SHORELINE CHANGES AND EVOLUTION OF THE COASTAL ZONE IN SOUTHERN KARNATAKA, INDIA - AN ANALYSIS BASED ON MULTI-TEMPORAL DATA

H.Gangadhara Bhat*, K.R. Subrahmanya **
Department of Marine Geology
Mangalore University
Mangalagangotri- 574 199,
India
* samsan-vip@zetainfotech.com
** subrahmanya@usa.net

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ABSTRACT

A coastline of about 100 km in southern Karnataka, India has been investigated in the present study. The analysis of shoreline changes in the past 90 years has been carried out to understand the coastal dynamics and its influence on the natural and man-made features. The maps generated based on earliest available topographical maps have been compared with the maps generated based on the high spatial resolution (5.8 m) PAN data of IRS-1C of 1996 and 1998. The multidated data products study indicates the gradual shifting of the estuarine mouths of Nethravathi-Gurupur, Mulki-Pavanje and Udyavara to the north. A part of the changes in the morphology can traced to human interference by way of construction of engineering structures. The breakwater of New Mangalore Port, the breakwaters at the mouths of Nethravathi-Gurupur estuary, Udyavara estuary and seawalls elsewhere have contributed substantially to the modification of shoreline. An evaluation of depositional and erosional sites in the coastal zone indicates that the area covered by depositional features marginally exceed those under erosion. The enlargement and emergence of the land can be attributed to tectonic uplift.

1 INTRODUCTION

Studies relating to long-term shoreline changes using aerial photographs (Davis, 1976; Dolan et al., 1979, 1980; Leatherman, 1979, 1983; Leatherman and Zaremba, 1986; Stafford, 1971; Stafford and Langfelder, 1971; Wahle, 1973; Smith, 1990) and using satellite images (Nayak and Sahai, 1985; Prabhakar Rao et al., 1985; Shaik et al., 1993; Wagle , 1982, 1989; Gangadhara Bhat and Subrahmanya, 1993; Gangadhara Bhat, 1995; Ramasamy , 1992; Chen and Rau, 1998 and others) have been carried out by many researchers. Because of their synoptic viewing capability, multispectral observations and the repetivity , the remotely sensed data products are extensively used for detecting long-term shoreline changes and to know the evolution of the coastal and nearshore areas.

A coastline of about 100 km in Southern Karnataka, India has been investigated in the present study. It extends from Talapady (12^{o} 46'N and 74^{o} 52' E) in the south to Udupi (13^{o} 21'N and 74^{o} 44' E) in the north.. The shoreline of the study area is straight and covered with sandy beaches except at two or three places where it is rocky. The area enjoys a humid tropical climate and receives an annual rainfall of more than 3.5 m. The important rivers draining this area from south to north are Nethravathi, Gurupur, Pavanje, Mulki and Udyavara (Fig. 1). The Nethravathi and Gurupur rivers originate above the Western Ghats and flow for a distance of 148 km and 87 km respectively and have a common exit to the Arabian sea near Mangalore. They cover a drainage area of about 4260 km^2. The other three rivers originate below the Western Ghats and are having lengths less than 40 km. The waves approach the shoreline of this area from WNW and NW during post-monsoon season with maximum wave heights of 2-2.5 m and WSW, SW and W with maximum wave heights of over 4 m during monsoon season. The southern Karnataka coast has a microtidal environment with a mean tidal range of 1.22m (Subrahmanya, 1998).

The present study has been undertaken to understand the various coastal processes operating in this sector and to analyse the shoreline changes over the past 90 years. The study also aims at evaluating the effects of coastal structures on the adjacent shorelines and also to know the evolutional history of the coastal zone.

2 MATERIALS AND METHODS

Survey of India topographical maps on 1: 63,360, 1:50,000 and 1:25,000 scale surveyed during 1910-1912, 1967 and 1980 respectively; 1:50,000 scale aerial photographs photographed during 1979; Naval Hydrographic charts on 1:15,000 scale (1980) and Indian Remote Sensing satellite data products surveyed during 1988, 1992, 1994 , 1996 and 1998 period in different scales have been used. All the aforementioned maps have been brought to the same scale of 1:50,000 using an optical pantograph and the changes that took place over the past 90 years have been recorded . The area influenced by tides is negligible on this scale, since the difference between the mean low tide and the mean high tide is 1.5 m and the submergence of the land along the shoreline is less than 5-6 m during the high tide period. However the cartographic accuracy has been maintained with sufficient care by comparing the multidated data products of post-monsoon season.

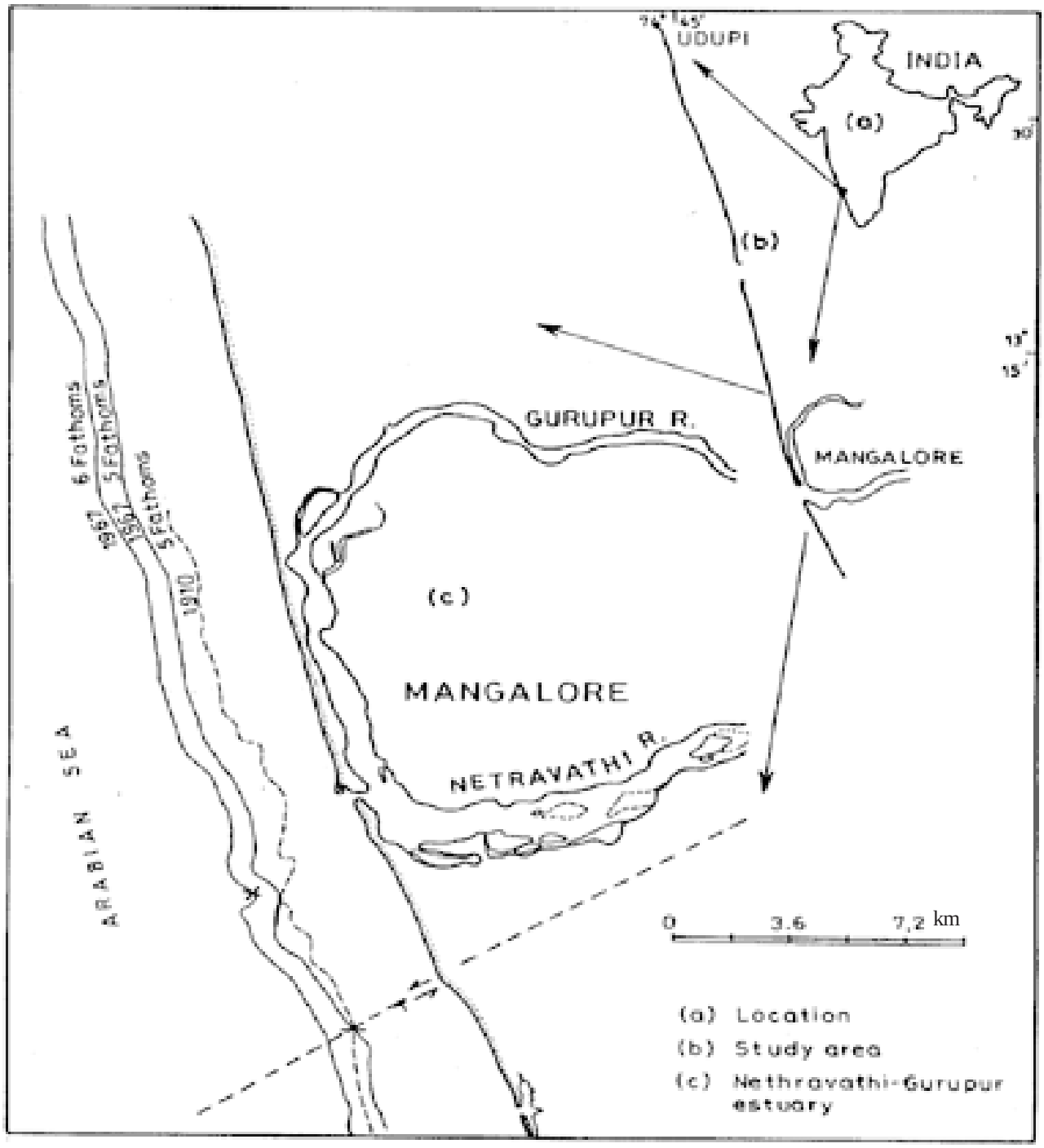

Fig. 1 Map showing location (a & b) and changes in the bathymetry controlled by an ENE-WSW trending fault.
X-Indicates previous position of the offshore channel carved by Nethravathi River.

3 RESULTS

The barrier spits are the most dynamic features, as seen by the changes in their configuration over the years. Because of this reason spit development on either side of the three estuarine mouths have been studied in detail. The northern spit of Nethravathi -Gurupur estuary (Bengre spit) shows growth towards south, whereas Mulki-Pavanje and Udyavara have their longer spits pointing to the north. Comparison of the 1967 maps with those of 1910-1912 and 1949 shows accretion of Ullal spit and erosion of Thannirbhavi and Bengre spit. Maps generated based on aerial photographs of 1979 and satellite images of 1988 and later periods show a reversal of trend i.e., accretion of Bengre and erosion of Ullal spits. Maps of 1996 and 1998 show rapid widening of the Bengre beach and further narrowing of the Ullal spit.

The multidated data products study also indicates the gradual shifting of the estuarine mouths of Nethravathi-Gurupur, Mulki - Pavanje and Udyavara to the north. Mulki- Pavanje shows the development of a large bar in front of the estuarine mouth. Presence of beach ridges near Panambur, Hejamady-Padubidri and north of Udyavar and widening of the beaches to the north of Bengre, Suratkal and Udyavara suggests prevalence of depositional environment. Beach erosion has been reported at Someshwara, Ullal, Mukka-Sasihitlu, south of Hejamady, Kapu and Near Udyavara in the past.

There have been considerable changes in the morphology of the barrier spits. Some of these modification can be ascribed to human interference by way of construction of engineering structures. The breakwaters of New Mangalore Port, the breakwaters at the mouths of Nethravathi-Gurupur estuary, Udyavara estuary and seawalls elsewhere have contributed substantially to the modification of shoreline. The Bengre spit which was a site of erosion turned into an accreting zone subsequent to the construction of a seawall at the southern tip of the spit and the breakwaters at the mouths of Nethravathi-Gurupur estuary. The consequence of this was severe erosion in the Ullal spit. Northern part of New Mangalore Port which was a stable area prior to construction of breakwater during the mid seventies, shows an accreting trend. Construction of sea-walls (to protect the beaches against erosion) have resulted in shifting of erosion sites to the downdrift (southern) side.

Table 1: Changes in the position and width of Nethravathi-Gurupur estuarine mouth between 1910 and 1998

Sl.No.	Period	Data Products	Position of the Nethravathi-Gurupur River Mouth		
			From	To	Width
1	1910-1912	Survey of India Topographical Maps	12° 50' 10" N -	12° 50' 22"N	375m
2	1949-1960	Naval Hydrographic Charts	12o 50' 22" N -	12° 50' 34"N	360m
3	1967	Topographical maps	12° 50' 37" N -	12° 50' 42"N	150m
4	1979	Naval Hydrographic charts	12° 50'24" N -	12° 50'42"N	550m
5	1982	Topographical maps	12° 50' 41"N -	12° 50' 51"N	350m
6	1992	Indian Remote Sensing Satellite Imagery (IRS)	12° 50' 44" N -	12° 50' 53"N	250m
7	1996	IRS imagery (Geocoded)	12° 50' 44" N -	12° 50' 51"N	225m
8	1998	IRS imagery (Geocoded)	12° 50'18"N -	12° 50' 32"N	425m

4 DISCUSSION

Of the spits noticed on either side of the three estuaries, the Bengre and the Udyavara spits are spectacular with length of more than 8 km. The Bengre spit is pointing towards south, whereas the Udyavara spit is pointing northwards. The other spits like Pavanje, Mulki and Ullal are less than 2-3 km in length. According to Evans (1942); Schwartz, (1984); and Bird (1984) the growth of the spit is largely due to long-shore drift and length of spits above the water increases only when the waves and shoredrift move sand from the direction of their land connection. The study carried out by Kunte and Wagle (1991) along the southern Karnataka coast based on the spit growth direction indicates that long-shore drift is either towards north or south depending upon monsoon season. According to them the bi-directional shore drift could be the primary agent for sediment redistribution and confinement within the region, thereby keeping the prograding coast straight, smooth and stable. According to Reddy et al., (1978, 1982) the predominance of southerly drift of the coastal currents during major part of the year could be responsible for the growth of Bengre spit. It is obvious that littoral drift cannot explain the disposition of Bengre and Udyavara spits as they are oriented in opposite directions. Further the Gurupur river had a separate exit to the sea just north of the present New Mangalore Port, as indicated by the presence of paleochannels which have been identified in the satellite imagery and aerial photographs. Subrahmanya and Jayappa (1987) opine that the river Gurupur has migrated southerly in four stages. The river started migrating to the south and its migration was temporarily arrested by a fracture which is the continuation of a NNE-SSW trending lineament. The continued southerly migration was assisted by littoral drift which made the river to turn south and finally join the river Nethravathi near Bengre to form a common estuary.

Comparison of the oldest and recent data products reveals that there is a shift in the erosional as well as accretional sites from time to time. According to Jayappa (1996), the migration of the eroding sites could be due to the shifting of waves convergence zones or due to man made structures. Based on the multidated data products study Gangadhara Bhat (1995) indicated that from 1910 to 1990 period Hejamadi Kodi (northern spit of Pavanje-Mulki river) has experienced loss of land (about 2.5km^2) due to shifting nature of the river mouth and the southern Mulki spit has gained about 3km^2 of land. Considering that the dominant littoral drift is southwards, the growth of the Udyavara and Pavanje spits to the north needs an alternate explanation. Based on the regional remote sesnsing study Ramasamy et al., (1995) have conjectured two major E-W trending cymatogenic arches in southern India, of which one falls along Mangalore-Madras. It was suggested by Subrahmanya (1996a) that the Indian peninsula is undergoing deformation which has resulted in buckling and uplift along a near E-W trending line extending from Mulki on the west coast and Pulicat Lake on the east coast. Because of this uplift, streams on either side of the Mulki-Pulicat lake Axis (MPA) have been migrating in opposite directions. The uplift is confirmed by several other lines of evidence. Considerable amount of fluviatile sediments occur at higher levels as river terraces along the upstream of the Nethravathi river course (Gangadhara Bhat and Subrahmanya, 1993) which points to deepening of the valley indicating rejuvenation of the river. An evaluation of depositional and erosional sites in the coastal zone indicates that the area covered by depositional features marginally exceed those under erosion. The presence of beach ridges in the northern sector, presence of oyster shells above the present high tide line near Suratkal (Subrahmanya, 1996b) , presence of paleo- tidal flats around Nethravathi- Gurupur estuary, the shallowing of the nearshore zone to the north of Mangalore, all these point to emergence of land in this sector. Tide gauge records of Mangalore area which indicate a relative fall in sea-level of about 1mm/year substantiate this inference.

Although southerly drift and uplift along MPA can explain the origin of most of the features noticed , one aspect i.e. migration of Nethravathi-Gurupur estuarine mouth towards north, in the past few decades has been an enigma. To understand this phenomenon, bathymetric charts have been made use of. Comparison of the bathymetric map of 1910-1912 with the extrapolated bathymetric map of 1967 shows seaward movement of the 5 fathom contours to the north of Nethravathi-Gurupur estuary thereby pointing to shallowing of the nearshore. Landward migration of the same contour to the south of Nethravathi-Gurupur estuary indicates deepening of the nearshore Fig. 1). The shallowing/deepening occurs along a line which when extended coincides with a cliffed shoreline and lineament on the land. The rocky outcrops are to the north of the lineament which also marks the upthrown side (shallowing of the nearshore). Under the influence of this movement, the Nethravathi river has migrated slightly northwards there by building up the Ullal spit. A careful study of the bathymetry also reveals the region through which Nethravathi river could have discharged to the sea.

5 CONCLUSIONS

The multidated data products study indicates growth and migration of barrier spits and erosion and accretion of beaches which in some areas is adjacent to coastal engineering structures. On the whole there is predominance of the depositonal landforms like the barrier beaches, spits and beach ridges. This clealry demonstrates that the southern Karnataka coast is an accretional coast. In addition to the longshore littoral drift, the ongoing upwarp along the Mulki-Pulicat lake axis is contributing to continuous modification of the shoreline.

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