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Change in Depositional Environment of Maharashtra Coast, Central West Coast of India

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Abstract: Deposition of organic matter in nearshore and offshore regions largely depends upon the contribution from terrestrial inputs. Rivers are the major pathways of organic matter to these regions. Any change in fluvial or estuarine inputs therefore will significantly affect the biogeochemical processes operating in nearshore and offshore environments. Significant change in distribution patterns of grain size, organic carbon, TOC/TN ratio, diatom assemblages and carbon isotope ratio values have been noted in the cores collected from Khonda creek, Dudh creek, Vaitarna estuary, Amba estuary, Kundalika estuary, Rajapuri creek and Savitri estuary. All these estuaries and creeks located along central west coast of India indicated a transition from river dominated depositional environment in the past to marine dominated depositional environment in recent years. Since these estuaries and creeks are the pathways of terrestrial material load to eastern Arabian Sea region, decrease in input of terrestrial material load over time has significantly affected the biogeochemical processes operating in this region.

Keywords: Creeks, Deposition**,** Estuaries, Organic matter, Sediments

INTRODUCTION

Coastal regions are the important sites of biogeochemical transformations including biological production, sediment retention and nutrient transformation (Bianchi, 2007). An estimate of over 80% of global burial of organic carbon occurs in margins adjacent to the rivers (Berner, 1982; Hedges, 1992; Hedges and Keil, 1995). Deposition of organic matter largely depends upon contributions from marine and terrestrial sources in coastal regions. Recent studies have highlighted coastal and nearshore areas as important sites where both terrigenous and marine derived organic matter is actively recycled (Aller, 1998; Aller et al., 2004; Blair et al., 2003, 2004; Gordon and Goni, 2003; Stein and Macdonald, 2004). The elevated sediment accumulation rates and the input of recalcitrant organic matter from terrigenous sources both contribute to the efficient sequestration of carbon in the coastal regions (Goni et al., 2005). Information about processes controlling the delivery of organic matter to coastal sediments and mechanisms that underlie their preservation is therefore important to our understanding of global biogeochemical cycles (Canuel et al., 1997).

Rivers draining into the sea are the major pathways of terrestrial input (organic and clastic matter) to coastal and near shore regions. Any change in riverine freshwater input and associated material load therefore directly influence the coastal and offshore regions. Intertidal mudflat and mangrove sediments within estuaries and creeks are known to act as repositories, which store signatures of such changes effectively in different geochemical phases. Study of variation in marine and terrestrial organic matter sources within these sediments provide important information on changes in riverine inputs from past to present. And this information can be used to understand its possible influence on biogeochemical processes operating in the off shore regions. However, impact of such changes will be significant on global level, only if they occur on a larger geographical area for similar time frame and this needs to be assessed.

Rivers supplying freshwater and terrestrial organic and inorganic particulate and dissolved material to Arabian Sea are rapid, short and swift flowing and having hardly any delta formations as compared to those rivers in the east. It is suggested that, in addition to large rivers, smaller rivers also significantly contribute to the overall global carbon budget. Thus, studies should be carried out on smaller rivers to better understand the influence of environmental changes on coastal regions. However, earlier studies carried out along west coast of India emphasized on metal pollution (Fernandes and Nayak, 2012a, b; Siraswar and Nayak, 2011 Fernandes et al., 2011; Kumar and Edward, 2009; Nair and Ramchandran, 2002; Nair and Sujatha, 2012; Harikumar et al., 2009; Ram et al., 2003). Significant work has also been carried out to understand sources and factors controlling metal distribution (Singh and Nayak, 2009; Pande and Nayak, 2013a, b; Volvoikar and Nayak, 2013a, b; Singh et al., 2013), distribution and association of metals within clay fraction (Volvoikar and Nayak, 2014) and bioavailability of metals (Volvoikar and Nayak, 2015; Dessai and Nayak, 2009). Limited studies that were carried out on margins and near shore areas of west coast of India also focused mainly on pollution aspect (Karbassi and Shankar, 2005).

Maharashtra state located along the west coast of India harbors a number of westward flowing rivers. It is the state with highest number of dams in India. Coastal Maharashtra is also one of the most rapidly industrializing and urbanizing regions of India. Thus, mudflat and mangrove sediment cores of Vaitarna estuary (Volvoikar et al., 2014), Kundalika estuary (Pande and Nayak, 2013), Rajapuri Creek (Pande, 2014), Savitri estuary (Pande, 2014), Vashishti estuary (Pande, 2014), Amba estuary (Pande et al., 2014), Dudh creek (Volvoikar and Nayak, 2013a) and Khonda creek located along the coast of Maharashtra state have been studied (Table 1) individually to understand changes in depositional environment from past to present (Fig. 1). In this paper an attempt is made to understand the processes operating all along the coast of Maharashtra state and its significance based on the results of our earlier studies.

STUDY AREA

The coast of Maharashtra is characterized by pocket beaches flanked by rocky cliffs, estuaries, bays and mangroves at some places; while mudflats are found mainly along estuaries and creeks (Nayak, 2005). The coast is affected by medium to high tidal range. In addition to spring and neap tides, semi diurnal tides, seem to have more impact on the tidal estuaries and creeks (Karlekar, 1993). The narrow strip of land between the Arabian Sea and the Sahyadri hills of Maharashtra state is known as Konkan coast. The rocky Konkan coast of Maharashtra is characterized by impressive sea cliffs, sea caves and shore platform at number of places (Mate, 1993). The dominant geomorphic process in the region is terrestrial erosion resulting from high relief (Deswandikar, 1993). Common mangrove species reported from this region are *Avicennia alba*, *Avicennia marina* and *Sonneratia apetala*. *Avicennia officinalis*, *Rhizophora mucronata* and *Rhizophora apiculata* (Naskar and Mandal, 1999). The region is the part of the Deccan volcanic province (DVP) or Deccan Trap. The basaltic terrain has an undulating topography with landforms typical of the DVP (Shankar and Mohan, 2006). The Deccan Trap basalts have uniform tholeiitic composition, are dark green to black volcanic rocks with a wide variety of textural character (Wensink, 1973). In the Northwestern part these tholeiitic basalts show notable picritic and alkali occurrences. They are largely microporphyritic with phenocrysts of plagioclase, subordinate augite and rare olivine (Sano et al., 2001, Sen, 2001). The sediments within the estuary and creeks along this coast will be influenced by the mineral and chemical composition of rocks within the catchment area.

Table 1. Details of sampling locations of sediment cores.

Estuary/ Creek	Name of the Place	Station Location	Core Length (cm)
Khonda Creek	Aagwan	19º57'33.1"N; 72º46'07.1"E	42
Dudh Creek	Murbe	19º44'43.9"N; 72º42'39.6"E	56
Vaitarna Estuary	Chikaldongri	19º28'56.3"N; 72º46'58.7"E	102
Amba Estuary	Dharamtar	18º41‘47.60"N; 73º12‘41.05"E	50
Kundalika Estuary	Revdanda	18º32‘20.76"N; 72º56’11.41"E	66
Rajapuri Creek	Nandale	18º32’55.39"N; 73º00’30.59"E	98
Savitri Estuary	Bankot	17º59‘4.54"N; 73º3’53.18"E	100

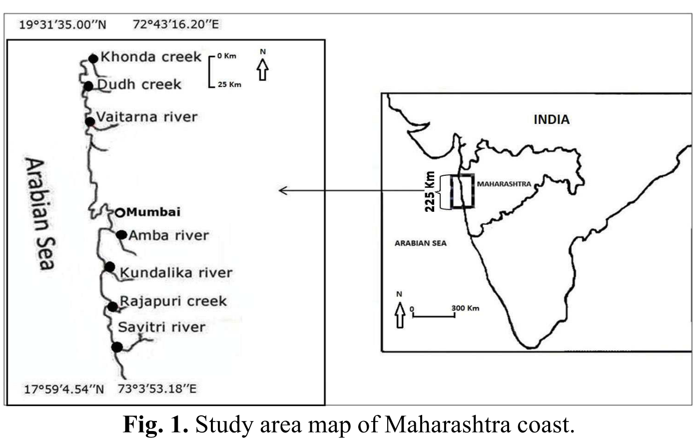

Fig. 1. Study area map of Maharashtra coast.

MATERIALS AND METHODS

Sediment cores were collected using hand operated PVC corer. Following the collection, sub sampling was done at 2 cm interval with the help of a plastic knife in case of all the cores uniformly. The sub-samples were immediately sealed in clean plastic bags, labeled and stored in ice box and transferred to the laboratory. Sampling stations were located using hand held Global Positioning System (GPS). Sediments were oven dried at 60°C in the laboratory. Portion of the dried sample was powdered and homogenized using an agate mortar and pestle. Un-ground sediment samples were used for the analysis of sediment components (sand: silt: clay) and study of diatoms. While, powdered and homogenized samples were used for the estimation of total organic carbon, bulk sediment chemistry, TOC/TN and bulk sedimentary stable carbon (ä^{13}C$_{org}$). In-order to determine the sand: silt: clay ratio, pipette analysis was carried out following Folk (1968). The organic carbon in sediment sub-samples was estimated using the method given by Gaudette et al. (1974) also known as Walkey-Black method. The method utilizes exothermic heating and oxidation with potassium dichromate ($K_2Cr_2O_7$) and concentrated sulphuric acid (H_2SO_4). Total decomposition of sediments for metal analyses was carried out, wherein 0.3 g of finely powdered sediment sample was digested in open Teflon beaker. 10 ml of 7:3:1 acid mixture of HF, HNO_3 and $HClO_4$ was added slowly to the sample. Care was taken to avoid excessive frothing. The mixture was kept overnight and later dried completely on a hot plate at 70° C. After drying, again 5 ml of the above mixture was added to the beaker and dried for 1 h in order to ensure complete digestion of the sediment. To this 2 ml of concentrated HCl was added and dried completely. To the dried sample 10 ml of 1:1 HNO_3 was added and warmed for few minutes. The solution was then made to 100 ml using Milli Q water and was then stored in pre-cleaned plastic bottle. The solution was then aspirated into flame atomic absorption spectrophotometer (AAS) (Varian AA240FS) for the analyses of the metals viz. iron (Fe), manganese (Mn), aluminium (Al), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni) and lead (Pb). Care was taken to avoid contamination at every step. While, for ä^{13}C$_{org}$ analysis, acid treated, powdered, oven dried sediment sub-samples were run on a Thermo-Finnigan Delta-V-Plus continuous flow isotope ratio mass spectrometer attached to an elemental analyzer (Thermo EA1112). Whereas, the homogenized and not powdered sediment samples were used for diatom isolation using the method described by Battarbee (1986).

RESULTS AND DISCUSSION

Significant change in distribution patterns of grain size, organic carbon, TOC/TN ratio, diatoms and isotopes were observed in the cores collected from Khonda creek (Fig. 2), Dudh creek (Fig.3) (Volvoikar and Nayak, 2013), Vaitarna estuary (Fig. 4) (Volvoikar et al., 2014), Amba estuary (Fig. 5) (Pande and Nayak 2013a), Kundalika estuary (Fig. 6) (Pande and Nayak, 2013b),

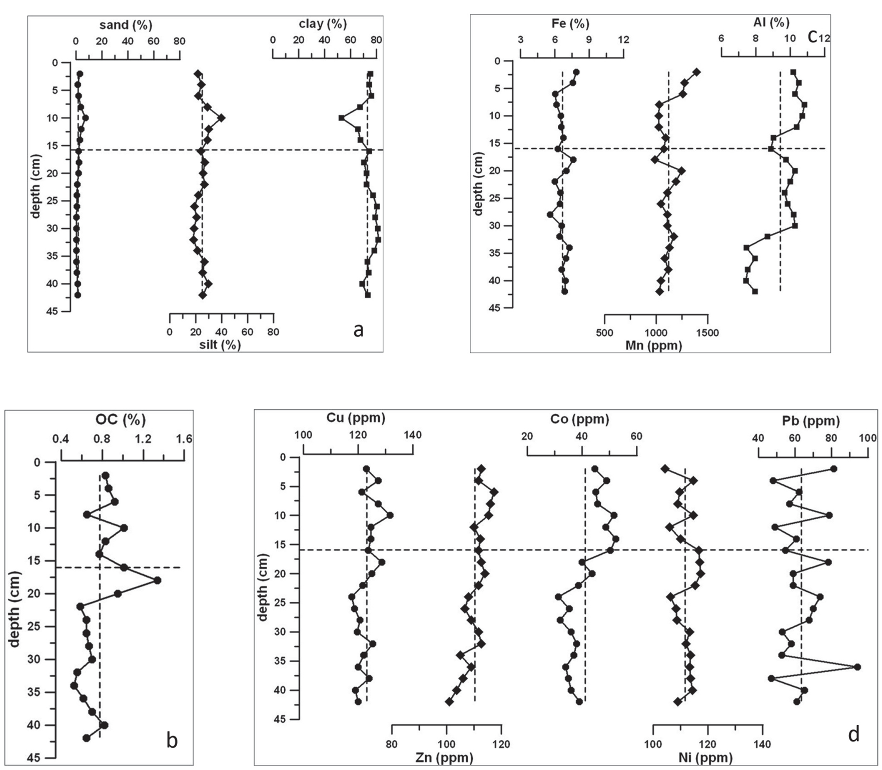

Fig. 2. Distribution of a. sediment components b. OC c. major and d. trace metals in Khonda creek.

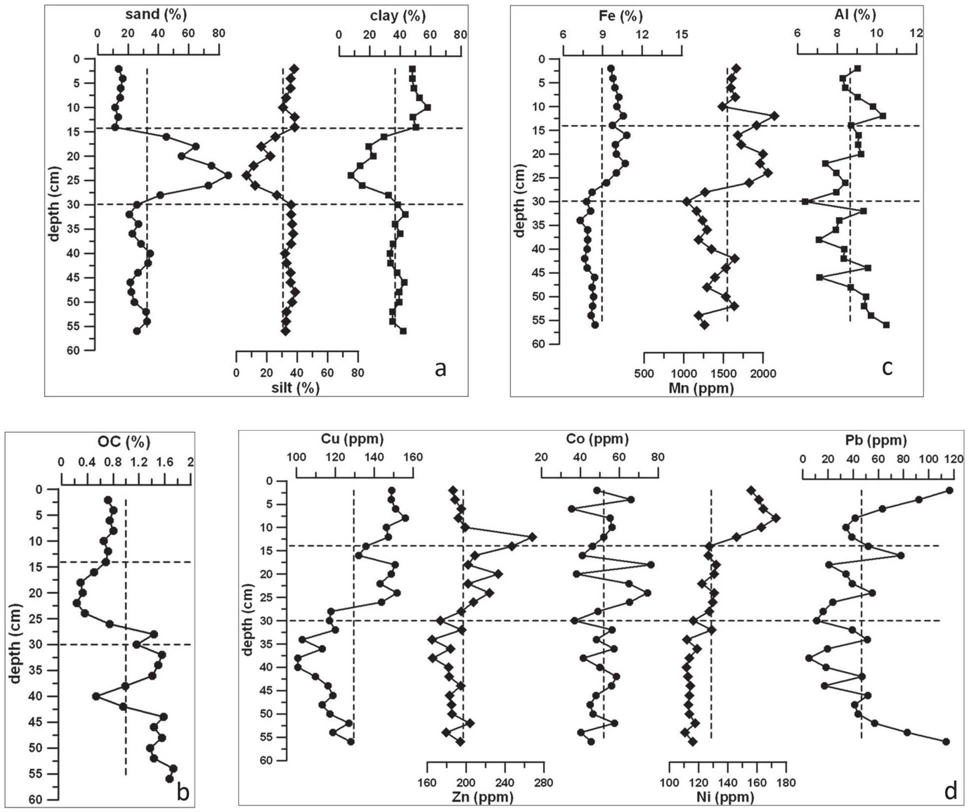

Fig. 3. Distribution of a. sediment components b. OC c. major and d. trace metals in Dudh creek (Volvoikar and Nayak, 2013).

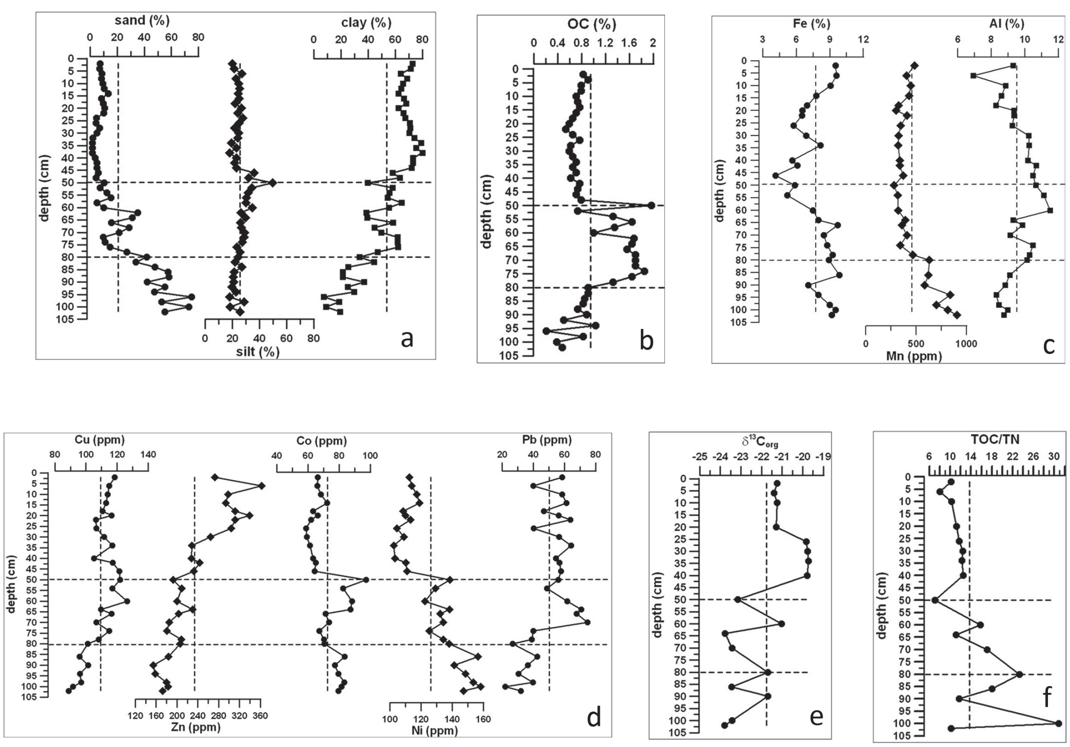

Fig. 4. Distribution of a. sediment components b. OC c. major and d. trace metals e. ä13C_{org} and f. TOC/TN in core collected from Vaitarna estuary (Volvoikar et al., 2014).

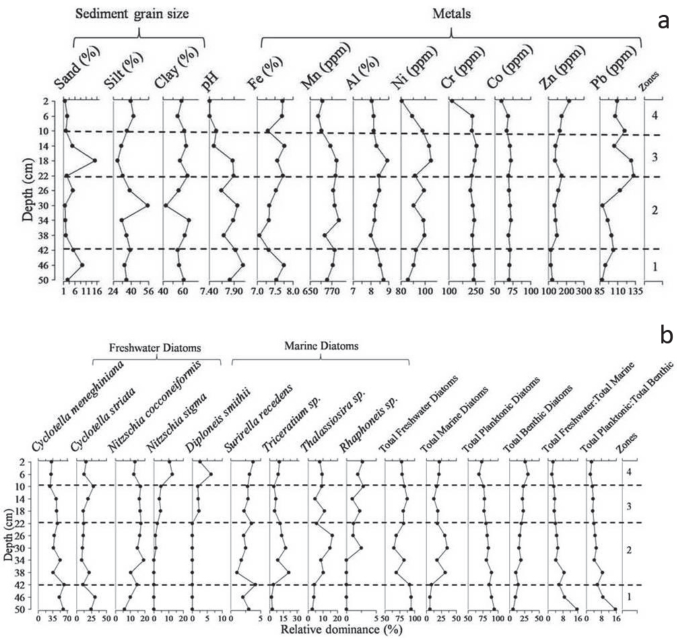

Fig. 5. a. Distribution of sediment components and metals b. diatoms in core collected from Amba estuary (Pande and Nayak, 2013a).

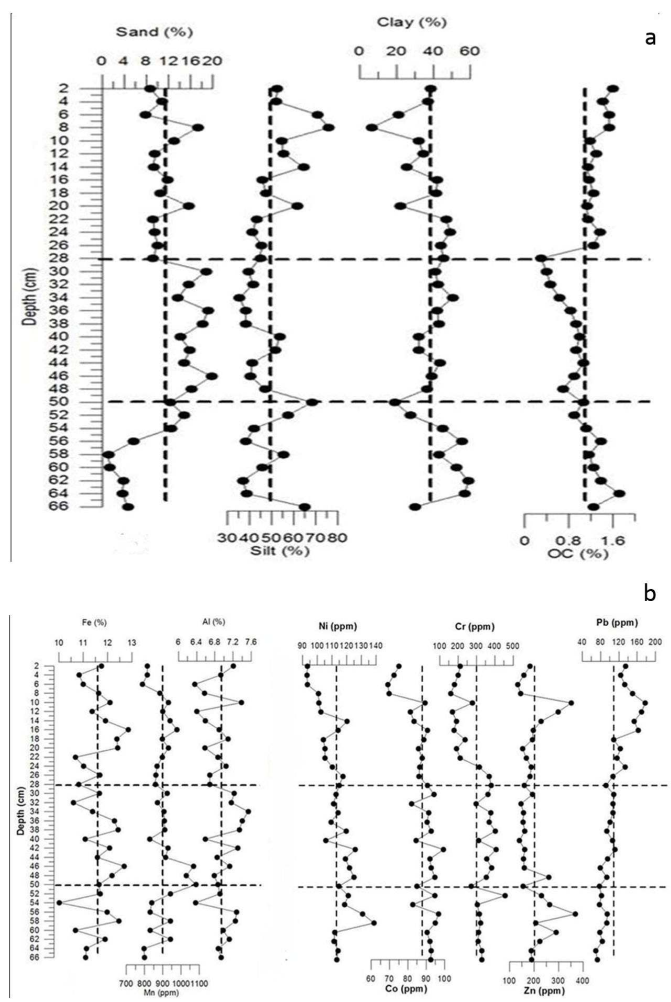

Fig. 6. a. Distribution of sediment components and b. metals in core collected from Kundalika estuary (Pande and Nayak, 2013b).

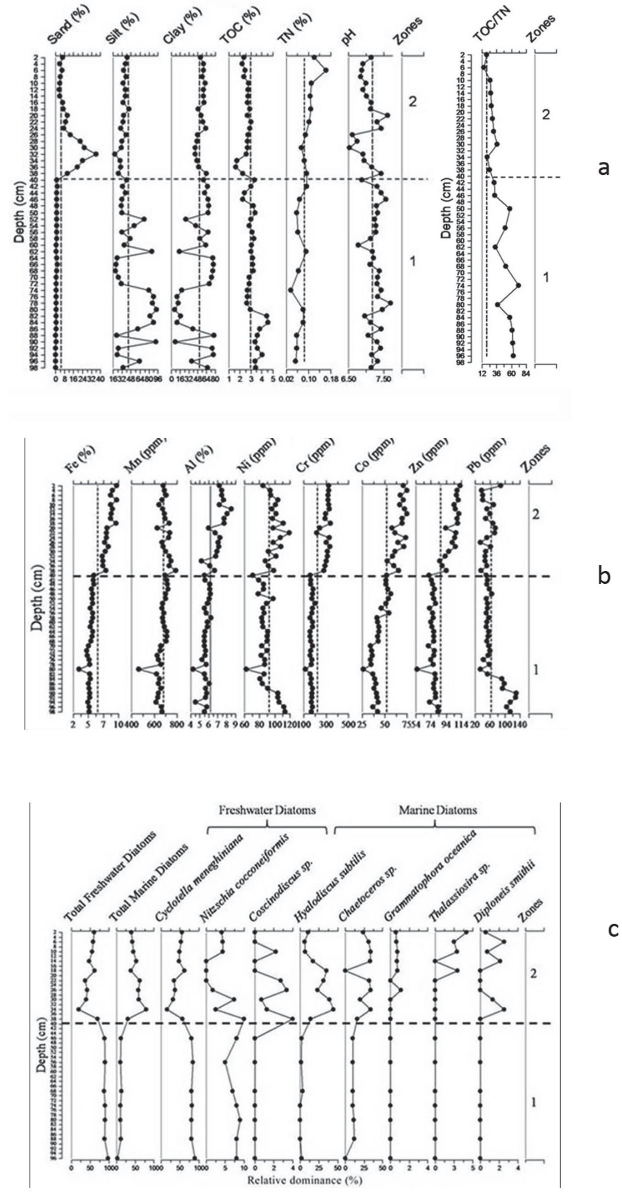

Fig. 7. a. Distribution of sediment components, OC, TOC/TN b. metals c. diatoms in core collected from Rajapuri creek (Pande et al. 2014a).

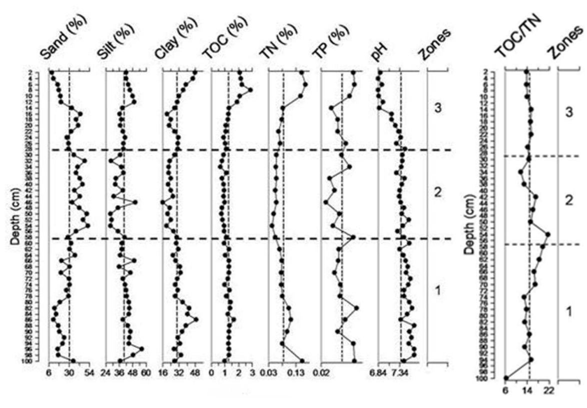

Fig. 8. a. Distribution of sediment components, OC, TOC/TN in core collected from Savitri estuary (Pande 2014).

Rajapuri creek (Fig. 7) (Pande et al 2014) and Savitri estuary (Fig. 8) (Pande 2014) present along the central west coast of India. Relatively higher deposition of fine sediments towards the bottom of the cores collected from Dudh creek (Volvoikar and Nayak 2013), Rajapuri creek (Pande et al 2014) and Savitri estuary (Pande 2014) pointed towards deposition under calm conditions in the past. Further, increased sand percentage noted in the middle section of the cores collected from Dudh creek (Volvoikar and Nayak 2013), Rajapuri creek (Pande et al 2014), Savitri estuary (Pande 2014) and Kundalika estuary (Pande and Nayak 2013b) suggested a change from calm to higher hydrodynamic conditions. In the top section of the cores higher percentage of fine sediment has been reported from Dudh creek (Volvoikar and Nayak 2013), Rajapuri creek (Pande et al 2014), Savitri estuary (Pande 2014), Vaitarna estuary (Volvoikar et al 2014) and Amba estuary (Pande and Nayak 2013a) suggesting a further change to calmer conditions in recent years. The type of organic matter deposited in estuaries along central west coast of India also showed a corresponding change. Wherein, the relatively higher TOC/TN ratio in the bottom sections of the cores collected from Rajapuri creek (Pande et al 2014), Savitri estuary (Pande 2014) and Vaitarna estuary (Volvoikar et al. 2014) indicated periods when sediment received relatively higher proportion of terrestrial organic matter in the past. Whereas, overall decrease in TOC/TN ratio in the top sections, suggested decrease in terrestrial input in the recent years. These results were also supported by diatom records in Amba estuary (Pande 2014), Rajapuri creek (Pande et al 2014) and Savitri estuary (Pande 2014) and stable carbon isotopic composition in Vaitarna estuary (Volvoikar et al 2014). Thus indicating a transition from river dominated to marine dominated depositional environment over the years within these estuaries. Metal concentration also showed increase towards surface of most of the cores, further providing supporting evidence for increased marine inundation in recent years (Volvoikar and Nayak 2014) all along the Maharashtra coast.

Since, all the estuaries transport a portion of the material derived from its catchment to the adjacent near shore region, such changes in sediment particles, organic matter, nutrients and metal input in almost all the studied estuaries and creeks of Maharashtra state should significantly affect the depositional environments of the near shore and offshore regions as well. It can therefore be strongly suggested that the biogeochemical processes in near shore and offshore regions of Maharashtra coast i.e. eastern Arabian Sea will also be widely affected.

FUTURE SCOPE

These studies were based on undated cores and age-dates needs to be investigated further for better understanding of time dependent changes in processes along the coast. In addition, earlier studies on terrestrial-marine influence in Rajapuri, Savitri and Amba estuaries were based on results of diatom studies, while that of Vaitarna estuary were based on stable carbon isotopic studies in addition to that of TOC/TN ratio. Similar studies should also be carried out on other estuaries and creeks present along west coast of India. The use of proxies should also be made uniform to get a precise knowledge and clear idea of recent changes in depositional environment along west coast of India. Such studies carried out all along the coast may help to establish whether the change as observed is controlled by global/eustatic sea level rise or is controlled by local/regional factors resulting from reduction in precipitation, construction of dams, and diversion of fresh water.

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