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Source and processes from core sediment samples off Mahanadi and Krishna rivers, western Bay of Bengal

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Abstract: A total of sixteen samples representing surface,10 cm and 20 cm of sediment core depth between water depth of 25 m and 2600 m from the continental shelf region off Mahanadi and off Krishna were analyzed for grain size, clay minerals, total organic carbon and selected elements to understand the source and processes. The study revealed an overall decrease in sediment size from shallow to deeper water depth as well as from Mahanadi (north) to Krishna (south), indicating transportation direction. Total organic carbon content is low (<1%) and higher content was associated with finer sediment fraction. High sand content in shallow water stations off Mahanadi indicates high hydrodynamic conditions as compared to that off Krishna. High smectite content off Krishna suggests Deccan Basalt and their associated black cotton soil as their source whereas high illite content off Mahanadi suggests source belongs to Archean Proterozic Gneissic complex (APGC) along with its major supply from the Himalayan region through Ganges and Brahmaputra. Ba values obtained off Mahanadi indicate the source of felsic rocks. High concentration of Fe, Mn and Ti off Krishna supports the source of basic igneous rocks. Relatively high coarse sediment (sand) as well as high illite content off Mahanadi river mouth, suggests a change in land use pattern and climate in the catchment area of rivers.

Key words: Mahanadi, Krishna, Clay Minerals, Metals, TOC

Introduction

Rivers are the major linkage between terrestrial and ocean environment. They are one of the important pathways by which products of weathering on the continents are carried to the adjacent continental shelf. Sediment accumulation and distribution on the continental shelf reflect the influence of the processes that operated in the area. Thus, understanding the characteristics of the sediment in the regions of the continental shelf off different river mouths is essential for understanding source along with the processes involved during and after sediment deposition. Bay of Bengal like the Arabian Sea is landlocked in the north and are influenced by a seasonal reversal of the monsoon winds. Despite, all these similarities, both are largely distinct in their geochemical processes.

The sediment characteristics namely grain size, organic carbon, metal concentrations have been used earlier as proxies to understand nutrient cycling and productivity changes in the Bay of Bengal. Shelf sediments of the Ganges delta with emphasis on the western part of Bengal was studied by Mallik (1976), and reported that the sediments at the Hooghly River mouth, part of the great Ganges-Brahmaputra delta sediment, consist of sands, silts, clays and their various admixtures and there has been addition of coarser sediments from the rivers like Hooghly and Dhamra. Rao (1960) investigated organic matter content in the continental shelf sediments off the east coast and reported low organic carbon due to low plankton production and intense oxidation conditions. Krishna et al. (2013) stated that the strong influence of river discharge on the relative composition of sediment organic matter (OM) through transportation of terrestrial OM from the peninsular India. Rao et al. (1988) studied the clay mineral suites in the Bengal shelf and explained that the clay minerals in sediments closely reflect their sources but their relative abundance depends largely on the energy conditions of the shelf environment and the properties of the individual clay minerals. According to Pragatheeswaran et al. (1986), the sediments off Chennai are more contaminated in heavy metals and organic carbon than Visakhapatnam shelf sediments. Muthuraj and Jayaprakash (2008) studied the distribution of trace metals in the sediments of the Bay of Bengal and revealed higher concentration of trace metals owing to finer grain size and higher organic carbon. Tripathy et al. (2014) and Mazumdar et al. (2015) studied major and trace elements in the Bay of Bengal slope and plain region and inferred the factors controlling the distribution and preservation of the elements as well as changes in provenances. Mazumdar et al. (2015) further, stated that the sediment geochemistry enables distinction of specific contributing sources, which could potentially be related to modern climatic and geomorphological conditions. Das and Krishnaswami (2007) mentioned that significant association of Fe and Ti from Krishna Basin sediments indicates their source as Deccan Basalt. However, from the point of view of geochemical aspects, studies on provenance and sedimentary processes are few in the Bay of Bengal. Therefore, the objective of the present study is to understand the source and depositional processes occurring in the continental shelf region off Mahanadi and Krishna river mouth. In this study, an attempt is made to fill the gap of knowledge on sedimentary processes and identification of provenance through geochemical proxies.

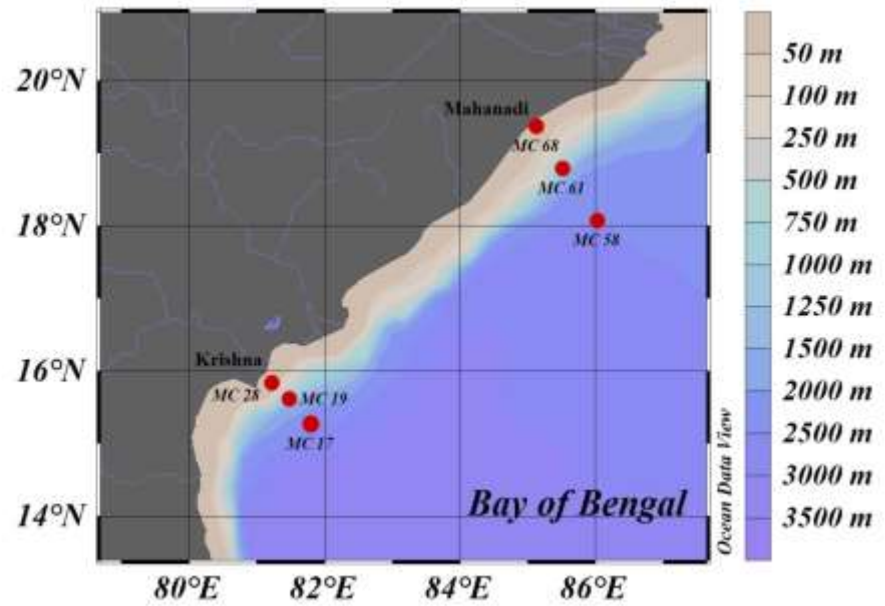

Fig1. Location of the sediment core sample

Study area

The study area lies off Mahanadi and Krishna river mouth regions (Fig.1). The Krishna and Mahanadi rivers drain the Indian subcontinent and deposit the sediment load into the Krishna and Mahanadi offshore basins along the western margin of the Bay of Bengal. The Krishna River originates in the Western Ghats at an elevation of 1337 m above mean sea level and estimated sediment flux of the river is 67.72 $*10^6$ ton yr^{-1} (Ramesh and Subramanian, 1988). While Mahanadi River originated in the Eastern Ghats at an elevation of 80 m above mean sea level. The geology of Mahanadi river catchment area is characterised by the Precambrians of Eastern Ghats. The rock types include khondalites, charnockites, leptynites, granites, gneisses, along with limestones, sandstones and shales of the Gondwanas. The coastal tracts constituted by the recent deltaic alluvium of the river with littoral deposits (Chakrapani and Subramanian, 1990; Meert et al., 2010; Mazumdar et al., 2015). While the Krishna river catchment area consisting of late Archaean and early Proterozoic crystalline rocks, Tertiary Deccan traps (basalt) and recent sediments outcrop locally (Ramesh and Subramanian, 1988). The coastal region of Mahanadi experiences subtropical climate with a temperature of about 21°C and 29º C in winter and summer respectively (Hart, 1999), whereas in the coastal Krishna the climate is humid with the highest temperature of around 35°C (Das and Panchal, 2018). The area receives bulk precipitation from south-west monsoon during June to September while northeast monsoon provides precipitation from October to January. In the northern Bay of Bengal, the fresh-water discharge stratifies and changes the surface water circulation and salinity (Levitus and Boyer, 1994; Benshila et al., 2014; Saalim et al., 2018). Because of its narrow shelf, nutrient concentrations are almost negligible in deeper regions, despite the huge amount of nutrients brought by river system (Qasim, 1977; Sen Gupta et al., 1977; Sarma, 2002). As compared to the Arabian Sea productivity in Bay of Bengal is very low due to strong stratification, cloud cover and turbidity (Madhupratap et al., 1996, 2003).

Materials and Methods

Sampling and Collection

A total of six sediment cores, three each from transect off Mahanadi and off Krishna collected from water depth, ranging from 29 to 2500 m are used in the present study. The samples were collected using multi-corer onboard RV Sagar Kanya (Cruise no. 308) in the month of January 2014 (Table 1) and investigated to understand the source and processes in the recent past of Western Bay of Bengal. The samples were subsampled at 1 cm interval, labeled and brought back to the laboratory in a frozen condition for analysis. In the laboratory, samples were dried at 60° C in the oven and used for further analysis. For the present study, samples from 0-1, 10-11 and 20-21 cm core depth were analyzed.

Transect	Core no.	Water depth (m)	Latitude (˚N)	Longitude (˚S)
Off Mahanadi	MC 68	29.2	19˚36.48	85˚13.09
	MC 61	1537.9	18˚78.29	85˚52.30
	MC 58	2386.4	18˚06.61	86˚03.25
Off Krishna	MC 28	31.6	15˚82.96	81˚22.37
	MC 19	1463	15˚61.18	81˚48.39
	MC 17	2574	15˚26.69	81˚79.88

Table 1: Location and water depth (m) of sediment cores

Laboratory analysis

The samples for grain size analysis were washed with distilled water to remove salinity and then treated with 10 % sodium hexametaphosphate to dissociate clay particles and hydrogen peroxide was added to oxidize the organic matter. Grain size was then determined using pipette method (Folk, 1968) which is based on Stoke's settling velocity principle. A portion of each subsample was powdered and homogenized in an agate pestle and mortar, and used for the determination of TOC using the Walkley (1947) Black method, modified by Jackson (1958). The glycolated clay slides were scanned from 3º to 30º 2Ɵ at 1.2º 2Ɵ/min on Rigaku Altima IV using nickel-filtered CuKα radiation. Clay minerals were identified and quantified following the procedure given by Biscaye (1965).

Smectite crystallinity was measured from the ratio of the height of the smectite peak above the background (p) and the depth of valley (V) on the low angle side of the peak. Illite crystallinity was calculated measuring the width (Δ2θ) from the peak height of diffraction peak of illite (Biscaye, 1965). Illite chemistry was calculated from the ratio of 5 and 10 Aº peak areas of illite. Further, sediment samples were digested using HF, HNO_3 and $HClO_4$ acid mixture with a ratio of 7:3:1 for total metal analyses. The concentration of Fe and Mn were determined using Atomic Absorption Spectrometer (Thermo Scientific-SOLAAR M6 AAS model) and Ti and Ba using Induced coupled plasma–mass spectrometry (ICP-MS). Together with the samples, certified reference standards from the National Institute of Standards and Technology, USA were digested and run, to test the analytical accuracy of the method. The average recoveries were 90–97%. Internal chemical standards obtained from Merck were used to calibrate the instrument and recalibration checks were performed at regular intervals.

Results and Discussion

Distribution of sediment components off Mahanadi and Krishna River

In transect M1 (0-1 cm) off Mahanadi river mouth sand (34.9%) and silt (26.09%) was found to be high at MC 68 and low at MC-61 with values of 0.75% and 24.04% respectively. Clay concentration was highest at MC 61 (75.2%) and lowest at MC 68 (39%). TOC increased with water depth and found to be high at MC 58 (0.75%) and lowest at MC 68 (0.42 %). Along the transect K1 (0-1 cm) off Krishna river mouth sand (8.19%) and silt (57.97%) was found to be high at MC 28 and low at MC 17 with values of 0.22% and 30.34% respectively. Clay was found to be high at MC 17 (69.44%) and low at MC 28 (33.84%) while TOC was found to be higher at MC 19 (0.97%) and lowest at MC 28 (0.48%).

In transect M2 (10-11 cm), sand was found to be high (79.98%) at MC 68 and low (0.24%) at MC 61 while, silt was found to be high at MC 58 (30.44%) and low at MC 68 (1.61%). Clay concentration was highest at MC 61 (72.88 %) and lowest at MC 68 (18.4%). TOC exhibited an increasing trend from MC 68 (0.09%) to MC 58 (0.93%). Along the transect K2 (10-11 cm) off Krishna river mouth sand (7.68%) and silt (50.63%) was found to be high at MC 28 whereas lower concentration of sand (0.25%) was found at MC 17 and silt at MC 19 (26.42%). Further, clay concentration was found to be high (73.28%) at MC 19 and low (41.68%) concentration at MC 28. TOC in this transect was found to be high at MC 19 (0.94%) and lowest at MC 28 (0.68%).

Along the transect M3, (20-21 cm) relatively high concentration of sand (4.85%), silt (53.44%) and TOC (0.96%) was found at MC 58 and low at MC 61 while high (74.88%) content of clay was found at MC 61 and low (41.71%) at MC 58. In the transect K3 (20-21 cm) sand (0.38%) and silt (21.45%) was found to be high at MC 19 and low at MC 17 while clay concentration was found to be high (79.44%) at MC 17 and low (78.16%) at MC 19. TOC was found to be high (0.97%) at MC 19 and low (0.82%) at MC 17.

Further, the data on sediment components of all the studied cores are presented in figure 2 for easy understanding the variations.

Source and transport mechanism of sediment components

Among the sediment components in transects off Mahanadi and Krishna river mouth sand and silt, concentration decreased with increasing water depth away from the coast. Clay concentration was predominant along all transects and found to be higher at a depth of 1537 m along the Mahanadi river transect. When the concentration of sediment components was compared from Mahanadi (north) to the Krishna (south) river mouth regions, the grain size decreased indicating a direction of transport from north to south. The topography, lithology and catchment area of Mahanadi facilitates the erosion processes due to the change in land use pattern and climate (Beura, 2015). The increased process of erosion supplied a huge amount of sediment load to the Mahanadi River resulting in the decreased carrying capacity of the river and deposition of coarser sediments off Mahanadi river mouth. The occurrence of coarser grain size sediments off river mouth due to tidal effect and accumulation of sediments from terrestrial input was reported by Raj and Jayaprakash (2008). The distribution of sediment components along transects indicated the possible direction of transportation from shore to offshore and material supply from rivers to the bay. Further, decrease in grain size from off Mahanadi to Krishna river mouth regions indicated relatively higher energy environment prevailing off Mahanadi facilitating deposition of coarse grain sediment and preventing accumulation of finer sediments. TOC showed an increasing trend on moving away from the coast in transect of Mahanadi while along transect off Krishna TOC was found to be higher at 1463 m depth. Overall, TOC concentration was found to be low (<1%) in the study area despite relatively high sediment influx draining through the rivers. Organic matter must have been transported through suspended mode along with finer sediments and carried away from the coast.

Distribution of clay minerals off Mahanadi and Krishna River

Along the transect M1 (Table 2), illite showed high (65.57%) concentration at MC 68 and low (57.73%) concentration at MC 61. Kaolinite showed high (26.18) concentration at MC 61 and lowest (14.67%) concentration at MC 58. Smectite (21.11%) and chlorite (2.63 %) showed high concentration at MC 58 while lowest concentration of chlorite (1.3%) and smectite (14.75%) was found at MC 61 and MC 68 respectively. In the transect K1 (Table 3), a higher concentration of illite (34.78%) was found at MC 28 and lower concentration (7.37%) at MC 17. Kaolinite showed high concentration (15.09%) at MC 19 and lowest concentration (11.52%) at MC 17. Smectite was found to be high (78.8%) at MC17 and low (50.72%) at MC 28 while, chlorite was found to be high (2.51%) at MC19 and low at MC 28 (1.31%).

Along the transect M2 (Table 2), illite was found to be highest (75.36%) at MC 68 and lowest (57.14%) at MC 58. Kaolinite (19.04%) and chlorite (3.17%) were found to be higher at MC 61 and lower at MC 68 with values of 11.41% and 1.63% respectively. Smectite was found to be higher at MC 58 (25.92%) and lower at (11.59%) MC 68. In the transect K2 (Table 3), illite was found to be high (26%) at MC 19 and low (15.38%) at MC 28. Kaolinite (18.53%) and chlorite (3.08%) were found to be higher at MC 17 and showed lower values at MC 19 (8.55%) and MC 28 (1.92%). Smectite showed highest concentration (69.23%) at MC 28 and low value at MC 17 (61.08%).

Along the transect M3 (Table 2), illite (69.23%) and chlorite (2.79%) showed higher concentration at MC 58 and lower concentration with values of 60.46% and 1.32% respectively at MC 61 while kaolinite (22.51%) and smectite (15.69%) showed higher concentration at MC 61 and lower concentration at MC 58. In the transect K3 (Table 3), illite was found to be high (34.78%) at MC19 and low (17.88%) at MC 17 while kaolinite, chlorite and smectite were found to be higher at MC17 and lower at MC 19.

Further, the data on clay minerals of all the studied cores are presented in figure 2 for easy understanding the variations.

Provenance and environmental significance indicated by clay minerals

Illite is the dominant clay mineral followed by kaolinite, smectite and chlorite in all the samples studied off Mahanadi river mouth (Table 2) while off Krishna river mouth (Table 3) region smectite was the dominant clay mineral followed by illite, kaolinite and chlorite. Illite showed a -decreasing trend on moving away from the coast off Mahanadi river mouth similar to that of sand indicating that it has been derived from the weathering of rocks present in the catchment area. Higher abundance of illite in the off Mahanadi sediments compared to Krishna sediments indicated its supply from felsic source rock which belongs to Archean Proterozoic Gneissic Complex (APGC) (Mazumdar et al., 2015). Illites are widely formed due to glacial weathering under arid conditions in cold regions from muscovite (Weaver, 1989). The presence of muscovite mica, associated with metamorphic rocks such as phyllites must be the major source of illite which must have been dispersed by turbidity currents from Ganges and Brahmaputra (Kolla and Biscaye, 1973; Rao and Rao, 1977; Kolla and Rao, 1990). The decrease in illite concentration from Mahanadi (north) to Krishna (south) is possibly due to loss of energy towards Krishna which prohibits illite-rich sediment to reach southwards. Smectite forms due to chemical weathering in the low latitude region (Biscaye, 1965). High concentration of smectite off Krishna river mouth indicated that it has been derived from the Deccan trap basalts (Raman et al., 1995; Kulkarni et al., 2015; Mazumdar et al., 2015) and from late Archaean and early Proterozoic crystalline rocks drained through peninsular rivers. Higher values of smectite off Krishna river mouth suggested that low energy conditions prevailed in the region as under low energy conditions smectite gets deposited with finer grain size while a high concentration of illite off Mahanadi River indicated high energy condition which is also evident by grain size distribution. Kaolinite is also present which must have formed from rocks such as

Archean granites, gneisses, charnockites and khondalites by alteration of minerals like K-feldspar and other typical aluminosilicate like sillimanite. Sillimanite alters into gibbsite during chemical weathering which in turn changes into kaolinite (Nakagawa et al., 2006; Rao and Raman, 1979; Soman and Machado, 1986). Chauhan and Vogelsang (2006) suggested a low concentration of kaolinite in this region possibly due to its equatorward dispersal. Chlorite is available in lower concentration as compared to other clay minerals may be due to the unstable nature of chlorite under humid conditions (Diju and Thamban, 2006). The results obtained are in good agreement with those obtained earlier by Raman et al. (1995) and Phillips et al. (2014). Smectite and illite crystallinity and illite chemistry were calculated for identification of degree of weathering and confirmation of the source of clay minerals. Smectite crystallinity in most of the samples varied from 1.5 to 2.0 Δ°2θ suggesting the occurrence of moderately crystalline smectite in the study area. Illite crystallinity was 0.2 Δ°2θ indicating the dominance of very well crystalline illite derived from the physical weathering which is also supported by illite chemistry. It was found below 0.5 in samples off Mahanadi River indicating the presence of Fe-Mg rich illite derived from physical weathering of rocks from the Himalayan region while the samples off Krishna River suggested Al-rich illite formed through hydrolysis (Bejugam and Nayak, 2017) probably from leaching of felsic rocks of Eastern Ghats.

Distribution of metals off Mahanadi and Krishna River

In the transect M1(Table 2), metals like Fe, Mn and Ba (8.66%, 2.7% and 777 ppm respectively) were found to be higher at MC 58 and lower (3.59%, 0.16% and 314 ppm respectively) at MC 68 while Ti was found to be higher (2.26%) at MC 68 and lower (0.49%) at MC 61. Along the transect K1(Table 3), all the metals like Fe, Mn, Ti and Ba (8.37%. 0.14%, 2.27% and 224 ppm respectively) showed higher concentration at MC 28 while Fe (5.93%) and Ti (0.71%) showed lower concentration at MC 19 and Mn (0.07%) and Ba (200 ppm) at MC17.

Along the transect M2 (Table 2), Fe was found to be higher (5.03%) at MC 61 and lower (1.33%) at MC 68. Mn (0.11%) and Ti (0.83%) was found to be higher at MC 68 and lower at MC 58 with values of 0.04% and 0.4% respectively while Ba was found to be higher (401 ppm) at MC 58 and lower (351 ppm) at MC 68. In transect K2 (Table 3), metals like Fe, Mn and Ti (6.66%, 0.09% and 1.62% respectively) were found to be higher at MC 28 while Fe (5.96%) and Mn (0.02%) were found lower at MC 19 and Ti showed lower values at MC 17. Ba was found to be higher (272 ppm) at MC17 and lower (144 ppm) at MC 28.

Along transect M3 (Table 2), Fe (4.4%) and Mn (0.1%) showed high concentration at MC 61 and low concentration at MC 58 while Ti and Ba were found high (0.47% and 497 ppm respectively) at MC 58 and low (0.4% and 361 ppm respectively) at MC 61. In transect K3 (Table 3), Fe, Mn and Ti were found high at MC 19 and low at MC 17 while Ba showed almost similar concentration at MC 17 (219 ppm) and at MC 19 (217 ppm).

Further, the data on metals of all the studied cores are presented in figure 2 for easy understanding the variations.

Source and processes governing the distribution of metals

Metals in the study area are present in the order of Fe>Ti>Mn> Ba (Table 3). Fe content was lower in transects off Mahanadi river mouth region as compared to transect off Krishna River and its concentration in the study area was higher than Post Archean Australian Shale (PAAS) values of 5%. The average Fe concentration in continental crust is 5.63 % (Taylor, 1964) and Fe content in Deccan basalts varies from ~9-11 % (Pattanayak and Shrivastava, 1999). These iron-rich source rocks upon weathering produce iron-rich clay minerals, Fe-rich oxyhydroxides and unaltered ferromagnesium minerals (Das and Krishnaswami, 2007). Ti concentration in the samples was higher than PAAS value of 0.6 %. High Ti values off Krishna indicate mafic source rocks while along transect off Mahanadi Ti was slightly lower indicating a dominance of felsic source rocks. High Ti concentration off Krishna River may be derived from Deccan Trap basalts which are rich in titanium (Das and Krishnaswami, 2007; Bejugam and Nayak, 2017). Mazumdar et al. (2015) stated that the Mahanadi River basin comprises Late Archaean and early Proterozoic granite batholiths, tonalite-trondjhemite gneisses (TTGs), and chanockites and khondalites of the Eastern Ghats constitute 56% of the catchment area. Further, they mentioned that relatively higher illite contents in the Mahanadi basin sediments compared to the K-G basin samples suggest the dominance of felsic source rocks, which characterize the Archaean-Proterozoic Gneissic Complex. This supports the results of the present study of higher illite in the northern transects off Mahanadi River mouths and higher smectite in samples off Krishna river mouths. Along the Mahanadi river transects Mn concentration was slightly higher as compared to transect off Krishna. Mn concentrations were higher than crustal PAAS values of 0.09% (Taylor and McLennan, 1985) in majority of the samples indicating the presence of structurally unsupported hydroxides. Along Mahanadi river transect Ba showed an increasing trend on moving away from the coast similar to that of organic carbon indicating its biogenic origin from marine productivity. While along the Krishna River Ba is found enriched in the surface samples suggesting that it has been derived from the terrigenous influx. Deccan basalts show restricted mobility of Ba after weathering (Das and Krishnaswami, 2007) which is attributed to the low Ba concentration off Krishna river mouth. Further, Ba is noted to be higher at deeper water depths in most of the transects as the formation of barytes in the water column takes place well below the photic zone (Babu et al., 2002) as it requires sufficient water depth for their preservation. The increase of Ba with water depth was reported earlier by Von Breymann et al. (1990) and Calvert and Price (1983) in the surface sediments off NW Arabian Sea and Namibian continental slope respectively.

It is noted that relatively the concentration of Fe and Ti was found to be higher in the off Krishna sediments whereas Mn and Ba were higher off Mahanadi indicating Ba may also be supplied from weathering of acid igneous rocks from the catchment of Mahanadi in addition to its biogenic nature.

Conclusion

The investigation of sediment samples representing the surface, 10 cm and 20 cm of sediment core from off Mahanadi and off Krishna, western Bay of Bengal indicated sediment transportation from near shore to offshore and from Mahanadi (north) to Krishna (south). Higher hydrodynamic conditions off Mahanadi river mouth was responsible for retaining coarser sediments comparative to off Krishna river mouth regions. Clay mineral study and metal analysis revealed that mafic igneous rocks present in the catchment area of Krishna River and felsic igneous rocks present in the catchment of the Mahanadi River are the major source for smectite and illite abundance in the study area respectively. Variation in sediment size, abundance and distribution of clay minerals and metals in the study area indicated change in provenance, land use - land cover pattern and climate in the catchment area of rivers, and also depositional processes~~.~~

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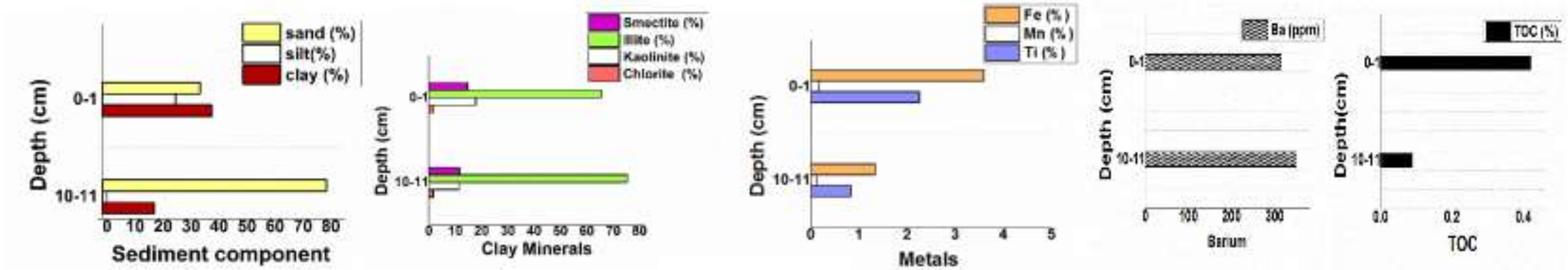
Mahanadi	Water depth (m)	Sub sample	Sand (%)	Silt (%)	Clay (%)	TOC (%)	Illite (%)	Kaolinite (%)	Chlorite (%)	Smectite (%)	Fe (%)	Mn (%)	Ti (%)	Ba (ppm)
Transect M1 (0-1cm; n=3)														
MC 68	29.2	0-1 cm	**34.9**	**26.09**	39	0.42	**65.57**	17.88	1.78	14.75	3.59	0.16	**2.26**	314
MC 61	1537.9	0-1cm	0.75	24.04	**75.2**	0.6	57.73	**26.18**	1.3	14.77	5.25	0.24	0.49	369
MC 58	2386.4	0-1 cm	11.9	24.58	63.52	**0.75**	57.77	14.67	**2.63**	**21.11**	**8.66**	**2.7**	0.82	**777**
Transect M2(10-11cm; n=3)														
MC 68	29.2	10-11 cm	**79.98**	1.61	18.4	0.09	**75.36**	11.41	1.63	11.59	1.33	**0.11**	**0.83**	351
MC 61	1537.9	10 -11cm	0.24	26.87	**72.88**	0.48	63.88	**19.04**	**3.17**	13.88	**5.03**	0.08	0.47	397
MC 58	2386.4	10 -11 cm	0.52	**30.44**	69.04	**0.93**	57.14	14.67	2.25	**25.92**	4.52	0.04	0.4	**401**
Transect M3(20-21cm; n=2)														
MC 61	1537.9	20-21 cm	0.23	24.88	**74.88**	0.57	60.46	**22.51**	1.32	**15.69**	**4.4**	**0.1**	0.4	361
MC 58	2386.4	20- 21cm	**4.85**	**53.44**	41.71	**0.96**	**69.23**	12.58	**2.79**	15.38	4.27	0.06	**0.47**	**497**

Table 2: Sediment component, TOC, clay minerals and metals off Mahanadi

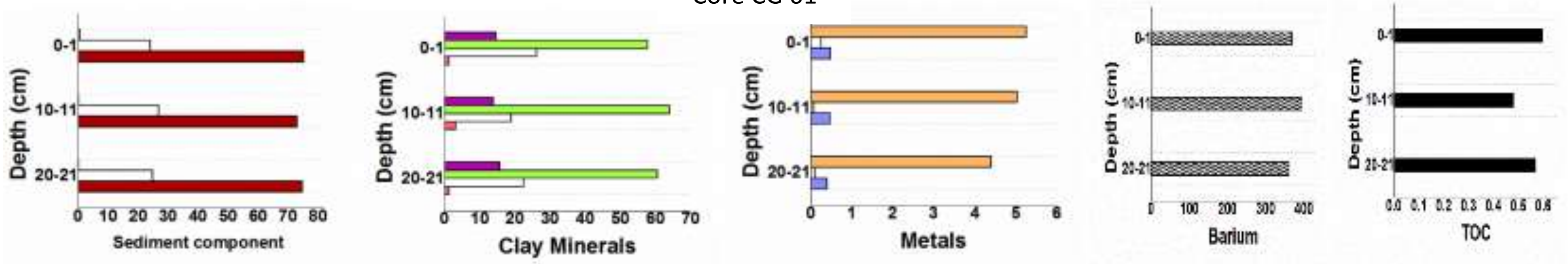
Krishna	Water depth (m)	Sub Sample	Sand (%)	Silt (%)	Clay (%)	TOC (%)	Illite (%)	Kaolinite (%)	Chlorite (%)	Smectite (%)	Fe (%)	Mn (%)	Ti (%)	Ba (ppm)
	Transect K1(0-1cm; n=3)													
MC 28	31.6	0-1 cm	**8.19**	**57.97**	33.84	0.48	**34.78**	13.17	1.31	50.72	**8.37**	**0.14**	**2.27**	**224**
MC 19	1463	0-1cm	0.35	37.25	62.40	**0.97**	24.87	**15.09**	**2.51**	57.51	5.93	0.08	0.71	218
MC 17	2574	0-1 cm	0.22	30.34	**69.44**	0.88	7.37	11.52	2.30	**78.80**	7.47	0.07	0.92	200
	Transect K2(10-11cm; n=3)													
MC 28	31.6	10-11 cm	**7.68**	**50.63**	41.68	0.68	15.38	18.47	1.92	**69.23**	**6.66**	**0.09**	**1.62**	144
MC 19	1463	10 - 11cm	0.29	26.42	**73.28**	**0.94**	**26.00**	8.55	2.44	63.00	5.96	0.02	0.98	212
MC 17	2574	10 – 11 cm	0.25	27.34	72.20	NA	17.3	**18.53**	**3.08**	61.08	6.58	0.05	0.79	**272**
	Transect K3(20-21cm; n=2)													
MC 19	1463	20-21 cm	**0.38**	**21.45**	78.16	**0.97**	**34.78**	13.17	1.31	50.72	**7.46**	**0.08**	**0.95**	217
MC 17	2574	20 – 21cm	0.22	20.34	**79.44**	0.82	17.88	**14.07**	**1.56**	**66.48**	6.16	0.02	0.73	**219**

Table 3: Sediment component, TOC, clay minerals and metals off Krishna, NA Not Analyzed

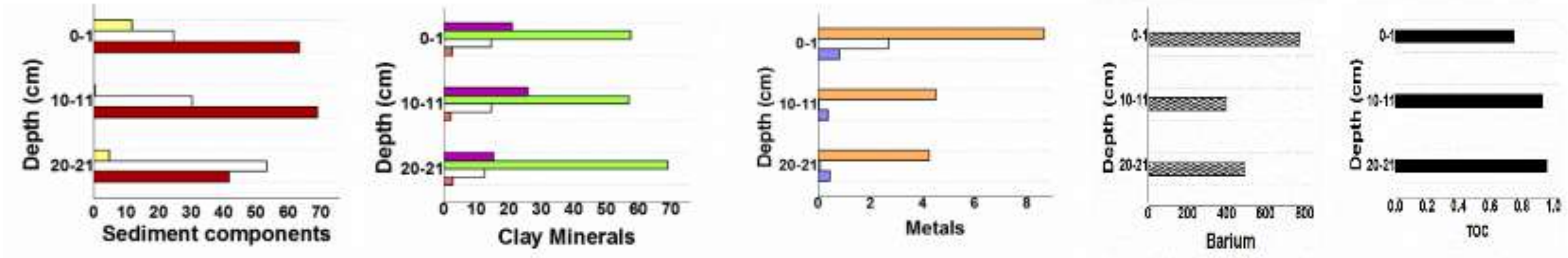
Core MC 68



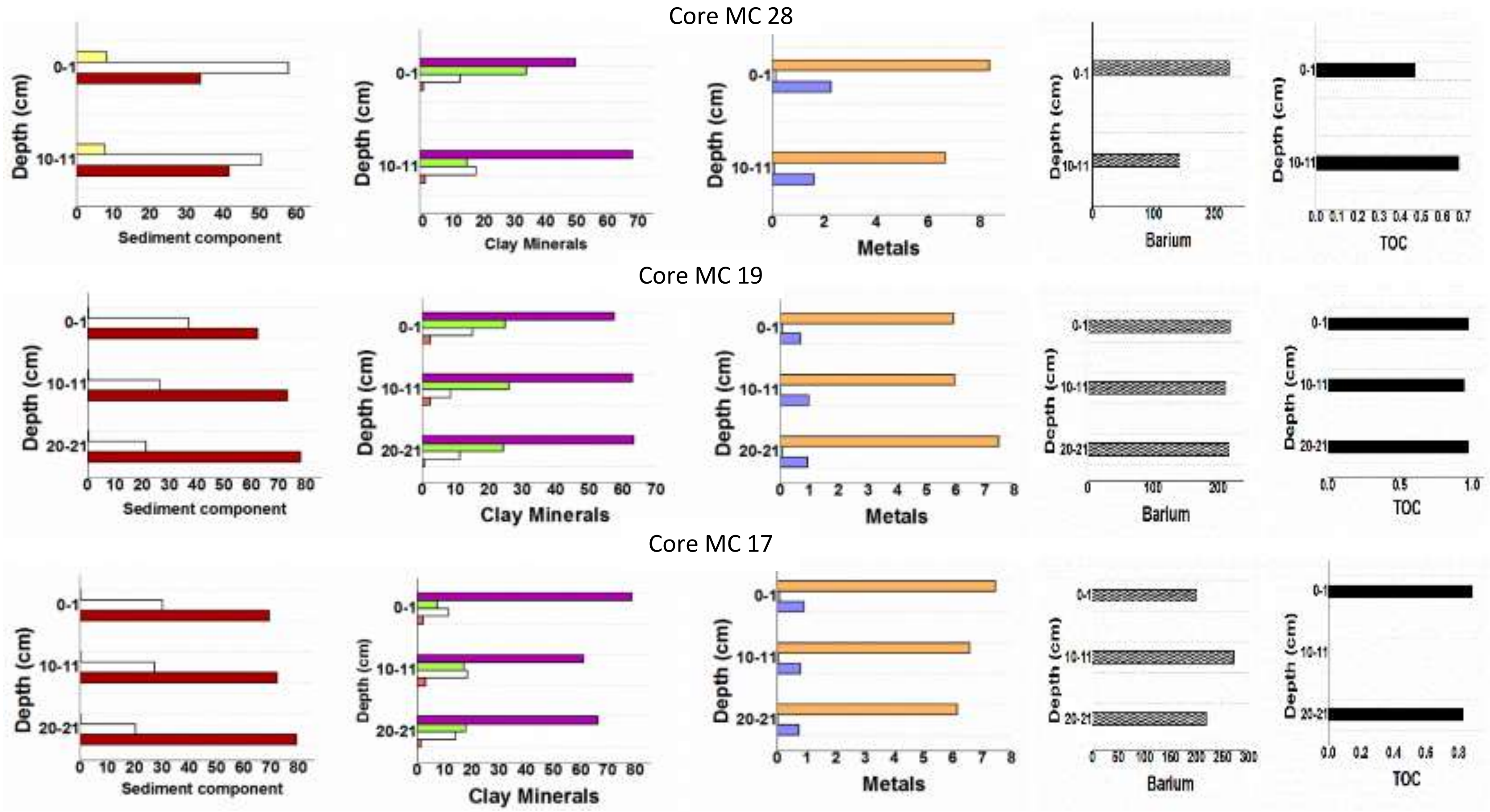
Core CG 61



Core MC 58



A



B

Fig. 2. Down core variation of sediment components, clay minerals and selected metals off Mahanadi (A) and Krishna (B) river mouths.

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