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Existence and Experience of Purba Medinipur Coastal Belt on its Morpho-Dynamic Journey with the Distinctive Geology and Geomorphology

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Abstract: ***This paper reflects the development of coastal existence of Purba Medinipur along the diversified Bengal Coast. In detail study on Medinipur coastal territory shows that sea levels remained very dynamic during the Holocene Period. Evidence of Quaternary sea level changes are found were responsible for the origin almost parallel distinct dune colonies along with typical beach profile having various geomorphic features through the geological past along this coastal swathe. The existence of tropical and sub-tropical monsoon climate with its seasonal phenomena and other river-coastal processes take part in a vital role for such a long-term geomorphic development of this coast. In this study, the coastal territory of the part of West Bengal, which is responsive to quick shoreline change, is preferred. Applying RS and GIS techniques on the multi-temporal satellite image and toposheets, shoreline extraction have been carried out to evaluate the erosion-accretion prototype in the region at both regional and local extent. Depending on the erosional pattern, the intact study area was divided into different erosion cells which exhibit that this coastal region has been experiencing erosion. So, this study may be an attempt to make an understanding not only about the morpho-dynamic behavior of this coast with its geological landform signatures over time, but geo-historical document to measure the existed threats and detect the managemental ways along this corridor.***

Keywords: Beach profile, river-coastal processes, shoreline change, erosion cells and morphodynamic

1. Introduction

The present geomorphic division like the beach, active dunes, mud flats, etc of the present day study area has developed within last 6000 years with the last sea level fall after Holocene climatic optimum through sand deposit by Subarnarekha River (Bandopadhyay-2000, p 17). Several scientific studies show that the sea levels along the Bay of Bengal coast remained very dynamic in nature through geological time. The entire process response system of the coastal tract of Bengal Basin started operating after the rise of sea level around 6000 years BP. In Midnapore coastal tract, the development of successive rows of dunes with intervening clayey tidal flats is due to punctuations in the regression of the sea during Holocene. But, an erosional regime is prevailing in the western part of the Medinipur coastal plain. Based on tidal amplitude only, West Bengal coast can be sub-divided into two different coastal environments namely: 1. The macro tidal (tidal range > 4 m) Hugli estuarine plain characterized by a network of creeks encompassing the islands with spectacular mangrove vegetation and off-shore linear tidal shoals from Sagar Islnd to the border of Bangladesh to the east. 2. Meso tidal (tidal range 2 – 4 m) Medinipur (Digha-Sankarpur-Junput) coastal plain to the west of the Hugli estuary with rows of sandy dunes separated by clayey tidal flats from Sagar Island to Orissa border to the west. This study shows the major geomorphological footprints through time at different geographic segments of this coastal belt and also enlightens the morpho-dynamic shoreline with its nature and causes through geo-historical journey.

2. Methodology

Intensive visits to the study area, extensive literature survey and experimental documentary analysis are three key measures to prepare this paper and for conducting this study. Reports of Geological Survey of India, Survey of India, Department of Tourism-Govt. of West Bengal, Department of Environment-Govt. of West Bengal, Digha Development Authority, Institute of Wetland Management and Ecological Design, Ministry of Forestry and Environment, etc. and recent research papers published in different regional, national and international journals and presented in different seminars, programmes, etc. are very essential and helping tools to complete this study. Basic cartographic materials like Geological and Geomorphological Maps (1:50000) of GSOI (1995), Toposheet-73 O/6, 73 O/10, 73 O/14(1931-'32 & 1968-'69) of SOI and IRS IC LISS-III, 2000 (23.5m), IRS P6 LISS-III, 2005(23.5M), IRS-IC, WSS-3, Geocoded FCC 73O6, 73O10 and 73O14 (1:50000) of NRSA (1997), have been used. Besides these, different cartographic and GIS techniques have been applied as necessary as.

3. Objectives

This study is oriented towards understanding the some specific aspects. These are:

1. Geological Background and Geomorphic Signatures of this area to show the geo-history of the coastal tract;
2. Sub-surface Geology of this coastal sector;
3. Major Geomorphic features of the study area;
4. Morpho-dynamics of Midnapore shoreline and
5. General causes of accretion and erosion of Midnapore coastal tract.

4. Geographical location of the Study Area

India is blessed by a long shoreline enclosing the State from three sides, i.e. East, South and West. Compared to the western part, the eastern coast of the Indian subcontinent, experience lots of dynamism in terms of the coastal stability (Chatterjee, 1995). West Bengal has a substantially long coastline of almost 325 kilometers (including islands) characterized by high floral and faunal biodiversity, diverse geomorphic features and anthropogenic intrusions (Bhattacharya, 2001, Bhattacharya et al., 2003). The area selected for this study is the part of this extensive shoreline of Bay of Bengal along the West Bengal coast. The coastal stretch is about 50-60 km long extending from Talsari to Khejuri including Digha-Sankarpur tract, the Pichhabani inlet, Tajpur-Mandarmani coast, Dadanpatrabar-Junput sector and Hijili-Khejuri segment, which is known for straightness of the coastline, flatness and compactness of the beach (Gupta, 1970). This region is traversed by two irrigation canals viz. Khadalgobra and Ramnagar Canals, which jointly discharge water into the sea at the point known as Digha Mohana, as a result of which an estuarine zone is created in this area. The study area is also discontinued by Jatranala, Pichhabani and Jaldha inlets. About 40km east from Digha town near Nij Kasaba(Khejuri), is Rasulpur river which opens onto the Hooghly estuary. Geographically this vast coast line contains a great geomorphic and biochemical diversity in respect of landforms, soil texture, marine plants and animals. The latitudinal and longitudinal stretch of the coastline is about 21°38'13.126"N to 21°42'30"N and 87°35'7.718"E to 87°46'14.29"E respectively.

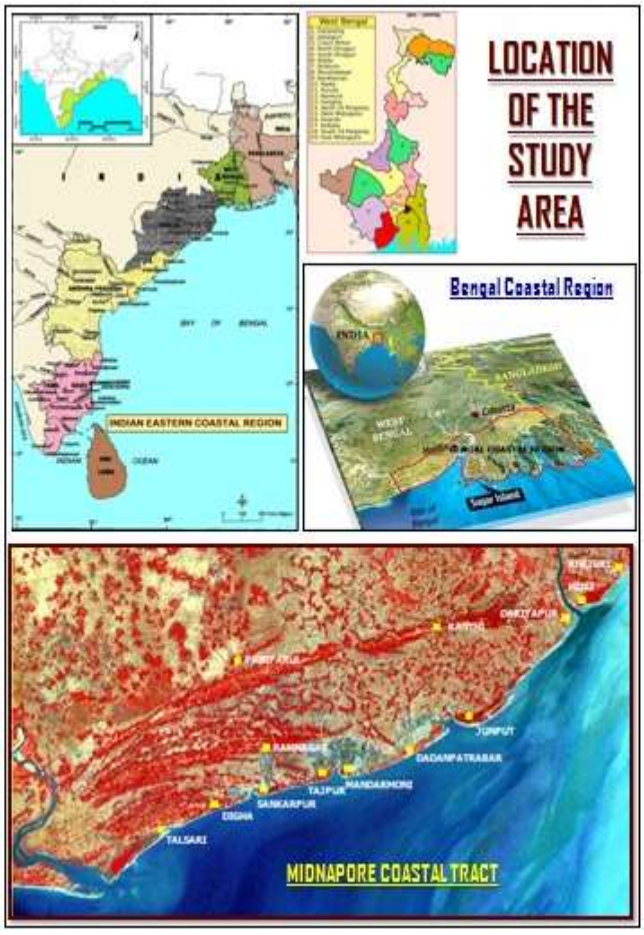
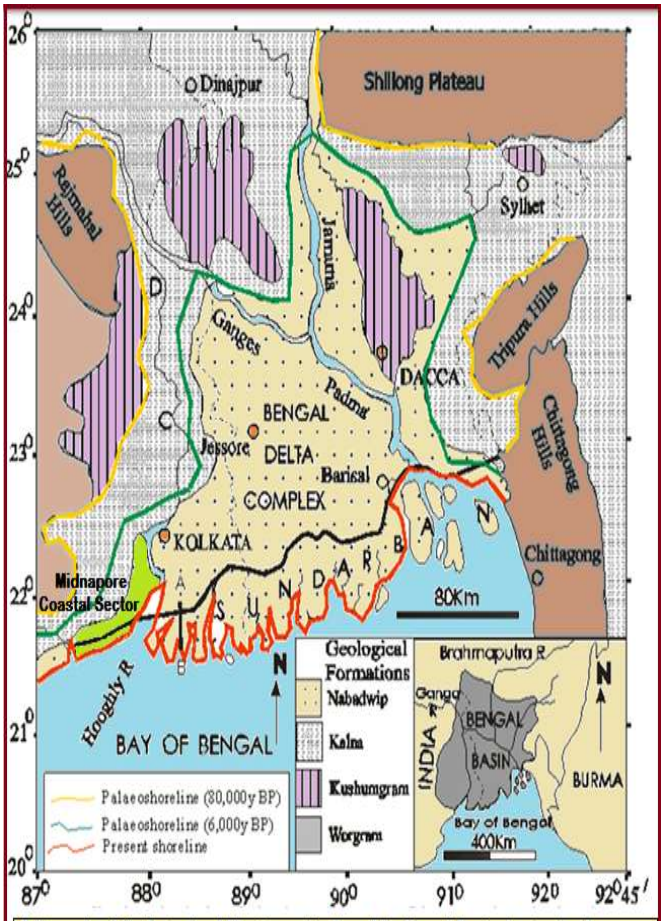


Figure 1: Location Map and Related Images of the study area

5. Geological Background and Geomorphologic Signature of the Study Area

The study area, i.e. Coastal Regulation Zone of West Bengal is the eastern and southern part of Bengal Geosynclines (stable shelf in the west and deep basin in the east) bordered in the west by the Indian shield, which is separated by a series of buried basin marginal encephalon faults. Intensive Geophysical surveys and deep drilling data in this alluvial plain of West Bengal revealed that the extensive subaqueous basaltic lava (Rajmahal Trap) is overlying Permo-Carboniferous coal bearing Gondwana sediments of continental environment. Later geological history is the repetition of marine transgressions and regressions which were the major phenomena controlling the depositional environment during the evolution of this basin. The sediments overlying the trap were deposited mainly in the continental environment. The drainage system originated from Indian shield (Chhotanagpur plateau part) was the then geological agents of sediment transportation and deposition. The first evidence of traIisgression in the basin is during Cretaceous but upper Cretaceous was a phase of regression. Other phases of transgressions are early Paleocene (local), Eocene (extensive), late Oligocen~Miocene (extensive), and Pliocene (two phases - early and late Pliocene). Late Paleocene, late Eocene-early Oligocene, mid Miocene, and upper most Miocene were the phases of regressions. Although the Quaternary was in general in regressive phase but oscillatory environment was also there at that time (Tiwary & Banerjee, 1985). The Eocene Hinge Zone, a zone of tectonic flexure and fault, passing Calcutta Ranaghat-Mymensingh 'separates the relatively stable shelf from the deeper basin of the geosynclines. Post Eocene eastward tilting cause very thick pile of stratigraphic horizons in the eastern part. Raman and co-members (1986) from isochronal interval mapping of the stratigraphic horizons concluded that Krishnanagar-Ranaghat area was a depositional low and Contai area was a high probably with an another

depositional low in the present day offshore during Cretaceous and Paleocene times. Niyogi (1970) has reported the presence of Belda-Contai upland which was not occupied by any large river in the recent past. He concludes also that this upland evolved mainly from the delta of Subarnarekha and Kasai. Palaeo-Damodar river trend was the main source of sediment supply during the Cretaceous-Eocene period. During Creteous time, Ghatal area was under the influence of restricted lagoon environment, which was replaced, by open marine shelf environment during the Paleocene and Eocene (Raman et al., 1986).



A General zed Geological and Physiographic Map of the Bengal Basin showing land-sea distributio n, successive migration of coast line through ages, major landforms, drainage and geological units.

Figure 2 & 3: Geological Map

Chakraborti (Chakraborti, 1991) contradicted this view of Niyogi and recommended an inter-fingering relationship with the rows of dunes, beach ridges and clayey inter tidal flat of the adjoining coastal plain in the east. In the eastern side of Subamarekha delta, according to Niyogi (1970), six regular cycles of beach ridges alternating with a variable number of bars are visible which are indicative of shifting of shoreline. But it is not clear whether these ridges are analytic of punctuations in the regression of Holocene sea. According to Chakraborty, only one beach ridge is present in the association of dune rows in the mesotidal Midnapore coastal plain. This ridge has been termed as "Older beach ridge" from its morpho-arrangement by Chakraborty. According to him, the successive rows of dunes (viz. Ancient, older and Beach front dunes) with intervening clayey tidal flats and local sandy beach ridges are indicative of punctuations in the regression of the Holocene sea in this area. He also suggested that the "Ancient dune complex" all along the Midnapore coastal plain (about 10-15.kms north of the present day shore tine) indicates the position of the ancient strand line in the area. The C14 dating of the sediments from ancient fluvio-tidal flat (5760 +140 YBP) bordering the Ancient dune complex in the south confirms that the higher strand line in the post glacial (Holocene) period is at present represented by the "Ancient dune complex" which is around 6000 YBP - the optimum Flandrian transgression. The C14 dating of sediments from ancient inter tidal flat (just south of Ancient dune complex) gives an age of 2920 + 160 YBP, which indicates the first punctuation in the regression of Holocene sea in the area under consideration.

Table 1: Thickness of on-lapping and off-lapping sequences in coastal tract of Medinipur, West Bengal

Area	Well Location	Older eroded Surface/land derived sediments			On-lapping sequence		Off-lapping sequence		Remarks
		Depth (m.bgl)	Thickness	Sediment Type	Thickness	Sediment Type	Thickness	Sediment Type	
Midnapore Coastal Plain	Negua(bordering ancient dune complex ancient strand lines)	67.44	2.84	Gravel with small amount of 'caliche' and Fe nodules	7.06	Sticky Grey Clay	57.54	Alternating sequence (fine to coarse and clay with a basal layer of gravel, mixed with kankar and Fe nodules of 3m	The increased thickness of Quaternary sediments in Hooghly estuary in comparison to Midnapore coastal plain may be due to 'Structural lowering' or Geosynclinal down warping.
	Digha(bordering older dune/beach front dune complex)	97.53	12.19	Very coarse sand; sub-angular to sub-rounded	12.20	Sticky Grey Clay mainly with sand (fine to medium)	73.14	Alternating sequence of sand (fine to medium), silty clayf sand(6.09m) and clay with a basal layer of very coarse sand (sub-angular to sub-rounded)	

Source:- (Chakraborty, P.-1994)

6. Sub-surface Geology

According to Chakraborty(1991), this coastal area is underlain by unconsolidated sediments of sand, silt and clay. These sediments have been categorized into seven different zones based on their their physical, mineralogical and biological characteristics. The depositional environments indicate marine and non-marine conditions alternating with each other.

Table 2: Terrain Analysis and Classification of Medinipur Coastal Region

Particulars	*Terrain Units*	*Geomorphological Units*	*Geological Units*
Marine Coastal and Fluviotidal Facies	• Beach face • Beach front dune complex • Present day mud/sand flat • Older beach ridge • Older dune complex • Older tidal pond • Ancient inter-tidal flat • Ancient dune complex • Ancient tidal pond • Ancient fluvio-tidal flat	• Active marine coastal plain • Abandoned marine coastal plain • Inactive marine coastal plain • Inactive fluvio-tidal flat	• Recent Medinipur Coastal Deposit • Older Medinipur Coastal Plain • Ancient Medinipur Coastal Plain

Source:- (Chakraborty, P.-1991)

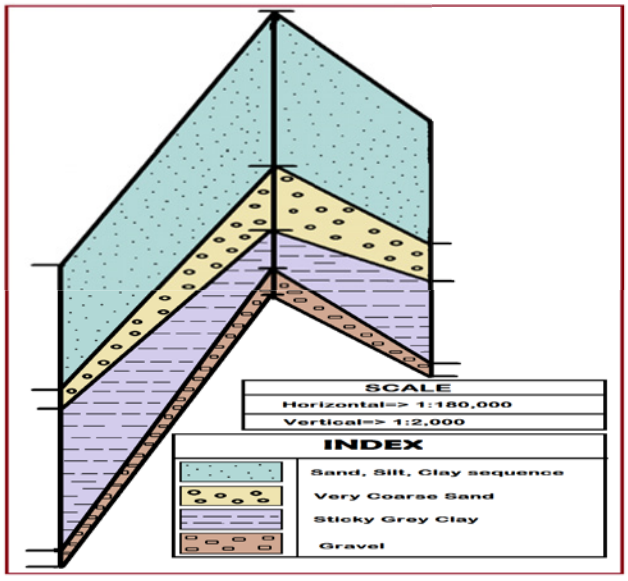


Figure 4: Sub-surface Geological Section from well logs Hooghly Estuary

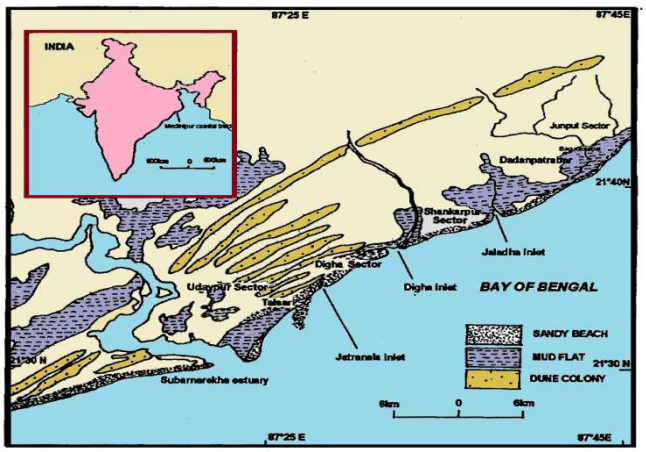


Figure 5: Major Geomorphic Featues of Coastal Medinipur

6.1 Major Coastal Geomorphic Features

1) Estuary: The River Hooghly forms a big estuary near its mouth, which is the major waterway for ships of Calcutta

port and Haldia port, boats and launch. In Midnapore part, mouth of Rasulpur forms the only estuary. This estuary is highly productive area of living marine resources.

2) Tidal flats/Mud flats: A mud flatslTidal flat is one of the most important categories of the landuse / landcover feature in any Coastal Regulation Zone (CRZ). In the western part of West Bengal coast i.e. in Medinipore coastal sector it is sandy. Three types of mud flats are found namely; Saline water mud flat, brackish water mud flat and Fresh water mud flat. In two seas facing sectors the mud is very saline and major portion is inundated by daily tides while mud flats of central and deep-inland sector get inundation by pushed back freshwater during spring tide and monsoon period only. Out of 223.947 sq. km. area (excluding Mangrove swamp area) of mud flats about 81.27 % (181.994 sq.km.) is restricted in Sunderban sector and Medinipore coastal sector constitute about 5.94 % (13.295 sq. km.). The rest lies in central sector (28.183 sq. km.) and deep-inland sector (0.475 sq.km). Mud flat of central sector is restricted to the recent chars of Rupnarayan River, Kaliaghai River and Haldi River. A vast stretch of mud flat (6.644 sq.km) lying in between Kaliaghai river and Kapaleshwari N near Daspur(73 N/12 SE) become waterlogged for about six months during monsoon and post-monsoon period. This mud flat is converted to rice field during dry season by pumping out stored water ignoring the value of this wetland.

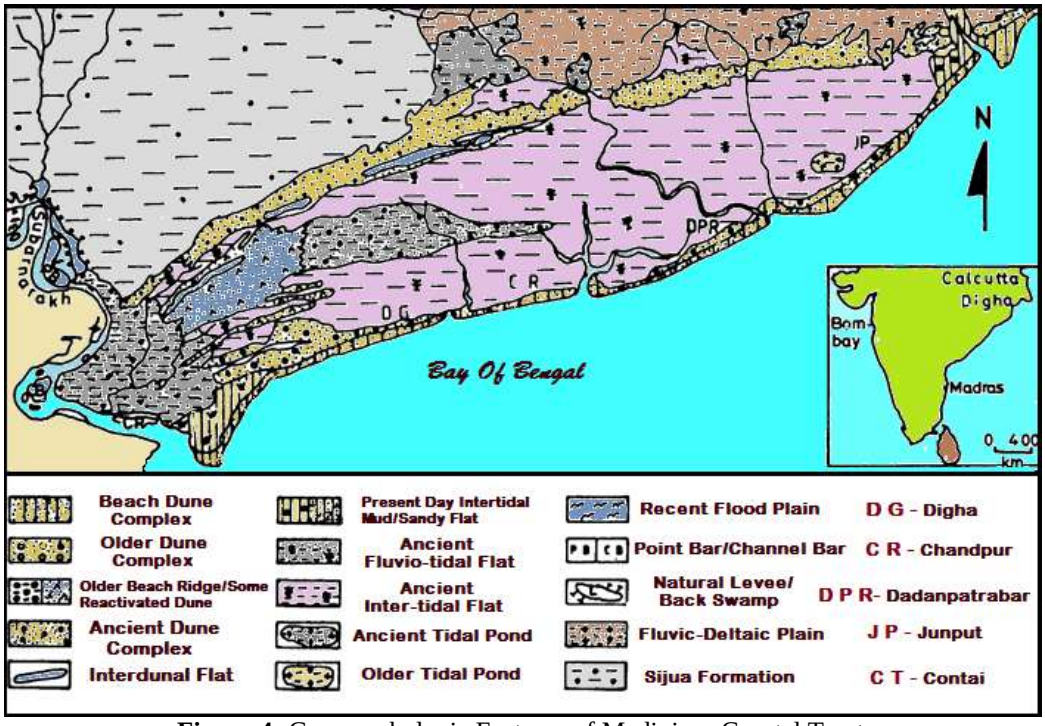


Figure 4: Geomorphologic Features of Medinipur Coastal Tract

3) SandlBeach/SpitIBar: Beaches in West Bengal coast are sandy or muddy. Sandy beaches are noticed in the western part of Hooghly estuary whereas vast extension of muddy beach is found in 24-Parganas parts i.e. to the east of Hooghly estuary especially to the east of Bogkhali. Well-developed beach is found near Digha, Dattapur, Shaympur, Dadanpatra, Baguranjalpai, Dariapur, Nij Kasba, etc along Midnapore coast. In other parts beaches are narrow and it is almost absent on Southeastern part of the coast. Exposition of older mudflat in Bogkhali coast and Sankarpur coast is the clear indication of beach erosion. Formation of spit is found near Junput (73 0/13 NW) at the mouth of Pichaboni khal another minor hook shaped projection is found at the mouth of Sankarpur harbour. The beachfront dune complex of Medinipur coast has been included under this unit.
4) Salt Marsh:- Appearance of salt marshes have been noticed in the images IRS IB, 1992 data near Khejuri and at the mouth of Rasulpur River named as Nij Kasaba(Hijili). But, it should be notified here that the tropical marshy vegetation of the newly appearing shoals or places is being replaced by mangrove species anthropogenically and naturally in the most recent years.
5) Sand dunes:- Three spectacular dune complexes, namely Contai Dune Complex(Ancient Dune Complex), Ramnagar Dune Complex and Beach front Dune Complex are one of the two unique land cover units of West Bengal Coast. These rows of dunes are stretched from Subarnarekha estuary to Hooghly Estuary. Among these three, the northern most dune complex, Contai Dune Complex, is well developed and it is about 6000 years old based on C^{14} dating. Although, more than 90 sq. km area is covered by dunes but in CRZ area it is only 5.84 sq. km. This is simply due to the facts that the major part of this land cover unit is lying outside the CRZ area beyond the line of 500 meters from High Water Line (HWL) and some parts of this within CRZ area have been included under other land use units viz. Habitation, Sand Beach, Agriculture, Man-made forest, etc.

Coastal dune morphology consists of distinct parallel dune chains and depressions (Pethick, 1984) which have

a significance of geomorphic evolution throughout geological time (Dey and Haque, 2003). Two main geomorphic classes of the dunes of this area are observed, these are Palaeo-dunes and Neo-dunes. Between these two dune colonies, inter-dunal depression is well-existed.

- Paleo-dunes are older dune chain having 2-10 m heights which indicates the early shoreline positions during 2920±60 years BP. Banerjee and Sen(1987, pp 307-320) opined that regression of sea along this coastal tract around 6000 years BP resulted seawardshifting of shoreline and formation of Paleo-dunes. These dunes were got maturity by the growth of natural vegetation under stabilized environmental condition during last 3000 years BP. Aeolian action is slowly responsible for decrease in dune height. The older sand ridge (0.5-1.0 m) is actually situated almost parallel to the active dune chain beyond 3 km from beach and complex in nature. This area is featured by thin soil profile whereas the sandy terrain of beach and dunes is found without any soil cover.
- Inter-dunal depression/mud flats are existed beyond 200m nearly parallel to the sea from Orissa to Old Digha in between Paleo-dunes and Neo-dunes. These occur between the front dunes and the older dune tracts, which are marked by high tide level and storm tide level. Thin layers of mud with remobilized sands from the dunes are found covered by grasses and bushes.
- Neo-dunes are existed on the upper face of the beach. Some seasonal small dunes(1.5-4.5m) normally form during the drier season by sand drifts. It is accepted that further regression of sea and seaward shifting occurred after 3000 years BP (GIS, 1995) which resulted a new platform for developing another dune chain in front of Paleo-dunes. In Udaypur sector, some front dunes are now gradually stabilizing by free growth of vegetation due to accretion for southward shoreline drifting. Other sectors of this coast have experienced by the neo-dune (12-19m of height and >45° of steep slope) belts having a tendency to shift landward and readjusting their position with recent rise of sea level. These dunes collapse and decay during Monsoon. Vegetation cover is little and these are found on the margin of sea beach. Erosion marks on the front dunes indicate the present high tide level.

6) Salt Pans: These are observed near Dadanpatrabar, Junput, Tajpur, Nij Kasaba, etc. along with this coastal belt. But, recently these pans are being widely used for aquaculture hugely destroying its ecological, hydrological and morphological significance.

6.2 Morpho-dynamics of Midnapore Shoreline

Evidence of marine coastal sediments, mangrove roots and marine shells are found bellow 26.6 km depth under the surface in Kolaghat-Tamluk region(21°55´N-21°31´N and 87°38´E-88°11´E), which indicate the previous position of shoreline during the Pleistocene epoch(Chanda and Hait, 1996, pp. 117-124). The Geological Survey of India(1995, p-3) has detected that shoreline positioned 5-15 km inland from the present shoreline around 6000 years BP. Around 3000 years BP the shoreline position was 2-5 km inland from present shoreline. Landward shifting due to rise of sea level and subsequent land erosion is a major environmental issue of Medinipur coastal tract in recent. In well-known work of O'Malley(1911), Bengal District Gazetteers, Midnapore, the possibly history of recent shoreline shifting of this area has been described. The evidences from the maps of Valentijn(1664 AD), Van Der Brook(1668 AD),James Rennel(1777 AD) and plot chart of Thomas Bowrey(1688 AD), suggest that erosion is not a contemporary phenomenon along this area. Evidences also suggest that over the last three centuries the problem of erosion has aggravatory along parts of Midnapore coastal tract. Goswami(1997, pp 61-88) assessed that about 6000 m land eroded from 1775 to 1986 at and around Digha at an annual rate of 28.4 metres/year. Both Digha and Sankarpur sectors are suffering by rapid beach narrowing and lowering. From west to east Digha beach is now narrowing progressively and at the eastern end of Old Digha Township, the actual beach width remain only 5-10 km.

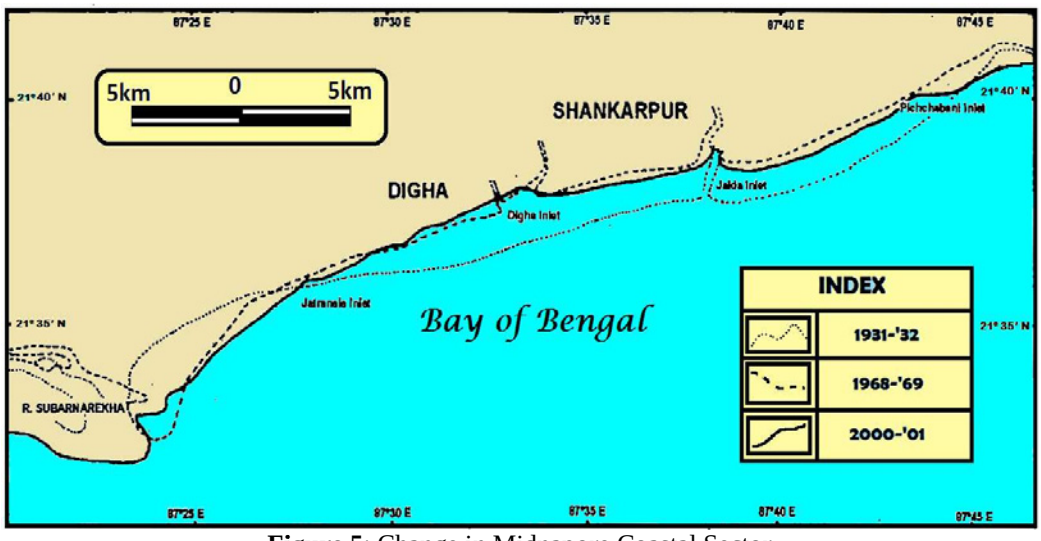


Figure 5: Change in Midnapore Coastal Sector

From the recorded data and comparative study with Survey of India toposheets, satellite images and field data, it is observed that during 1931-'32 to 1968-'69 the westward part of Medinipur coastal tract (from Subarnarekha River to Jatranala inlet having length as 13 km) was under prominent accretion. Rest of the area, from Jatranala to Pichhabani inlet, about 28.5 km was under erosion. Though from Jaldha to Pichhabani inlet there was a little accretion during this period, net positive change of shoreline was landward during that time. During 1968-'69 to 1997, a remarkable change is found along the coast. A new zone of accretion has emerged towards the east, from Jaldha inlet to Pichhabani inlet(13.5 km). But from Jatranala to Jaldha inlet(15 km) rapid erosion occurred (Dept. of Environment, 1996, pp 17-19).

The beach–dune morphology of sandy alluvium coast along Midnapore shoreline is swiftly varying due to storm characteristics, elevation of the shoreline and a variety of human behavior at in attendance. The extensive sea beach and beach-fringed dune belt of Talsari barrier & mainland coast and Mondermoni-Silampur barrier coast had acted as natural barrier in opposition to the tidal waves and storm surges in the long-ago. By bearing in mind the magnitude of wave run-up, the highest reach of the waves on the beach, virtual to coastal elevation, a new scale has been developed that categorizes net erosion and accretion during storms. Different impact regimes (swash regime, collision regime, over wash regime, and inundation regime), their morphologic responses and greater potential hazards have been estimated for mapping geomorphological changes along the coastline. Reclamation of pre-mature tidal floodplains of the low lying coastal plain (behind the dune belt), reduction of tidal prisms and temporary flood spill grounds, and recreational uses of shore fringed sand dunes are major human activities that influences the magnitude of coastal changes along the Bay of Bengal shoreline at present.

The shoreline in the study area according to Santra and Mitra, 2013 has never been constant and shows a continuous changing pattern. (Both the spatial and temporal variations in the deposition and accretion have been observed in the study area. The temporal intervals (being 1950 to 1963, 1963 to 1990, 1990 to 2000 and 200 to 2005) used in the study for assessing the changes have not been uniform. However, the erosion and accretion patterns clearly show a nonstop geomorphic sculpturing over the coastal tract in each temporal gap. Erosion mechanism as a constant factor for the coastline modification in the most of the areas, whereas a little segment near Pichhabani inlet shows deposition. In the western part of the study area erosion was prominent between 1950 and 1963. However, it gets more distinct between the time intervals of the next 27 years. In the following 15 years, the coastline shows a gradual shift towards contiguous land as a consequence mainly of wave erosion. Analysis shows that the proportion of land and water has been continuously changing in the study area along the coastline. Excluding the contribution of inland water bodies, it has been estimated that between 1950 and 2005, almost 10% of the land has been engulfed by the water.

Table 3: Erosion-accretion rate

Time Gap	Gross Erosion(Area)		Gross Accretion(Area)	
	Ha	% to Total	Ha	% to Total
1950-1963	837.03	3.18	33.77	0.001
1963-1990	1356.43	5.16	20.9	0.001
1990-2000	158.59	0.01	13.57	0.001
2000-2005	167.26	0.01	8.92	0.0001

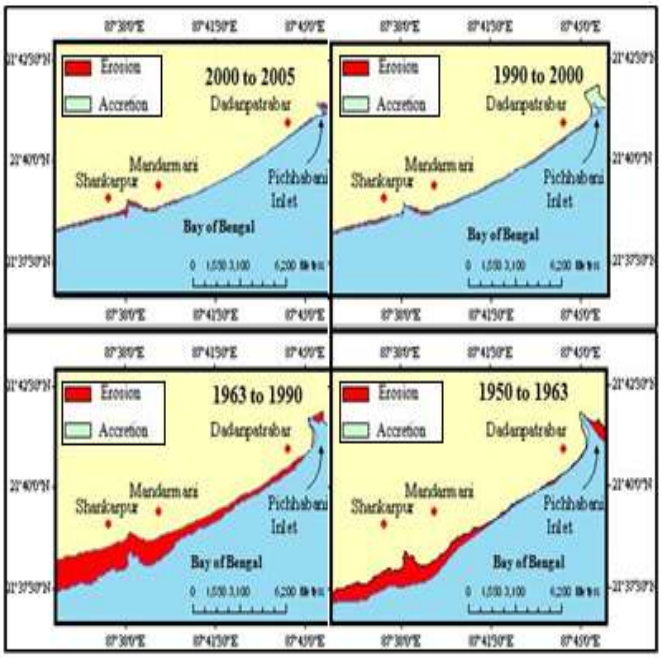
Source:-Santra and Mitra, IJGG, 2013

Total accretion is considerably less with respect to erosion. Whereas between 1950 and 2005, 837.03 ha were eroded from the coastal surface, only 33.77 ha accretion has occurred. This pattern of erosion and accretion indicates that the equilibrium between erosional and accretional processes in this spatial unit is towards negative, which is rather indicative of relative isostatic instability in near future.

According to the total landward-shift of the coastline from 1950 to 2005 along the cross sections, the entire stretch has been divided into four cells having different degree of erosion induced coastal shift. These cells are nothing but a zone based on the prevalent dominance of erosion, and has been designated as erosional cell in the study. The cell 1 corresponds to the shift above 1500m, cell 2 between 1000 and 1500, Cell 3 to 500 to 1000 and cell 4 to below 500m. The Eastern part of Dadanpatrabar has not been taken into consideration as there depositional activities are much stronger than erosion.

The entire analysis of the change detection comes to the conclusion that the entire study area can be divided into two regimes depending on the spatio-temporal coastal change pattern -

- Shankarpur to the western portion of the Dadanpatrabar sector chiefly under an erosional regime and
- Eastern portion of Dadanpatrabar to rest of the study are belonging chiefly to accretional regime



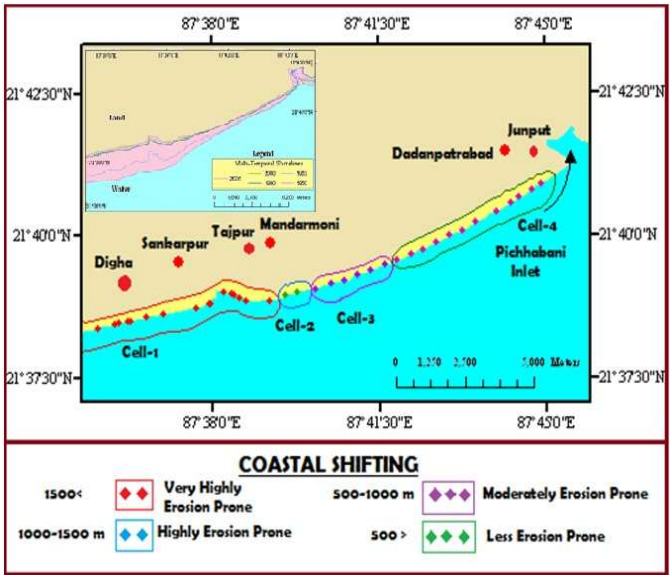


Figure 6 &7: Spatio-temporal occurrence of erosion and accretion from 1950 to 2005 Source:-IJGG, 2013

Extensive geological evidence gathered by Bhattacharya et al. (2003) confirms that this coastal stretch belongs to a meso-tidal (tidal amplitude 2-4 m) regime having semidiurnal tides with slight diurnal inequality. On the other hand, the impact of macro-tidal (tidal amplitude >4m) Hugli (river) estuary is more pronounced towards the eastern part of the study area (Chakraborty, 1990). The moderate to high tidal amplitude creates tidal currents which act as an effective means for reworking the tidal and estuarine sediments (Bhattacharya et al., 2003). The coastal zones, on the other hand, characterized by sea facing sand dunes (Chatterjee, 1995, Bhattacharya et al., 2003). When slightly high amplitude waves attack the base of the sea facing sand dunes, it leads to freefalling of loosened sand particles from dune tops. The sands so avalanched are heaped up as fan deposits at the base of the dunes and later mixes with foreshore beach materials. . Rip currents and alongshore currents mixed with this foreshore sands hit the coast at mutually right angle directions in most of the places along this coast (Bhattacharya, 2001). This geomorphic process leads to landward retreat of the beach, lowering of beach profile and loss of dune vegetation. Nevertheless, the trend changes towards the eastern sides of the study area where waves are observed to hit the beach at 30 to 40 degree angle. Besides, some riverine deposition of river Hooghly is observed here (Kuehl et al., 1997). These two factors substantially reduce the erosion in that part of the coastal zone. Apart from this gradual process, as a part of Bay of Bengal coast, the study area usually gets struck by the severe cyclonic storms (Kalboishakhi) at least 2 to 3 times per year (Rana et al., 2010). The wave height in this storm sometimes crosses 8m. This aggravates the erosion process along the coasts toppling all natural and man-made barriers behind the backshore. Researches of Unnikrishnan and Shankar (2007) also highlighted a sea level rise as another probable cause of a coastal breach in this section of the Coast. The sea-level rise estimated near Digha Shankarpur (near Vishakapatnam coast) area1.06–1.75 mm/yr, with an average of 1.29 mm/yr. It has also accelerated the coastal erosion in the study area. Besides these natural forcing of the shoreline modification, the authors have also identified anthropogenic activities as one of the major causes of the shoreline breach specifically near the Shankarpur coastal stretch. In addition to the Government Endeavour, every year, some hundred thousand rupees are spent in building parallel to shore dykes made of sand-filled bags in this region. All these constructions have strong detrimental effects on the coast as these accelerate the erosive power of the waves. Each time, when the sea waves dash against the protective devises, (which also hit equally hard against the beach) they erode the embankments much faster, lowering the beach profile and retreat of coastal terrain.

6.3 General Causes of Accretion-Erosion and Modification of Midnapore Coastal Plain

Coastal erosion and accretion are complex processes that need to be investigated from the angles of sediment motion under wind, wave and tidal current action; beach dynamics within a sediment/littoral cell; and human activities along the coast, within river catchments and watersheds and offshore, both at spatial and temporal scales. In terms of temporal scales, the issue of sea-level rise is complex and produces a range of environmental problems. As the sea level rises, the water depth increases and the wave base becomes deeper; waves reaching the coast have more energy and therefore can erode and transport greater quantities of sediment. Thus, the coast starts to adjust to the new sea level to maintain a dynamic equilibrium.

The key physical parameters that need to be understood to identify coastal erosion as a problem in the coastal zone are:

- Coastal geomorphology of this coastal sector is generally featured by Strong littoral drift on a very fine grained and flat beach bordered by dune field in the landward side,
- Wind is the main force in wave generation; under the right environmental conditions, wind may transfer sediment from the beach environment landward on all open coastlines. On this coastal belt loss of sandy materials in land by wind action is one of the key factors to coastal erosion.
- Tides are influential in beach morphodynamics. They modulate wave action, controlling energy arriving on the coast and drive groundwater fluctuation and tidal currents. The interaction of groundwater with tides in the coastal forest environment is crucial in understanding why coastal forest clearance causes intensive coastal erosion in particular environments. Here, Strong tides up to 6.5m height during cyclonic storms in the months of September and October, when the south-west trade wind goes through pulsation and helps to cause the erosion.
- Possibility of faulting in the Digha shore face in the recent past.

Equally significant human activities that must be considered over the range of spatial and time scales are:
Activities along the coast: Building houses via land reclamation or within sand dune areas and port/harbour development has a long-term impact on shoreline change; protective seawalls in Digha and Sankarpur lead to erosion at the end of the structures generate beach scouring at the toe of seawall and shorten the beach face. Removal of dune vegetation and mangroves has exposed low energy

shorelines to increased energy and reduced sediment stability, causing erosion within five to ten years.

Niyogi(1970), Chatterjee(1974) and Chakraborty(1977) have tried to identify the causes of beach erosion at Digha on the basis of data available to them. The causative factors identified by them are also same to these causes.

In accretion justification, Midnapore Coastal sector (Digha-Dadanpatrabr) is reared up and by the sand from Subarnarekha and Mahanadi which was confirmed from the heavy mineral analysis and silt from Hooghly Rivers. Moreover, sub-tidal sand bars also act as the source of sand for the beaches of this sector.

7. Role of Vegetation Cover and Seasonal Changes in Modification of Coastal Morphology

Seasonal changes of tropical monsoon influence the width and angle of sea beach, height and angle of typical coastal dunes and existence and extension of mud flats. Wind direction and wave action, both are the main players in the variation of sand supply with season over coastal tract. Local sea level rising during Monsoon and strong wave erodes the upper front dune, compels to shift the beach and dune colonies slightly landward and breaks the harmony of sand tract and continuity of dune ridge. Whereas, during Post-Monsoon reconstruction of sand dunes and beach profile is started by the influence of North-east wind with decreased wave action and Steepness and height of beach and dunes are reduced. Along this coastal tract, 2-5 m/year landward shifting and 0.5-1.0 m in height of neo-dunes is very acute with seasonal change.

Vegetation cover is another key factor to indicate the nature of coastal dunes. Dune movements have been observed to depend not only upon the sand and wind speed, but, pattern and intensity of vegetation cover play a very important role (Dey, Bhakat, 2001). Based on vegetation existence, nature of dunes is existed in the form of stable, semi-stable and mobile tone. Unfortunately, huge dune address has been semi-stable and mobile from its permanency Along this coastal belt, specifically in and around Digha-Sankarpur, Tajpur-Mndermani, Junput-Dadanpatrbar and Hijili-Khejuri anthropogenic hot spots.

8. Future Scope of the Study

There are some specific limitations, which should be addressed as a means of improvement for further study. This study has equipped based on intensive literary survey, raw satellite data and field ground truth information used for image processing but it was not possible to perform a questionnaire survey and enough instrumental survey and analysis in the field because of time limits. Planning is never whole without local people's opinions incorporated. The study can be considered as the guideline or instruction for ecotourism planning based on coastal environment including the geology and geomorphology of this coastal corridor. Yet, this research will expose opportunities for further research and investigation, and help decision makers to review what options exist for improving and humanizing coastal environment with its tourism facilities over Medinipur coastal belt as the Coastal and Beach Tourism Circuit in Purba Medinipur of West Bengal, Digha–Shankarpur–Tajpur-Mandarmani-Junput-Hijili-Nijkasaba, has been increasing its tourism gravity day-to-day. and how they can better ecotourism planning especially, from a point of reducing the negative impacts from comprehensive development in this region.

9. Conclusion

From this analytical study, it has been observed that the entire terrain extending between Shankarpur-Mandarmani and Dadanpatrabar is under the threat of rapid erosion except the extreme western parts where riverine accretion is taking place. Formation and changing behavior of distinct shoreline and dune colonies clearly indicate the dynamic nature of existed natural environment along this coast during Holocene period. Seasonal character, vegetation cover and sub-surface geology play in the vital roles to modify the coastal morphology. It should be notified that there is a tendency of sea level rise at a remarkable rate during the last 300-500 years along Medinipur coastal tract (Niyogi, 1970, pp 1-36). There is an ample evidence of sea level rise at a considerable rate (>2mm) in this part during recent years (Hazra et al, 2000, pp 25- 37). Human intervention, particularly over the last four decades has also been very significant for the change in coastal environment. Finally, the present study may be revealed for the assessment of Coastal Medinipur from the view point of its dynamic geology and morphology.

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