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Geochemistry of Core Sediments from Gulf of Mannar, India

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ABSTRACT: The Gulf of Mannar, located between India and Sri Lanka, is a shallow embayment of the Bay of Bengal. The gulf, which has been declared a bio-reserve is a highly productive area endowed with rich marine fauna including corals. In order to study the origin and nature of the sediments and paleo-environment, 2.6 m length core was collected with 5cm interval at 1320m water depths. Textural studies indicate that the sediments have been poorly sorted and most of the sub samples are silty clay and few top samples are sandy silty clay. The nature of organic matter also indicate high sedimentation rate. Based on the behaviors of $CaCO_3$, Organic matter (OM) and textural parameters the core was studied under the three units. The first unit represents surface to 65cm (unit-1), the second unit (unit-2) represents 65cm to 165cm and third unit represents 165 cm to the bottom of the core. The major oxide geochemistry shows higher concentration of detritus constituents. The trace element studies indicate ferruginous nature for all elements except Cu and Zn. The element/Al ratios also are computed. The geochemical analysis for trace elements like Mn, Cr, Cu, Ni, Co, Pb, and Zn has been carried out for core sediments. Normalization with Al values for all the trace elements have been calculated.

Key words: Sediment texture, Calcium carbonate, organic matter, Major elements, Trace metals

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INTRODUCTION

The Bay of Bengal has attracted a fair share of attention with regard to its sedimentation geology, notably the origin and history of the Bengal sediments (Stewart *et al.,* 1965). Geochemical investigations of this vast expanse are, however, limited, and confined to the deep (Ramesh and Ramasamy 1997). The continental shelf off the east coast (Rao, 1978; Paropkari, 1990) Visakhapatnam (Gogate *et al.,* 1970; Rajamanickam and Setty, 1973), river Godavari (Rao and Rao, 1975) also has been studied. According to Pragatheeswaran *et al.* (1986), the sediments off Chennai are more contaminated in heavy metals and organic carbon than Visakhapatnam shelf sediments. The enhanced levels of Cu, Hg and organic carbon were attributed to input from industrial sources including organo-mercurial paint industry and oil refineries. Ramanathan *et al.* (1988) analyzed major and minor element geochemistry of water and suspended and bed sediments collected from the upper reaches of the Cauvery estuary to understand the geochemical processes in tropical estuarine systems. The investigation of the characteristics of the sediments from a core collected from the Gulf of Mannar revealed high concentration of $CaCO_3$ (61.4%) and low organic carbon values, distinctly different from the anoxic sediments of Bombay (Ray *et al.,* 1990). Palanichamy *et al.* (1995) inferred that industrial effluents pollute the waters of Arumuganeri region, Gulf of Mannar; they also recorded higher suspended solids due to discharge of effluents from the chlor-alkaline industries and land drainage. Vanmathi (1995), in her study of sediments of Tuticorin coast, concluded that heavy metals, especially cadmium, are significantly higher than in other coastal regions, affecting the biota in the region. Selvaraj *et al.* (2004), in his study on the Kalpakkam coastal waters and sediments, recorded high concentrations of Fe, Cu, Hg and Pb; he attributed the enriched levels of Pb, Cu, Cr, Cd and Zn in sediments to mainly anthropogenic input along the coast and the river Palar.

Geochemical studies of surficial sediment as well as sediment cores are helpful in the assessment of pollution (Holm, 1988; Ahmad et al., 2010, Al-Juboury, 2009; Chibunda, 2009; Chibunda et al., 2010; Geetha et al., 2008), changes in climatic conditions (Faganelli, *et al*., 1987; Karbassi and Amirnezhad, 2004; Karbassi and Shankar 2005) accumulation or mobilization of trace elements in the sediments of aquatic environment (Al-Masri, 2002).Sediments act as sinks and sources

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*Corresponding author E-mail: rajanmsundar77@yahoo.com of contaminants in aquatic systems because of their variable physical and chemical properties (Rainey, *et al.,* 2003; Marchand, *et al.,* 2006; Pekey, 2006; Prijiu and Narayan, 2007; Praveena, *et al.,* 2008; Sundararajan, *et al.,* 2009; Sundararajan, and Usha Natesan, 2010).During their transport, the trace metals undergo numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena (Akcay *et al.,* 2003; Abdel-Ghani *et al.,* 2007; Abdel- Ghani and Elchaghaby, 2007; Praveena, *et al.,* 2008; Harikumar *et al.,* 2009; Mohiuddin *et al.,* 2010) which affect their behaviour and bioavailability. The review of geochemical research carried out so far on and off the east coast reveals that considerable amount of work still remains to be done with regard to geochemistry and metal pollution in sediments. It is well understood that very few studies have been carried out on these aspects, especially in the Gulf of Mannar.

MATERIALS & METHODS

Sediment core for the present study was collected from Tuticorin offshore, (Lat. 8°19’06" and Long. 78°38’57" at a depth of 1320m Gulf of Mannar (Fig.1). The Gulf of Mannar is a transitional zone between the Arabian Sea and Indian Ocean proper and is connected with the Bay of Bengal through a shallow sill, the Palk Strait. The area under investigation off Tuticorin in the Gulf of Mannar presents great interest because it is an industrial belt consisting of many major industries involved in the production of chemicals, petrochemicals and plastics. In addition, a major harbor, thermal power plant, heavy water plant and human activities from around Tuticorin to Tiruchendur have altered the eco-system prominently. The area investigated forms the southern part of the South Indian Granulite facies terrain, which includes part of Madurai Block (MB) and the Kerala Khondalite Belt (KKB). The southern part of MB is represented by charnockites in the western part and gneisses in the eastern part which are inter-banded with supra-crustal mainly of meta-sedimentary sequences made up of quartzite, carbonate and metapelite with a minor metabolic component. KKB is bounded by the Cardamon Hills in the north and the Nagerkoil Charnockite Massif in the south, which consists of high-grade supra-crustal. The MB and KKB, which are separated by the Achankoil Shear Zone (AKSZ), are mostly similar in geochronology characteristics (Santhosh and others 1992; Harris and others 1994). Core sampling was done at one particular location during December 2000 for the present study. This location was selected as it is very close to the mouth of the river which can decipher the influence of coastal region .Collection of core samples was done under Academik Alenksandr Sidorenko cruise program organized by National Center for Antarctic Ocean Research, Dona Paula, Goa. The sub-samples were sliced at 5 cm depth interval resulting in 52 numbers of samples. The water depth at the coring site were 1320 m and the sub-samples were tightly packed, transported to the laboratory and stored at -4° C until further analysis. The geochemical data in the present study have not been corrected for compaction, as it is likely to be uniform down the length of the core (Clark et al., 1998). During the first stage of work, sand and mud (silt + clay) were estimated following the procedure of Ingram (1970). Carbonate content ($CaCO_3$) was measured following the procedure of Loring and Rantala (1992) and organic carbon (OC) was determined following the procedure of Gaudette et al., (1974). Major elements (Si, Al, Fe, Ca, Mg, Na, K, and P) and trace elements (Mn, Cr, Cu, Ni, Co, Pb, and Zn) were determined after preliminary treatment and total decomposition of sediments following the procedure of Loring and Rantala (1992). The final solution was analyzed using AAS (Varian Spectra AA220) which is equipped with a detritum background corrector. Further standard reference material MESS1 was used to ensure the quality control and accuracy of the analysis (Table 1). The geochemical elements delivered to the creek are not only from anthropogenic sources but also by natural flux of elements from the catchment areas. One of the popular methods to distinguish the fraction of metals or enrichment is by normalization with respect to Al (Kemp et al., 1976; Van Metre and Callender, 1997; Loring, 1991). Moreover, Al is successfully and widely used as a normalizer and it also compensates for variations in the grain size and composition because it represents the quality of alumina silicates which is the most important carrier for adsorbed metals in the aquatic environments. The variability of the normalized concentrations is expressed as enrichment factors (EFs), which is a ratio of the content of the element in the analyzed layer to the content corresponding to the pre-industrial period: EF = (Cx/CAl)s/(Cx/CAl)c where, (Cx/CAl)s ratio of concentration of element x and aluminum in the sample, (Cx/CAl)c ratio of concentration of element x and aluminum in unpolluted sediments Continental crustal values (Taylor and McLennan, 1985). An EF around 1.0 indicates that the sediment originates predominantly from lithogenous material, whereas an EF much greater than 1.0 indicates that the element is of anthropogenic origin (Szefer et al., 1996).

RESULTS & DISCUSSION

The relative abundance in Sand, Silt and clay content with sediment types inferred for the sub samples of core are presented in Fig. 2. The sand percentage ranges from 4.33% to 19.08% except for the

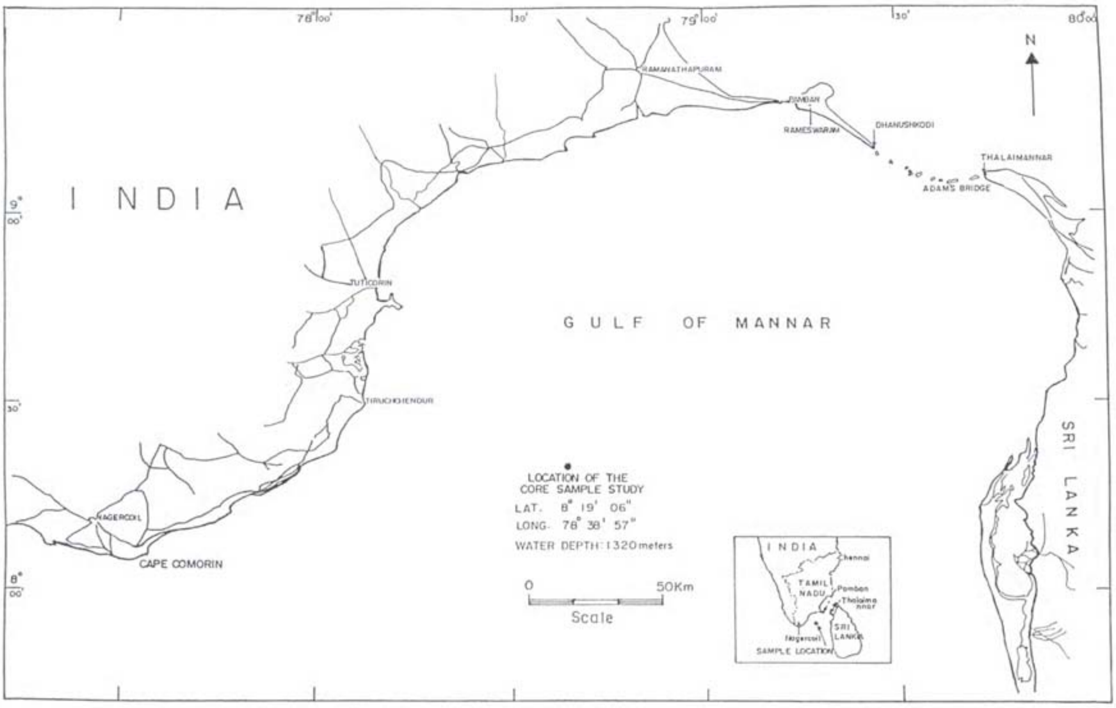

Fig. 1. Study area

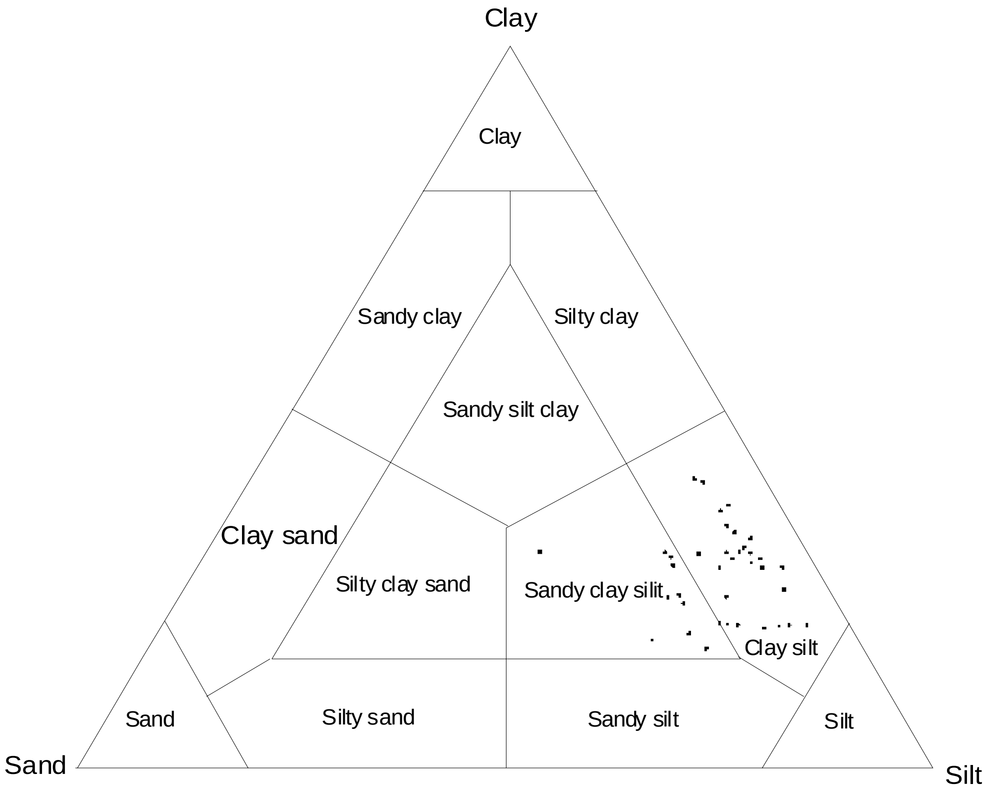

Fig. 2. Trilinear diagram showing the sediment type

Table 1. Comparison of MESS1 values with the present study

Elements	Present results	MESS 1	Recovery (%)
SiO_2 (%)	65.40	67.50	96.89
Al_2O_3 (%)	10.34	11.03	93.74
Na_2O (%)	2.16	2.50	86.40
K_2O (%)	2.15	2.24	95.98
CaO (%)	0.67	0.67	99.26
MgO (%)	1.19	1.44	82.64
Fe_2O_3 (%)	3.72	4.36	85.32
P_2O_5 (%)	0.13	0.15	85.62
Mn ($\mu g\ g^{-1}$)	505.20	513.00	98.48
Cr ($\mu g\ g^{-1}$)	68.20	71.00	96.06
Cu ($\mu g\ g^{-1}$)	24.80	25.10	98.80
Ni ($\mu g\ g^{-1}$)	28.20	29.50	95.59
Co ($\mu g\ g^{-1}$)	10.40	10.80	96.30
Pb ($\mu g\ g^{-1}$)	33.21	34.00	97.68
Zn ($\mu g\ g^{-1}$)	180.37	191.00	94.43

surface samples in which the sand percentage is high (30.60) Apart From the surface samples maximum percentage of Sand is present at 30cm to 40cm depth and low percentage of sand is present at the depth interval 90cm to 100cm. In general all the samples in the core are depleted in sand fraction. The increase in the sand fraction is seen in the top (surface to 50cm depth) and bottom (215cm to 255cm dept) of the core. The silt content ranges from 39.40% to 74.80%. The minimum percentage of silt is recorded in the surface sample (39.40%) and the maximum percentage of (74.80%) is recorded at the depth interval 190 to 195 cm. Next to the surface sample the lowest value is recorded in the bottom most sample, which is having 52% of silt. In general, silt content increases towards depth. The higher value of silt is seen from 185 cm to 215 cm depth. The clay content of the core sample ranges from 17.83% to 40.20% and the lowest value is recorded at a depth of 60cm to 65cm and highest value is recorded at a depth of 70 cm to 75 cm and highest value is recorded at the bottom most sample. Only few samples show higher concentration of clay exceeding 30%.

The analyzed sub-samples data of sand, silt and clay were plotted in a tri-linear diagram for sediment nomenclature (Fig. 2. after Trefethen, 1950). Most of the sub-samples fall in the field of clay silt. Thus entire core is mostly dominated by silt. The top four samples (depth from surface to 20 cm), (depth 30 cm to 35 cm) and, (depth 35 cm to 40 cm) and (depth 60 cm to 65 cm) fall in the field of sandy clay silt.

In general sub-samples of the core are dominated by mud (silt +clay) which shows the fines have been derived from the near by region of southeastern coast of India and northwestern coast of Sri Lanka. Analysis of the data from western Simpson Lagoon (Naidu *et al*. 1982; Sweeney, 1984) revealed that the proportion of silt and clay is the most important factor in the distribution of heavy metal abundances. This is consistent with the many studies of near shore sediments throughout the world (Sweeney and Naidu, 1989) Nickel is found to subsist the best discriminator between different texture classes in Simpson Lagoon (Sweeney, 1984).Sediment accumulation in marine environment is mainly dependent on the rate of input and distribution of sediment types. Grain size parameters have been used commonly to characterize the sediments in the shelf environment (Nittrouer *et al*., 1983). The bottom topography of any modern environment is affected by the distribution and transport processes of the sediments present in the area (Swift, 1970). Jonathan (2004), who studied the surface and core sediments off Tuticorin have reported high content of sand in the continental shelf region. According to him the finer particles brought to the coastal zone are transported to deeper region due to underwater currents. The average mud content of the core samples is around 90% and sand is present only around 10%. With in the mud fraction silt forms 64% of the total sediments. The grain size distribution is very homogenous and it does not show much down core variation. This may be due to the absence of turbulence during the sedimentation in the region. The velocity of the water current is considered too slight to disturb sedimentary strata in the innermost part of Gulf of Manner.

Many natural chemical substances circulate through the environment and are important to the chemistry and biology of the earth .The circulation of these substances is defined by its reservoirs, processes affecting it fluxes, termed "biogeochemical cycle". Results of textural analyses indicate that the sediment core samples of Gulf of Mannar are dominated by fine material. Silt and clay sized material (less than 4f (63mm)) typically comprises >90% of the sediment by weight and the sand fraction represents relatively a minor component within the mud; the silt fraction dominates the clay fraction. Thus, the sand-sized particles are relatively rare in the coarse sediments. The core is characterized by thin sandy silt clay overlying fine clayey silt. The grain size distribution, which does not show much variation, indicates homogenous nature. The muddy nature of the sediments also indicates calm sedimentation without any turbulence. The higher water content of the mud-dominated samples indicates that they were deposited relatively recently. The mud accumulation indicates that these muddy sediments are deposited seasonally. The silt and clay fraction have been flushed out and transported from the Indian coast and continental shelf region especially from Tuticorin to Capecoumerin coast and were deposited in the deep sea of the Gulf of Manner. The North Equatorial Counter Current and Indian Counter Current, which are circulating south of Capecoumerin in clock wise and anticlockwise directions and having their influence in the study area. The North Equatorial Counter Current, which is also passing through the study area has transported the fine sediments from the continental region and deposited in the continental slope region. Out of the 52 samples analyzed, seven samples are sandy clayey silt and all other samples are clayey silt. Even the sandy clayey silt is present between surfaces to 65cm only.

The depth wise concentrations of $CaCO_3$, and organic matter (OM) are given in Table 2. Calcium carbonate is generally known as a dilutor of trace metal concentration and is contributed mainly by terrestrial run off and organisms in water column. The $CaCO_3$ content in this core is generally high and it ranges from 1.60% to 13.01%. The lower concentration of 1.60% was shown by the sample at a depth between 165 cm to170 cm. The higher concentration of 13.01% was noticed at the depth 230 cm to 235 cm. The $CaCO_3$ content shows a lot of variations towards depth. Up to 40 cm depth it does not show any variation. From 45 cm depth it shows gradual depletion up to a depth of 195 cm with some deviations. From 195 cm it increases with depth. Most of the organic matter in the sediments is derived from plant life of the sea or land or both. The amount of sedimentary organic matter depends upon the rate of deposition of organic and inorganic matter and rate of decomposition of organic matter following its deposition. The sedimentation of organic matter through water removes organic pollutants from the water column (Mackereth, 1965). In other words, organic matter plays a major role in concentrating trace metals. The organic matter concentration in the sub-samples of the study area ranges from 0.12% to 2.52%. The higher value of 2.52% is recorded at depths 65 cm to 70 cm and 85 cm to 100 cm and lower value of 0.12% is recorded at a depth interval of 185 cm to 190 cm. A fluctuation in the organic matter through depth is noticed. From the surface OM content gradually decreases down the core. Even though the core is dominated by mud, the concentration of organic matter is generally low. Slightly higher concentrations observed in the surface samples may be due to the adsorption and incorporation of organic materials from overlying water column. Based on the behaviors of calcium carbonate, organic matter and textural parameters, the core was analyzed under three units. The first unit represents surface to 65 cm (unit 1), the second unit represents 65 to 165 cm (unit 2) and the third unit represents 165 cm to bottom of the core.

Calcium carbonate gradually decreases towards depth and in bottom segment it shows slight increase. The high value of calcium carbonate in the bottom segment is mainly due to high sedimentation. The lower concentration in the middle part suggests that the active detritus dilution has reduced the concentration of calcium carbonate. Three sedimentary units distinguished by the carbonate profile have been demarcated in the present study. It holds good even for the other parameters. Unit one represents the modern sedimentary facies, which represents the depth from surface to 65cm. Unit two represents the sediments from 65 to 165cm and the third unit comprises of sediments from 160 to 255cm. In the present study, the average concentration of organic matter is 1.55%, which is similar to the concentration recorded by Paropkari (1979). In the sediments of northwestern continental shelf of India (Ramesh and Ramasamy, 1997) who has reported average values of 1.54, 1.14, 1.04 and 1.7% of organic carbon from four sediment core studies of lower Bengal Fan and Jonathan (2004) who

Table 2. Calcium carbonate and organic matter of sediments in the core(%)

Samp.No	Depth(m)	$CaCO_3$	Organic Matter
1	0 - 5	8.01	2.28
2	5 -10	8.01	2.40
3	10 - 15	7.61	2.34
4	15 - 20	7.61	2.22
5	20 - 25	8.01	2.16
6	25 - 30	8.01	2.22
7	30 - 35	7.81	2.04
8	35 - 40	8.01	2.28
9	40 - 45	8.01	2.41
10	45 - 50	6.00	2.34
11	50 - 55	7.01	2.10
12	55 - 60	7.01	1.80
13	60 - 65	6.00	2.04
14	65 - 70	6.00	2.52
15	70 - 75	6.00	2.22
16	75 - 80	6.00	1.92
17	80 - 85	6.00	2.22
18	85 - 90	6.00	2.52
19	90 - 95	6.00	2.52
20	95 - 100	6.00	2.22
21	100 - 105	5.00	1.92
22	105 - 110	6.00	1.86
23	110 - 115	6.00	1.80
24	115 - 120	5.60	1.62
25	120 -125	4.00	1.44
26	125 - 130	7.01	1.56
27	130 - 135	7.01	1.62
28	135 - 140	4.80	1.80
29	140 - 145	6.61	1.92
30	145 - 150	5.00	1.32
31	150 - 155	2.00	0.72
32	155 - 160	5.60	0.12
33	160 - 165	1.60	0.48
34	165 - 170	6.00	0.72
35	170 - 175	5.00	0.84
36	175 - 180	5.00	0.84
37	180 - 185	6.00	0.48
38	185 - 190	5.00	0.12
39	190 - 195	2.00	0.60
40	195 - 200	5.00	0.72
41	200 - 205	2.00	0.90
42	205 - 210	9.01	1.02
43	210 - 215	5.00	1.08
44	215 - 220	8.01	1.14
45	220 - 225	7.01	1.00
46	225 - 230	13.01	0.72
47	230 - 235	8.81	1.80
48	235 - 240	8.81	1.02
49	240 - 245	10.01	1.50
50	245 - 250	9.60	1.20
51	250 - 255	10.01	1.32
52	255 - 260	12.41	0.84
Mean		**6.60**	**1.55**

has reported 1.54, 1.79 and 1.15% of organic matter from the study of three sediment cores of the continental shelf of Gulf of Mannar, near Tuticorin. In the down core variation, the sediments show depletion towards depth. At a depth of 152 – 155 cm and 180 – 185cm the sediments have recorded very low percentage of organic matter. The general decrease in organic carbon is due to the domination of decomposition over protection. A distinct maximum supply of terrigenous organic matter is obvious at 65-70cm and 85-95cm. In the lower part of the core (unit-3), the sediments are poor in organic matter and rich in carbonate and have been deposited under a well mixed, oxygenated water column (Pratt, 1984; Barlow and kauffman, 1985).

The measured concentration of major oxides of the sediment core is given in Table 3. The silica contents of the core sample are generally moderate. The higher concentration of silica (56.87%) is found at a depth of 190 cm to 195 cm. The lowest concentration of silica (38.20%) is recorded at a depth of 245 cm to 250 cm. There is no much down core variation in the silica content. The mean silica concentration is 45.38%. The alumina content ranges from 9.61% to 14.46%. Higher concentration of alumina (14.46%) is present in the sub sample at a depth of 130 cm to 135 cm and the bottom shows lowest value of 9.61%. The total Fe has been estimated as Fe_2O_3. The Fe content is generally low. The higher concentration of Fe_2O_3 (6.47%) is noticed at a depth of 175 cm to 180 cm. and the lowest value (2.56%) is recorded at the depth interval of 5 cm to 10 cm. There is no uniform depletion or enrichment in the iron content towards bottom of the core. However, the upper part of the core is having lower concentrations of Fe content than the middle part. The mean value of iron content of the core is 5.433%. CaO is very high when compared to other major oxides except silica. The concentration of MgO and Na_2O are poor and K_2O and P_2O_5 are very poor. CaO ranges from 8.60% to 31.20 % with a mean value of 17.57% and MgO varies from 1.26% to 3.89% with a mean concentration of 2.92%. However, Na_2O varies from 1.68% to 7.84% and the concentration of K_2O falls between 0.72% and 4.72%. The mean concentrations for Na_2O and K_2O are 4.29% and 2.62%, respectively. P_2O_5 shows concentrations ranging from 0.52% to 0.97%. The mean values for CaO, MgO, Na_2O, K_2O and P_2O_5 for the core sample are 17.57%, 2.92%, 4.29%, 2.62% and 0.72%, respectively. Na_2O shows a general depletion towards depth. K_2O shows a sudden enrichment from 85 cm depth and from this depth it shows a gradual slight downward depletion. CaO and Fe_2O_3 show enrichment in the top and bottom of the core. MgO shows depletion in the top of the core. The concentration of elements is in the order of SiO_2>CaO>Al_2O_3>Fe_2O_3> Na_2O> MgO >K_2O>P_2O_5, which indicates that the analyzed sediments are enriched in CaO.

Major element analysis effectively represents the composition of the solid fraction being eroded from the continent (Taylore and McLennan, 1985). Based on mean as well as range of concentration of major oxides, generally, the following decreasing order was noticed in the present study. SiO_2>CaO>Al_2O_3> Fe_2O_3>Na_2O>MgO>K_2O>P_2O_5.This trend shows that Si is the dominant element followed by CaO andAl_2O_3. The mean silica concentration (45.38) indicates that the silica is present in moderate amounts. The Al normalized values of silica ranges from 3.99 to 5.60 having an average value of 4.38. The Si/Al ratio of the core does not show much variation towards depth and the average value (4.38) is just above the upper crustal value (3.83). Hence, it indicates that most of the sediments have been derived from the continental margin. The higher Si/Al ratio is due to the variations in quartz in the sediments (Calvert et al., 1993).CaO forms the second major oxide in the present study next to silica; concentration of high CaO is due to both biogenic and lithogenic material. The continental margin of the southeastern Indian coast, which is dominated by sedimentary limestones (Armstrong, 1999) might have contributed more CaO to the Shelf and slope sediments (Jonathan et al., 2004). Hence the higher concentration of CaO is attributed to terrigenous input. Hence, it is possible to note the contribution of biogenic organic and inorganic material for the CaO concentration. The mean concentration of CaO in the core is 17.57%, which is higher than the concentration of CaO in other parts of the Bengal fan (Ramesh and Ramasamy 1997). The behavior of Fe in the core sediments is governed largely by the distribution of Ferro magnesium minerals and dispersed oxy-hydroxides. The Fe/Al ratio does not show much variation towards depth. The mean Fe/Al ratio is 0.59, which is higher than the upper continental crustal value (0.44). It indicates the minor influence of oxy-hydroxides, other than terrigenous material.

Mg/Al ratio is also consistent with this interpretation. The mean Mg/Al ratio of the present core (0.27) is slightly higher than the value of upper continental crust (0.17). The down core variation of Mg/Al ratio shows increment towards depth, which is similar to Fe/Al ratio. Hence the ferromagnesium minerals are the main contributor for these elements, which have been derived from the continental margin. The behaviors of K and Na largely reflect the distribution of K-and Plagioclase feldspar in the sediments. The Na/Al ratio decreases towards depth. The mean Na/Al ratio (0.48) is slightly higher than the upper continental crustal value (0.31), which indicates contribution of Na_2O to the sediments is not only from the feldspar. The P/Al ratios do not show much

Table 3. Major elements in the core samples

Samp.No	Depth(m)	SiO_2	$Al2O_3$	Na_2O	K_2O	CaO	MgO	Fe_2O_3	P_2O_5	Total	CIA
1	0 - 5	44.33	13.37	6.96	0.92	27.20	2.06	4.40	0.75	99.99	27.09
2	5 -10	43.56	12.50	7.20	0.96	26.40	1.26	2.56	0.87	95.31	25.88
3	10 - 15	45.57	12.27	7.84	0.96	27.60	1.86	2.83	0.85	99.78	25.96
4	15 - 20	43.87	11.50	7.76	0.88	29.20	1.98	2.78	0.75	98.72	23.82
5	20 - 25	40.03	11.88	6.96	0.88	31.20	2.47	4.83	0.80	99.05	25.58
6	25 - 30	40.56	11.27	7.52	0.80	28.60	2.37	2.84	0.77	94.73	25.79
7	30 - 35	43.03	13.07	6.72	0.96	24.60	2.92	5.20	0.77	97.27	28.40
8	35 - 40	43.03	13.46	6.56	0.96	23.00	2.76	4.85	0.71	95.33	30.56
9	40 - 45	48.19	13.26	5.68	0.96	18.00	3.36	5.69	0.71	95.85	35.84
10	45 - 50	41.79	11.95	5.84	0.96	18.20	1.46	5.57	0.80	86.57	31.50
11	50 - 55	45.03	11.23	5.52	0.96	17.80	2.56	5.42	0.67	89.19	31.20
12	55 - 60	43.79	11.40	4.24	0.72	18.20	2.75	5.87	0.76	87.73	32.82
13	60 - 65	48.87	11.95	4.56	0.72	18.60	2.74	5.66	0.69	93.79	32.66
14	65 - 70	47.57	10.87	4.96	0.80	19.80	2.96	5.63	0.67	93.26	28.55
15	70 - 75	45.36	13.07	4.64	0.80	17.40	2.87	5.72	0.67	90.53	36.24
16	75 - 80	41.36	13.86	4.16	0.80	18.40	2.82	5.89	0.67	87.96	37.23
17	80 - 85	40.17	12.88	4.16	0.72	17.40	3.20	5.94	0.92	85.39	36.51
18	85 - 90	45.03	13.46	3.68	0.96	8.60	2.55	6.36	0.79	84.15	47.64
19	90 - 95	43.79	13.46	4.72	1.12	15.20	3.10	6.13	0.65	91.77	35.01
20	95 - 100	41.36	14.05	4.64	1.04	16.00	3.23	6.27	0.67	90.86	35.48
21	100 - 105	50.19	13.86	3.68	0.80	15.60	3.51	5.88	0.75	97.15	37.04
22	105 - 110	41.36	13.07	4.56	0.88	19.20	3.31	6.01	0.65	92.72	30.73
23	110 - 115	41.36	14.05	3.84	0.80	16.20	3.12	5.86	0.62	88.89	37.00
24	115 - 120	41.36	11.40	4.16	0.88	16.60	3.49	6.02	0.67	87.86	30.15
25	120 -125	46.29	13.66	3.36	0.80	15.40	2.89	5.68	0.67	91.31	36.97
26	125 - 130	41.36	14.05	2.96	0.72	15.80	3.11	5.96	0.62	86.82	40.37
27	130 - 135	49.36	14.46	2.72	0.64	15.60	3.03	5.73	0.69	94.31	42.13
28	135 - 140	49.36	14.25	4.32	0.88	13.40	3.30	6.06	0.91	95.92	38.77
29	140 - 145	49.36	12.88	3.92	0.80	13.40	3.65	6.07	0.52	93.72	38.28
30	145 - 150	53.03	12.46	3.84	0.72	14.60	3.55	6.27	0.97	98.56	34.94
31	150 - 155	51.79	12.46	3.12	0.80	13.00	3.27	6.11	0.88	93.75	36.60
32	155 - 160	54.29	11.68	4.24	0.88	13.40	2.66	5.97	0.85	97.33	34.06
33	160 - 165	49.36	11.68	3.28	0.88	13.20	3.18	6.20	0.82	91.00	33.91
34	165 - 170	49.36	11.49	3.04	0.88	13.20	2.92	6.23	0.75	90.03	37.35
35	170 - 175	49.36	13.27	3.52	0.96	9.80	2.54	6.50	0.61	89.12	44.53
36	175 - 180	49.36	13.48	2.32	0.88	9.80	3.23	6.47	0.67	87.65	49.66
37	180 - 185	50.56	12.46	3.84	0.88	10.20	2.71	6.18	0.77	90.56	41.88
38	185 - 190	50.56	13.69	3.76	0.96	10.80	3.43	6.31	0.79	93.10	42.97
39	190 - 195	56.87	14.11	2.72	0.88	10.40	3.89	5.95	0.69	97.35	45.14
40	195 - 200	49.35	14.11	5.44	0.96	10.00	3.85	6.11	0.72	95.02	40.12
41	200 - 205	48.35	13.92	2.64	0.80	10.80	3.58	6.11	0.72	88.76	42.20
42	205 - 210	41.40	12.06	2.80	0.80	11.80	2.94	5.64	0.82	80.26	44.88
43	210 - 215	46.45	11.63	3.44	0.72	12.40	3.12	5.16	0.79	86.43	36.89
44	215 - 220	45.55	10.81	3.04	0.56	20.00	2.98	4.85	0.75	91.02	28.97
45	220 - 225	44.34	10.81	2.96	0.40	18.00	2.72	4.06	0.72	86.57	30.58
46	225 - 230	42.17	12.70	5.52	0.48	16.60	3.09	4.79	0.85	91.24	34.46
47	230 - 235	41.52	12.05	3.20	0.48	17.00	2.45	5.05	0.85	85.32	35.24
48	235 - 240	40.13	11.22	2.24	0.40	25.80	3.17	5.25	0.75	90.80	44.40
49	240 - 245	40.13	11.22	2.24	0.40	24.80	3.34	5.07	0.67	89.71	44.12
50	245 - 250	38.20	11.63	1.68	0.40	24.00	2.92	5.46	0.72	86.29	47.54
51	250 - 255	41.40	10.99	2.64	0.40	19.29	2.63	4.87	0.57	85.03	52.68
52	255 - 260	40.12	9.61	3.50	0.40	22.20	2.84	3.88	0.57	86.22	25.49
Mean		**45.38**	**12.54**	**4.29**	**0.79**	**17.57**	**2.92**	**5.43**	**0.74**	**91.48**	**36.03**

variation towards depth. The mean P/Al ratio is 0.06. The relatively low P/al ratios and lack of relationship with P/Al and organic suggest that organic contributions of P in these samples are of minor importance and that detritus phases mainly control their P contents. Even though the over all geochemistry shows detritus nature of the sediments, the different units of the core shows some variations in their chemical signature.

The Al normalized values of the major elements of the three units are compared and it shows variations in Si/Al, Na/Al, K/Al and Ca/Al ratios (Table 5). The mean values of Si/Al ratio of the three units show high values for Unit-3, followed by Unit-1 and Unit-2. This high Si/Al ratio for the core of Unit-3 reflects the higher quartz content than unit 2 and 1. The high Fe/Al and Mg/Al ratios in unit 2 and 3 reflect the chlorite and smectite/illite ratios in this horizon. The Mg/Al ratio is higher in unit 3, than in 2 and Fe/Al ratio is higher in unit 2 than in 3. These variations may be due to marked increase in chlorite in unit 2, Mg being a more sensitive reflection of the presence of chlorite than Fe (Calvert, 1990).There is no much variation in P/Al concentration between the two units in this study.

The measured concentration of the trace elements of the core sediment is given in Table 4. Manganese in the core ranges from 83 mg/kg to 151 mg/kg except at the depth interval 160 cm to 165 cm where the concentration of Mn suddenly increases to 379 mg/kg. The next highest concentration (151 mg/kg) is encountered at 85 cm to 90 cm depth of the core, whereas, the lowest concentration is recorded at the bottom most sample of the core. In general, upper part of the core shows slightly higher values when compared to lower part.

The down core variation of Cr shows wide range from 49.6 mg/kg to 512 mg/kg. The mean concentration of Cr is 170 mg/kg.The mean value of cu is 38 mg/kg. Nickel ranges from 34 mg/kg to 149 mg/kg in the core and there is not much variation in the concentration of Ni. The higher concentration of Ni (149 mg/kg) is seen in surface layer of the core. The mean concentration of Ni is 65.5 mg/kg. Slight increase in the concentration of Ni is observed at a depth of 140 to 150cm and 205 – 210cm. Thus, down core profile of Ni does not exhibit a systematic variation.

The lower concentration of Co ranging from 4 mg/kg to 11 mg/kg was observed in the present study. The mean concentration is very low (6.7 mg/kg) and it shows a higher value of Co (8 mg/kg) at a depth of 155 to 160cm. The mean value of Pb is 10.9 mg/kg. Concentration of Zn ranges from 71 mg/kg to 128 mg/kg in the sub-samples. The mean concentration is 81 mg/kg. The mean value of Cd is 0.2 mg/kg.The association of the minor elements with the principal sediment components of the core is summarized by the results of the factor analysis. It can be seen that the trace elements are strongly fractionated between the three components and can therefore be used to refine the chemical characterization of the different sediment units already revealed by the distribution of the major elements. In addition, the conditions of sedimentation and effects of digenesis will also influence the distribution of some of the trace elements. The distribution of trace elements shows the following decreasing order based on the mean of trace elements in the core Cr>Mn>Zn>Ni>Cu>Pb>Co>Cd. Manganese concentrations with 83 mg/kg value is the lowest observed in the core and shows a rather constant down core distribution except a maximum of 379 mg/kg at 160-165cm. Small fluctuations co-vary with aluminum concentrations suggesting ferruginous source for the manganese. The mean Mn/Al ratio (20.70) is very much less than the upper continental crustal values (75) and average shale (85) (Taylor and McLennan, 1985). The Mn peak at 160-165cm may be due to the presence of Pleistocene/Holocene boundary. Similar observations have been described from the Pleistocene/Holocene boundary by (Ramesh and Ramasamy, 1997). The Al normalized values of the trace elements of the three units are given in Table 6 and fig. 3.The distribution of Cr and Ni permits a more defined identification of the mineralogical change in the core. The Cr/Al and Ni/Al ratios co-vary and are highest in unit 2. Both ratios decrease in unit 1, with a Cr/Ni > 1. In the Cr/Al and Ni/Al ratio there is no much variation among the units, and the total core is markedly enriched in chlorite and smectite in relation to illite. The ratio between Cr and Ni is constant and it indicates terrigenous source for Cr and Ni. Cu and Zn appear to behave coherently in the core sediments, although there is difference in their detailed behaviors. Cu/Al and Zn/Al co-vary in all the units. Both the values are highest in unit 3 and low in unit 2 and again high in unit 1. For Cu/Al and Zn/Al ratios the upper continental crustal value are 3.10 and 8.8, which are much lower than the values in the present study. Certain minor and trace elements are enriched (i.e. occur at concentrations significantly above the crustal abundances) in many organic rich sediments (Calvert, 1976). The mean Co/Al ratio of 1.02 is much lesser than the upper continental value (1.24). The mean Co/Al values of unit 1 (0.93) and unit 2 (0.95) remain similar and it shows slight enrichment in unit 3 (1.16). The mean Pb/Al ratios of the core sediments are much lesser than the crustal value (2.48). The Pb/Al ratios are 1.75 for unit 1, 1.39 for unit 2 and 1.90 for unit 3. Hence, these trace metals have been derived from ferruginous input. Comparisons of trace metal concentration in the

Table 4. Trace elements in the core(mg/kg)

Samp.No	Depth(m)	Mn	Cr	Cu	Ni	Co	Pb	Zn	Cd
1	0 - 5	133.0	78.5	38.0	44.0	6.0	11.0	72.0	0.2
2	5 -10	134.0	94.5	41.0	50.0	5.0	30.0	82.0	0.2
3	10 - 15	136.0	231.8	38.0	79.0	6.0	9.0	94.0	0.2
4	15 - 20	130.0	96.2	41.0	48.0	6.0	10.0	83.0	0.2
5	20 - 25	131.0	90.3	39.0	47.0	6.0	10.0	76.0	0.2
6	25 - 30	126.0	129.4	35.0	51.0	6.0	10.0	76.0	0.2
7	30 - 35	137.0	110.5	40.0	71.0	6.0	9.0	81.0	0.2
8	35 - 40	125.0	93.7	40.0	52.0	6.0	10.0	111.0	0.2
9	40 - 45	140.0	343.6	39.0	95.0	6.0	9.0	82.0	0.2
10	45 - 50	133.0	109.6	44.0	53.0	7.0	14.0	88.0	0.2
11	50 - 55	130.0	125.2	35.0	56.0	6.0	8.0	76.0	0.2
12	55 - 60	141.0	257.5	37.0	78.0	6.0	9.0	78.0	0.2
13	60 - 65	135.0	115.9	37.0	51.0	6.0	8.0	75.0	0.2
14	65 - 70	130.0	90.3	37.0	49.0	6.0	8.0	77.0	0.2
15	70 - 75	126.0	111.7	35.0	50.0	6.0	8.0	76.0	0.2
16	75 - 80	129.0	163.0	36.0	59.0	6.0	10.0	79.0	0.2
17	80 - 85	138.0	110.5	37.0	52.0	6.0	8.0	78.0	0.2
18	85 - 90	151.0	142.8	36.0	57.0	4.0	5.0	75.0	0.1
19	90 - 95	138.0	109.6	35.0	48.0	6.0	8.0	76.0	0.2
20	95 - 100	146.0	104.2	36.0	51.0	7.0	8.0	76.0	0.2
21	100 - 105	124.0	156.2	38.0	55.0	6.0	14.0	71.0	0.1
22	105 - 110	142.0	80.2	39.0	45.0	6.0	10.0	81.0	0.2
23	110 - 115	139.0	236.9	69.0	78.0	7.0	11.0	128.0	0.2
24	115 - 120	145.0	148.7	41.0	61.0	7.0	13.0	85.0	0.2
25	120 -125	130.0	117.2	36.0	50.0	7.0	9.0	79.0	0.2
26	125 - 130	152.0	99.5	33.0	44.0	7.0	9.0	91.0	0.2
27	130 - 135	148.0	189.4	29.0	70.0	7.0	9.0	75.0	0.2
28	135 - 140	147.0	77.7	36.0	43.0	7.0	12.0	84.0	0.2
29	140 - 145	146.0	512.0	32.0	149.0	7.0	8.0	76.0	0.2
30	145 - 150	150.0	510.7	33.0	124.0	7.0	9.0	80.0	0.2
31	150 - 155	142.0	295.3	30.0	92.0	7.0	9.0	75.0	0.2
32	155 - 160	136.0	92.8	37.0	47.0	8.0	13.0	82.0	0.2
33	160 - 165	379.0	158.8	38.0	70.0	7.0	10.0	75.0	0.2
34	165 - 170	140.0	125.6	32.0	53.0	7.0	8.0	73.0	0.2
35	170 - 175	149.0	430.1	35.0	146.0	9.0	13.0	83.0	0.2
36	175 - 180	146.0	342.7	29.0	102.0	7.0	10.0	75.0	0.2
37	180 - 185	144.0	177.7	35.0	65.0	8.0	13.0	76.0	0.2
38	185 - 190	148.0	202.4	30.0	79.0	8.0	13.0	74.0	0.2
39	190 - 195	135.0	248.2	29.0	87.0	7.0	9.0	71.0	0.2
40	195 - 200	139.0	285.6	36.0	93.0	11.0	19.0	81.0	0.3
41	200 - 205	138.0	239.8	34.0	84.0	7.0	12.0	75.0	0.2
42	205 - 210	132.0	422.9	33.0	123.0	7.0	17.0	77.0	0.2
43	210 - 215	121.0	166.3	46.0	76.0	7.0	15.0	88.0	0.3
44	215 - 220	110.0	165.1	64.0	65.0	7.0	16.0	103.0	0.1
45	220 - 225	101.0	49.6	59.0	34.0	7.0	17.0	91.0	0.2
46	225 - 230	114.0	110.5	35.0	48.0	7.0	12.0	72.0	0.2
47	230 - 235	102.0	191.9	37.0	61.0	7.0	13.0	79.0	0.2
48	235 - 240	105.0	53.8	38.0	50.0	7.0	9.0	83.0	0.0
49	240 - 245	107.0	51.2	39.0	40.0	7.0	9.0	73.0	0.2
50	245 - 250	130.0	63.0	40.0	47.0	7.0	7.0	85.0	0.2
51	250 - 255	98.0	60.1	37.0	43.0	7.0	9.0	77.0	0.2
52	255 - 260	83.0	69.3	47.0	42.0	7.0	10.0	83.0	0.2
Mean		**136.8**	**170.0**	**38.1**	**65.5**	**6.7**	**10.9**	**81.0**	**0.2**

Table 5. Al normalization for major elements in the core samples

Samp.No	Depth(m)	Si/Al	Na/Al	K/Al	Ca/Al	Mg/Al	Fe/Al	P/Al
1	0 - 5	3.99	0.73	0.11	2.75	0.18	0.44	0.06
2	5 -10	4.20	0.81	0.12	2.85	0.11	0.45	0.07
3	10 - 15	4.47	0.90	0.12	3.04	0.17	0.51	0.07
4	15 - 20	4.59	0.95	0.12	3.43	0.20	0.54	0.07
5	20 - 25	4.06	0.82	0.12	3.55	0.24	0.54	0.07
6	25 - 30	4.33	0.94	0.11	3.43	0.24	0.55	0.07
7	30 - 35	3.96	0.72	0.12	2.54	0.25	0.54	0.06
8	35 - 40	3.85	0.68	0.11	2.31	0.23	0.48	0.06
9	40 - 45	4.38	0.60	0.11	1.83	0.29	0.57	0.06
10	45 - 50	4.21	0.69	0.13	2.06	0.14	0.63	0.07
11	50 - 55	4.83	0.69	0.13	2.14	0.26	0.64	0.06
12	55 - 60	4.63	0.52	0.10	2.16	0.27	0.68	0.07
13	60 - 65	4.92	0.54	0.09	2.10	0.26	0.63	0.06
14	65 - 70	5.27	0.64	0.12	2.46	0.31	0.70	0.07
15	70 - 75	4.18	0.50	0.10	1.80	0.25	0.58	0.05
16	75 - 80	3.59	0.42	0.09	1.79	0.23	0.57	0.05
17	80 - 85	3.76	0.45	0.09	1.83	0.28	0.60	0.08
18	85 - 90	4.03	0.38	0.43	0.86	0.22	0.63	0.06
19	90 - 95	3.92	0.49	0.55	1.53	0.26	0.60	0.05
20	95 - 100	3.54	0.46	0.52	1.54	0.26	0.59	0.05
21	100 - 105	4.36	0.37	0.42	1.52	0.29	0.57	0.06
22	105 - 110	3.81	0.49	0.55	1.99	0.29	0.61	0.05
23	110 - 115	3.54	0.38	0.43	1.56	0.25	0.55	0.05
24	115 - 120	4.37	0.51	0.57	1.97	0.35	0.70	0.06
25	120 -125	4.08	0.35	0.39	1.52	0.24	0.55	0.05
26	125 - 130	3.54	0.30	0.33	1.52	0.25	0.57	0.05
27	130 - 135	4.11	0.26	0.30	1.46	0.24	0.52	0.05
28	135 - 140	4.17	0.43	0.48	1.27	0.26	0.56	0.07
29	140 - 145	4.61	0.43	0.48	1.41	0.32	0.63	0.04
30	145 - 150	5.12	0.43	0.48	1.58	0.32	0.67	0.08
31	150 - 155	5.01	0.35	0.39	1.41	0.30	0.65	0.08
32	155 - 160	5.60	0.51	0.57	1.55	0.26	0.68	0.08
33	160 - 165	5.09	0.39	0.44	1.53	0.31	0.71	0.07
34	165 - 170	5.17	0.37	0.42	1.55	0.29	0.72	0.07
35	170 - 175	4.48	0.37	0.42	1.00	0.22	0.66	0.05
36	175 - 180	4.41	0.24	0.27	0.98	0.27	0.65	0.05
37	180 - 185	4.89	0.43	0.48	1.11	0.25	0.67	0.07
38	185 - 190	4.45	0.39	0.43	1.07	0.29	0.62	0.06
39	190 - 195	4.85	0.27	0.30	1.00	0.31	0.56	0.05
40	195 - 200	4.21	0.54	0.60	0.96	0.31	0.58	0.05
41	200 - 205	4.18	0.27	0.30	1.05	0.29	0.58	0.06
42	205 - 210	4.13	0.33	0.36	1.32	0.28	0.63	0.07
43	210 - 215	4.81	0.41	0.46	1.44	0.31	0.59	0.07
44	215 - 220	5.07	0.39	0.44	2.50	0.31	0.59	0.07
45	220 - 225	4.94	0.38	0.43	2.25	0.29	0.51	0.07
46	225 - 230	4.00	0.61	0.68	1.77	0.28	0.51	0.07
47	230 - 235	4.15	0.37	0.42	1.91	0.23	0.56	0.08
48	235 - 240	4.31	0.28	0.31	3.11	0.32	0.62	0.07
49	240 - 245	4.31	0.28	0.31	2.99	0.34	0.61	0.06
50	245 - 250	3.96	0.20	0.23	2.79	0.29	0.63	0.07
51	250 - 255	4.54	0.34	0.38	2.37	0.27	0.58	0.06
52	255 - 260	5.03	0.51	0.57	3.12	0.34	0.53	0.06
Mean		**4.38**	**0.48**	**0.33**	**1.93**	**0.27**	**0.59**	**0.06**

Table 6. Al normalization for trace elements in the core samples

Samp.No	Depth(m)	Mn/Al	Cr/Al	Cu/Al	Ni/Al	Co/Al	Pb/Al	Zn/Al
1	0 - 5	18.80	11.10	5.37	6.22	0.85	1.56	10.18
2	5 - 10	20.26	14.29	6.20	7.56	0.76	4.54	12.40
3	10 - 15	20.95	35.71	5.85	12.17	0.92	1.39	14.48
4	15 - 20	21.37	15.81	6.74	7.89	0.99	1.64	13.64
5	20 - 25	20.84	14.37	6.21	7.48	0.95	1.59	12.09
6	25 - 30	21.13	21.70	5.87	8.55	1.01	1.68	12.75
7	30 - 35	19.81	15.98	5.79	10.27	0.87	1.30	11.72
8	35 - 40	17.56	13.16	5.62	7.30	0.84	1.40	15.59
9	40 - 45	19.96	48.98	5.56	13.54	0.86	1.28	11.69
10	45 - 50	21.04	17.34	6.96	8.38	1.11	2.21	13.92
11	50 - 55	21.88	21.08	5.89	9.43	1.01	1.35	12.79
12	55 - 60	23.38	42.70	6.14	12.93	0.99	1.49	12.93
13	60 - 65	21.36	18.33	5.85	8.07	0.95	1.27	11.86
14	65 - 70	22.61	15.70	6.43	8.52	1.04	1.39	13.39
15	70 - 75	18.22	16.16	5.06	7.23	0.87	1.16	10.99
16	75 - 80	17.59	22.23	4.91	8.05	0.82	1.36	10.77
17	80 - 85	20.25	16.22	5.43	7.63	0.88	1.17	11.45
18	85 - 90	21.21	20.06	5.06	8.01	0.56	0.70	10.53
19	90 - 95	19.38	15.39	4.92	6.74	0.84	1.12	10.67
20	95 - 100	19.64	14.02	4.84	6.86	0.94	1.08	10.23
21	100 - 105	16.91	21.30	5.18	7.50	0.82	1.91	9.68
22	105 - 110	20.54	11.60	5.64	6.51	0.87	1.45	11.72
23	110 - 115	18.70	31.87	9.28	10.49	0.94	1.48	17.22
24	115 - 120	24.04	24.66	6.80	10.12	1.16	2.16	14.09
25	120 -125	17.99	16.22	4.98	6.92	0.97	1.25	10.93
26	125 - 130	20.45	13.39	4.44	5.92	0.94	1.21	12.24
27	130 - 135	19.35	24.76	3.79	9.15	0.92	1.18	9.80
28	135 - 140	19.50	10.31	4.78	5.70	0.93	1.59	11.14
29	140 - 145	21.43	75.14	4.70	21.87	1.03	1.17	11.15
30	145 - 150	22.76	77.48	5.01	18.81	1.06	1.37	12.14
31	150 - 155	21.54	44.80	4.55	13.96	1.06	1.37	11.38
32	155 - 160	22.01	15.02	5.99	7.61	1.29	2.10	13.27
33	160 - 165	61.34	25.70	6.15	11.33	1.13	1.62	12.14
34	165 - 170	23.03	20.66	5.26	8.72	1.15	1.32	12.01
35	170 - 175	21.23	61.27	4.99	20.80	1.28	1.85	11.82
36	175 - 180	20.47	48.06	4.07	14.30	0.98	1.40	10.52
37	180 - 185	21.85	26.96	5.31	9.86	1.21	1.97	11.53
38	185 - 190	20.44	27.95	4.14	10.91	1.10	1.80	10.22
39	190 - 195	18.09	33.25	3.89	11.66	0.94	1.21	9.51
40	195 - 200	18.62	38.26	4.82	12.46	1.47	2.55	10.85
41	200 - 205	18.74	32.57	4.62	11.41	0.95	1.63	10.19
42	205 - 210	20.69	66.29	5.17	19.28	1.10	2.66	12.07
43	210 - 215	19.67	27.03	7.48	12.35	1.14	2.44	14.30
44	215 - 220	19.24	28.87	11.19	11.37	1.22	2.80	18.01
45	220 - 225	17.66	8.67	10.32	5.95	1.22	2.97	15.91
46	225 - 230	16.97	16.45	5.21	7.14	1.04	1.79	10.72
47	230 - 235	16.00	30.10	5.80	9.57	1.10	2.04	12.39
48	235 - 240	17.69	9.06	6.40	8.42	1.18	1.52	13.98
49	240 - 245	18.03	8.63	6.57	6.74	1.18	1.52	12.30
50	245 - 250	21.13	10.24	6.50	7.64	1.14	1.14	13.82
51	250 - 255	16.86	10.34	6.36	7.40	1.20	1.55	13.24
52	255 - 260	16.33	13.63	9.25	8.26	1.38	1.97	16.33
Mean		**20.70**	**25.40**	**5.83**	**9.86**	**1.02**	**1.67**	**12.32**

Table 7. Comparison of trace metals in sediments with various coastal regions around the world and southeast coast of India (mg/kg)

Location	Mn	Cr	Cu	Ni	Co	Pb	Zn
Present Study							
Core (Range)	83-379	49.6-512	29-69	34 -149	4 -11	5-30	71-128
Average	136.8	170	38.1	65.5	6.7	10.9	81
(1) Gulf of Aqaba (Red Sea)	53-655	15-186	7-27	19-76	21-56	83 -225	31-260
(2) Palos VerdesPeninsula, Southern California	-	74-1,480	14-937	16-134	-	19-578	54-2,880
(3) HalifaxBay	-	-	7	12	7.6	17	33
(4) China Shelf Sea	530	61	15	24	12	20	65
(5) Tokyo Bay	1,098	77.3	53.47	32.63	-	50.68	322
(6) Narragansett Bay	410	155	190	28	8	140	250
(7) Boston Harbour	-	231.5	112	34.7	-	135	176
(8) Gulf of St. Lawerence	700	87	25	36	14	21	84
(9) Bombay Coast	1192	103	100.9	52	38.2	16.4	96.2
(10) Tuticorin coast	305	177	57	24	15	16	73
(11) Kalpakkam, Bay of Bengal	356	57	20	30	9	16	71
(12) Shallow cores, Bay of Bengal	529	84	26	64	-	-	-
(13) Surface sediments, Gulf of Mannar	296	167	-	24	7	16	73

1) Abu-Hilal (1987); 2) Hershelmen and others (1981); 3) Knauer (1977); 4) Yiyang and Ming-cai (1992); 5) Fukushima and others (1992); 6) Goldberg and others (1977); 7) Bothner and others (1998); 8)Loring (1978, 1979); 9) Dilli (1986); 10) Jonathan and others (2004).11) Selvaraj et al., (2004); 12) Sarin et al., (1979); 13) Jonathan and Ram-Mohan (2003).

study area with various other coastal regions around the world are indicated in Table 7.

CONCLUSION

The sediments have been poorly sorted and most of the sub samples are silty clay and few top samples are sandy silty clay. The slightly higher values of the sand fraction when compared to the other sub samples are due to shell fragments and undecomposed organic matter and not due to sand grains. The nature of organic matter also indicates high sedimentation rate. The major oxide geochemistry shows higher concentrations of detrital constituents. Calcium carbonate and organic matter concentration controlled the Calcium oxide concentration of the sediments. Ferromagnesium minerals controlled the concentration of Fe and Mg in the sediments. The trace element study indicates except for Cu and Zn, ferruginous nature. Aluminum silicates and ferromagnesium mineral have greater contribution in the lower most part of the core. Calcium carbonate

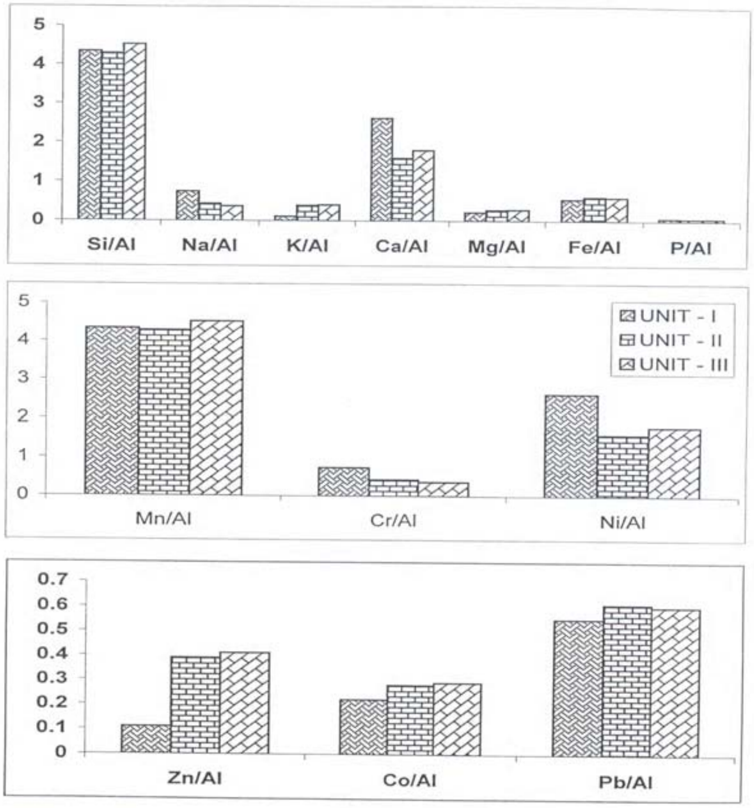

Fig. 3. Unit wise comparison of metal/Al ratio

and organic matter bound materials have greater contributions in the upper part of the core. The contributions from alumina silicates and biogenic materials may play a role in the unit. The study indicates a sudden change of Mn concentration at a depth of 160cm to 165cm. Based on the chemical signatures of the major and trace elements, the behaviors of the biogenic materials and sediment texture it may be concluded that Pleistocene/Holocene boundary may exist between unit 2 and unit 3, (i.e. at a depth of 165cm).

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