFOROV (1966). This hypothesis appears to be true for the coastal features like beach ridges, dunes and lagoons which suggests emergence of the coast. However, one cannot

ignore the other coastal features of the same study area which suggest submergence of coast. There is no evidence of new barrier initiation at the present time on Kerala coast nor is there a submerged offshore bar indicated on available maps. Therefore, the above mentioned possibilities explaining evolution of barrier islands do not appear to be completely reliable.

The fourth theory which suggests that barrier islands could have originated as the result of partial submergence of a beach ridge previously built up and adjacent to a former shoreline so that a lagoon is formed to landward, was proposed by MCGEE in 1890 and GANONG in 1908 and has recently been reviewed by HOYT (1967). In view of this, it is interesting to note in this area that barrier islands and spits are mostly backed by paleo beach ridges (Figure 6). The highly irregular inner shore of this submergent aspect suggests that, in the past, either submergence of the coast or a relative sea level rise must have encouraged transgression and an encroachment of the sea upon the land. As a result, beach ridges previously built up as a response to regression of the sea and adjacent to the former shoreline must have been engulfed by sea water to form barriers. This theory seems to be convincing as size, shape and spacing between present-day paleo beach ridges are comparable to those of barriers except that of the Vypin-Cochin barrier island which might have formed from a few successive beach ridges. After a standstill position, it appears that due to land emergence, the sea receded by breaching ridges at different places and hence forming barrier islands or spits. This regressional phase is clearly indicated by the paleo shoreline (Figure 6) lying behind (landward side) existing spits and barriers.

The above mentioned speculative type of a barrier evolution theory looks more convincing if several evidences for sea level fluctuations are observed carefully. RAO and RAMANUJAM (1975) who based their study on the foraminifera from the Quilon beds occurring up to 13 km inland have expressed the view that during middle to lower Miocene, shallow marine conditions prevailed in this part of Kerala. The distance of the beds from the present strandline denotes that this phase of high sea level was a major one. The beds at Warkalli (Kerala) which probably accumulated in a coastal lagoon of the Pleistocene suggest high sea level. PASCOE (1964) has also reported the existence of an old sea beach at the base of the Warkalli cliff. The occurrence of carbon free sedi-

ments and the predominance of iron stained quartz in the southwestern shelf area (NAIR and HASHIMI, 1980) are indicators of aerial exposures of the sediments during the late Pleistocene, due to low sea level. Several evidences indicate that the Kerala coast along with the west coast of India has passed through several transgressional and regressional phases in the past (KALE and RAJAGURU, 1985).

At the southern end of Vypin island, the lagoonal portion between the two distal ends (Figure 3a and b) has filled in quickly probably due to continued emergence of coastal land. Additionally, seaward growth of the same island indicates a regressive nature of the barrier (KRAFT, 1982). According to Leatherman's classification (LEATHERMAN, 1980), these barrier islands are microtidally regressive as they are long, narrow and have multiple dune ridges and few inlets.

The recent evolution is indicated by (1) a southward progradation of the southern distal end, and a northward-inward progradation of the northern distal end of the Maniyat barrier island system, (2) the progradation and joining of the Alleppey barrier island system, and (3) island growth and merging. In the study area, general parallelism of coastal features, straight and smooth shorelines, and a trend of modern evolution suggest that shoreline development is largely influenced by longshore drift, which is towards both the north and south.

Considering the transgressional and regressional nature of the coast, the physiography of the barrier island, shoreline changes and the environment setup of the study area, it may be concluded that the evolution of the barrier islands of Kerala has taken place in three prominent stages: (1) Initial emergence of land during which paleo beach ridges were formed (regressional phase), (2) subsequent submergence of land which is characterized by the engulfment of beach ridges (transgressional phase), and (3) emergence of the coast during which breaching (regression phase) of ridges and barrier island formation took place. Further field evidence is required to substantiate this theory as this study was carried out using remotely sensed data.

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