

Status of Coastal Zone Studies and Future Trends: Special Reference to Western India.

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ABSTRACT

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IGCP495: Quaternary Land-Ocean Interactions: Driving Mechanisms and Coastal Responses

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Introduction

Thirty years on from the first IGCP coastal project, the global sea-level community is now well-equipped to develop local, regional and global records of relative sea-level (RSL) change. It is also increasingly able to describe linkages between terrestrial, coastal and marine environments through the application of new techniques of sediment finger-printing, dating, as well as quantitative models of coastal change, sea-level change and sediment flux.

However, we have so far been less successful in determining the *driving mechanisms* of the patterns we observe and reconstruct. This contrasts with many other areas of Quaternary science where, motivated by the emerging climate records from ice sheets and oceans, research scientists are eagerly pursuing the driving mechanisms of climate change or ocean circulation through hypothesis testing and model building.

With this challenge in mind, the international sea-level community supported the development of a new UNESCO sponsored International Geoscience Programme (IGCP) that would focus particular scientific attention on driving mechanisms behind land-ocean interactions over Quaternary timescales. The resulting project – *IGCP 495 Quaternary Land-Ocean Interactions: Driving Mechanisms and Coastal Responses* – was approved in 2003 and began formally in October 2004 with the first International conference, held in Bar Harbour, Maine (USA). The project will run for five years and, at the time of writing, is now in its second full year. As such it is an appropriate opportunity to provide an update on the progress of the project in such a way that we hope will help stimulate further research into this important research topic.

Aims of IGCP Project 495

IGCP 495 aims to focus the efforts of the coastal research community on establishing the driving mechanisms behind Quaternary sea-level change and coastal evolution. The project interest is primarily on the coastal zone, where a rich sediment and landform archive provides a superb opportunity for studying interactions and determining driving mechanisms over a range of spatial (global to local) and temporal (millennia to years) scales. The project seeks to develop fundamental new knowledge regarding the driving mechanisms that influence land-ocean interactions of wide interest to the Quaternary, earth science, and marine scientists. We hope that its strong

applied component will be directly relevant to coastal managers concerned with coastal forecasting and future sea-level change.

The work of IGCP 495 has two dimensions: the vertical dimension of RSL change and the lateral dimension of changing shoreline position. These changes in the coastal zone result from external forces (such as sea-level and climate change) and internal forces (including the coastal sedimentary budget).

Under the first dimension, effort is focussed on developing high-resolution (centimeter to meter scale vertical resolution and annual to centennial scale age resolution) records of vertical changes in RSL that can be meaningfully compared with other local, regional and global environmental records derived from terrestrial and marine environments. Research here is seeking to develop new quantitative models of RSL change based on a range of fossil indicators, as well as a more standardised approach to data collection and analysis to facilitate international correlation. A key objective is to test hypotheses regarding the driving mechanisms behind vertical changes in sea-level over different spatial and temporal scales, including the influences of ocean circulation, climate change and neotectonics.

The second dimension uses a combination of geological and archaeological data to better understand the interaction of terrestrial and marine processes in controlling lateral changes in shoreline position. This involves close co-operation with workers in related disciplines, including those focused on fluvial and nearshore environments. Importantly, research under this aspect of IGCP495 requires collaboration with archaeologists interested in documenting and understanding the history of human impact on the coastal zone. This latter synergy provide important new insights into the timing, controls and magnitudes of sediment flux to the coast, and the longer-term impacts of human action on coastal and nearshore environments.

The new challenges

For the coastal and sea-level community, IGCP 495 poses several important challenges:

- To develop new, high resolution, records of Late Quaternary sea-level change and coastal evolution that can be meaningfully compared with the emerging high-precision palaeoenvironmental records from the ice sheets (cores), the oceans (e.g. corals, high-resolution sedimentation cores) and other terrestrial archives (e.g. peat bogs, deltas, estuarine sequences, aeolian deposits and loess sequences).
- To develop new methodologies for determining the driving mechanisms behind sea-level and coastal change, including capabilities for coastal and sea-level forecasting. This will require the close co-operation of field scientists, laboratory and theoretical studies from a variety of disciplines.

- To develop new techniques to resolve the importance of terrestrial and oceanic processes in controlling coastal stratigraphic sequences, sea-level change and coastal evolution. Where possible, this will explore the opportunities provided by the often rich archaeological record for human activity in coastal areas and coastal catchments.
- To apply these techniques to better understand the timing and magnitude of sediment and nutrient (including carbon) flux from land to ocean, and vice versa, in a wide range of depositional settings and over a variety of timescales.
- To explore the implications of these coastal records for our understanding of existing terrestrial and oceanic records of Quaternary environmental change, including the leads and lags associated with oceanic and terrestrial records. Where possible and appropriate, to develop numerical models to capture these interactions over a range of spatial and temporal scales, in the past and in the future.
- To provide an improved scientific background against which the role of humans as agents of coastal change can better be appreciated. In particular, we seek to determine the impact of human activity on sediment and water flux on the coastal zone, as well as the effects of land claim and sea defence construction on tidal amplitude.
- To apply the outcomes of this research to the real-world problems of coastal management in developed and developing countries. This involves the development of regional scale predictive models of coastal evolution that require close co-operation with, for example, members of the geotechnical community. Coastal change in the future will be driven by a combination of local, regional and global processes. This project seeks to better understand these processes, including defining the potential driving mechanisms behind future sea-level change (global to regional changes in vertical sea-level) and shoreline evolution (including sediment budgets and human impacts) at regional to local scales. This includes a focus on palaeo-extreme events, such as storm surges, tidal surges and tsunamis.

Application of Remote Sensing for Coastal Zone Management in India

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Coastal zone is an area of interaction between land and sea and thus both terrestrial and marine environment influence this zone. The interaction between various natural processes and human activities is an important factor. Coastal zone in India assumes its importance because of high productivity of its ecosystems, development of industries, concentration of population, exploration of living and non-living resources, discharge of industrial waste effluents and municipal sewage and spurt in recreational activities. Thus, there is a need to protect coastal environment while ensuring continuing production and development. In view of this, the Govt. of India has declared coastal stretches of bays, estuaries, backwaters, seas, creeks, etc. which are influenced by tidal action up to 500 m from High Tide Line (HTL) and land between Low Tide Line (LTL) and HTL as coastal regulation zone (CRZ) during 1991. Restrictions were imposed on setting up and expansion of industries, operations and processes in CRZ to manage development in coastal areas. In order to regulate these activities in coastal areas, it is necessary to have knowledge about present land use conditions and precise delineation of HTL and LTL. Remote sensing data, especially Indian Remote Sensing (IRS) data, having moderate (23-36 m) and high spatial resolution (6 m), have been used to generate database on various components of coastal environment of the entire country. It was possible to create a database of wetland conditions (mangroves, coral reef, mudflats, beach) between HTL and LTL, land use (agriculture, forest, barren land, built up land) up to 500 m from HTL as well as delineation of HTL and LTL on 1:25,000-scale for the entire country. The synoptic and multi-spectral nature of satellite data allowed preparation of such maps with sufficient accuracy and at reasonable cost. A minimum area of 0.25 ha has been mapped. A Classification system has been evolved such that these maps can be used to define coastal regulation zones highlighting ecologically sensitive zones (CRZ I), developed areas (CRZ II), undeveloped areas (CRZ III) and Islands (CRZ IV). This is the first step for preparing management plans. These maps provided baseline information for planners and decision makers and have been used by the State Governments for management plans. Separate maps for identifying areas under erosion and deposition, coral reefs and mangroves were also prepared. The classification accuracy have been achieved is 85 per cent or better at 90 per cent confidence level. The control accuracy 20 m has been achieved. The cost per sq km is only about US \$ 6. This database currently being organised in GIS and simple additive modelling has generated management plans. The major advantage of remote sensing data is monitoring of change periodically. This has helped to resolve some of the disputes related to implementation regulations in the coastal zone. The important achievement has been the acceptability of satellite-based information on CRZ by both the executive and judicial authorities. It is now almost mandatory for all industries, governmental as well as non-governmental agencies to use satellite-derived information for the coastal regulation zone activities. Realising the value of the remote-sensing derived information, the state and central agencies responsible for

the implementation of CRZ, are increasingly adopting remote sensing data for their routine use.

Imprints of Sea Level Changes along Kasargod-Kanyakumari coast, Kerala

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It is now well established that sea level changes of various amplitude and duration have punctuated the geological history of the earth. Although the outline of the western coast was defined during the Gondwana break-up, the Late Quaternary sea level oscillations have contributed to the shaping of the coastal belt to a great extent. The coastal belt is inhabited by a large part of the population, hence any developmental project along the coast must take into account the trend of sea level changes and tectonism. There could be several factors contributing to changes in the sea level, the most dominating among these are glaciation and tectonism. Polar ice volume equal to the present have existed for 40 million years (Prentice and Mathews 1988, Hay 1992). Barrett et al (1987) put the onset of Antarctic glaciation at 36 million years. The cooling of the region surrounding Indian Ocean was triggered by the closure of the Indonesian Seaway, 3 million year ago, due to northward drift of Australia and New Guinea and passage of cold north Pacific waters into the Indian Ocean. Pleistocene period is characterized by marked fluctuations in climate. Four glacial ages Gunz (275 ka), Mindel (180 ka), Riss (115 ka) and Wurm (18 ka) were recorded during Pleistocene.

Imprints of Last Glacial Cycle (Wurm) have been picked up from the continental shelf off Kasargod during the cruise SD-188 on board GSI research vessel Samudra Shaudhikama, and along the coast from Kanyakumari to Kasargod. During the cruise SD 188 off Kasargod, bathymetric and shallow seismic surveys were carried out across the entire width of the shelf, core and grab samples were collected from carbonate ridges, relict sand and the intervening swales. A 111 cm long vibrocore VC 8794 was collected from a depth of 63.15 m off Kasargod. The statistical parameters were computed for the 5 sub-samples at 25 cm interval, including top and bottom. The sediment at the top and bottom are negatively skewed. The skewness and mean size support a low energy depositional environment through out the sediment column collected in the core, with an indication of gradual increase in the depth of the environment which can be attributed to the rise in sea level. The sediment at the bottom is brownish clay containing silt with some shell fragments. Rock fragments with limonitic stains due to oxidation could have formed during sub-aerial exposure of the -91 cm (bsf) sediment in the core.

Two sub-samples containing carbonized wood have been recorded from the vibrocore VC-8 797. In the core the carbonized wood occurs at two levels eg. at -89cm and again at -375cm subsurface. The presence of carbonized wood at that depth (about 53 m) is indicative of a marshy to lacustrine environment. The sediments between the two horizons of carbonaceous material are also composed of carbonaceous clay. Such a sequence is only strengthening the evidences in support of a lagoon-like environment existing perhaps close to the sea similar to kayals/backwater today. The older sediments underlying the bog wood horizon are composed of

sandy silt to fine sand indicating a high energy environment unlike that of lagoon. The occurrence of oxidised (limonitised) sandy sediment indicates the sub-aerial exposure of the sediments, which could be possible if the sea level was at -50m below the present at the time of deposition of these sediments.

Sample No.G-8790 was collected from a depth of 101 m in the outer continental shelf off Kasargod during the cruise SD 188 on board RV Samudra Shaudhikama. The sample is composed predominantly of broken shells of gastropod, lamellibranch, coralline debris, substantial amount of microfauna – foraminifers - and scanty fragments of barnacle. Black, opaque, well rounded grains of ilmenite constitute about 5-6 percent of the total +230 fraction. These grains do not show signatures of long distance transportation and their occurrence in the sediments within relic carbonate sand at a depth of 101m in the outer continental shelf assumes great significance.

Ridges and terraces across the continental shelf

	QL1	QL2	KG3	KG4	KR5	KR6
R	115.9	127.3	123.5	118.5	101.2	122.9
I	92.3	102.8	96.8	103.8	76.3	112.3
D	81.4	91.6	86.2	94.3	73.9	87.2
G	77.4	85.5	73.5	85.2	64.9	79.2
E			60.8			74.1
S						61.5
T		27.3-43.6	0-44.5			
E		43.6-48.8	44.5-50.25			
R	32.1-37.6	48.5-52.9	50.25-54.25	22.7-36.2	14.42-47.2	
R	37.6-40.1	52.9-55.7	54.25-57.25	39.6-50.4	47.2-52.1	23.5-50.6
A	40.1-48.7	55.7-58.7	57.25-60.8	58.2-70.2	52.1-62.6	
C	48.7-56.8	58.7-64.9		74.0-76.6		
E	56.8-60.6	64.9-83.1				
S						

Onshore

On shore geological traverses were taken along a 60 km stretch of coast starting from Kotte Kunnu through Valapattanam, Cannanore, Tellicherry and Mahe upto Badagara. During the field work around Cannanore, Tellicherry and Mahe, signatures of high sea level stands were recorded in the form of wave cut notches on the lateritised Tertiary (Varkkalai bed) formations found as promontories on the Arabian Sea. The wave-cut notches were found at 1.50, 1.70 and 2.50 m above the present sea level. In the promontory south of Tellicherry the formation of beach rock above the present sea level is another indication of high sea level stand during the Late Holocene. It may be possible to date the shell fragments in the beach rocks to date the notches if the two processes can be correlated. During the field work along Trivandrum-Varkkala sector, very high (20m) cliff, facing the sea were seen between Rathikkal, Varkkala and Edavai. The cliff, along the beach, is a product of coastal erosion of a lateritic promontory developed over Plio-Miocene Varkkalai Beds. Wave cut concave notches have been recorded from these rocks at 2.35m to as high as 15 m above present mean sea level.

In the coastal area at about 500m ESE of Kovakulam, the presence of beach rocks were recorded attaining height of 4.15m above the present sea level. These were formed during periods of marine incursion on land, prior to the beginning of Last Glacial Cycle, dated (^{14}C) at 40 ka BP. Wave cut notches have also formed at 1.27m and 3.05m above the present high tide level, indicating two levels of high sea stands. Aeolian sand cemented with calcium carbonate is seen to overlie the granitic rocks. At about 23 km west of Kovakulam there is a large (1km x 2km) occurrence of *teri* sand along the coast. Teri sands were formed as coastal aeolian dunes and were oxidized during arid climate of Last Glacial Maxima as those of Pondicherry, Tugidam and Chilka in the east coast.

The imprints of sea level changes on the west coast have been recorded from the shelf off Quilon and Kasargod and the consistency of the LGM strandline at 122m is significant. Literature survey indicates that from around 36 ka to 22.5 ka there was regressive phase and lowering of sea level, due to glaciation/cooling. Around 18 ka BP the sea level reached the lowest of the regression to 122m water depth, during the peak of glaciation. The global warming led to deglaciation which gave rise to transgression until the sea reached the present level about 6 ka BP, as observed by other researchers. Transgression continued and sea level rose to may be 4.75m above the present sea level and two short spells of cooling known as Little Ice Ages lowered the sea level to where it is today and due to recent global warming the sea level has a rising trend.

Influence of Sea Level Rise along the West Coast of India Related with Global Warming On

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India has a coastline of about 7500 km with contrasting geological setting. Based upon the available models, global sea level rise of 10-25 cm per 100 y has been predicted due to emission of green house gases. To separate out the influences due to the global climatic changes the available mean sea level historical data during 1920-1999 at selected locations along the west coast of India were evaluated. There is a large contrast in the observed sea level changes. These results suggest that the rate of sea level rise is not uniform along the Indian Coastline. Though the macrotidal site at Kachchh has witnessed maximum sea level rise, the Gulf of Khambhat is evidencing a reduction in sea level. The similar variable trend is observed along the different locations, which further suggests that besides the global influence, the local factors also contribute significantly to the sea level stands. The shoreline changes in response to morphodynamic processes along the west coast of Indian are highly variable. Based on integrated studies of sea level and shoreline changes in past 30 y, the most vulnerable areas are identified.

Underwater Heritage of India: Threatened Cultural Resource on the Coastal Zone

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Coastal zone is a saviour as well as repository of the past human activities. On one hand it provides living and non-living resources for growth and survival of mankind overtly or otherwise like facilitating ports and harbours. It also entrenches vast quantity of artefacts and antiquities from bygone era, that recount tales of glory of the period. Archaeological discoveries suggest that western coast of India hosts' a large number of harbour sites varying in chronological sequence right from the Harappan period to modern period. Similarly the sunken shipwrecks have stories to tell about emergence and development of our maritime expertise in building relationship with other maritime countries in terms of trade and culture. With a prospect to bring to foreground such submerged heritage, National Institute of Oceanography (NIO) has initiated systematic programme of coastal and underwater explorations along the Indian coast. As the finds caught the imagination of the public, other Institutes and organisations like the Archaeological Survey of India, National Institute of Ocean Technology, Chennai, Tamil University, Thanjavur, Centre for Heritage Studies, Kerala also joined in this endeavour and contributed significantly, in one or other way.

Considering even the recent history of India, there are enough evidence that more number of port sites, that were active once upon the time, are now in the bleak. The Romans and the Greeks had their colonies in India as also Indians had established trade colonies in Africa and Southeast Asian countries. The Cholas, for example, were important maritime power and had organised several naval battles and had trade contacts with the southeast Asian Countries and the Vijaynagar dynasty had active trade relation with Arabs. On the other hand, Marathas were an unquenchable maritime power during medieval period. Portuguese, were the first European maritime power to enter in the Indian Ocean, followed by French, Dutch, Danes and British. They conquered several bastions along the coast of India. All these would not have been possible without harbour facilities along the coast. Sudden storms and cyclones, navigational errors, accidents, mutiny, pirates etc, must surely have left behind remnants of the craft and cargo, i.e. wreck sites. These ancient harbour sites as well as wrecks therefore provide vital links, which help us, to eulogise our past maritime achievements. In fact, shared cultural heritage, i.e. European artefacts along the African and Asian continents and vice a versa, provide the proof of our maritime contacts. Onus is now on the scientific community to consider them as starting point and with the help of systematic exploration, scientific analysis and logical conclusions bring them to lime light.

National Institute of Oceanography has taken first step in this direction by supporting activities related with marine archaeology since 1983. In the two

decades there has been significant achievements. On the western coast, the underwater archaeological survey so far has been limited to Gujarat, Maharashtra, Goa and Lakshadweep waters with very interesting finds. While underwater stone structures noticed off Dwarka, do give an impression of some submerged settlement, they are difficult to comment up on with authority in the absence of any datable material. On the other hand, stone anchors of different types and sizes from Bet Dwarka to Porbandar, Veraval and Bhavnagar and also from Konkan coast and Kerala coast vindicate the fact that maritime prowess India had during earlier period. Coastal archaeological excavations at Bet Dwarka and Porbunder have revealed Saurashtra coast has been the focal point of human settlement from the protohistoric period onwards. Around the Christian era, boats from Mediterranean Sea reached on this coast as evident from the amphorae shards from various sites along this coast. Archaeological findings also indicate that our ancient people have utilized marine resources for building up their economy and the products have been traded across the country and beyond. A Portuguese period (early 17th century AD) shipwreck discovered off Goa which has four iron cannons and a large number dressed granite slabs besides a large number of pottery, elephant tusks and hippopotamus teeth, perhaps testifies this. Another shipwreck in Goa have a large number terracotta house building material such as floor tiles, pillar columns and decorative tiles. While four steam engine shipwrecks have been found in nearshore Lakshadweep waters dating back to the 19th century by NIO, recently ASI has studied a wreck in Lakshadweep waters dating back to 18th century. Goa can boasts of several port capitals within the coastal zone, like Gopakapattanam, Elha, Chandor etc. A site recently discovered in Kerala reveals presence of a wooden boat in a canal, just 200 m from the shore.

The prominent prospective port sites to be studied in detail include Dholavira, and a few more Harappan ports in Rann of Kachchh, Miyani, Viswada, Madhavapur, Gopnath, on the Saurashtra coast, Sopara, Elephanta, Janjira, Kalyan, Bassein, Chaul and Malvan on the Maharashtra coast, Karwar, Mangalore, Nitra, Bhatkal, Malpe, Banavasi, Honnavara, Udyavara on the Karnataka coast and Muziris and Beypore on the Kerala coast. These and some other sites are likely to yield critical information about our maritime heritage.

As the real appreciation of the maritime cultural heritage has begun only now, a good quantum of work remains to be done, so far as exploratory surveys are concerned. However, the coastal belt commands great demand from industrial sector in view of rampant globalisation, for construction of new port facilities or factories and so on. Such activities are surely to destroy whatever evidence available of our past achievements. It is necessary that environmental impact assessment for mega land utilisation project on the coastal area compulsorily include identification and excavation from marine archaeological point of view, at least to study and save such artefacts, if present for posterity before they are lost forever.

Marine Archaeological Findings at Gulf of Cambay

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The Gulf of Cambay, a funnel shaped extension of the Arabian Sea, is sandwiched between mainland Gujarat and the Saurashtra Peninsula. The area was well known for maritime activity from c.700 BC onwards. Accounts of Greek travellers like the *Periplus of the Erythraean Sea* refers to the ports like Barygaza, Souppara, Kalliena etc and the thriving trading activities carried out from these ports. The gulf drained by the rivers Narmada, Tapi, Mahi and Sabarmati from the mainland on the east and small rivers from the Saurashtra peninsula reveal varying geomorphological features that include, sandy beach, mud flats, beach ridges, lagoons, estuaries, marshes and rocky patches.

The gulf with a tidal variation of 4 to 12 meters and the currents measuring upto 6 knots presents an agitated sea. Structurally, the Gulf of Cambay is a highly complicated terrain affected by major faults and fractures. These faults undergo periodic reactivation, resulting in lot of **neotectonic** activity in the **Gulf of Cambay**, often affecting the seabed itself.

The geophysical surveys carried out in the year 1999-2000 showed features that are unusual in the marine domain and they are unlikely to have been due to natural geological processes. Further investigations indicated that the presence of **two palaeochannel** and some **structure like features** on either side of it.

The **palaeochannel** in **zone I** is seen to be aligned roughly along **WNW-ESE** direction with little course variation here and there and at some places this was seen for maximum width of about 500m. Wherever there was palaeochannel, the dredge sample could recover very good alluvium with fresh water shells. Samples were collected through gravity core at different locations in the palaeochannel area and was sent for **(OSL) Optically stimulated Luminescence [OSL]** dating to the department of Earth Science at Manipur University. The **OSL** dates of **3000 BP** obtained for the **palaeochannel** from this study showed that the area was part of the **main land till as recently as 3000 BP** and **its submergence was due to the tectonic activity that it underwent.**

The presence of archaeological material in these areas was confirmed by the samples collected through dredge and cores. Notable materials collected include pottery pieces, semi carbonised wood piece, hearth material, an upper Palaeolithic stone tool and stone beads. The carbonised wood was sent to National Geophysical Research Institute, Hyderabad, Birbal Sahni Institute of Palaeobotany, Lucknow, and Institute of Earth Science, Hanover, Germany for ^{14}C analysis. The piece of wood forming the part of the geological and archaeological column gave an age of about 9500 BP. Detailed geophysical survey that included side scan survey, sub-bottom profiler and magnetic surveys were carried out from November 2002 to February 2003. The area under survey was divided into two zones viz., zone.1 in the north and zone.2 in the south.

The Sidescan Sonar Survey results show that Zone-1 is characterized by surface sediments ranging from clay to gravel, compressional features with

minor sand ripples etc., whereas mega sand ripples and sand waves are the seabed features identified from Zone-2. The predominant orientation of the sand ripples are roughly parallel to the tidal direction and it suggests that they are natural features developed by the tidal currents of Gulf of Cambay, while the sand waves may be the result of some structural features beneath them. Sub-bottom Profiler Surveys were conducted side by side with the Sidescan Sonar Surveys aiming at delineating/unearthing any significant structures buried below the seabed, which are anthropogenic in nature. Magnetic Surveys were aimed at obtaining magnetic signatures of the surface and subsurface magnetic bodies from the marine archaeological point of view. The magnetic anomalies observed over Zone-1 are of less amplitude, indicating that these could be caused by shallow structures or structures with minor magnetic properties and can be of importance to marine archaeological investigations. The magnetic relief obtained in the Zone-2 suggests a deep-seated origin of magnetic causative bodies. The application of magnetic surveys proved to be an important component in the archaeological investigations, which helped us to isolate the archaeological structures from the natural and geological structural trends in the area.

Geochemical studies on trace and REE in marine sediments and archaeological samples were carried out to understand the **provenance** of the **geological** and **archaeological** materials collected in the region. The analysis indicates that the materials are *insitu* product and is not transported from the surrounding region.

The marine archaeological investigation in the Zone 1 area of Gulf of Khambat indicated the presence of Mesolithic hunting gathering community in this area. Their presence strongly suggests overlaps in time between the microlithic and semi-urban chalcolithic culture in the Gulf of Cambay area. About 248 microlithic tools, identified with Mesolithic cultural phase, were collected and these tools were made of semi precious stones like quartz transparent and smoky, jasper, flint, agate plain and banded, chalcedony, corundum, and chert. They vary in sizes from .5cm to 4 cm in length.

The exploration through dredge brought to light various types of artefacts that include wattle and daub house materials, clay sealing, house floor material, refractory material like parts of hearth. The wattle and daub collected indicate the use of different binding material for construction of houses. The XRD analysis on the floor material revealed that the people used burnt earth material for levelling the floor, over which a thick layer of clay was used for finishing the house floor.

Samples from wattle and clay materials and a pottery piece from one of the wattle and clay material were sent for TL/OSL dating to the Luminescence Dating Laboratory, London and Luminescence Lab, Department of Earth Science, Manipur University. The analysis at Oxford and Manipur University for the construction materials gave a calibrated age ranging from 3ka to 10ka.

The dates obtained indicate that the early settlers in the Cambay area were proficient in their use of fire in a controlled manner and are advancing towards the sedentary form of life at an early period in the Gulf of Cambay region. The TL/OSL dates and ¹⁴C dates indicates the existence of human settlement in this area for a long period of time.

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Ecology of Western Indian Coast

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The Indian coastal zone is endowed with rich habitat diversity, unique flora and fauna coupled with increasing anthropogenic pressure. The habitat diversity differs in the west as well as east due to the differing coastal landforms on both the coasts. Steep slopes, rises, promontories and drowned estuaries characterize the West Coast of India while the East Coast shows a sequence of delta formations. We have extensively used remotely sensed data to study the extent and ecological condition of various habitats of the Indian coast including the vital and critical habitats. The orbital remote sensing technique provides synoptic, multi-spectral and repetitive coverage, which is very useful for studying the ecology of the coastal zone. The components that can be observed through remote sensing include spatial distribution of coastal ecosystems, their ecological status and changes in their conditions through time and space. Efforts have also been made to monitor some of the critical habitats. The recent studies also focus on zoning the dominant mangrove communities based on their ability to grow under varying tidal conditions, substrate, and salinity and to zone the coral reefs based on the ecology as well as morphology. Studies are underway to assess the health of the vital coastal ecosystems using a combination of medium as well as high-resolution satellite data that aid in developing Operation Ecosystem Reference Points of health.

In this paper the emphasis is being given to the ecological studies carried out for the West Indian coast. The **mangroves** along the West Coast have less diversity, stunted growth and mostly occur as patches either fringing the coast or occurring along the creeks and estuaries, with the only exception being the Gulf of Kachchh where the mangroves cover entire islands. Based on the different geomorphic set-up the mangroves have been classified as onshore, estuarine and gulf mangroves along the Western coast. The Gujarat coast has all the three types of geomorphic set-up and these mangroves stand second in India after Sunderbans as far as aerial extent is concerned. The Gulf of Kachchh has maximum diversity (4 dominant species and 5-6 species of rare occurrence). In other areas of Gujarat, such as the Kori creek, Saurashtra coast and Gulf of Khambhat coast, the mangrove community is mostly made up of *Avicennia*. Significant numbers of industries have come up on these coasts, which along with the jetties and their housing colonies have further degraded these mangroves. Maharashtra, Goa, Karnataka and Kerala coasts have mostly estuarine mangroves. The mangroves along the Thane estuarine region and the stretch between Diva and Dombivli in Greater Bombay district need protection from human interference. Mangroves near the mouth of the rivers in Goa are tall and dense, and those occurring in the upstream areas cover isolated patches. On the Karnataka coast the Sharavati estuarine complex harbors dense and diverse mangroves. Along the Kerala coast, there are practically no large tracts of land under mudflats and

mangroves. Increase in population density, multidimensional developmental activities and the conversion of backwaters for agricultural purposes are the main reasons for the decline of mangroves.

Coral reef is another unique and vital habitat that is present on the western mainland coast as well as make up the Lakshadweep islands further west off Kerala coast. With the help of satellite data the coral reefs of the Gulf of Kachchh have been mapped and monitored for their extent as well as condition for the last 30 years (1975-2005). From 1998 onwards these reefs have also been zoned based on their varying habitats, ecological as well as morphological zone. The reef edge, the reef slope, the reef crest and the moat harbor hard corals but their density, percent coverage and diversity are extremely low. The effect of high sedimentation is visible. Urgent sustainable conservation measures are required such that the reefs are compartmentalized into various zones of management. Methodologies are currently being developed to model the management of these reefs. The Lakshadweep island reefs are mainly atolls. Impact of anthropogenic pressure is now becoming increasingly evident on these reefs. Seagrass has increased in the lagoonal areas of these atolls that is an indication of nutrients excess. Currently models are being developed using satellite data as the major input to assess and monitor health of these reefs. On the western coast the only other area having coral reefs is the Malvan reef occupying an area of 1 sq km.

Marine algae are biologically important for their role in building calcareous banks and cementing coral reefs. Zonation of algae is governed by tides. In the region above high tidal where the tidal influence is negligible, no algae are found. In the inter-tidal zone having moderate tidal influence lesser number of algae (*Chaetomorpha* sp.) are present. In the inter-tidal and the sub-tidal zones, which are frequented by tides, algal vegetation is rich. Due to their less coverage, it has not been possible to study these habitats at species/community level using RS data. All the Gulf of Kachchh reefs have rich growth of marine algae. There are pheophyceae members like *Sargassum* and *Padina* that dominate the reef edge; the green filamentous and matty algae inhabit the mud depositions on the reef. The green, red and brown algae are found inhabiting the moat and the outer reef flat. In Lakshadweep coral reefs, primarily coralline algae predominate in the coral zone and macro-algae are present in lagoonal areas. An Algal Pavement was mapped near the outer reef crest of the Bangaram reef of Lakshadweep. Algae are strong indicators of health of the coastal critical habitats and are being used as operational ecosystem reference points.

Seagrass are advanced flowering plants that intermingle with both mangroves and coral reef communities at their respective seaward and landward boundaries, frequently providing link between mangroves and coral reef ecotypes. Seagrass (*Thalassia hemprichii*) has been mapped along with algae on the inward side of almost all the reef flats of the Gulf of Kachchh using high resolution IRS P6 LISS IV and IKONOS data. Seagrass *Urochondra setulosa* that has not been reported from any part of India grows on Pirotan island. The seagrass species have also undergone degradation and decline due to the cutting of mangroves. In the Lakshadweep reef

ecosystem, the seagrass inhabits the shoreward lagoon. Lately an increase in the extent of seagrass has been mapped on the Kavaratti reef and new seagrass growth surrounding the two main islands of Bangaram reef. Studies are underway to determine the cause of increase in seagrass that is otherwise an indicator of excess nutrients.

Vegetation that establishes on **sandy relief** beyond the high tide line ranges from low grass to shrubs. *Ipomoea pescaprae* is one of the most widely distributed of Angiosperm plants and forms the dominant community on the sandy shore. Sporadic sand vegetation has been mapped on the Gulf of Kachchh, on the sandy beaches of the coral reef islands and fringing reefs of the mainland. Vegetation on dunes was mapped on western and southern Saurashtra coasts, between the Narmada and Tapi and the south Gujarat coast. On these areas *Sporobolus*, *Ipomoea*, *Spinifex*, etc., and certain cultivated species, e.g., *Casurina*, *Prosopis*, *Acacia*, coconut palm, etc., commonly occur. Sand vegetation has also been mapped in the northern Maharashtra and Goa coast, between Coondapur and Mangalore.

Orbital remote sensing has proved its usefulness in mapping and monitoring of vital and critical habitats of the Indian coast. The large database of IRS data available since late eighties is an excellent source of data for condition assessment of vital mangrove areas and identification of areas under stress. With the proliferation of industrial complexes, mangroves are under severe threat, and it is necessary that they are preserved and/or conserved. A routine monitoring, at least twice a year, is now possible with the state-of-art Indian Remote Sensing Satellite. Data from high-resolution sensors will be extremely useful for assessment of bio-diversity as well as preparation of management action plans.

Sustainable livelihood in Coastal Zone Management: A study of South Gujarat villages

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In their struggle for survival and to sustain livelihoods, households construct a diverse portfolio of activities and social support capabilities. Since the integrated coastal zone management aims to bring together diverse and divergent interest of the people to promote the sustainable management of coasts and coastal resource, the formation of right social institutions merits attention. Hence it would be worthwhile to explore the conditions of poverty, diversification of livelihood activities and people's choice to join with micro-institution like SHGs as a strategy to avail economic support to strengthen their livelihood options. In this paper, we examine the conditions of poverty and livelihood options that exists in the south Gujarat coast. As far as the micro institutions are concerned the study hypothesize that various types of socio economic characteristics that exist in the coastal society can have differential impact on the stands adopted by different members of the society to join with self help groups. The present study gives an indication that the vulnerable and poorest of the poor are less inclined to join with self help groups because they could not visualise any expected gains (net of transaction cost) from joining with such institutions. In such a circumstance, it would be reasonable to point out that the decentralised organisations who promote self help groups for the purpose of strengthening the livelihood options in the coastal area, must pay more attention to bring the poorest of the poor and vulnerable sections of the society to such institutions, otherwise they may get alienated from the very cause of such institutional innovations.

Economic Valuation of Marine Biodiversity
A Case of Mangroves in Gujarat¹
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Marine biodiversity is an important part of the natural resource base of a state like Gujarat, which has the longest coastline i.e. about one fourth of the Indian coastline. The marine and coastal ecosystems in the state include salt marshes, mangroves, coral reefs, sea grass etc. Of these, mangroves are particularly important in view of its pivotal role both from the ecological and economic points of view. Till about nineteen sixties mangroves were largely viewed as 'economically unproductive areas' and were therefore destroyed for reclaiming land for various economic activities. Though the economic and ecological values of mangroves are now appreciated by researchers, the full value of mangroves is still not recognized in most economies, as most of these benefits do not enter the market.

In the recent years, some scholars have compiled the value of mangroves in monetary terms. However, most of these studies are conducted for developed countries and even when they are for developing countries, they are not comprehensive and the nature of the benefits and costs estimated are very much different from the same in India, where mangroves play an extremely important role in the life and livelihood of coastal population. There is therefore a need to compute monetary value of mangroves to understand its importance in our economy.

The main objective of this paper, which is based on a larger study on the subject, is to present the methodology and to estimate the value of mangroves to Gujarat economy. The value of mangroves occurs in multiple ways and at multiple levels to the economy. It has been computed by using different methods of valuation, like the replacement method, production method and contingency valuation method, to estimate the use and non-use values of mangroves in the state. In the end an effort has been made to infer policy/action implications of the study for improving the status of mangroves in the state

¹ The paper is based on a larger study entitled Valuation of Mangroves in Gujarat, supported by India Canada Environment Facility (ICEF), New Delhi

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The Shoreline Morphology of the Gujarat Coast: An Appraisal

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The Gujarat coast lies in the North-western part of India; which represents conspicuous shoreline morphology stretching from Kori creek to Umargaon, covering approximately 1600 kilometers in length. The shoreline is being none static; the features in this zone are undergoing the sub aerial and marine processes of erosion and deposition in time and space. These processes are very different in their rates and intensity. The strandline changes during the Quaternary and, the effects of tectonic movements on this shoreline have contributed more complex landforms development.

The Gujarat shoreline can be divisible into various segments/cells on basis of its configuration, morphology, and nature of on-shore, off-shore, and marine processes, onland geological parameters, etc.viz:

Kutch

- I. Shoreline facing Arabian Sea. (Kori creek-Mandvi)
- II. Shoreline over looking the Gulf of Kutch. (Mandvi-Navlaki)

Saurashtra

- III. Northern Shoreline overlooking the Gulf of Kutch (Navlaki-Okha)
- IV. Western Shoreline (Okha-Kodinar)
- V. Southern shoreline (Kodinar-Ghogha)

Mainland

- VI. Shoreline of Gulf of Cambay (Ghogha-Valsad)
- VII. Shoreline south of Valsad.

The shoreline configurations are controlled by the various bounding faults, Viz:

- The Gulf of Kutch fault,
- Western Saurashtra fault,
- Extension of Narmada fault,
- Cambay Graben faults, and
- West coast fault and

The Kori creek-Mandvi shoreline has an irregular and dissected coast with mudflats and mangroves swamps, which decreases as moving towards east. In Mandvi shoreline sandy beaches and dunes represents the sands of quartzose carbonates mainly derived from the Indus source. The shoreline east of Mandvi to Navlaki represents dominance of tidal flats which extends into the little Rann. The marsh support good Mangroves.

The Northern Saurashtra shoreline highly rocky crenulated with shallow tidal flats consist of islands, shoals, corals and the substrata; which is Trappean rocks covered with recent sediments. This patch is studded with corals, and Mangroves. The shoreline of Western Saurashtra is straight (NW-SE) and conspicuously rocky platforms backed by sandy beaches and dune ridges and occasionally cut by river or creek; where marshes are present. Generally the sediments are of carbonate sands. This shoreline represents both erosional and depositional landforms. Interpretation on two date images reveals that there is not much changes as compared with other shorelines. The southern Saurashtra shorelines appear to be similar to the earlier one, however, the direction is varied (NNE-SSW). This shorelines exhibits

submergence of Miocene paleo-dunes at many places and also now it reflects the Prograding nature of the shorelines. Classical examples are Diu Island, Jegri Island, Jhanjmer-Gopnath shore, etc. At many places the large mudflats are developed. Ghogha –Gopnath shore is partly within the gulf environment, but it reflects north-south trend mainly controlled by Sanand-Ghogha fault or West Cambay Graben fault. This shoreline is cut by Shetrunji Fault (NW-SW), along which the river flows. The mouth of Shetrunji is estuarine in nature exhibiting submerged mouth bars (Gopnath shoal, Sulthanpur shoal). The lower trunk of the stream has shifted on account of block movements. The north of Shetrunji the shoreline marks beaches backed by dunes comprising of silici -clastic sediments mainly derived from the Tertiary rocks. The famous Piram Island lies off of Ghogha. North of Ghogha the shoreline being an estuarine tidal flat.

Ghogha - Valsad shoreline characterizes estuarine condition. In this segment one can see many mouth bars, islands and mud banks. The multi date images reflect prominent changes and generally of Prograding nature. Recently, the Alia bet has grown enormously and after 1990 it has merged with the main land. Similarly the Kadia bet was earlier more than two islands, now they are united together and appears as one. This segment reflects more of deposition than erosion depending upon the location and local tectonic effects. The conspicuous erosion is seen along the Danti shore. Reasons are yet to be inferred correctly. If reasons are to be assigned;

- i. Shallow continental shelf,
- ii. Low altitude of the coastal plain,
- iii. High influx of sediment supply,
- iv. The relatively calm waters in the Gulf,
- v. Constant struggle between the waves propagated by SW monsoon and the swollen waters of the rivers.
- vi. Further it is my opinion that this area lies within the Cambay rift Graben, which is always active.

The Off-shore morphology of the Gujarat has been studied by NIO scientists, and is available in the literatures. However they have not studied in details in the Gulf regions. Their works are mainly on morphology, structures, sea level changes, movements of sediments and dating of sediments etc.

The shorelines are the interfaces between the terrestrial and the marine processes. If any one ask the question that, what are processes that move sediments, shape the shoreline landform and determine the geologic evolution of shorelines? It is now understood that the following parameters which control the development of landforms:

1. Waves, Storms Tides
2. Supply of the sediments
3. Uplifts vs. subsidence
4. Biologic factors
5. Aeolian processes
6. Eustatic changes.

On account of paucity in resources the holistic approach could not be arrived in any of the coastal segments of Gujarat. Integrated study is warranted.

The rock types of different cells have controlled landforms, drainage, and intensity of erosion by waves, and nature and supply of sediments. Strandline changes high or low during the Quaternary time left their imprints in the form of on-shore, off-shore, and shoreline features. However, the sea level curve existing is not satisfactory. Further, it is in general opinion that in addition to sea level changes, tectonism has played its own role.

Any omission and commission are deliberately done on many less understood and controversial areas.

Coastal Zone Database Management and Development of Information System for Gujarat using Remote Sensing and GIS

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The coastal zone, being one of the most dynamic area, is usually under tremendous pressure due to increasing population, expanding tourism, continued industrialization and over exploitation of coastal resources. This poses a major threat to natural resources and biological diversity. The uncontrolled development are not only destabilizing ecosystems but also making communities vulnerable to sea storms. Due to overuse and abuse, both biological diversity and biomass of the forest and marine ecosystems are undergoing rapid decline and changes. The ecosystem as a whole is a dynamic and regenerative forces, if “left alone”, natural mechanism operate to maintain an equilibrium between all living and natural environment (Beatly et al., 1994). However, there is a limit, to the extent of coastal ecosystems can withstand external assaults to its integrity. Sustainable use is the only alternative to resource depletion that accompanies excessive exploitation for short-term profit. This requires not only creation and management of coastal zone spatial and non-spatial database including land use/ land cover, coastal habitats, high and low water lines etc., but also an integrated coastal zone management information system to plan and coordinate all the varied interests in coastal resource uses. In order to protect and conserve the coastal environment, the Ministry of Environment and Forest (MOEF) via its notification (1991), has defined Coastal Regulation Zone (CRZ). Certain activities such as construction, mining, reclamation etc. have been either prohibited or restricted in CRZ. Prohibited and permissible activities in CRZ, procedure for monitoring and enforcement, classification of CRZ into CRZ-I, CRZ-II, CRZ-III and CRZ-IV and guidelines for various activities such as beach resorts, hotels, lodging houses in coastal areas are given in the notification.

Gujarat state has about 1600 kms long coast line in the country. Seeing the tremendous pressure on Gujarat coast, Remote Sensing data and Geographical Information System (GIS) has been used to design and develop a Coastal Zone Information System (CZIS) by Space Applications Centre (SAC) to provide decision support for implementing CRZ notification to planners/ administrators and to create user specific outputs of entire Gujarat State in collaboration with Bhaskaracharya Institute for Space Applications and Geoinformatics (BISAG), Gandhinagar and Department of Forests and Environment, Government of Gujarat, Gandhinagar. This comprises a GIS database of 244 CRZ maps on 1:25,000 scale including administrative boundaries, transport etc. prepared using satellite data pertaining to 1988-99 period. All the thematic data is organized in GIS using spatial master frame created at 1:25,000 scale. The Information System (CZIS) is a customized package developed around ARC/INFO GIS to retrieve all the existing spatial and non-spatial database information in a user friendly manner. This has an in built facility of selecting desired themes/ CRZs, calculating their areas and generating desired thematic maps. Moreover, SOI Toposheet-Wise thematic maps can also be generated with scale, legend, map index etc., by using ‘Output Map Generation’ sub-shell by giving only the Toposheet Number as an input.

Rift Tectonics and the Evolution of Sedimentary Basins in the Western Continental Margin of India

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Indian plate came into existence after initial rifting of the Gondwana land in Late Triassic and subsequent drifting in Middle Jurassic – Late Cretaceous time. It eventually collided with the Eurasian plate in Middle Eocene after northward drifting along counter clockwise path and similar rotation. The western continental margin is still in the divergent set up as the spreading of Arabian Sea on either side of Carlsberg Ridge continues. Due to this rift tectonics Cambay Basin, Kutch Basin, Saurashtra Shelf, Bombay Ratnagiri Basin, Konkan Basin, Kerala Basin, Deep water Basin of West Coast and Narmada Basins were evolved in the Western Continental margin of India at different stages.

The morphology of the continental shelf as well as the coastal areas is mainly controlled by the following three tectonic trends. These are Dharwar (NNW-SSE), Aravalli-Delhi (NE-SW) and Satpura (NE-SW). Many of the tidal inlets and creeks of the western continental margin coast are also controlled by the intersecting lineaments. During the major part of the Quaternary, the coastline has been emergent due to Neo tectonic uplifts of the land part and accelerated subsidence of shelf as evident by marine terraces, submerged forests and other evidences.

The eastern and western continental margins of India, though passive margins, differ markedly from the Atlantic type margins in their characteristics and evolutionary history. The western continental margin followed a more complex evolutionary history compared to the eastern margin. After its separation from Africa and opening up of Mozambique channel synchronous with the eastern taphrogenic episode, the composite Indo-Madagascar continent underwent sequential shearing, with loci of successive rifts progressively migrating towards cratonic interior of India, in the process producing continental slivers and intervening basins which witnessed various degrees of oceanisation – Madagascar, Mascarene Plateau, Seychelles and the Bombay High continental fragments manifest such slivers.

The central Graben (Mahim Graben) in western offshore and its northward extension, the Cambay basin represent the terminal phase of this shearing process. Implicitly, the Radhanpur Arch analogous to Bombay High-Bassein-Heera slivers would represent the younger and terminal candidates. While the Bombay-Ratnagiri, Kerala and Konkan basins developed as a consequence of the shear movements, the Kutch and Saurashtra basins, the erstwhile remnant of Tethyan platform, also got overprinted and subsided in conformity with newly evolved basins.

The early stage of basin development was characterized by a series of N-S ridges (Pratap ridge, Chagos-Laccadive Ridge, Laxmi Ridge) from east to west, separated by linear depressions which subsided rapidly. These depressions were filled up dominantly by longitudinal sedimentary transport during the initial stages, followed by transverse basin filling. Lacustrine to marginal marine organic rich fine clastic of early Eocene age are the principal source rocks both in the Central graben and the Dahanu depression.

Since the habitat of hydrocarbon is controlled by the tectonics involved, the understanding of the rift tectonics will unveil the untapped potential of hydrocarbon in the western continental margin of India.

Groundwater Resource Prospects & Problems in Coastal Regions of Gujarat State: An Overview

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Coastal regions of Gujarat inhibit unity in diversity. Its 1600 km long stretch is geopolitically divisible in to three units' viz. Kutch, Saurashtra and Mainland Gujarat. These units possess uniqueness in geologic, climatic and resource potentials. Agro-climatically these units are characterized by a significant range of variation 1) climate, hot arid – semi arid – moist; 2) moisture index > - 66.7, between - 66.7 & -55.8, and 55.8 -33.3%; and 3) rainfall <350 mm (arid), 500-700 mm (semi-arid) and 700->1000 mm (moist).

Gujarat coastal aquifers constitute the second richest groundwater repository after the Gujarat alluvial plain. Groundwater resource occur under water table and semi-confined to confined conditions. The aquifers composition is varying from basaltic (consolidated), sandstone & limestone (semi-consolidated) and alluviums (un-consolidated). Quantitatively average annual renewable groundwater resource potential of the state coastal regions, embracing 46 talukas stand at about 105.45 MCM.

Coastal regions being rich in natural resources have remained vulnerable to over exploitation. Rapid pace of past 30 years of developmental activities in these regions has put the groundwater resource under considerable stress. Progressive depletion in rainfall input & degradation of land use pattern has significantly influenced the aquifer recharge. Further, increased demand of dependable groundwater resource in agriculture & industrial sectors has considerably lowered the water table, inviting problems of groundwater salinization through sea water intrusion. The coastal segments of Mandvi – Mundra talukas of Kutch and entire coastal track of Saurashtra has witnessed an overall lowering of water table to the tune of more than 3m below MSL. Resultantly, almost 12,000 km² land area become saline and availability of good quality water has decreased by almost ~43%.

Over irrigation, use of chemical fertilizers & germicides and industrial waste disposal are the another causative factors of groundwater pollution. Amongst these, over irrigation through surface water canal system coupled with non-utilization of groundwater resource has led to cause severe water logging problem in the inland coastal regions, particularly along the mainland Gujarat. Rising trends in water table has also enhanced the salinity in groundwater and soil. Almost 12,950 km² (Pre-monsoon) is under the influence of water logging i.e. up to 3m bgl and the EC value more than 3000µm/cm particularly in Mahi and Kakrapar irrigation commands.

Therefore, the fragile coastal regions of Gujarat require a well led plan for efficient management of land and water resources. Strategies like artificial recharge, blending, change in crop pattern and lowering of water table, particularly the regions affected by water logging problem can be appropriately implemented as a part of mitigatory measures.

Assessment of Geoenvironmental Hazards of a Coastal District of Gujarat, India.

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The coastal belt of Jamnagar district is having both tidal flat dominated as well as beach dominated coast. The Gulf of Kachchh is present to the north, where most of the short lived ephemeral rivers debouch their sediments in the wide (1 to 10 km) tidal flat zone. The straight linear beach coast in the western part, borders the Arabian Sea. Low precipitation and lithology do not help many streams to carry sediments to beach coast. The tidal flat dominated coast is having irregular coast line with several tidal islands. Geomorphologically the coast is having present tidal flat, older tidal flat, estuaries, delta and pediplain areas. The present tidal flat supports mangrove vegetation over 30 to 35% areas. The irregular, detached, narrow older tidal flats occur as remnants around the estuaries and delta regions indicating evidence of marine regression up to 80 cm in sub-recent time. Most of the estuaries have been anthropogenically modified constructing spill over dam (*Bandharas*) along their mouths. River Ghee, Phuljhar, Sasoi, Und and Aji forms different sizes of deltas.

Geologically the tidal flat dominated coastal zone is having basaltic flows (Deccan Trap), overlain by Tertiary Laterites, limestone, marl, calcareous sandstone and thick clay beds, Pleistocene miliolite limestone, sub-recent calcareous sandstone, conglomerate, recent fluvio-deltaic sand-silt-clay, tidal mud and silt. In the eastern part sub-recent to recent fluvio-deltaic sediments directly overlie the basalts, in the central part the sub recent marine sediments belonging to older tidal flat are having narrow width. Thick (400m) marine tertiary sedimentaries and laterites are present in the western part. The deltaic region of Sasoi and Und show evidences of half graben structures as evidenced by sharp change in lithological assemblage and thickness.

Tectonics has played a major role in shaping the morphology of the coastal zone. The gulf coast of Jamnagar is fairly prone seismic activities as revealed from seismicity records and presence of active faults, few of which have been identified recently. Added to these, several evidences of neotectonism have made the north eastern part of the district a seismic hazard zone. Straightening of stream course, sharp change in the river course, formation of unpaired terrace and unusual deepening of stream channels even near to the coast are the evidence of neotectonism. The coastal belt along the gulf of Kachchh falls within the seismic zone III of India. It has a record of earthquake epicenter (Intensity- VI, near Hamspar, on 31st Oct, 1940) close to Lathi- Rajkot Fault (LRF). The ENE-WSW trending North Kahiawar Main Fault and N-S trending LRF intersect in the coastal zone. Part of Jamnagar district was affected by the Bhuj Earthquake, 2001 within the isoseismal line VIII and IX. Swarms of low intensity seismic activities ($M < 3$) have been recorded during the year 2003 for about a month around Sasoi reservoir.

Geoenvironmental Hazards identified in the tidal flat dominated coastal belt are:

1. Landward ingression of Brackish-Fresh water interface up to a distance of 3 km in last 15 years (1990 to 2005) has been recorded. This is due to extensive pumping/ overdrawal of groundwater in the mining area near Rann, Mewasa, Virpur and Limbdi as well as around Jamnagar city.

2. Pollution to land-water system has been observed around

a) Industrialized coastal zones of Jamnagar –Jambuda –Air Force area (Jamnagar mega urban centre)

b) In the north eastern part of the mega petroleum based industrial complex.

c) In the western part of district around Datrana and Juavanpur, around bauxite and laterite dominated areas of Havedi, Mevasa, Rann, Gokulpur and Hadmatia.

All these four areas are marked by higher values of NO_3 and SO_4 , enrichment of toxic elements like Pb, Ni and Cu and Cr in some of the above mentioned areas. GIS studies have shown that the enrichment of the toxic elements in ground water is more along the Brackish- Fresh water interface.

3. Seismic hazards: Based on the lithology, structure, engineering properties of the ground material and tectonism seismic hazard zones have been delineated. North-eastern coastal zone of the district having thick fluvio-marine sediments and dissected by active faults and lineaments, has been demarcated as highly seismic hazard zones for construction of civil engineering structures.

Present anthropogenic activities have created disbalance in the natural environment and accentuated the process of geoenvironmental hazards in the area and accentuated the process of geoenvironmental hazards in the area.

Mangrove Resources and Developmental Issues in Kachchh Coast

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Mangroves of Kachchh district is the single largest patch in the west coast spreading over an area of 727 sq.km. Confined mostly to the northwestern limits of the district, thick stands of considerable density is also present in Mundra coastal stretches. Similar to degradation trends observed in other coastal stretches of West coast, mangroves of Kachchh have undergone decline in their extent though of late signs of recovery is visible. Dependency of coastal populace for fodder, unprecedented developmental activities and reduced freshwater inflow due several upland activities are some of the major factors that pose serious threat to mangroves in Kachchh coast. Announcement of tax holidays after 2001 earthquake has further provided a boost to the industrial developments and investments worth 1000 crores are in pipeline. Many of the industries which are already functional are located in close proximity to mangroves which have already started showing signs of stress. This article analyses the present status and threats faced by mangrove resources and future scenario in the light of ongoing coastal developmental activities in Kachchh coast.

Limestone Mining along the Saurashtra Coast of Gujarat in context of coastal Communities

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The limestone, locally recognized as 'Doojto Patthar', is seen all along the coast of Saurashtra region of Gujarat from Dwarka of Jamnagar district till Jafrabad of Amreli District. Limestone from this coast is used for building purpose and also as raw material for industrial purpose. The former is popularly known as 'Gajiya Patthar' while later is called as 'Chunana patthar'. During Dariya Kinara Samvad Yatra is clearly seen that mining of limestone, has lead significant impact on livelihood of the coastal communities. It is observed that, in addition to degradation of natural resources, mining has also disturbed the social structure - relations, which is even more dangerous.

The current study is an effort to summarize the dialogue held with people of over 300 villages of Saurashtra coast, during 'Dariya Kinara Samvad Yatra', in context of role of limestone in their livelihood earnings, current status and responsible factors. The paper may try and show, what 'limestone' means to the thousands of people residing along the coast of Saurashtra for years, on the limestone.... with the limestone.

⁴ Dariya Kinara Samvad Yatra – A tour along the coast of Gujarat to understand changes in the livelihood of Coastal communities. It's a joint effort by more than 150 Voluntary organizations and individuals working on the issues of Coastal communities.

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Impact of river sand mining on bio-physical environment: A case study from the southwest coast of India

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Kerala State in the south west coast of India is blessed with 44 rivers. The sand reserve in these rivers is substantially low compared to the other rivers in Peninsular India, because of their small catchment area (<6000 km²) and limited riverbed resources. However, these rivers have been subjected to reckless exploitation of sand and gravel for constructions and other developmental activities. It is reported that sand and gravel mining is taking place several folds higher than the natural replenishments. This, in turn, leads to severe damages to the riverine ecology. Reduction in sediment supply from catchments and erosion of its own channel during high flow regimes are very common in many rivers of Kerala. These in many of the occasions, led to channel deepening (incision) and undermining of engineering structures such as river bank protection walls, water intake structures constructed within river channels for water supply schemes, bridges etc. Apart from these, sand mining provides employment opportunities to a section of the people of Kerala. It is a fact that its impacts on various environmental components and the broader economy of Kerala are not fully understood and adequately informed to the regulatory authorities. There is therefore a need to improve our understanding on various aspects of sand mining from the small mountaneous rivers in the south west coast of India (Kerala) that are known for their scenic beauty, pure flowing water and rich biological wealth.

The present paper is an attempt to address the impacts of sand mining on the environmental components of the small rivers of Kerala, in the south west coast of India. A few management plans are also suggested for improving the overall environmental quality of these rivers, which are affected severely by indiscriminate sand mining over the last two decades.