Chapter IV

BAY OF BENGAL:
SEDIMENT PROVENANCE

The surface sediment distribution in the Bay of Bengal largely reflects the type of sediments brought by the various rivers draining into it. The coastal sediments comprise of sand, silt and clay. Clay is the major detritus material over most of the region except in areas influenced by the G–B River system. In the G–B delta and Bengal Fan, silt is the major constituent (Mallick, 1976; Meybeck, 1979). To the west of the Andaman coast, silty clay occupies a very large area that extends almost up to the central region of the Bay. Siddiquie (1967) envisaged a general increase in foraminiferal content and unidentifiable calcareous fragments with decrease in terrigenous material and insoluble matter towards the central and southeastern parts of the Bay of Bengal.

The G–B River system not only controls the sediment composition of the Bay of Bengal but is also the largest sediment source to the world oceans (Milliman and Meade, 1983). The other major Indian rivers flowing into the Bay of Bengal derive their sediment load from the Deccan highlands of the Indian peninsula (Archean basement). The fine sand fraction enriched in quartz and heavy minerals settles down in estuarine channels while a predominant part of the fine fraction and suspended matter enriched in clays is transported to the outer shelf of the Bay of Bengal. The suspended matter undergoes compositional changes during its transport, attributed to the grain size distribution, as well as results in the formation of manganese dioxide coatings on the suspended particles (Stummeyer et al., 2002).

The fresh water discharge plays an important role in the circulation of surface waters of the Bay of Bengal (Howden and Murtugudde, 2001). This fresh water inflow coupled with the upwelling winds along the east coast of India during the monsoon period leads to the formation of a cyclonic gyre at the Bay head and occurrence of down welling along the east coast of India. According to Dube et al. (1995), the local effect of the northern fresh water inflow weakens the intensity of wind induced upwelling.

The Andaman Basin in the northeastern Indian Ocean is bound by Myanmar on the north, Thailand and Malaysia on the east and the Andaman and Nicobar Islands on the west and is separated from the rest of the Bay of Bengal. The surface waters of the Andaman Sea receive considerable fresh water inflow from the Irrawaddy River and the G–B River system. The deep water of the Andaman Sea is separated from the main Bay of Bengal area by the Andaman–Nicobar Ridge in the west. The Andaman Sea is connected to the Bay of Bengal by the Preparis and Ten Degree Channels, and by the Great Channel in the south (Sengupta et al., 1981; Kamesh Raju et al., 2004). With Preparis Channel being just ~250 m deep, the exchange of deep water is mainly through the Ten Degrees Channel (where the water depth is ~800 m) and the Great Channel (maximum depth of ~1400 m.) Due to the presence of ridges and surrounding sills, the Andaman Basin is cut off from the deep waters of the Bay of Bengal and the equatorial Indian Ocean. (Okubo et al., 2004; Dutta et al., 2007). The chemical and isotopic composition of the sediments in this basin would provide clues to the intensity and flux component of erosion from the Himalayan and Burman ranges. The sediment to the Andaman basin is mainly supplied by the Irrawaddy and Salween Rivers (Rodolfo, 1969; Kamesh Raju et al. 2004; Rao and Kessarkar, 2001; Vance et al., 2003; Rao et al., 2005).

The sediments carried by the various rivers reflect the lithology of the drainage basin with signatures of mineralogical and isotopic compositions.

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This becomes very important in understanding the sediment distribution in the Bay of Bengal and can be used to fingerprint the sediment provenance. The enormous fluvial input to the Bay during the South West Summer Monsoon (SWSM) is reflected in the high average content of lithogenic matter and a relative increase in the flux of biogenic opal. High carbonate dominated fluxes observed during SWSM and North East Winter Monsoon (NEWM) is mainly due to wind–induced nutrient supply, whereas high opal rich fluxes during SW–NE inter–monsoon are controlled by both upwelling as well as supply of riverine and shelf derived matter (Unger et al. 2003). The fluvial sediment input is the major source for detrital flux in the Bay of Bengal. In the northeastern part, the sediment flux is largely due to inputs from the G–B River system, while in the western part it is the peninsular rivers that are responsible for the sediment budget. These fluvial inputs can be differentiated by their contrasting clay mineral assemblages. For example, the sediment of G–B River system are high in illite and chlorite, whereas, the peninsular river sediment are rich in smectite (Goldberg and Griffin 1970; Rao, 1991). Although, the main sediment supplier to the Bay of Bengal has been the G–B River system, the contribution of the peninsular Indian river systems, which has remained a long–lived sedimentary source, cannot be underestimated (Kolla and Rao, 1990; Rao and Kessarkar, 2001). The illite–chlorite rich sediments from G–B River system can be traced right from the eastern Bay of Bengal in the north to the areas well south of the equator. The transport of these sediments has been affected mainly by turbidity currents. The Ninety East Ridge acts as a barrier preventing the coalescence of the two Bengal Fan lobes (Kolla and Biscaye, 1973; Kolla et al., 1976).

Earlier studies on the clay fractions of grab samples from the northwestern part of the Bay of Bengal revealed the presence of major quantities of illite and quartz with minor amounts of smectite, kaolinite and feldspar (Ramamurty and Shrivastava 1979). The surface clay mineral distribution on the southwestern continental margin of India shows high content of illite and chlorite in southern region of the study area pointing to

the evidence of sediment contribution from the Bay of Bengal waters, entering this region after the SW monsoon (Chauhan and Gujar 1996). The Rare Earth Elements (REEs) and metal distribution of the sediments of the G–B River system reflects the excessive crustal erosion in the high Himalayan regions, due to strong physical weathering processes, and the contribution of more material to the Bay of Bengal (Ramesh et al., 2000).

The Bengal Deep Sea Fan *aka* Bengal Fan is the world's largest submarine fan. The sediments are tunnelled to the fan via a delta–front trough, the *Swatch of no Ground.* The sediment distribution patterns of the fan shows westward inclination, with the thickest accumulation of mud near the submarine canyon, *Swatch of No Ground* incises the western shelf thereby leading to westward transport of sediments (Kuehl et al., 1997). In view of the above understanding of the Bay of Bengal basin in the northern Indian Ocean and its sediment distribution and characteristics, detailed studies were carried on surface sections of sediments from nearly 17 cores distributed spatially in the Bay of Bengal (including the Andaman Sea) (Fig. 4.1). Details of cores used for the study is given in Table 4.1.
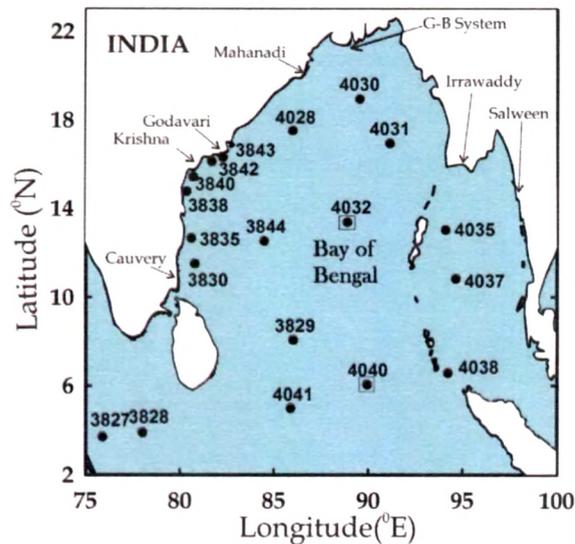

Fig. 4.1: *Core locations in the Bay of Bengal. Boxed filled circles are the two cores studied in detail. Rivers supplying sediment to the Bay are also identified.*

Sediment Distribution

Surface sections of the cores representing the contemporary sediment flux have been analyzed for CaCO$_3$, organic carbon (C$_{org}$), major and trace elements along with Sr and Nd isotopes to identify the source and distribution of modern sediments in the Bay of Bengal. Additionally, few river bed samples near the mouth of the Ganga (near Hooghly Estuary), Mahanadi, Godavari and Krishna Rivers that drain into the Bay of Bengal

Table 4.1: Location and water depth of the cores in the Bay of Bengal.

No.	Core No.	Latitude [^{o}N]	Longitude [^{o}E]	Water depth (m)
1	SS# 152-3827	3°42'	75° 55'	3118
2	SS# 152-3828	3° 54'	78° 4'	3166
3	SS# 152-3829	8° 3'	86° 02'	3669
4	SS# 152-3838	14° 46'	80° 21'	157
5	SS# 152-3840	15° 25'	80° 42'	193
6	SS# 152-3842	16° 7'	81° 41'	173
7	SS# 152-3843	16° 17'	82° 17'	690
8	SS# 152-3844	12° 31'	84° 29'	3327
9	SS# 172-4028	17° 30'	85°60'	2569
10	SS# 172-4030	18° 56'	89° 32'	1848
11	SS# 172-4031	16° 55'	91° 08'	2359
12	SS# 172-4032	13° 21'	88° 54'	3011
13	SS# 172-4035	13° 0.73'	94° 08'	2337
14	SS# 172-4037	10° 49'	94° 39'	3250
15	SS# 172-4038	6° 33'	94° 14'	1314
16	SS# 172-4040	6° 02'	89° 57'	2788
17	SS# 172-4041	4° 59'	85° 54'	4012

* SS- Sagar Sampada

were also analyzed for Sr and Nd isotopes (Fig. 4.1). The isotopic and geochemical composition of surface sediment composition of the Bay of Bengal is governed by three processes viz. detrital, biogenic and diagenetic, with detrital being the most dominant component. Major element geochemistry of the surface sediments show decreasing Al, Mg, Fe, and Ti concentrations from the coast to the open ocean (north to south, Fig. 4.3, Table 4.2), whereas the biogenic proxies CaCO$_3$, Sr, Ba show an increasing trend. A strong enrichment of Mn is observed in the surface sediment in near coastal

regions of G–B River system and the Irrawaddy River (Table 4.3). The correlation between organic carbon C$_{org}$ and CaCO$_3$ indicates increasing
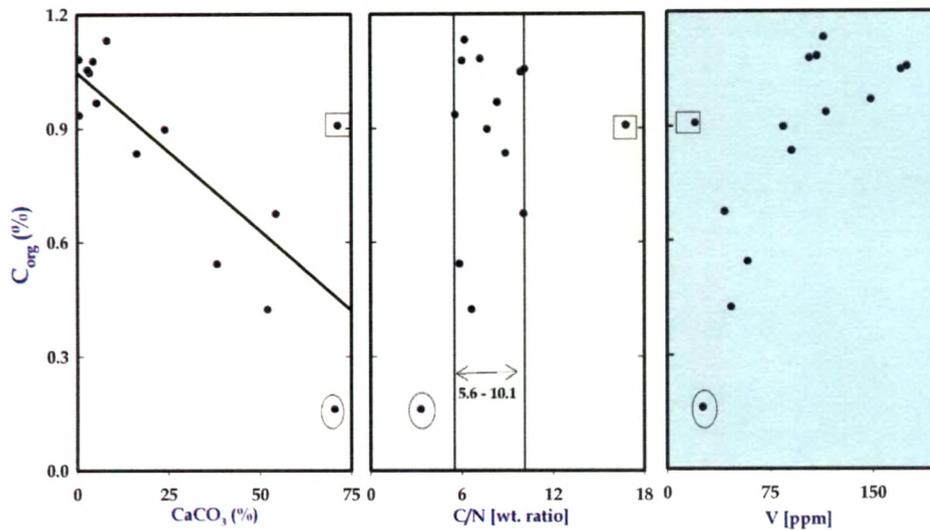
* The sample marked by box and circles is excluded for correlation and belongs to the station 3827, south of India and not from Bay of Bengal
# The sample marked by circle is from the southern Bay of Bengal

Fig. 4.2: *Correlation of Organic Carbon (C$_{org}$) in the surface sediments with CaCO$_3$, C/N ratio and V concentration. No apparent correlation of C$_{org}$ with C/N can be noticed indicating marine source of C$_{org}$.*

detrital contribution causing enhanced preservation of C$_{org}$ and decrease in CaCO$_3$. There is no apparent correlation of Corg with C/N indicates a predominant marine origin of the organic matter. This is corroborated by C/N ratio ranging from 5–10, typical for marine organic carbon. The V shows a positive correlation with C$_{org}$ due to its enrichment with increasing C$_{org}$ (Fig. 4.2).

Detrital Components

The composition, mineralogy and distribution of sediments in the Bay of Bengal reflects the strong physical and chemical weathering prevalent in the drainage basins of all the rivers flowing through the Indian subcontinent. This is strongly dependent on the monsoon intensity especially the SWSM. Besides this, the Bay of Bengal is also influenced by the NEWM. There are evidences

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Table 4.2: Concentration of trace elements, organic carbon (C_{org}), $CaCO_3$ and C/N ratio

in the surface sediments of the Bay of Bengal cores.

Core No.	Latitude (°N)	Longitude (°E)	Ni (ppm)	Cu (ppm)	Cr (ppm)	Sr (ppm)	Ba (ppm)	$CaCO_3$ (%)	C_{org} (%)	C/N
3827	3.7	75.91	48.8	37.5	21.1	1018	700	71.3	0.90	16.8
3828	3.893	78.03	47.3	39.2	23.5	749	685	69.1	--	--
3829	8.05	86.03	82.1	87.1	55.3	604	1116	38.2	0.54	5.8
3838	14.767	80.35	77.4	86.8	122.3	127	134	5.39	0.96	8.3
3840	15.415	80.70	64.4	115.9	103	147	150	5.55	--	--
3842	16.112	81.68	73.1	87.7	119.9	107	175	3.41	1.04	9.9
3843	16.29	82.28	71.1	102.1	114.4	110	188	2.89	1.05	10.1
3844	12.51	84.49	151.2	113.1	92.9	434	870	24	0.89	7.7
4028	17.5	86.00	89.4	57.1	114.6	101	404	0.61	1.08	7.2
4030	18.933	89.54	109.3	61.1	101.1	182	641	4.41	1.07	6.0
4031	16.917	91.14	136.8	70.8	88.9	343	826	16.3	0.83	8.9
4032	13.362	88.90	40.3	42.5	44.5	726	729	52	0.42	6.6
4035	13.012	94.12	71.9	45.7	94.7	288	535	8.13	1.13	6.2
4037	10.815	94.65	102.5	89.9	101.9	148	665	0.63	0.93	5.6
4038	6.553	94.24	22.2	19.6	26.3	701	2289	54.3	0.67	10.1
4040	6.032	89.94	21.5	26.9	19.6	923	730	70.4	0.16	3.3
4041	4.975	85.89	34.9	73.4	33.5	884	927	58.4	--	--

Table 4.3: Concentration of major and trace elements in the surface sediments of the Bay of Bengal cores.

Core	Latitude (°N)	Longitude (°E)	Al (%)	Fe (%)	Ca (%)	Mg (%)	Ti (ppm)	Mn (%)	V (ppm)	Zn (ppm)	Co (ppm)
3827	3.7	75.91	1.68	1.07	31.2	0.67	697	0.11	21	42	6.2
3828	3.893	78.03	2.13	1.31	29.5	0.64	859	0.11	22	41.3	7.1
3829	8.05	86.03	5.13	3.00	16.4	1.22	2344	0.43	59	90.2	22.6
3838	14.767	80.35	8.42	7.13	3.0	2.25	8088	0.08	149	79	36.1
3840	15.415	80.70	7.57	7.73	4.5	1.96	15340	0.97	230	94	50.7
3842	16.112	81.68	9.14	7.89	2.1	1.98	8358	0.94	171	90	40.7
3843	16.29	82.28	9.27	7.96	2.1	1.92	8545	0.08	175	96	39.4
3844	12.51	84.49	7.41	5.36	11.5	1.75	3530	0.55	85	124	35.3
4028	17.5	86.00	10.44	6.92	0.66	2.09	4074	1.69	109	152	32.3
4030	18.933	89.54	9.05	5.44	2.5	2.01	3889	1.70	104	152	32.2
4031	16.917	91.14	7.97	4.16	7.7	1.74	3155	1.16	91	149	27.4
4032	13.362	88.90	3.82	2.33	23.5	1.10	1567	0.16	47	51	13.4
4035	13.012	94.12	8.25	4.26	4.9	2.11	3007	2.13	114	84	17.5
4037	10.815	94.65	8.92	5.33	0.87	2.21	3214	2.05	116	104	23.4
4038	6.553	94.24	3.45	1.87	23.4	0.85	1360	0.06	42	56	8.1
4040	6.032	89.94	2.06	1.16	28.8	0.68	753	0.06	26	32	6.2
4041	4.975	85.89	3.21	1.89	25.4	0.81	1256	0.19	36	46	10.7

to suggest that both these monsoons have weakened or strengthened during the past several thousand years (Burton and Vance, 2000; Tiwari et al., 2005). At present, the SWSM is the most dominant and contributes abundant sediment flux to the Bay of Bengal.

The Al (%) distribution pattern of the surface sediments from the Bay of Bengal shows a large variation from 2–10% with the highest concentration towards the northern Bay of Bengal. The western Bay of Bengal shows an Al concentration of 9%. The Andaman Sea exhibits almost a uniform distribution of Al (8%) in the surface sediments (Fig. 4.3, Table-1). The open ocean Al concentration in the Bay of Bengal ranges from 4–7%. The decreasing pattern of Al concentration from the coast to the open ocean in the surface sediments of the Bay of Bengal is due to the decreased supply of detrital material to the open ocean and increasing concentration of the biogenic component (Siddique, 1967; Sengupta et al., 1992). The clay mineral assemblage in sediments from the eastern part of the Bay of Bengal is influenced by the G–B River system, in which the suspended particulates are dominated by illite and chlorite (Ramamurty and Shrivastava, 1979; Kolla and Rao, 1990; Rao, 1991; Kuehl et al., 1997; Weber et al., 1997; Goodbred and Kuehl, 1999; Rao and Kessarkar, 2001). The rivers draining the Himalayas have abundance of illite and chlorite compared to
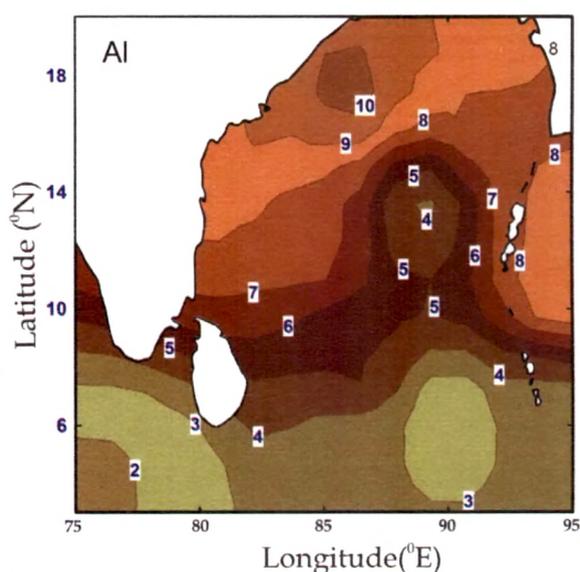
Fig. 4.3: Distribution of Al (%) in the Bay of Bengal surface sediments. Note, Al decrease from the coast to the open ocean.

those draining the Peninsular India. The latter are rich in smectite (Rao and Nath, 1988; Nath, 2001). Clay minerals are the principal carriers of Al_2O_3 with a wide range of concentrations ranging from 28.9% for illite, 25.2% for chlorite, 19.8% for smectite and 38.5% for kaolinite (Degens, 1967). The very high concentration of Al in the northwestern Bay of Bengal (see Fig. 4.3) are due to the sediments enriched with kaolinite brought by the peninsular rivers such as the Mahanadi and Brahamani and rivers draining the Eastern Ghats. Although, the peninsular rivers such as Godavari and Krishna bring sediments enriched with smectite, which has nearly half the Al content compared to kaolinite, the Al concentration in the western Bay of Bengal (off Godavari and Krishna) are comparable to the northern Bay of Bengal (off G-B River) and, a patch of high Al concentrations distinctly occurs in the northwestern Bay of Bengal. This suggests that the influence of sediments derived from G−B River system is insignificant in the northwestern pasrt (off Mahanadi and Brahamani Rivers), may be due to strong northeasterly currents prevailing during the SW monsoon. The Al content in the Andaman Basin is similar to that observed in the Bay of Bengal.

Unlike Al, Ti content increases from granites (~0.3%) to basalts (1.5%) (Lisitisyn, 1996). However, some of the highest concentrations are observed in the western Bay of Bengal unlike that shown by Al due to the sediment contribution from basaltic terrain by the peninsular rivers. The Ti concentration varies from 2000–8000 ppm with
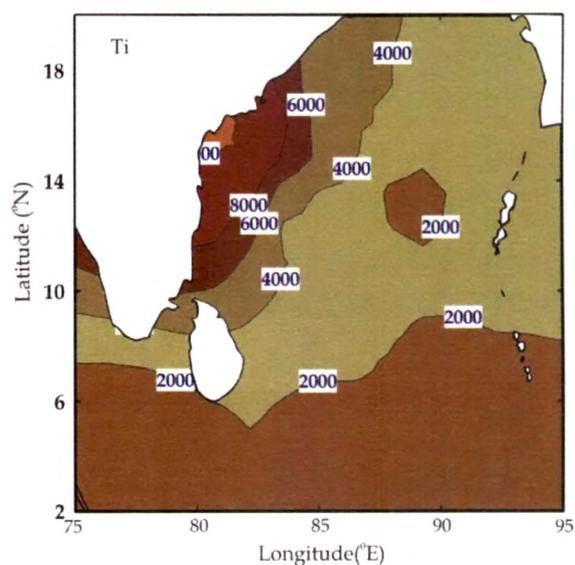

Fig. 4.4: Distribution of Ti (ppm) in the surface sediments of the Bay of Bengal.

decreasing concentration from the coast. Even the Andaman Basin sediment too shows lower values as reflected by the open ocean of 2000 ppm.

In sediment trap, the Al/Ti ratio is found to be much higher when compared to the typical crustal value, thereby implying a non–crustal source of excess Al in the Bay of Bengal. The analyses of sediments from the equatorial Pacific Ocean with low particulate flux of lithogenic material showed that excess Al is associated with the opal rain to the seafloor. In view of this, it has been suggested that Al can be used as a proxy for paleoproductivity, though it should be limited to only productive, open ocean areas which are not strongly influenced by inputs of aluminosilicates (Dymond et al., 1997; Pattan and Shane, 1999).

The distribution of Fe in the Bay of Bengal resembles to the distribution pattern of Ti with its highest concentration on the western shelf areas. The Fe concentration in sediments increases from acidic rocks to basalts and it is one of the most widespread elements in the earth's crust. The enhanced Fe concentrations observed towards the western Bay of Bengal are due to the

Fig. 4.5: Distribution of Fe (%) in the surface sediments of the Bay of Bengal. Western Bay of Bengal show Fe rich sediments, contribution from peninsular river.

contribution of Fe rich sediments from the peninsular rivers. The Fe content in the western Bay of Bengal ranges from 5–7% while in the eastern Bay of Bengal it is about 3–5% (Fig. 4. 5).

The ionic radius of chromium (Cr, 0.06 nm) is close to that of Fe (0.067 nm) and its concentration increases from granite (~10 ppm) to basalt (~300 ppm) and particularly in ultrabasic rocks (~0.4%). Thus, expectedly, some of the higher concentrations of 90–110 ppm of Cr are observed in the western Bay of Bengal that is influenced by the sediment derived from basaltic rocks of the peninsular India (Fig. 4.6). A general decreasing trend from the coast to the open ocean is observed in the Cr distribution attesting to its terrestrial source. The concentration of vanadium (V) varies like that of Cr but it decreases sharply in ultrabasic rocks (~50 ppm).
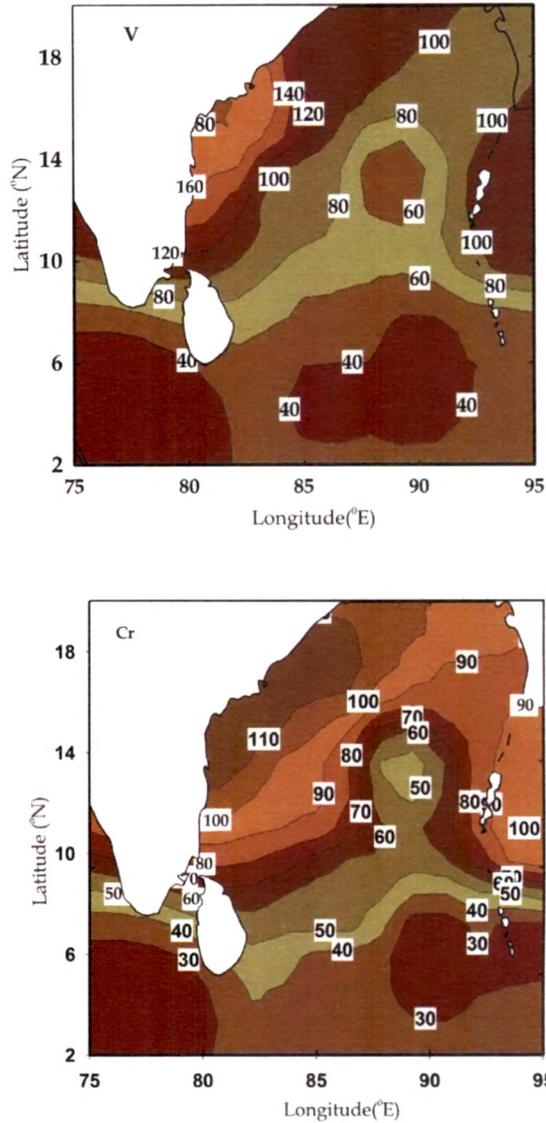
Fig. 4.6: Distribution of V and Cr in the surface sediments. Erosion of Basaltic rocks from the peninsular India is responsible for higher V and Cr in western region.

Some of the highest concentration of Cr in the Bay of Bengal is observed in the western region which is due to the erosion of basaltic rocks in the drainage area of the peninsular rivers (Fig. 4.6). Thus, distribution of V in sediments is an indicator of material from upper basaltic layers, whereas, Cr is an indicator of the lower basaltic layers.

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The manganese (Mn) content increases from 0.05% in granites to 0.17% in basalts. Thus, it is to be expected that the high Mn concentrations in the surface sediments have been derived from the basaltic drainage areas, which in the present case lies in western region
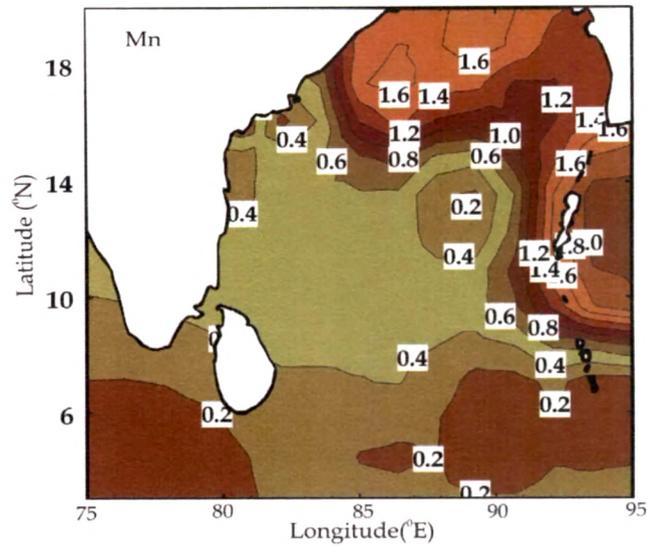

Fig. 4.7: Distribution of Mn (%) in the surface sediments of the Bay of Bengal. Higher Mn concentrations in the northern Bay of Bengal is due to enrichment of surface sediments in high sedimentation regions.

of the Bay of Bengal. However, the surface sediments of the western Bay of Bengal do not show high Mn concentration, whereas unexpectedly the northern Bay of Bengal sediments are highly enriched in Mn (Fig. 4.7). As mentioned earlier, the northern Bay of Bengal receives high sediment flux from the G–B River system. The enhanced sedimentation leads to preservation of organic matter which undergoes slow degradation within the sediments. The diagenetic changes in high sedimentation regions cause Mn from deeper sections to migrate upward to the surface (Chauhan and Rao, 1999: Mangini et al., 2001). Similar trend is observed in the northern Andaman Basin where enhanced sediment flux is contributed by the Irrawaddy and Salween Rivers (Rodolfo, 1969). Over all, detrital proxies show a decreasing trend from coast to the open ocean, due to the fact that majority of the sediment are deposited in the coastal environment.

Biogenic Components

The integrated primary productivity of the Bay of Bengal ranges from ~90–220 mg.C.m^{-2}.d^{-1} which is significantly lower compared to ~770–1780

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mg.C.m^{-2}.d^{-1} observed in the Arabian Sea. The high productivity in the Arabian Sea is attributed to the advection of nutrient-rich waters to the euphotic zone, whereas, in the Bay of Bengal inability of the weaker winds to erode the strongly stratified surface layers leads to reduced vertical mixing and hence the low productivity (Prasanna Kumar et al. 2002). Carbonate, which is contributed by the planktonic foraminifers, constitutes the major fraction of productivity in the Bay of Bengal. As a result, terrestrial contribution gets diluted by the carbonate production (Kolla et al., 1976a). The calcium carbonate content of the sediments ranges from ~2–70%. The highest concentration of CaCO$_3$ in the surface sediments of the Bay of Bengal is towards the open ocean where the contribution of the detrital component is least and lowest concentration is observed near the coastal regions (Fig. 4.8). The total Ca content of the sediment in the region is mainly due to CaCO$_3$ with a minor fraction of it coming from the dolomitic detrital sediments (Kolla et al., 1976a; Kolla and Rao, 1990). The Ca distribution of the surface sediments closely resembles to that of CaCO$_3$ suggesting a biogenic origin and it ranges from 2–28% (Fig. 4.8).
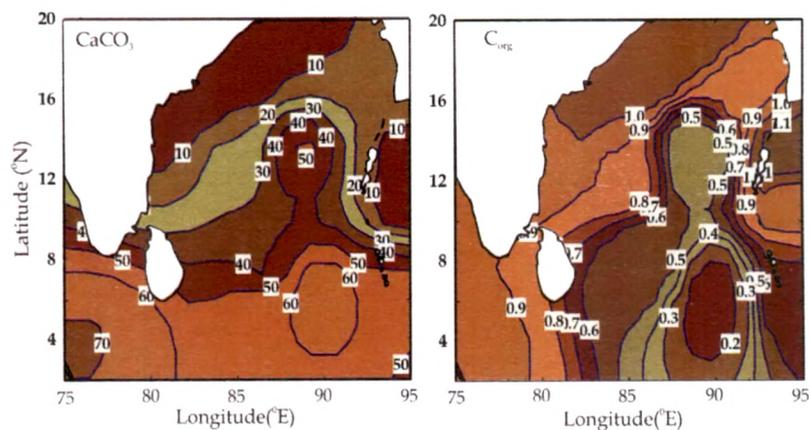

Fig. 4.8: Distribution of CaCO$_3$ and organic carbon (C$_{org}$) in the surface sediments of the Bay of Bengal. Increasing CaCO$_3$ from the coast to the open ocean indicates decreasing detrital contribution. Whereas, high C$_{org}$ near the coast reflects its enhanced preservation with increasing detrital flux.

Barium (Ba) is another productivity indicator and shows an increasing concentration from coast (~200 ppm) to the open ocean (~1000 ppm) thereby

indicating dilution caused due to the continental flux in the Bay of Bengal (Fig. 4.9). Strontium (Sr) concentration too shows a trend similar to that as observed for Ba thus mimicking as a productivity indicator.

While in the coastal sediments, organic carbon (C_{org}) content can be used as a productivity indicator, its reliability in the open ocean is suspect as around 98% of C_{org} gets oxidized in the water column during its traverse to the bottom sediments. In view of this, the decreasing trend of C_{org} in the Bay of Bengal sediments from coast to the open ocean is indicative of the preservation characteristics of the C_{org} rather than productivity (Fig. 4.8). Higher C_{org} near the coast suggests faster sedimentation rates and thereby better
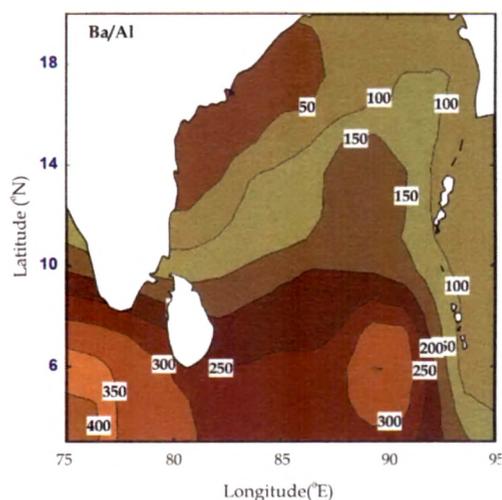

Fig. 4.9: Distribution of Ba/Al (ppm/%), productivity proxy in the surface sediments of the Bay of Bengal. Dilution of Ba due to increasing continental flux from coast to the open ocean can be observed.

preservation and for the open ocean low sedimentation rate makes it susceptible to oxidation. Naqvi et al. (1996) found lower respiration rates in the Bay of Bengal due to the weak north–south gradients in oxygen and total CO_2, conflicting with the higher sinking fluxes of organic carbon measured with sediment traps. Large terrigenous input in the Bay of Bengal is attributed for lesser degree of oxidation of particulate organic carbon in the water column as particulate organic matter gets protected from degradation by the inorganic matrix of the sinking particles (Hedges et al. 2001).

Strontium (Sr) and Neodymium (Nd) Isotopic Distribution

The large variation in Sr and Nd isotopic composition in the Bay of Bengal has been attributed to variable contribution from Himalayan and Trans−Himalayan lithologies (Colin et al., 1999; Galy et al., 1996; France−Lanord et al., 1993; Pierson-Wickman et al., 2001; Singh and France−Lanord, 2002). The higher erosion in

Fig. 4.10: $^{87}Sr/^{86}Sr$ and ε_{Nd} of the river mouth samples measured. Irrawaddy river data from Colin et al.. (1999).

the eastern syntaxes compared to other Himalayan ranges is related to rapid exhumation rates of this region, triggered by higher precipitation and the high incision potential of the Tsang Po River aka Brahmaputra River (Singh and France−Lanord, 2002). The enormous volume of sediments brought to the Bengal Fan is contributed from different Himalayan lithologies having distinct isotopic composition. They are High Himalaya Crystalline (HHC; $^{87}Sr/^{86}Sr$ = 0.75 and ε_{Nd} = −16), Lesser Himalaya (LH; ≥ 0.8 and −25) and Tethyan Sedimentary Series (TSS; ≤ 0.72 and −12 to −4) (Colin et al., 1999; Galy et al., 1996, 1999; Galy and France−Lanord, 1993; Singh and France−Lanord, 2002; Singh et al, 2008). The $^{87}Sr/^{86}Sr$ of the Bengal Fan turbidites ranges from 0.74−0.76 and ε_{Nd} values of −16 are similar to the High Himalayan Crystalline (France−Lanord et al., 1993). This indicates that the primary source of sediments to the Bengal Fan has been dominated by the sediments from the HHC (France−Lanord et al., 1993; Galy et al., 1996).
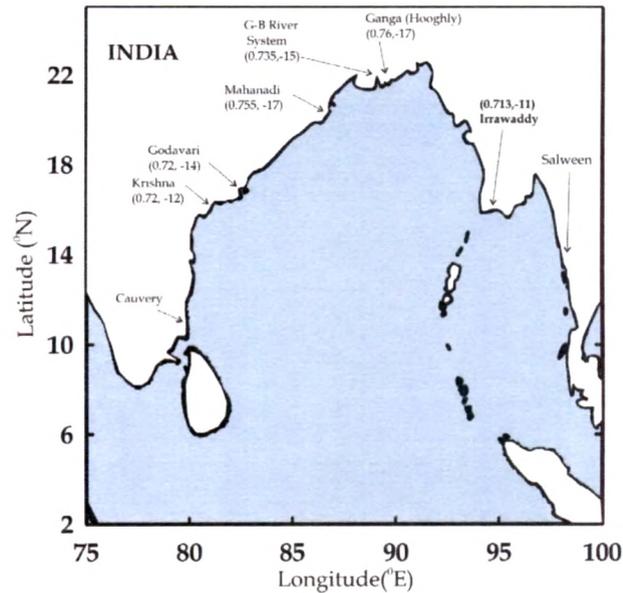
However, relatively lower values of $^{87}Sr/^{86}Sr$ observed in the sediments of the Bay of Bengal indicate other sources of sediment and are attributed to the peninsular rivers viz. the Krishna and Godavari (Subramanian 1980; Wijayananda and Cronan 1994). Based on the nature of distribution of elemental and isotopic composition of Sr and Nd in the Bay of Bengal (Colin, et al., 1999), four possible end members have been identified. These are the G–B River system ($^{87}Sr/^{86}Sr > 0.735$ and $\varepsilon_{Nd} < -15$), Irrawaddy River (≈ 0.713, ≈ -11) and the Peninsular Rivers (≈ 0.708, -18.0) (Ahmad et al., 2005). The fourth member has been inferred as derived from the detrital material from the erosion of the western part of the Indo–Burmese ranges, along the Arakan coast (≈ 0.716, -7.0).

Table 4.4: $^{87}Sr/^{86}Sr$ and ε_{Nd} in the silicate fraction of the surface sediments from the cores in the Bay of Bengal.

Core	Latitude (°N)	Longitude (°E)	$^{87}Sr/^{86}Sr$	Sr (ppm)	ε_{Nd}	Nd (ppm)
3827	3.7	75.908	0.7099	633	-12.97	22.2
3828	3.893	78.033	0.7070	---	-13.86	23.1
3829	8.05	86.033	0.7110	555	---	---
3830	11.495	80.792	0.7208	144	---	---
3835	12.655	80.618	0.7126	499	-17.5	27.1
3838	14.767	80.35	0.7204	82	-12.92	30.9
3840	15.415	80.695	0.7152	174	-17.74	31.5
4028	17.5	85.997	0.7332	94	---	---
4030	18.933	89.538	0.7268	120	-14.6	32.0
4031	16.917	91.14	0.7136	202	-12.72	30.0
4032	13.362	88.9	0.71721	174	---	---
4035	13.012	94.118	0.7125	158	-8.95	28.0
4037	10.815	94.645	0.7164	117	-10.21	33.8
4038	6.553	94.235	0.7138	179	-11.55	24.7
4040	6.032	89.942	0.7125	283	-11.1	29.3
4041	4.975	85.892	0.7134	378	---	---

The Sr and Nd isotopic composition of the silicate fraction of 16 surface sediments of the Bay of Bengal (Table 4.4) and bed sediments of the estuarine regions of the Ganga (Himalaya), Mahanadi, Godavari and Krishna

(peninsular) Rivers near their mouth were analyzed in order to ascertain the sediment provenance (Fig. 4.10).

The high $^{87}Sr/^{86}Sr$ (0.725–0.735) and low ε_{Nd} (−18 to −12) of the surface sediment samples of the northern Bay of Bengal indicate strong G−B River system influence. However, samples from

Fig. 4.11: $^{87}Sr/^{86}Sr$ and ε_{Nd} of surface sediment samples.

the western Bay of Bengal show mixed signatures of Sr and Nd isotopes
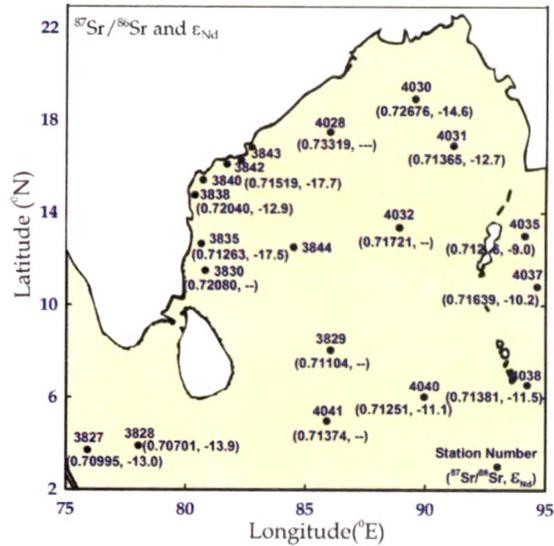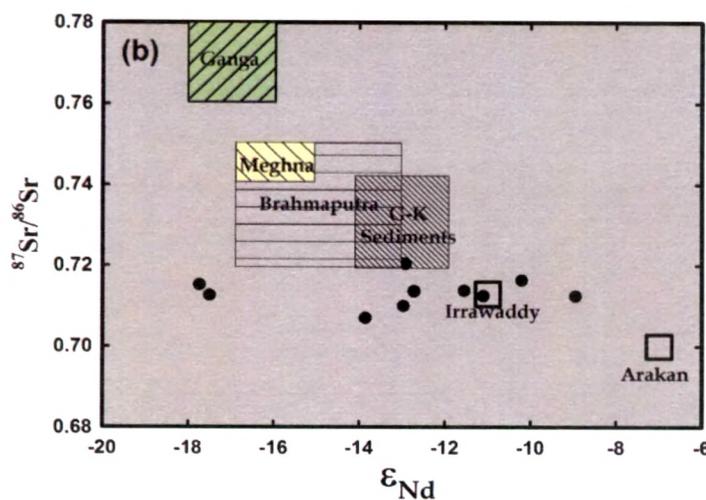
Fig. 4.12: $^{87}Sr/^{86}Sr$ versus ε_{Nd} plot of surface sedments. Also, shown are the boxes representing the end members. G-K (Godavari-Krishna) sediments values are the river mouth value.(Singh et al., 2008; Colin et al., 1999; Ahmad et al., 2005).

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derived mainly from the rivers draining the eastern continental margin of India, viz. Mahanadi, Godavari, Krishna and Cauvery. The low radiogenic Sr with high enriched ε_{Nd} in surface sediment samples from the Andaman Sea indicate the Irrawaddy River as the main contributor. The measured value of $^{87}Sr/^{86}Sr$ value of Ganga at Hooghly Estuary in bed sediments was 0.76 and ε_{Nd} of −16, for Mahanadi 0.755 and −17, for Godavari 0.72 and −14 and Krishna with 0.72 and −12. The Godavari and Krishna (G−K)
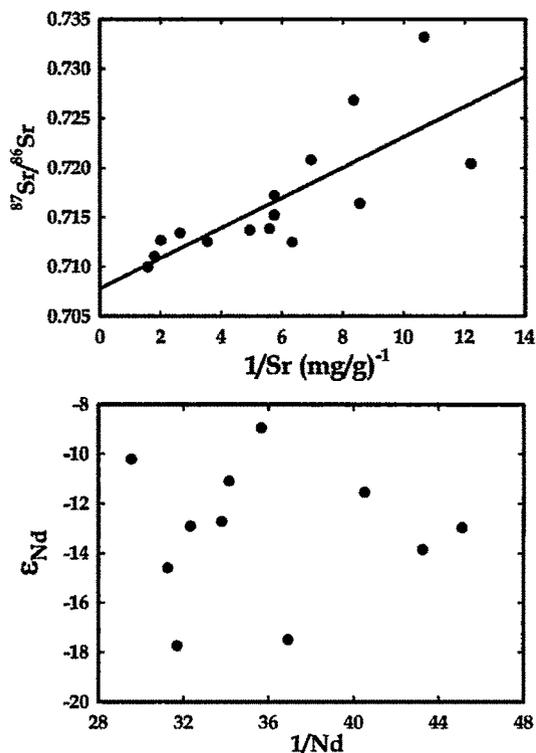

Fig. 4.13: $^{87}Sr/^{86}Sr$ vs 1/Sr and ε_{Nd} versus 1/Nd plot of the surface sediment.

River drain into the Bay of Bengal and contribute sediments from Deccan Traps and Archean basement of peninsular India (Archean). The $^{87}Sr/^{86}Sr$ and ε_{Nd} of the sediments analysed as part of this study are shown in Fig. 4.11. The $^{87}Sr/^{86}Sr$ of these sediments is 0.706 and ε_{Nd} of −18 (Fig. 4.12; Ahmad et al., 2005). But if we look into the $^{87}Sr/^{86}Sr$ isotopic ratio in the sediments at the junction with the Bay of Bengal, the values are significantly high. This implies the magnitude of the G−B River system influencing the sediment budget and also assisted by the channeling caused due the presence of the 90° East Ridge. This ridge acts as a barrier for the sediment movement towards east (Fig. 4.12). The mixing plot of Sr isotopic ratio versus 1/Sr of the sediments from the Bay of Bengal broadly indicates three sources of sediment to the basin (Fig. 4.13). Three components viz. the G−B River system, Irrawaddy River and the Peninsular Rivers are possibly responsible for the isotopic distribution of
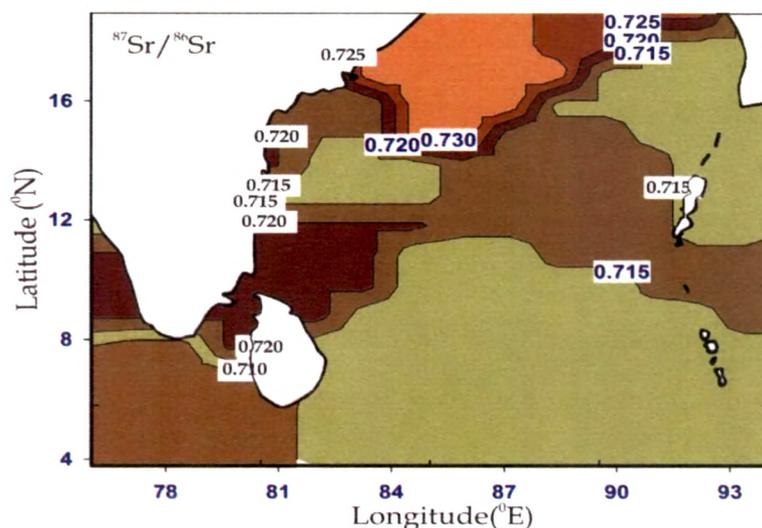
Fig. 4.14: Contour plot of $^{87}Sr/^{86}Sr$ distribution of sediments in the Bay of Bengal.

Sr and Nd. Similarly, the isotope plot of $^{87}Sr/^{86}Sr$ and ε_{Nd} shows that sediment distribution in the region is governed by the three end–members. The main sediment source seems to be G–B River system controlling the isotopic composition in the Bay of Bengal (Fig. 4.13). The Andaman Sea sediments are predominantly controlled by the Irrawaddy River. The sediments in the eastern Bay of Bengal and the northeastern Bay of Bengal display Sr and Nd isotopic characteristics possibly from two end members viz. G –B River system and Irrawaddy River (Fig. 4.14, 4.15). However, Colin et al., 1999 invoke another component of sediments from the Arakan coast responsible for such isotopic characteristics. It is likely that the Irrawaddy River can bring sediment into the Bay of Bengal through Arakan coast, while the Arakan coast by itself, can not account for large supply of the sediments resulting in such isotopic excursions in the sediments from the northeastern Bay of Bengal.

Once the sediment is brought into the Bay of Bengal, its dispersal is controlled by the surface circulation pattern. The surface circulation of the Bay of Bengal experiences seasonal reversal with East India coastal Current (EICC) flowing northeastward during summer monsoon from February until

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September with a strong peak in March–April and it flows south–eastward during winter monsoon from October to January with the strongest flow in November (Shetye et al., 1996). During the winter monsoon, it is expected that sediments draining
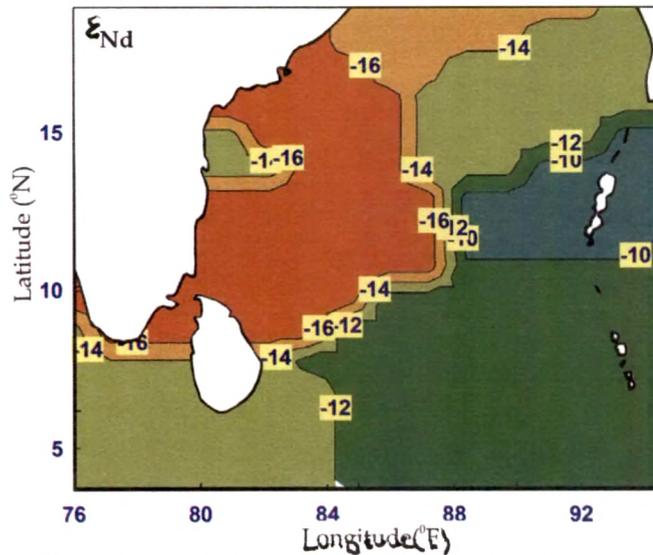

Fig. 4.15: Contour plot of ε_{Nd} distribution of sediments in the Bay of Bengal. Note, third end member with high ε_{Nd} from the eastern Bay of Bengal along the coast of Arakan through Irrawaddy River

from the Irrawaddy River are brought by the EICC to the Bay of Bengal through the Preparis channel. This seems to be a plausible mechanism for the lower values of $^{87}Sr/^{86}Sr$ and ε_{Nd} in the eastern Bay of Bengal. The $^{87}Sr/^{86}Sr$ and ε_{Nd} isotopic composition of the sediment from the station 4032 located strategically between two major sources (G–B and Irrawaddy River) show a mixed isotopic composition to attest for this assumption.