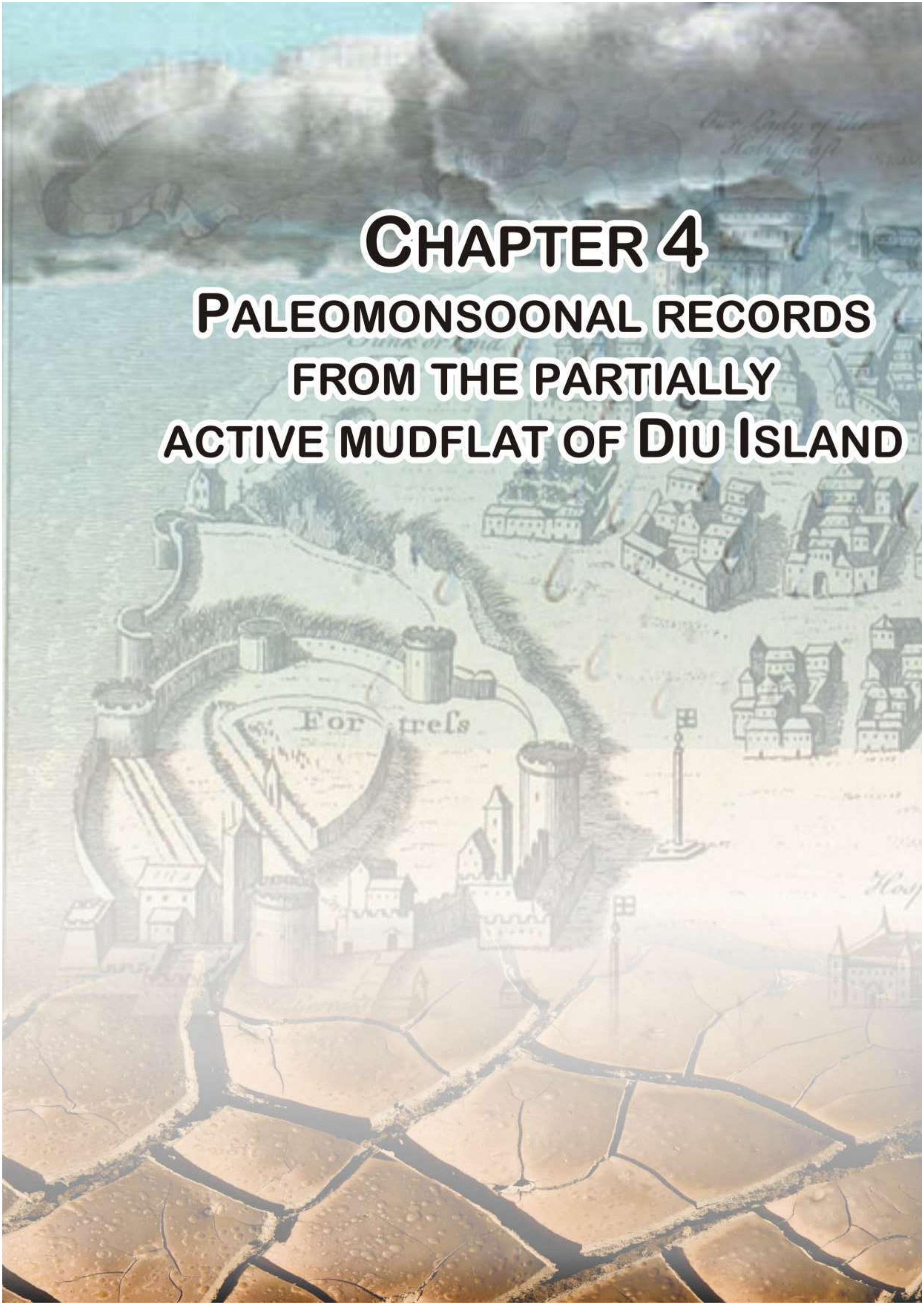

Chapter 4
Paleomonsoonal records from the partially active mudflat of Diu Island

4.1 Partially active mudflat: Diu

Globally, a significant amount of work has been carried out on Holocene climatic reconstruction. Similar is the case for Indian subcontinent wherein various marine and continental records have provided mid Holocene climatic history. Gujarat, the westernmost state India has also been studied for its mid Holocene climatic reconstruction, but most of the studies focused on mainland Gujarat. The present study is an attempt to reconstruct climatic history from the proxy records of Saurashtra peninsula.

Reconstruction of the high resolution climate from the partially active mudflats has been attempted from Diu Island and adjoining area, Southern Saurashtra Coast. Nearly 70 cm long sediment core DV was retrieved from the northern coast of Diu Island (20°44’53.4’N; 71°0’0.2”E) in the mudflat region. This site is inundated during exceptionally high tide and is exposed during low tide.

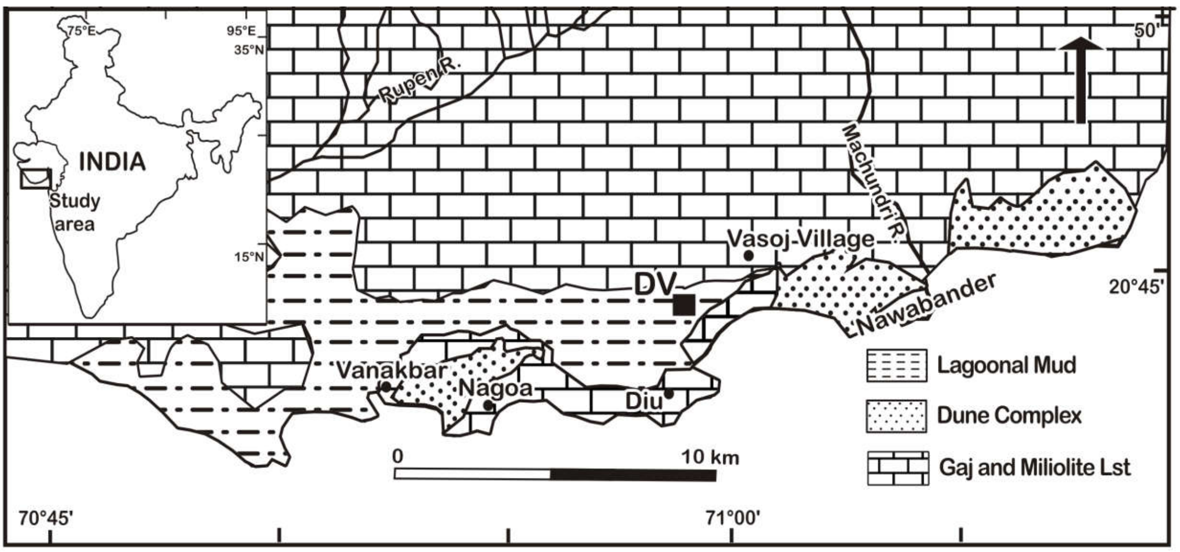

Figure 4-1. Core location of the active mudflat of Diu located approximately 0.5 km away from the relict mudflat. The sampling location is marked by Black Filled Square (Modified after Pant and Juyal, 1993).

4.2 Chronology

AMS radiocarbon dates are obtained on the organic carbon fraction of the sediment core from Diu (DV). The radiocarbon dates obtained for the core from depth 41 cm and 69 cm yielded ages of 2975 ± 40 and 3950 ± 40 yr BP respectively. The radiocarbon ages thus obtained are calibrated by mixed Marine Northern hemisphere calibration curve (Stuiver et al., 1998; Reimer et al., 2009; Reimer et al., 2013) using CALIB 7.0. The reservoir age correction (ΔR) of 165 ± 57 yr (Dutta et al., 2001; Southon et al., 2002) for the northern Arabian Sea region has been applied to the calibrated ages.The calibrated ages thus obtained are 2815 ± 50 cal yr BP at depth 41 cm and 4040 ± 60 cal yr BP at depth 69 cm (Fig.4–2). The surface is considered as present, as it is well preserved and the region receives sediments during high tides. As 1950 AD is taken as the present for C-14 ages, to normalise to the year of collection (2012), 64 yr has been added to the calibrated dates. Thus, the ages used for the 41 and 69 cm depths were 2880 ± 50 and 4105 ± 60 cal yr BP respectively. The sedimentation rate observed for this core is very low ranging from 0.14 to 0.23 mm/yr. As discussed in chapter-3, the sedimentation in relict mudflat (VV) occurred only during 4710–1500 cal yr BP. The core was raised from the partially active mudflat of Diu (DV), which indicates near continuous sedimentation during 4105 to 70 cal yr BP (Fig.4–2).

4.3 Results

In order to reconstruct the climatic history during last 4000 yr BP, various geochemical proxies are analysed for ascertaining temporal variations in detrital, productivity and salinity proxies to the study area. Geochemical proxies such as Al_2O_3, FeO, MgO, TOC/TN, Cu, Ni, Zn, Ba and Co are estimated to derive variations as a function of detrital flux, while $CaCO_3$, TOC, CaO/Al_2O_3, Cu/Al_2O_3, Ni/Al_2O_3, Sr/Al_2O_3

have been estimated to study the downcore variation in the in-situ productivity during last 4000 yr BP. MgO/[CaO+MgO] calculations have been done to ascertain the salinity variations in the region (Sinha et al., 2006).

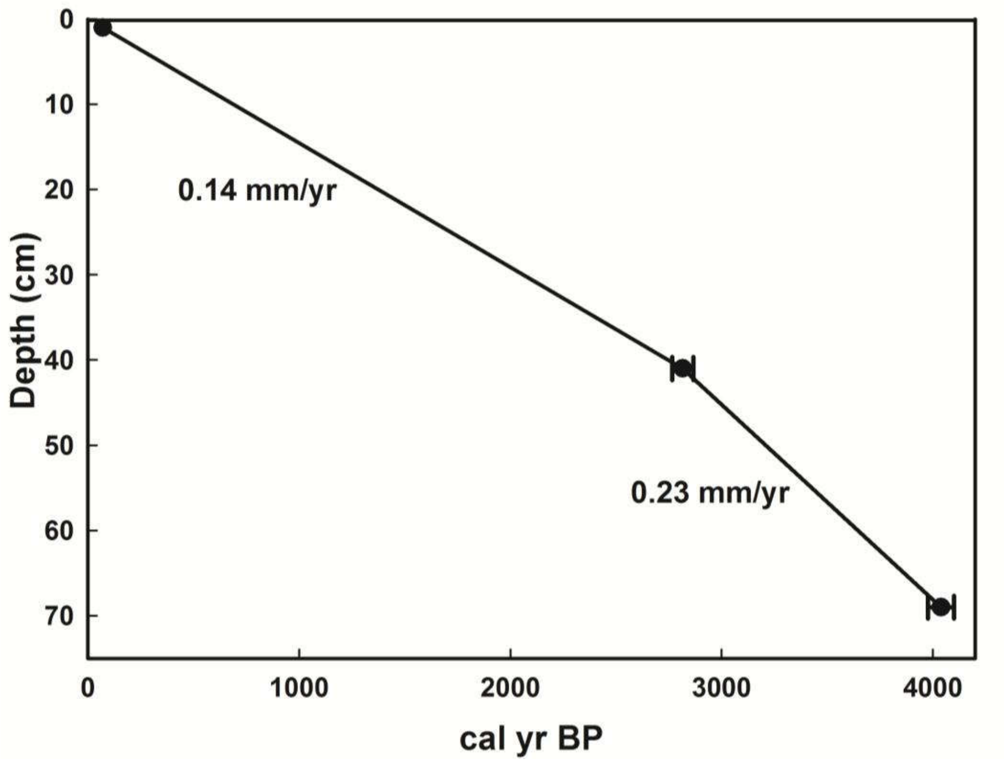

Figure 4-2. Age-Depth Model for Diu active mudflat (DV). The surface has been taken as present as the region receives sediment during exceptionally high tides.

Based on the distinguishable variations in geochemical proxies, the entire core has been divided into four units. From bottom to upwards, Unit-I ranges between 70–40 cm (4105–2880 cal yr BP), Unit-II ranges from 40–26 cm (2880–1930 cal yr BP), Unit-III with depth 26–6 cm deposited during 1930–355 cal yr BP and Unit-IV with depth of 6 cm to surface deposited during 355–70 cal yr BP.

(a) Unit-I (70–40 cm; 4105–2880 cal yr BP)

The major element concentrations (Al_2O_3, CaO, MgO and FeO) in the Unit-I ranges from 5.4–12.8 %, 5.3–24.3 %, 2.6–5.3 % and 4.5–11.2 % respectively (Fig.

4–3), while the $CaCO_3$, TOC (Fig. 4–5) and TOC/TN (Fig. 4–3) values are between 5.6–34.2 %, 0.36–1.17 % and 12.8–23.8. The trace element concentrations of Cu, Ni, Zn, Ba and Co range from 35–86 ppm, 34–59 ppm, 22–74 ppm, 182–265 ppm and 21–47 ppm (Fig. 4–4). The $\delta^{13}C$ and $\delta^{15}N$ value range from -22.7 to -19 ‰ and 7.3 to 3.2‰ respectively (Fig. 4–7).

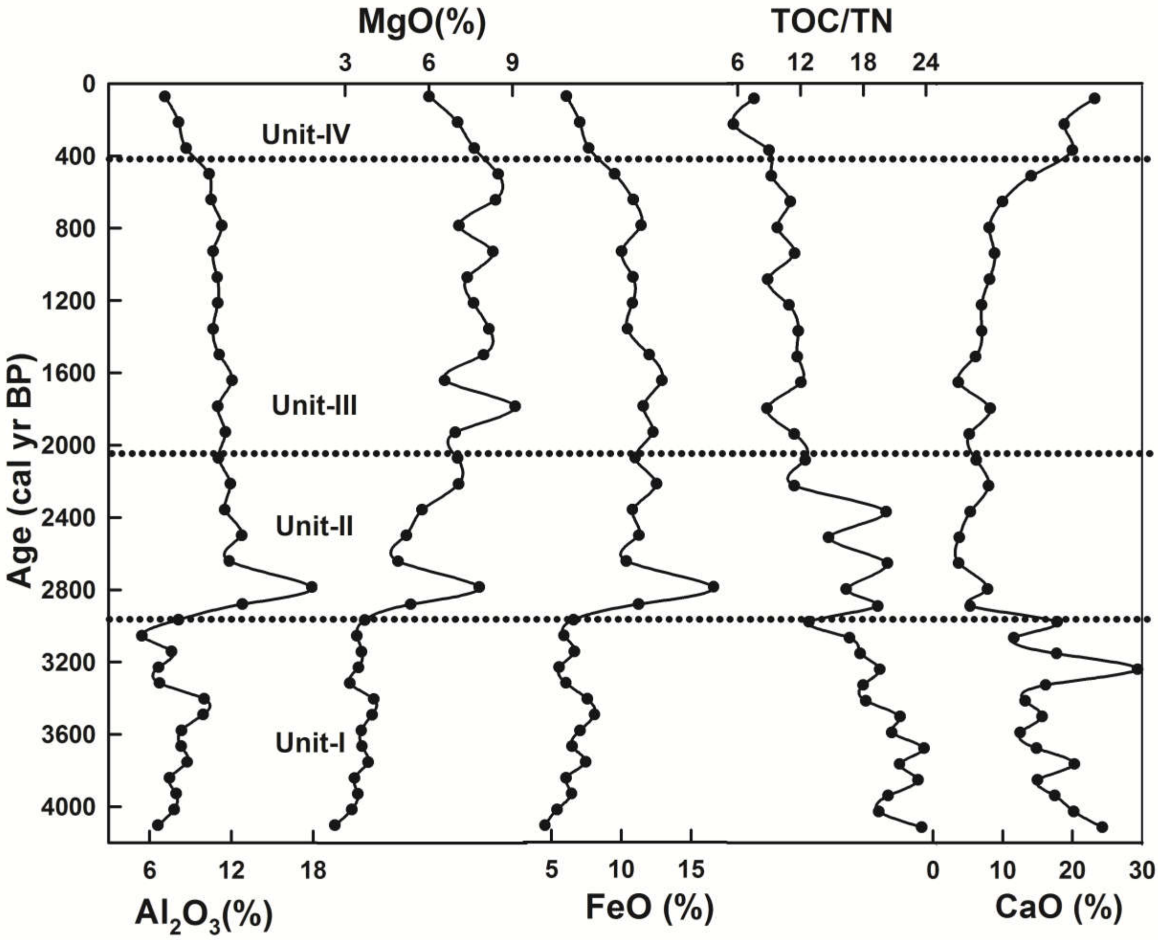

Figure 4-3. Downcore variation of the major elements during the last 4000 yr BP for the partially active mudflat of Diu (DV). An abrupt increase in the terrestrial proxy is indicated between 2800–3000 cal yr BP.

The terrestrial tagged elements of Unit–I show a fluctuating trend with increased values after 3230 cal yr BP till 2790 cal yr BP, and a gradual decrease in the Cu/Al_2O_3, Ba/Al_2O_3, CaO/Al_2O_3, Sr/Al_2O_3 and Ni/Al_2O_3 from the bottom to top (Fig.

4–5). From 3755–2880 cal yr BP, CaO/Al_2O_3, Sr/Al_2O_3, Ni/Al_2O_3, Cu/Al_2O_3 and $CaCO_3$ show marginally enhanced values. Similarly, the general trend of $CaCO_3$, TOC and TOC/TN indicat high values at the bottom with decreasing trend towards top of the Unit-I. In the case of $CaCO_3$, an enhanced value has been observed from 3405–2880 cal yr BP, while TOC shows increased value near termination of the deposition of Unit-I (< 2970 cal yr BP) with TOC/TN values >12 indicating terrestrial origin. The trace elements viz. Cu, Ni, Co, Zn and Ba along with the detrital tagged elements Al_2O_3, MgO and FeO too followed a similar trend indicating their land derived origin. The $\delta^{15}N$ showed enriched values during the deposition of Unit-I with moderate fluctuations. In the case of $\delta^{13}C$, depleted values during 4105 cal yr BP with a gradual increasing trend towards 2880 cal yr has been observed.

(b) Unit-II (40–26 cm; 2880–1930 cal yr BP)

In this Unit, the major elemental concentration for Al_2O_3, CaO, MgO and FeO ranges from 11.1–17.9 %, 3.7–8 %, 4.9–7.8 % and 10.4–16.6 % (Fig. 4–3). While the $CaCO_3$, TOC and TOC/TN contents range from 2.6–7.5 %, 0.76–1.0 % and 11.4–20.3 respectively (Fig. 4–4). The trace elemental concentration for Cu, Ni, Zn, Ba and Co varies between 69–118 ppm, 48–80 ppm, 43–114 ppm, 222–327 ppm and 28–48 ppm (Fig. 4–3). The $\delta^{13}C$ and $\delta^{15}N$ value varies between -21.2 to -18.9 ‰ and -1.6 to 6.5 ‰ respectively (Fig. 4–7).

The transition between Unit-I and Unit-II (2860–2635 cal yr BP) shows a marked shift towards enhanced signatures of detrital (Al_2O_3, FeO and MgO) and trace elements (Cu, Ni, Zn, Ba and Co).

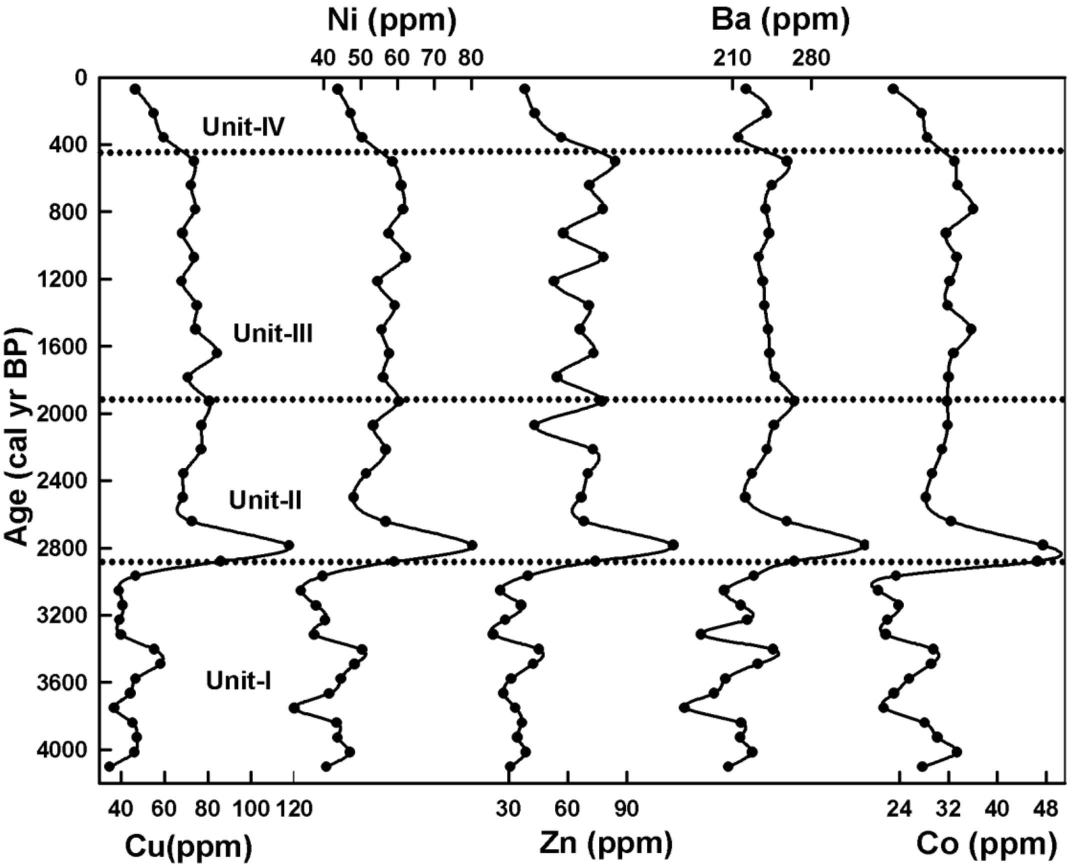

Figure 4-4. Downcore variation of the trace elements during last 4000 yr BP in the Diu partially active mudflat (DV).

The detrital proxies such as Al_2O_3, FeO and MgO do not show much fluctuation during this phase. Unlike Unit-I, low and consistent values for Ba/Al_2O_3, CaO/Al_2O_3 and Sr/Al_2O_3 have been observed in Unit-II. However, Cu/Al_2O_3 and Ni/Al_2O_3 show a prominent decrease during 2785–2215 cal yr BP with a marginal decrease in Ba/Al_2O_3 has been observed showing increasing trend by end of the deposition of Unit-II (Fig.4–5). In the case of $CaCO_3$ and TOC, consistent values with no major fluctuation has been noticed. However, during the transition zone between Unit-I and Unit-II, increased TOC concentration has been observed during 2880 cal yr BP, while in case of TOC/TN, the values remained >12 and showed fluctuating values till 2215 cal yr BP indicating a contribution of terrestrial organic carbon in the region.

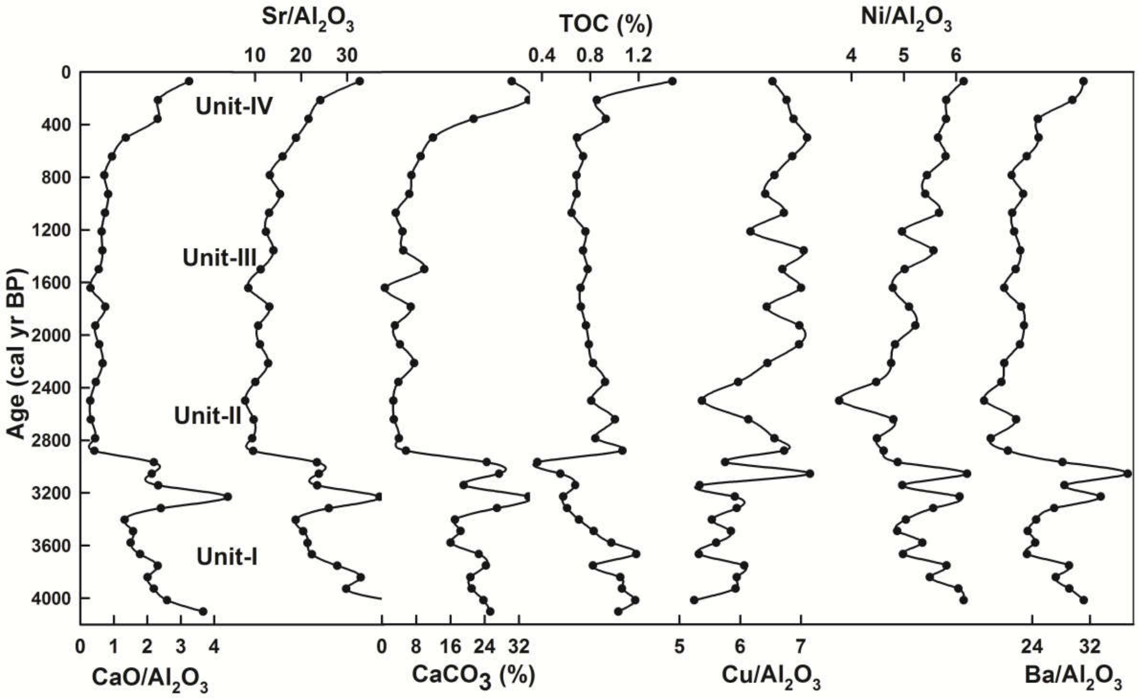

Figure 4-5. Downcore variation of the productivity proxies during last 4000 yr BP in the Diu partially active mudflat (DV). High productivity during 4000 cal yr has been indicated with a declining trend towards top.

After 2215 cal yr BP, values of TOC/TN with <12 have been observed indicating a reduction in the terrestrial organic carbon inputs. MgO/[MgO+CaO] values are significantly higher than those observed in Unit-I (Fig.4–6). Both FeO/Al_2O_3 and MgO/Al_2O_3 show low values in the beginning of the deposition of Unit-II with an increasing trend till 1930 cal yr BP. Enriched values of $\delta^{15}N$ has been observed till 2355 cal yr followed by an abrupt depletion after 2355 cal yr BP. In the case of $\delta^{13}C$, though the values fluctuate, they indicate a range within the mixed terrestrial and marine environment.

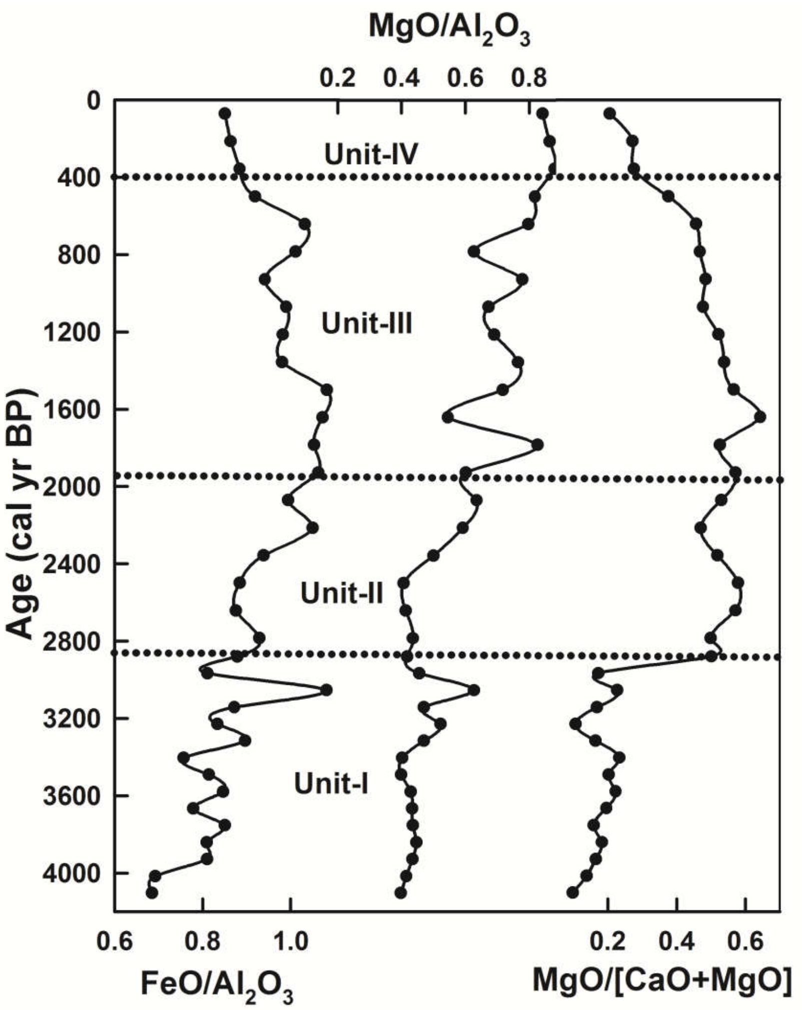

Figure 4-6. Downcore variation of weathering proxy and the salinity indicator during last 4000 yr BP in the Diu partially active mudflat (DV).

(c) Unit-III (26 – 6 cm; 1930–355 cal yr BP)

The concentrations of major element viz. Al_2O_3, CaO, MgO and FeO for Unit-III ranges from 10.4–12.0 %, 3.6–14.1 %, 6.6–9.1 % and 9.5–12.9 % respectively (Fig. 4–3). The concentrations of $CaCO_3$, TOC and TOC/TN range between 0.72–11.9 %, 0.65–0.78 % and 8.8–12 respectively (Fig. 4–3 and 4–5). The contents of trace elements such as Cu, Ni, Zn, Ba and Co range from 68–84 ppm, 58–62 ppm, 53–84 ppm, 233–258 ppm and 32–36 ppm (Fig. 4–3). The isotopic values for $\delta^{13}C$ and $\delta^{15}N$ range from -21.3 to -18.3 ‰ and -2.6 to 4.9 ‰ respectively (Fig. 4–7).

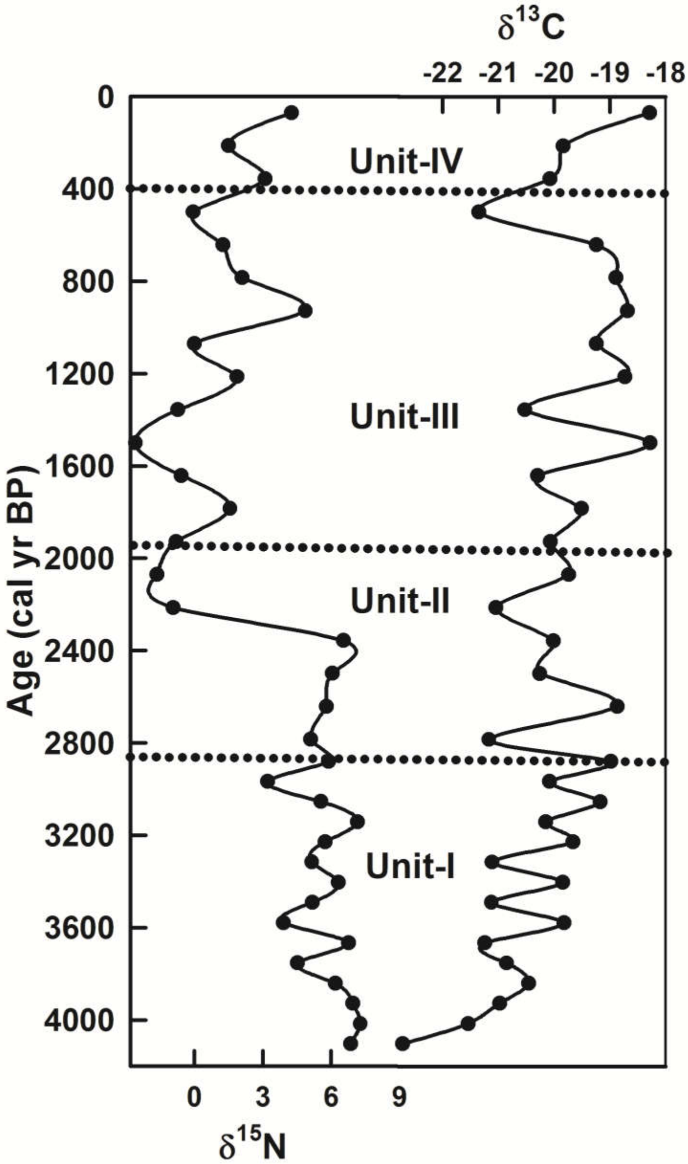

Figure 4-7. The downcore variation of nitrogen and carbon stable isotopes during last 4000 yr BP in the partially active Diu mudflat core (DV). Note, sudden shift in $\delta^{15}N$ at 2400 cal yr BP.

The detrital tagged elements along with other trace elements show consistent values with marginal fluctuations during Unit-III from 1930 till 640 cal yr BP and further a decreasing trend till 355 cal yr BP has been observed. Increasing trend in MgO/Al_2O_3 and a decreasing tend in FeO/Al_2O_3 with fluctuations are observed during the deposition of Unit-III. Cu/Al_2O_3 shows fluctuations with no significant trend and

Ni/Al_2O_3 shows a gradual increasing trend. Sr/Al_2O_3 and CaO/Al_2O_3 remain consistently low till 800 cal yr BP followed by an increasing trend. Although, TOC shows consistent values throughout Unit-III, $CaCO_3$ shows an increasing trend. TOC/TN shows a gradual decreasing trend throughout Unit-III with values of <12 indicating enhanced contribution of organic carbon predominantly of marine origin. The $\delta^{15}N$ in this unit shows an increasing trend till 930 cal yr BP with significant fluctuations, followed by a depletion in the values till 355 cal yr BP. In case of $\delta^{13}C$ no significant trend is observed.

(d) Unit-IV (6 cm– surface; 355–70 cal yr BP)

In Unit-IV, the concentration of major elements such as Al_2O_3, CaO, MgO and FeO vary between 7.1–8.7 %, 18.8–23.2 %, 6.0–7.6 % and 6.1–7.7 % respectively (Fig.4–3). The $CaCO_3$, TOC and TOC/TN values range from 21.4–34.3 %, 0.85–1.48 % and 5.6–8.9 respectively (Fig. 4–3 and 4–5). The trace element concentrations of Cu, Ni, Zn, Ba and Co range between 47–60 ppm, 44–50 ppm, 38–57 ppm, 215–241 ppm and 23–29 ppm respectively (Fig. 4–4). The isotopic signatures of $\delta^{13}C$ and $\delta^{15}N$ vary from -20.1 to -18.3 ‰ and 1.5 to 4.27 ‰ respectively.

All the detrital proxies as well as the trace element concentrations show a decreasing trend towards the top. Similarly, the weathering proxy FeO/Al_2O_3 and MgO/Al_2O_3 also indicate a declining trend towards the top of the Unit–IV. However, most of the productivity proxies show an increasing trend. The surface though represents an active mudflat with low sedimentation rate, the sampling resolution for each 2 cm section of the core is 70 years thereby the top section represents an integrated climatic history of 70 cal yr BP. Both the $\delta^{15}N$ and $\delta^{13}C$ show an increasing trend during last 355 to 70 cal yr BP.

4.4 Discussion

On the basis of geochemical proxies, different climatic phases can be interpreted in various units during the last 4000 yr BP. Therefore, Phase-I, Phase-II, Phase-III and Phase-IV represents 4105–2880 cal yr BP (70–40 cm), 2880−1930 cal yr BP (40–26 cm), 1930–355 cal yr BP (26–6 cm) and 355–70 cal yr BP (6 cm– surface) respectively. Though this core from the active mudflat of Diu (DV) is contemporaneous record for relict mudflat (VV), the improved resolution and continuous deposition of sediment in the region till present (year of core collection- 2012 AD) has provided climatic history bracketing a time period of 4000 to 70 cal yr BP.

(a) Phase-I (70–40 cm; 4105–2880 cal yr BP)

A near consistent value for most of detrital proxies indicate no major fluctuation in the climatic condition except between 3230–2790 cal yr BP, where significant enhancement in detrital elemental concentration is observed pointing towards increased continental flux, which is further supported by the trace elemental (Cu, Zn, Ni, Ba and Co) concentrations. Similarly, MgO/[MgO+CaO] being a salinity indicator (Sinha et al., 2006), shows low value throughout the Phase-I (4105–2880 cal yr BP) representing the influence of fresh water due to the enhanced continental flux. In the absence of perennial river, the continental flux in the study region is primarily governed by the monsoon, hence, any changes in the terrestrial proxy is a function of monsoonal fluctuation in the region. Therefore, enhanced monsoonal spill might have resulted in the increased detrital contribution during 3230–2790 cal yr BP. All the three proxies are indicative of calcareous productivity viz. Sr/Al_2O_3, Ca/Al_2O_3 and $CaCO_3$, and show synchronous variation with an initial high productivity during 4105 cal yr BP with a subsequent gradual decrease till 3405 cal yr BP.

Similar to calcareous productivity proxies, organic carbon proxy (Ni/Al_2O_3, Ba/Al_2O_3 and TOC) also shows a similar trend. Such enhanced productivity during 4105 cal yr BP with a declining trend towards 2880 cal yr BP, indicates warm and humid conditions which weakened towards 2880 cal yr BP. However, an increased productivity between 3230 and 2790 cal yr BP has been observed with increased detrital flux between 3230–2790 cal yr BP indicating improved monsoonal conditions in the region. Such temporal improvement in the moisture conditions (enhanced monsoonal spill) has been witnessed in the relict mudflat of Vasoj (VV) between 3560 and 3180 cal yr BP. Phytolith based study carried out at the fluvio-laccustrine sediment succession from Itola, mainland Gujarat deposited during mid–late Holocene suggested weakening of southwest monsoon with persistence of winter precipitation during 3960 cal yr BP (Singh et al., 2007). Likewise, another phytolith study carried out on sedimentary sequence of Mahi estuary, Kothiyakad, mainlad Gujarat, indicated enhanced winter precipitation between 3660–3440 cal yr BP (Prasad et al., 2007). Based on palynological study carried out at the swamp, northwest of Amarkantak town, Madhya Pradesh, indicated onset of warm and moderately humid climate, attributed to active SW monsoon between 3600 and 2761cal yr BP (Chauhan, 2015).

Increased TOC and TOC/TN at the bottom of the core during 4105 cal yr with a declining trend towards the top of the Phase-I has been observed. The TOC/TN > 12 indicates organic carbon contribution from terrestrial origin (Meyers, 1997). Generally, the coastal region comprises unique floral group known as mangroves which accumulates large quantities of organic matter (Chmura et al., 2003). It has been estimated that the TOC, TOC/TN and $\delta^{13}C$ for the mangroves ranges from 0.6 to 31.7 %, 7 to 27 and -29.4 to -20.6 ‰ respectively (Bouillon et al., 2003). The palynological study of the Vasoj relict mudflat (VV) (discussed in Chapter-3) indicated presence of intense mangrove forest during 4710 cal yr BP with a declining density of the mangrove till 1500 cal yr BP. Thus, the enhanced TOC with >12 TOC/TN in the core during 4105 cal yr may be attributed to the contribution of mangrove forest in the region. Based on the study carried out by Yang et al.(2013), the TOC/TN, $\delta^{15}N$ and $\delta^{13}C$ average values for the mudflat sediment are nearly 15.4 ± 1.9 %, 6.85 ± 0.61 ‰ and -23.87 ± 0.58 ‰ respectively. The depleted values of $\delta^{13}C$ with enriched $\delta^{15}N$ are consistent with Yang et al., 2013 and connote the presence of mangrove forest. On the basis of geochemical proxies (productivity, salinity and terrestrial), it can be elucidated that the region was experiencing warm and humid climate during 4105 cal yr BP which weakened towards 2880 cal yr BP. However, an abrupt enhanced precipitation during 3230–2790 cal yr BP resulted in the improvement of moisture conditions in the region. Such warm and humid condition with a declining trend has also been indicated by the relict mudflat of Vasoj (VV) (Banerji et al., 2015).

There exists various continental and marine records that have archived similar warm and humid conditions during 4105–2880 cal yr BP. In the Indian subcontinent, reduced monsoonal conditions between 4000 and 3500 cal yr BP have been suggested with the help of palynological and magnetic susceptible studies at Dokriani Glaciers, Central Higher Himalaya, India (Phadtare, 2000). On the basis of multiproxy data, the laminated sediment core collected from the north-eastern Arabian Sea off Pakistan indicated intense summer monsoon activity between 5000 and 3900 yr BP followed by winter precipitation between 3900 and 3000 yr BP (Luckge et al., 2001). Similarly, palynological study of the marine core retrieved off Karwar, Karnataka exhibited warm and humid conditions during 4500–3500 yr BP followed by onset of drier climate post 3500 yr BP (Caratini et al., 1991).

(b) Phase-II (40–26 cm; 2880–1930 cal yr BP)

With the beginning of Phase-II, enhanced values of detrital elements along with the trace elements imply that there persisted enhanced terrestrial flux in the region between 2860 and 2635 cal yr BP. In absence of any major river such enhancement in the terrestrial flux may be attributed to the enhanced monsoonal condition. Following this, near constant values in detrital proxies during 2635–1930 cal yr BP, no major change in the detrital elements indicate that there was no major climatic fluctuations during the Phase-II. In case of in–situ productivity, no major change has been observed in case of calcareous productivity, but the declining trend in the organic carbon productivity shows a reduced monsoonal conditions. Weathering proxies like FeO/Al_2O_3 and MgO/Al_2O_3 also indicated reduced values implying reduced weathering in the region. In case of salinity indicator proxy, higher MgO/[MgO + CaO] compared to Phase-I have been observed implying high salinity persisted during the Phase-II which further suggests decreased fresh water input from the continent. Therefore, based on the increased salinity with reduced terrestrial flux and in-situ productivity it is implied that the region was experiencing an arid climatic conditions. On the basis of lithosection, palynological, geochemical proxies, the relict mudflat section of Vasoj (VV) archived calcareous marl section between 2825–1835 cal yr BP indicating that the region experienced extreme aridification (Banerji et al., 2015). However, due to low time resolution for the relict mudflat, precise period for the aridification in the climate could not be resolved. Nevertheless, the contemporary core for the relict mudflat (VV) from the active mudflat of Diu (DV) has indicated that the aridification occurred between 2500 and 2215 cal yr BP. This was followed by enhanced terrestrial flux and productivity as indicated by depleted $\delta^{15}N$ and organic carbon productivity proxies (Cu/Al_2O_3, Ni/Al_2O_3).

The persistence of arid climate during the same period has been suggested by the multiproxy study of the Nal Lake, mainland Gujarat during 3–2 ka (Prasad et al., 1997). Similarly, arid climatic conditions during 2.1 ka has been indicated by the stable isotopic study of alluvial plains of Narmada valley, mainland Gujarat (Laskar et al., 2013). There exists marine records from the Arabian Sea that suggested aridification during ~2000 yr BP. On the basis of stable oxygen isotopic variation in the forams from the core retrieved from the continental margin of the Arabian Sea, an arid climatic condition is observed during 2000 yr BP (Tiwari et al., 2006). Study based on stable isotope and geochemical proxies also indicated reduced southwest monsoonal conditions between 1800–2000 yr BP (Chauhan et al., 2010).

(c) Phase-III (26 – 6 cm; 1930–355 cal yr BP)

The global climatic variability during last 2000 yrs BP have been extensively studied (Barber et al., 2000; Briffa, 2000; Proctor et al., 2000; Agnihotri et al., 2002; Mangini et al., 2005) due to the influence of both natural and anthropogenically induced climatic perturbations. The climatic history of this period has been divided into five climatic periods viz. RWP, DACP, MWP, LIA and MW (Lamb, 1965; Norgaard-Pedersen and Mikkelsen, 2009; Oppo et al., 2009; Chen et al., 2011). The MWP, LIA and MW has been the focus of discussion in most of the previous studies (Agnihotri et al., 2002; Rühland et al., 2006; Warrier and Shankar, 2009; Warrier et al., 2014) due to the interplay between natural and anthropogenic impacts. In the global context, the present unit (Phase-III) signifies nearly all the climatic events mentioned above excluding the MW.

During the Phase-III, the detrital tagged elements showed no significant fluctuations in the region. Al_2O_3 is considered to be the least mobile element during chemical weathering (Garcia et al., 1994). Therefore, the enhanced values of FeO/Al_2O_3 and MgO/Al_2O_3 along with consistent value of detrital elements (Al_2O_3) indicate increased weathering conditions in the region. The calcareous and organic carbon productivity proxies do not show much variation. After 800 cal yr BP, a marginal enhancement in the productivity has been indicated by all related productivity proxies such as Sr/Al_2O_3, $CaCO_3$, Ca/Al_2O_3, Cu/Al_2O_3, Ni/Al_2O_3 and Ba/Al_2O_3. The period during 800 to 400 cal yr BP nearly represents a global climatic event known as MWP. Therefore, such enhanced detrital flux with increased productivity after 800 cal yr BP indicates that warm and humid conditions persisted coinciding with the global warming event of MWP (Lamb, 1965). Additionally, the decreasing trend of the salinity indicator MgO/[MgO+CaO] also showed increased fresh water influx (reduction in the salinity) associated with improved monsoonal conditions. Similarly, when the present observations are compared with relict mudflat of Vasoj (VV), marginal improvement in the moisture has been indicted by the relict mudflat section between 1800–1500 cal yr BP. Being a relict mudflat section (VV), the sediment depositional process ceased after 1500 cal yr BP, but the active mudflat has provided the depositional history till 70 cal yr BP.

An intense flooding event at Mahi river basin, Diapatan, Mainland Gujarat has been observed during MWP indicating intensification of monsoon in the region

(Sridhar, 2009). Evidence of reduced aridity, punctuated with short monsoonal spells has been inferred during this period from the Nal Sarovar lake sediment of Central Gujarat (Prasad et al., 1997). Similarly, a multiproxy study on the lower Narmada valley, mainland Gujarat, Western India invoked existence of high magnitude flooding events resulted due to enhanced monsoonal activity (Sridhar et al., 2015). In the Indian context, the existence of MWP has been noticed from various studies (Rühland et al., 2006; Warrier and Shankar, 2009; Quamar and Chauhan, 2014; Warrier et al., 2014) during which warm and humid climatic conditions persisted in the Indian subcontinent.

(d) Phase-IV (6 cm– Surface; 355–70 cal yr BP)

As the region is deprived of any major river, the gradual decrease of detrital proxies along with enriched $\delta^{13}C$ and $\delta^{15}N$ indicates reduced continental flux and thereby reduced monsoonal strength compared to Phase-III. Nevertheless, gradual increase in the productivity has been observed which indicates that the region was experiencing favourable conditions that supported in situ productivity. Therefore, with reduced detrital flux and increased productivity it can be inferred that the region was experiencing warm climatic conditions during last 355 cal yr BP. Such warming in the climate has been observed by some of the studies carried out in the Indian context. The multiproxy study of the peat section from Kumaon, Higher Himalayas indicated climate warming during last 200 yr BP (Rühland et al., 2006). Moreover, the retreating glaciers punctuated by numerous advances and retreats have been observed in the Himalayan region with the culmination of LIA after 1795 AD (Chaujar, 2006; 2009).

4.5 Was there a sea regression after 3000 cal yr BP?

The Saurashtra coast encompasses various geomorphic features that indicate both sea level change as well as tectonic upliftment in the region (Baskaran et al., 1987; Pant and Juyal, 1993; Banerji et al., 2015). There was enhanced freshwater influx during Phase–I as suggested by low range of salinity indicator (MgO/[CaO+MgO] = 0.097 to 0.17). An increase in the salinity (from 0.2 to 0.64) can be observed at the end of Phase I (after 3000 cal yr BP) along with elevated detrital proxy which resulted due to activation of ephemeral rivers caused by enhanced monsoon (as discussed in previous section). The improved flux should have reduced the salinity, on the contrary, the salinity increased at the end of Phase–I and remained nearly constant thereafter.

Radiocarbon dating of calm shells from Diu Island, southern Saurashtra coast testify elevated sea levels of nearly 2 m which was followed by regression masked by tectonic component (Juyal et al., 1995). Additionally, a study on relict mudflat of Vasoj Village (VV), southern Saurashtra coast which is nearly 0.5 km away from the present sampling site also indicated high sea level during 4700 cal yr BP following which a regression took place and the sedimentation process ceased after 1500 cal yr BP (Banerji et al., 2015). Therefore, it can be elucidated that a high sea level persisted between 4105–3000 cal yr BP when the region was experiencing a lagoonal conditions with high in–situ productivity following which the sea regression caused lagoon to transform into mudflat. This interpretation is further supported by the evidences from the relict mudflat which was connected (as a single lagoon) with the present sampling site (DV) during 4700 cal yr BP to 1500 cal yr BP. Later sedimentation ceased in the relict mudflat (VV) but the sedimentation process continued in DV. However, further geomorphic and geochemical evidences are required to elucidate the high sea stand and the causes of sea regression (sea level change / tectonic or both).

4.6 Climatic Reconstruction of last 4000 yr BP from Diu active mudflat

The multiproxy data for the mudflat sediment from Diu (DV) allow us to reconstruct the climate (monsoon) variability since the last 4000 cal yr BP. Based on the geochemical and isotopic proxies, it can be suggested that the region has experienced fluctuating monsoonal condition (warm and humid condition) during 4000 cal yr BP which continued till 2880 cal yr BP (Fig. 4–8). This study indicates that during the last 4000 cal yr BP, maximum monsoon strength was observed during 3230–2790 cal yr BP (Fig. 4–8) which was followed by onset of aridity which persisted between 2880 and 1930 cal yr BP. The arid climate was trailed by warm and humid climatic till 355 cal yr BP which is in accordance with the RWP, MWP and LIA (Fig. 4–8). However, for the present study the climatic condition during LIA could not be fully resolved due to low sample resolution, hence further high resolution data for the last 2000 yr is required to pinpoint the climate that prevailed during LIA in the region.

The above discussion suggests that the region experienced marginally high sea level during Phase–I. By the end of this phase (around 3000 yr BP) the enhanced salinity might have resulted due to the transformation of lagoon into mudflat. However, further evidences are required to attest the sea level change in the region which will be discussed in Chapter 7.

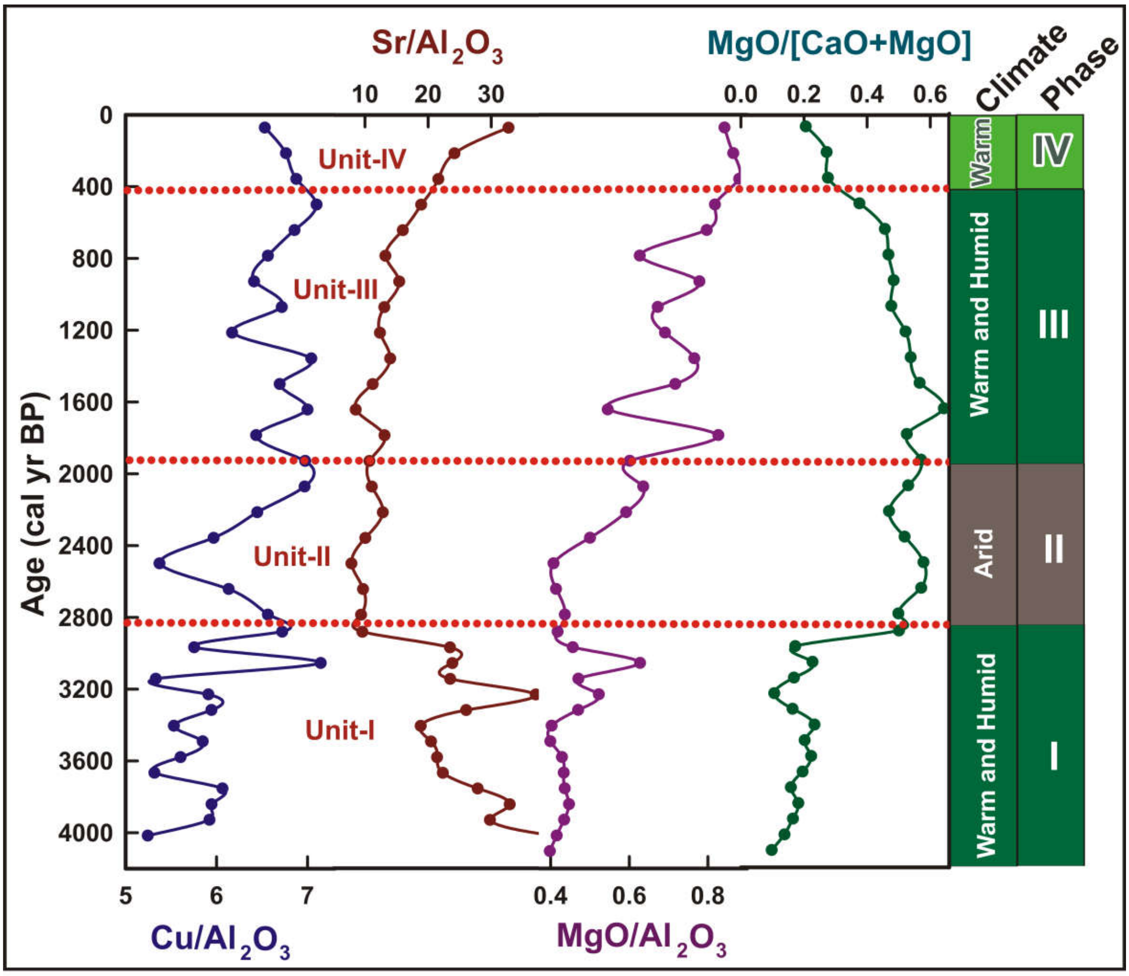

Figure 4-8. Reconstruction of the climatic history during last 4000 yr BP from active mudflat of Diu (DV) along southern Saurashtra coast.