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GEOCHRONOLOGY AND GEOCHEMISTRY OF A SEDIMENT CORE FROM BOMBAY COAST

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ABSTRACT

Radiometric, mineralogical and compositional analyses of a sediment core from the continental shelf region off Bombay coast are reported. The ^{210}Pb excess method yielded a sediment accumulation rate of 2.5mm/yr which is in agreement with accumulation rates observed elsewhere for shelf sediments. Mineralogically the clays are largely composed of smectite ($> 60\%$). Chlorite and kaolinite are in very minor amounts ($< 7\%$). Illite concentration is variable and increases with increasing age. This is related to the periodic fluctuations of illitic rich materials derived from the Indus river being washed southwards on to the shelf regions. Elemental concentration of certain major and trace metals (Al, Fe, Mn, Cu, Cr, Zn, Ni, Co, Pb) show that there is no regular pattern in the distribution of these elements with depth. Metal/Al ratios vary within a factor of 2 during the past 300 years.

Key-words : radiometry, clay mineralogy, continental shelf, off Bombay.

INTRODUCTION

The western continental shelf of India is a prominent submarine topographical feature stretching all along the western boundary and extending from about 50 km in the southern part, near Cape Comorin, to about 200 km in the north, near the Gulf of Cambay. But for the northern part where the Indian rivers Narmada and Tapti drain into the Arabian Sea, the general continental drainage all along the coast is characterised by small rivers and streams. Though the Indus river is the principal contributor of sediments to the Arabian Sea (0.44×10^{15}g/yr, Holeman, 1968). it is also important to know the sediment contributions and distribution patterns from other sources all along the continental boundary. Of particular interest is the knowledge about the characteristics, deposition rates and the chemistry of the shelf sediments. Studies on continental shelf sediments not only helps to understand the variations in climate, weathering patterns in the adjacent landmasses and the effects of pollution but also throws light on the possible changes in the chemistry and mineralogy of the materials that are likely to reach the deep seas.

Earlier works on the western continental shelf sediments regarding geochemistry and deposition rates are those of Borole, Sarin and Somayajulu (1982) and Baskaran, Sarin and Somayajulu (1984). In an attempt to contribute to the understanding on the accumulation trends of sediments, geochemical and mineralogical studies were carried out on a sediment core recovered from this region.

MATERIALS AND METHODS

Three sediment cores 2579, 2586 & 2592 collected from the Bombay High region (Fig. 1) by NIO research ship RV *Gaveshani* in June 1983 were initially selected for detailed investigation. Radiochemical studies on these cores to estimate ^{210}Pb revealed that two of the cores did not have sufficient activity expected for the water depths from which they were collected. The results presented below are thus confined to only one core, 2586 (lat 19° 50'N : long 71°10' E water depth 52 m).

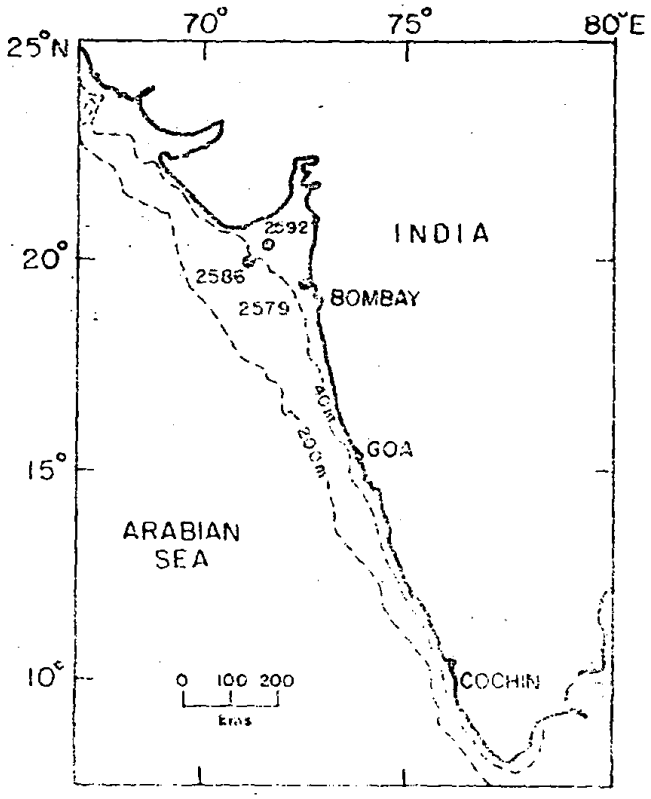

Fig. 1. Location map of the sediment cores used in the present study.

Analytical methods

Major and minor element analyses were carried out by digesting 0.5 g of powdered dry sample by HF, $HClO_3$ and HNO_3 treatments in a teflon dish and by bringing it into solution in 50 ml, 0.5 M HCl. Elemental concentrations were measured in HCl solutions using a Perkin Elmer AAS 305 A. (Sarin, Borole and Krishnaswami, 1979; Borole, 1980). Reagent blanks as well as U.S.G.S. standards W-1 and G-2 were also run simultaneously to check the reproducibility of the results which were between 3-8%.

To obtain the percentage organic carbon 0.40 g sample was heated at 450°C for 8 hours and the weight loss on ignition was determined. The percent $CaCO_3$ was determined by methods outlined by Vogel (1978).

The ^{210}Pb, U and Th measuremests were made following the procedures of Krishnaswami and Sarin (1976). Sedimentological parameters like sand, silt and clay components were determined using methods of Jackson (1975) and Folk (1980).

For the study of clay minerals, selected samples were size fractionated and oriented sample slides were prepared for the $< 2\ \mu$ fraction. X-ray diffractograms were obtained on a Philips XRD 1730. To identify the clay minerals, samples were glycolated as well as heated to 550°C for 1 hour. Relative proportions of the individual clay minerals were estimated following the methods outlined by Matter (1974).

RESULTS AND DISCUSSION

The variations in the proportions of total clay and the relative proportions of clay minerals together with the ^{210}Pb excess with depth is shown in Table I. The variations in the organic carbon, calcium carbonate and the various major and trace metals with age are shown in Table II.

^{210}Pb excess

The variation of ^{210}Pb excess as seen from Table I is rather low and irregular and the extrapolated to surface activity of the sediment column is just 3.2 dpm/g The ^{210}Pb excess activity is plotted as a function of depth in Fig. 2

Table I : Sand, silt and clay composition and ^{210}Pb excess in gravity core 2586

Sample depth (cm)	Sand (%)	Silt (%)	Clay (%)	Relative % of clay minerals				^{210}Pb excess	
				Smectite	Illite	Kaolinite	Chlorite		
								(dpm/g)	
0-2	—	—	—	—	—	—	—	3.00	0.13
2-4	—	—	—	—	—	—	—	1.72	0.10
4-6**	1.1	49.8	49.1	—	—	—	—	2.02	0.12
6-8	—	—	—	85.3	10.0	2.6	3.0		—
8-10	—	—	—	—	—	—	—	1.10	0.20
10-12	—	—	—	—	—	—	—	0.64	0.10
12-14	—	—	—	—	—	—	—	0.92	0.18
16-18	—	—	—	84.8	10.5	2.1	2.7		—
28-32	4.4	54.0	41.6	—	—	—	—		—
40-44	—	—	—	82.3	12.5	2.5	2.8		—
52-56	—	—	—	70.5	16.7	6.4	6.4		—
60-64	—	—	—	70.0	19.1	5.5	5.5		—
68-72	4.3	55.9	39.8	72.1	15.9	5.7	6.2		—
72-76	—	—	—	69.1	17.4	7.0	6.3		—
76-80	—	—	—	61.7	29.2	4.0	5.1		

* ^{210}Pb excess = ^{210}Pb measured — ^{226}Ra (all in units of dpm/g) ^{226}Ra concentration of (6-8) cm section was measured to be 0.90 ± 0.03 dpm/g — this value is used to calculate ^{210}Pb excess in all sections. ** ^{238}U = 1.7 ± 0.1 ppm : ^{232}Th 8.8 ± 0.3 ppm $^{234}U/^{238}U$ = 1.11 ± 0.08 and $^{230}Th/^{238}U$ = 1.29 ± 0.09

Table II: Elemental and other constituents concentration.

Sample depth (cm)	Time span (yrs)	$CaCO_3$ (%)	Organic C (%)	Fe (%)	Al (%)	Mn (ppm)	Cu (ppm)	Cr (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)	Pb ppm
0-2	0-8	9.7	7.6	6.8	7.8	1192	100.9	103.0	96.2	52.0	38.2	16.4
2-4	8-16	8.2	6.1									
4-6	16-24	7.7	7.0	7.4	9.0	1216	105.5	119.6	115.3	48.3	56.7	19.4
6-8	24-32	8.1	7.8									
8-10	32-40	8.5	4.1	6.6	8.3	1131	101.8	113.0	96.0	55.8	44.9	35.6
10-12	40-48	7.8	2.9									
14-16	56-64	8.4	6.6	6.6	8.2	1012	99.0	105.9	99.7	46.1	38.3	21.0
16-18	64-72	8.9	3.7									
12-14	48-56	8.9	3.4									
18-20	72-80	8.6	5.9									
20-24	80-96	9.2	5.5	6.9	8.6	1169	99.3	112.7	106.3	50.9	38.4	27.1
24-28	96-112	9.2	5.4									
28-32	112-128	9.8	4.3	6.7	5.8	917	95.7	110.3	95.0	46.6	31.4	8.6
32-36	128-144	9.4	5.4									
36-40	144-160	9.9	4.5									
40-44	160-176	9.5	2.7	7.0	N.D.	961	100.7	112.7	147.4	58.9	36.1	10.9
44-48	176-192	9.5	5.3									
48-52	192-208	9.6	5.5	6.6	8.2	965	93.7	114.0	112.9	49.2	46.2	27.4
52-56	208-224	10.7	4.0									
56-60	224-240	10.3	2.3	6.6	7.8	1047	93.2	130.7	98.0	56.9	47.2	26.1
60-64	240-256	10.8	2.7									
64-68	256-272	9.5	2.9									
68-72	272-288	10.5	5.9	6.5	8.1	886	86.8	102.1	110.7	42.3	56.7	20.3
72-76	288-304	10.4	5.8									
76-80	304-320	9.9	5.5	6.7	8.2	924	97.4	107.6	109.3	54.2	53.6	28.4

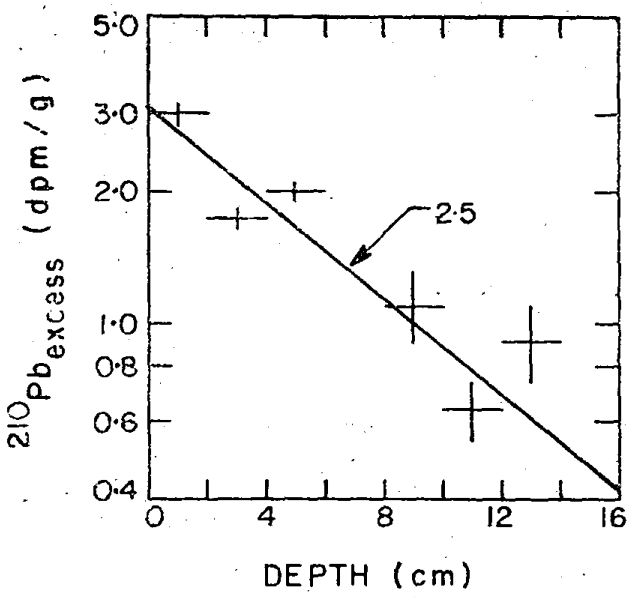

Fig. 2. Plot of ^{210}Pb excess versus depth for core 2586. (Number indicated across best-fit line is the accumulation rate in units of mm/yr

and the best fit line through the data points yielded an accumulation rate of 2.5 mm/yr.This rate is comparable to the accumulation rates obtained for near-coastal regions of the Indian subcontinent (Kalesha, Rao and Somayajulu, 1980). The low extrapolated to surface ^{210}Pb excess activity is similar to the values obtained by Borole (personal communication, 1984) for the western shelf sediments.

The U and Th measurements carried out on one section (footnote of Table I) fall in the general range observed for other near coastal sediments. There is no appreciable excess ^{230}Th viz. $^{230}Th/^{238}U = 1.29 \pm 0.09$.

Mineralogy

Sedimentological investigations showed that the sediments are essentially composed of approximately equal proportions of silt and clay. Silt increased from 49.8% in the surface portions to 55.9% in the bottom sample. Clay decreased from 49.1% in the surface portion to 39.8% in the deeper (68-72 cm) portion. Sand was a minor constituent throughout increasing from 1.1% in the top section to 4.4% in the deeper portion.

Mineralogical studies show the clay mineral suite to be predominantly composed of smectite (>60%). Illite is present in the range of 10.1 — 29.2%. Kaolinite and chlorite are also present but in small amounts (< 7%). The relative abundances of the clay minerals is shown in Table I. From the x-ray diffractograms, it is seen that smectite and illite are present as discrete phases. This

is indicated by the sharp and discrete reflections at 14 Å and 10 Å respectively. There however appears to be some mixing between smectite and chlorite for on glycolation there is a general broadening and shifting of the 14 Å reflection towards 17 Å . As is obvious from Table I the variations in the relative abundances of the clay minerals with time is rather interesting. Smectite which constitutes 85.3% of the total clay mineral content in the sample corresponding to (16-24) yrs. decreases steadily to 61.7% in the deepest sample corresponding to (304-320) yrs, while illite for the same time span increases from 10.0% to 29.2%. The variations in kaolinite and chlorite are small and they were minor constituents (2-7%) throughout the section.

The variations in the clay mineral abundances may be interpreted as due to changes in the weathering patterns of the adjacent continental areas. Since these areas are largely basaltic regions (Deccan Traps) they do account for the high concentrations of smectite. Chlorite also is possibly derived from the same source area. The mixing of smectite and chlorite as observed in the diffractograms also points to this conclusion, for, though mixing is indicative of conversion processes in progress, on such short time scales transformation of smectite to chlorite is improbable. The presence of illite as a discrete phase suggests that it is probably derived from a different source. Its abundance is more or less uniform in the most recent samples but corresponding to 320 years it becomes a dominant constituent (29.2%). This sudden influx of illitic rich sediments should be due to some other source. It is probable that the tidal barrier theory of Nair, Hashmi and Purnachandra Rao (1981) is not a continuous phenomenon through time and during periods when it is in operation can result in fluctuation of illite rich material from the Indus river being carried on to the continental shelf regions near the Gulf of Cambay. It is interesting to note that based on clay mineral studies of 10^4 — 10^5 year old Saurashtra miliolite samples Baskaran and Somayajulu (1986) also found periodic inwashing concentration of illite. However detailed mineralogical and geochmical study of longer cores will help to understand the causes and extent of mineralogical fluctuations.

Organic C and $CaCO_3$

The organic C and $CaCO_3$ variations with time are shown in Fig. 3. Organic C varies from about 8% in the surface layers (0-8 cm) to 2.3% in the (56-60) cm section. However there is no gradual decrease. There are increases and decreases, but on overall basis the bottom sections have lesser organic C (Table II). The mean of 25 samples is 4.9 ± 1.5%. There is hardly any variation in $CaCO_3$ (7.7 to 10.7% with a mean of 9.3 ± 0.9%).

Metal concentrations

The concentrations of Al, Fe, Mn, Cu, Cr, Zn, Ni, Co and Pb are given in Table II and the metal|Al ratio variations as a function of time are shown in Fig. 3.

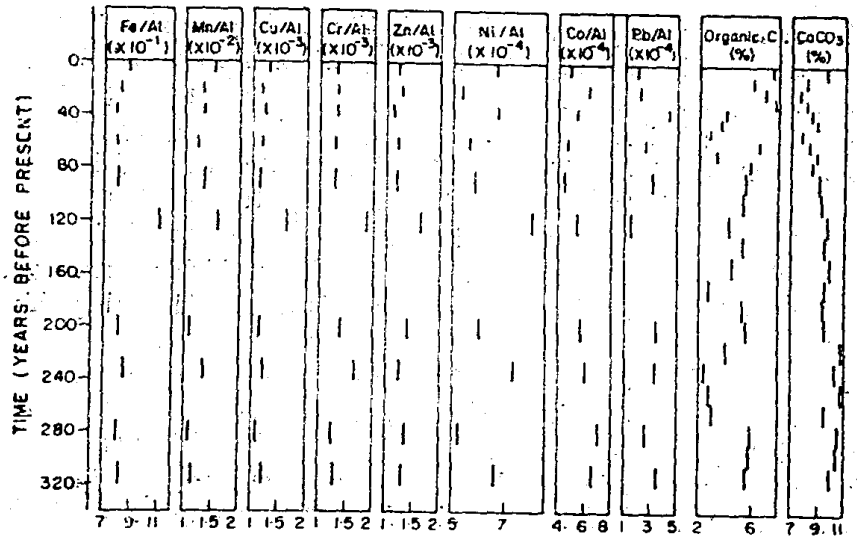

Fig. 3. Variation pattern of metal / Al ratios versus time.

The down core variation of Al concentration is 5.8 — 9.0% (mean = 6.8 ± 0.3%) whereas Fe is strikingly constant (variation 6.5 — 7.0%, mean = 6.8 ± 0.3%). The down core variations, mean ± standard deviation for trace elements are : 917-1216, 1038 ± 114 ppm for Mn, 86.8-105.5, 97.6 ± 4.9 ppm for Cu, 102.1-130.7, 112.1 ± 7.7 for Cr, 95-147.4, 107.9 ± 14.3 ppm for Zn, 42.3-58.9, 51 ± 4.9 ppm for Ni, 31.4-56.7, 44.3 ± 8.3 ppm for Co and 8.6-35.6, 21.9 ± 7.6 ppm for Pb. The Fe, Al and trace elemental concentrations obtained in this study are in reasonable agreement with those measured for coastal Arabian Sea by Borole, Sarin and Somayajulu (1982) Baskaran, Sarin and Somayajulu (1984) as well as with the earlier measurements (Rao, Rajamanickam, Murty and Reddy, 1976, Murty, Rao, Paropkari and Topgi, 1980).

To see the po sible pollution effects in coastal regions of Bombay, this core was investigated for Pb whose concentration in the surface layers (deposited in recent years) are expected to be high. However, the variation in the Pb abundance are irregular with high values appearing in surface and in some deeper layers also.

In a few samples elemental concentrations were measured in two size fractions viz. the clay fraction and the sand + silt fraction. It is found that Fe, Al, Cu, Cr and Ni are slightly more concentrated in the clay fraction, whereas Mn is more concentrated in the sand + silt fraction by 10.15%. No obvious differences could be noticed in the case of Zn and Pb.

Metal/Al Ratios

To take into account the variation of clay fraction and changes in the intensity of weathering that leads to the deposition of material in the sea, the metal concentrations are normalised to that of Al. The metal/Al ratios variations as

a function of time in the past are plotted in Fig. 3. In general it is seen that the metal/Al ratios for all the analysed metals vary within a factor of two during the to the other (Fig. 3). The one noticeable feature is that at about 120 yrs. B.P. past about 300 yrs. Ni/Al and Pb/Al show relatively more variation compared the ratios Fe/Al, Mn/Al, Cu/Al, Cr/Al, Zn/Al and Ni/Al were all high compared to the ones before and after this period whereas Pb/Al and to some extent Co/Al were low. The lowest Al concentration in the sediment occurred during this period. Either the magnetic mineral content at this depth was high or more of the Fe, Mn, Cr, Zn (and less of Pb) were deposited relative to Al during this period. Overall there is not much of a drastic change in the constituents of these Bombay coastal sediments. The irregular Pb/Al ratio variations cannot be explained easily. While the higher values of this ratio during the past 100 yrs could be attributed to pollution, it is difficult to explain the high ratios in 200-300 yr sections. Detailed mineralogical and geochemical studies on much longer cores should throw more light on the weathering patterns and chemistry of the resultant detrial material with time.

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