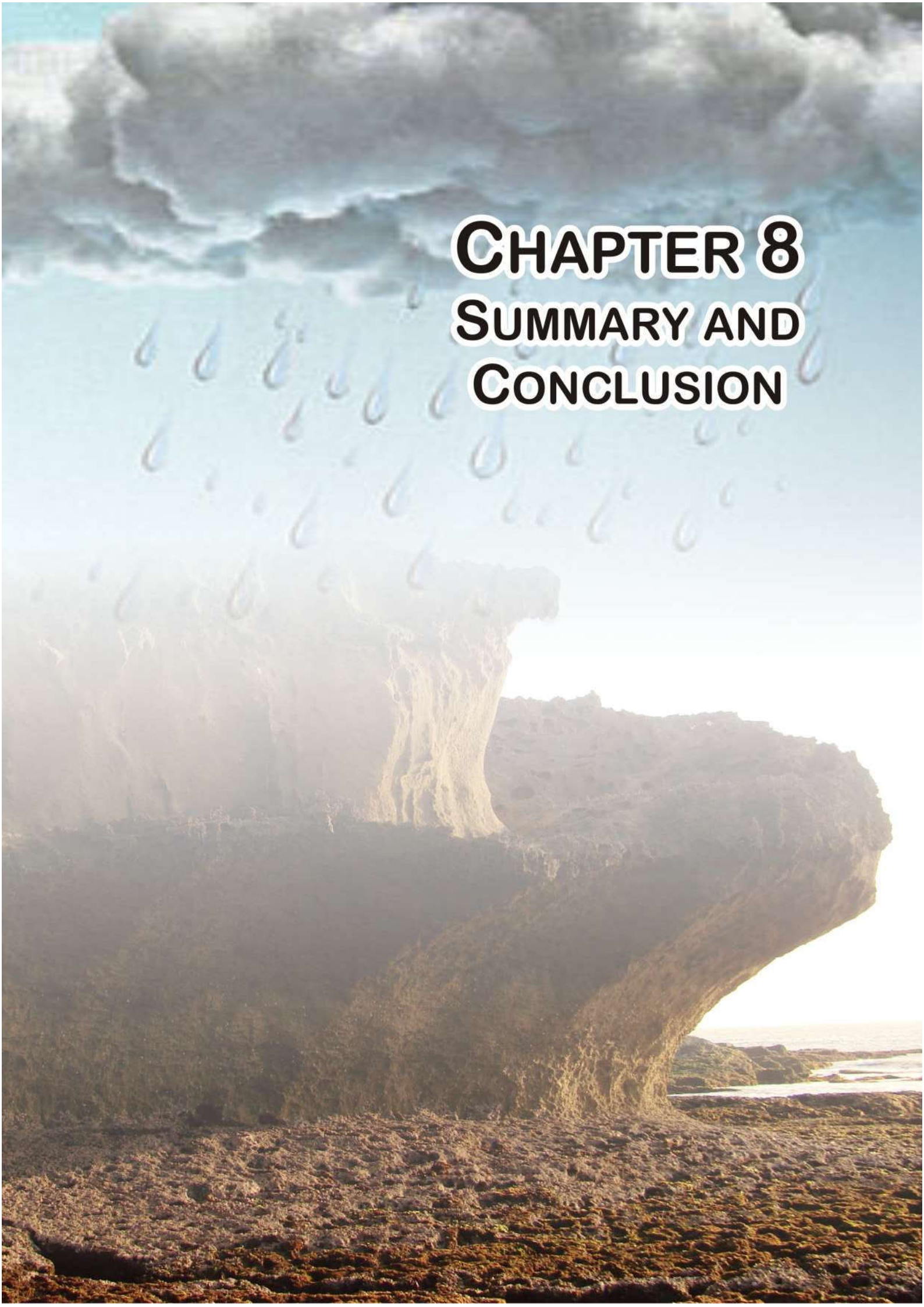

CHAPTER 8
SUMMARY AND CONCLUSION

8.1 Summary

The coastal landscape of Saurashtra peninsula provides an opportunity to study the land–sea interaction during the quaternary period. In view of this, the mudflats of southern Saurashtra coast (VV, DV, RH) have been the focus of this study with an aim to reconstruct the mid–late Holocene climatic history and further to ascertain the tectonic component responsible for the present configuration. Two sediment cores from active mudflats of Diu (DV) and Rohisa (RH) are raised while samples are collected from a dug pit of the relict mudflat section (VV) near Vasoj village. Additionally, the coastal notch situated along Southern coast of Diu is also investigated. The notch is formed by the sea erosion through undercutting the cliff ranges from several centimetres to several meter depth.

The chronology of the sediment cores and the relict section are ascertained using radiocarbon dating. The relict mudflats (VV) samples are analysed for various geochemical and palynological studies while the active mudflat sediment core (DV and RH) for their geochemical parameters including productivity, weathering and detrital proxies. In addition, measurements of stable isotopes like Carbon, Nitrogen and Sulphur are conducted on all the samples of cores and lithological section.

8.1.1 Mid-Late Holocene Climatic reconstruction along Southern Saurashtra Coast

The relict mudflat (VV) indicates a depositional history during 4710–1500 cal yr BP. The palynological and geochemical investigation suggests that the climate of the region had ameliorated between warm and humid to arid conditions along with a marginally high sea level. More specifically, during the period 4710–2825 cal yr BP the region experienced warm and humid conditions and marginally high sea level with a

gradual decrease towards 2825 cal yr BP. However, there was marginal intensification of monsoon during 3560–3180 cal yr BP. Evidence similar to the marginally enhanced monsoonal conditions were also observed in the mainland Gujarat at Itola (Singh et al., 2007), Kothiyakad (Prasad et al., 2007) and Wadhawana (Prasad et al., 2014). Following the warm and humid period, the region experienced an arid climatic condition during 2825–1835 cal yr BP with marginal sea level regression. During the period 1835–1500 cal yr BP the region experienced a marginally warm and humid climatic conditions. After 1500 cal yr BP, the sedimentation in the relict mudflat (VV) region had ceased thereby restricting any further reconstruction. This is on the other hand indicative of another sea level regression which prevented sedimentation anew.

As the climatic history is based on relict mudflat (VV) of the litho–section, it is important to correlate the reconstructed climatic records with that of the contemporaneous active mudflat of Diu Island (DV). Therefore, the sediment core from the active mudflat of Diu Island was studied for various paleoclimatic geochemical proxies which represent a climatic history of last 4000 yr to present. Similar to relict mudflat of Vasoj (VV), the active mudflat (DV) of Diu Island also experienced warm and humid climatic conditions between 4105–2880 cal yr BP followed by an arid climatic conditions which unlike the relict mudflat, continued till 1930 cal yr BP. The arid climate was followed by warm and humid conditions in the region. The relict mudflat record terminated at 1500 cal yr BP, whereas the active mudflat has provided a climate history till present. The warm and humid condition between 1800–1500 cal yr BP of relict mudflat in fact continued till 355 cal yr BP as indicated by the Diu active mudflat. After 355 cal yr BP the region experienced warm climatic condition.

The climatic history of the last 2000 yr has been a crucial period that experienced both natural and anthropogenically induced climatic alterations. The climatic history of this period for southern Saurashtra coast has been imprinted in the Diu active mudflat (DV). Nevertheless, it is important to generate high resolution climatic rand comparison was made with that of active mudflat of Diu. In view of this a sediment core raised from the Rohisa active mudflat (RH) has been studied that has archived depositional history of last 2000 yr.

Similar to Diu mudflat (DV), the geochemical analyses of the Rohisa sediment core (RH) suggest warm and humid conditions with fluctuating monsoonal condition during 1969–1546 cal yr BP and the period compares well with the global climatic period called RWP. This period was followed by a warm and humid climate with consistent monsoon during 1546–503 cal yr BP corresponding to the MWP. In the transitional period between RWP and MWP the proxy records indicate a dry and arid climate for nearly 100 yr. This may point towards a possible indication of persistence of DACP. However, being such a short span, a high resolution climatic archive is required to interpret this as DACP. The concise climatic reconstruction of climate during the span from 4700 cal yr BP–2012 AD is represented in Fig. 8–1.

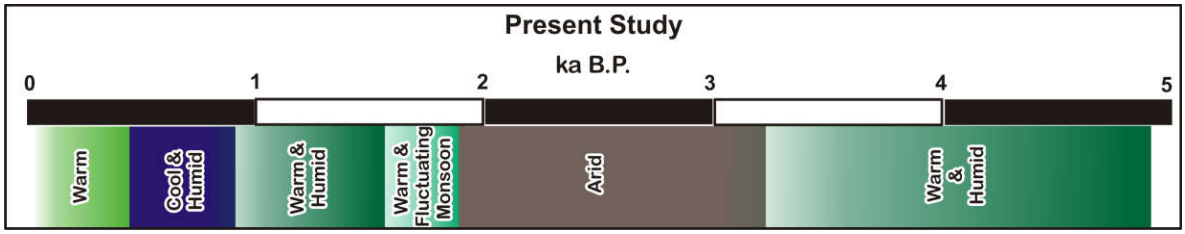

Figure 8-1 Overview of the climatic reconstruction between 4710 cal yr BP– 2012 AD along southern Saurashtra coast.

The MWP was followed by a cold and humid period between 503–193 cal yr BP that corresponds to global climatic period called LIA. The humid climate during LIA could be due to the influence of westerlies wherein the southern shift of ITCZ led to intensification of westerlies, and resulting in enhanced winter precipitation in the region (Kotalia et al., 2012; Brown and Johnson, 2005; Newton et al., 2011; Konecky et al., 2013). Between 193 BP– 2012 AD, warming in the climate has been observed which is known as MW and a similar observation has been made for the Diu active mudflat (DV) where in the last 300 cal yr BP representing a warm climatic conditions.

8.1.2 Comparison of present study with that of previous study

Mid–late Holocene climatic reconstruction is the utmost requirement as the period has witnessed short climatic perturbations. There exist studies indicating monsoon intensification during MWP (Prasad, 2014), however, there is no continuous record of climatic reconstruction for the last 2000 year.

This study supplements the present understanding and provides a continuous record of climatic perturbation since last 4710 cal yr BP. The present study has also provided continuous high resolution climatic history of last 2000 yr and showed that the region responded in unison with global climatic events (Fig. 8–2).

8.1.3 Mid-Late Holocene Tectonic History along Southern Saurashtra Coast

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; Juyal et al., 1995; Banerji et al., 2015). One of the important features along the Saurashtra coast is the tidal notch situated along the southern coast of Diu near

Vanakwara. The elevation of the relict mudflat is nearly 3 m while the present day tidal reach is up to 1 m which implies that there was 2 m of sea regression during last 5 ka. Such high estimation in the sea level lowering appears to be due to the tectonic component playing a complementary role in the region. Therefore, the notch of Vanakwara, Diu Island was thoroughly examined. Based on the height of the notch, elevation of relict mudflat and present day tidal influence, it was interpreted that during the last 5 ka a tectonic upliftment of nearly 1 m along with 1 m of sea level regression took place along the southern Saurashtra coast.

The stable isotopes have been effectively used by various studies for interpreting the climatic perturbation during the past. However, in the present study an attempt has been made to correlate the Sulphur isotopic variation along with the total sulphur content in interpreting the sea level changes caused by the tectonic component. In general, the negative (depleted) sulphur isotope values represent bacterial reduction of sulphate and such situations are prevalent in the lagoonal or estuarine conditions. In case of mudflat environment enriched $\delta^{34}S$ values are observed as the region gets submerged during high tides and exposes during low tides resulting in low bacterial activity.

In all the three sections, one relict (VV) and two active mudflat core (DV and RH), an abrupt shift of sulphur isotope from depleted to enriched values has been observed within a short span of time. Such rapid shift indicates that the region was transformed from estuarine/ lagoonal to mudflat area due to the relative lowering of the sea level. However, sea level lowering in such a short duration an unacceptable proposition.

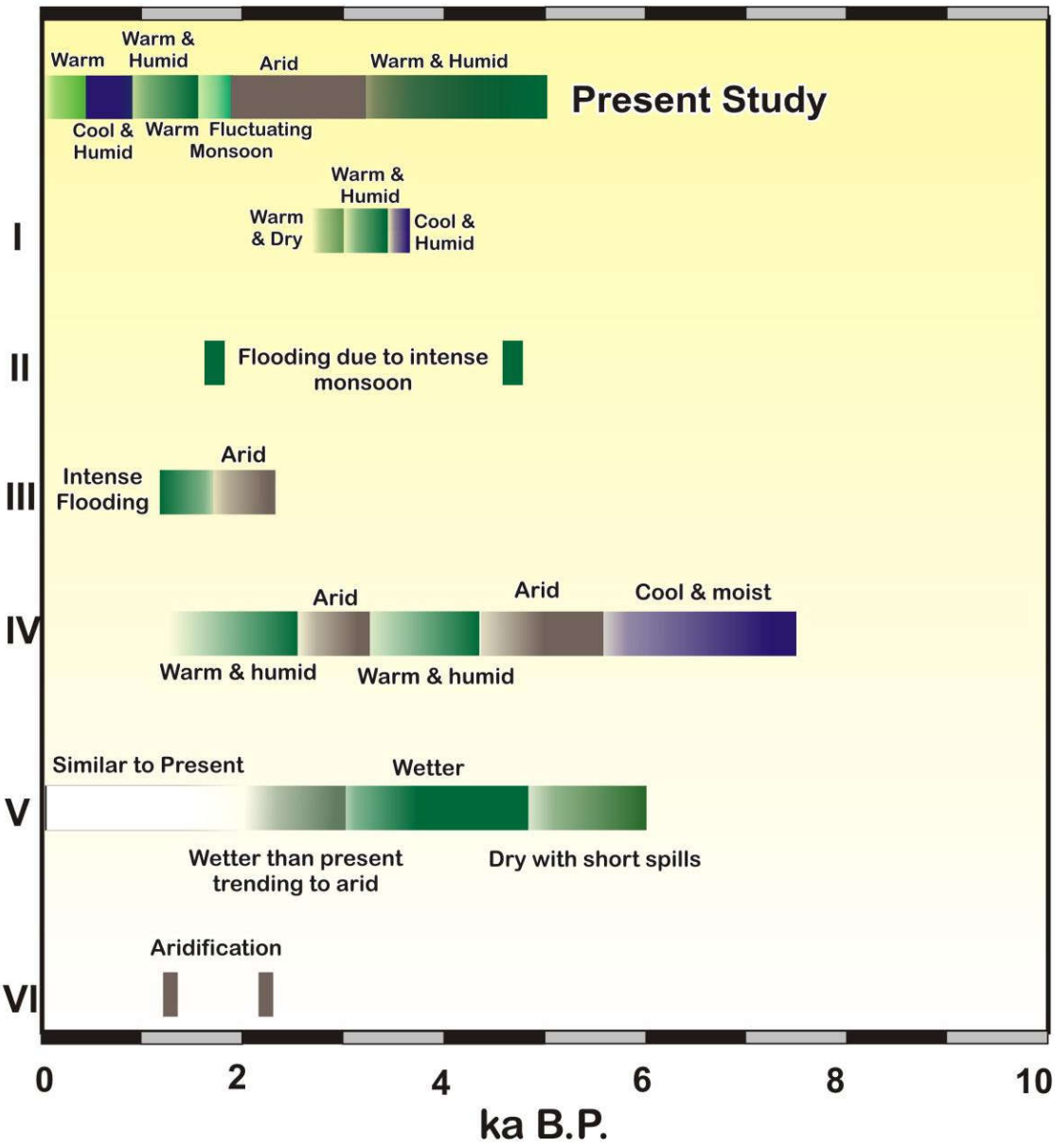

Figure 8-2. Schematic of the mid-late Holocene climatic reconstruction for the present study along with previous studies carried out in Gujarat. (I– Prasad et al.,2007; II– Sridhar, 2007; III– Sridhar et al.,2007; IV– Prasad et al.,2014; V– Prasad et al., 1997; VI– Laskar et al.,2013).

Therefore, in the present context with the database available at hand, tectonic adjustment in the region appears a possible strong competitor towards an acceptable and realistic explanation.

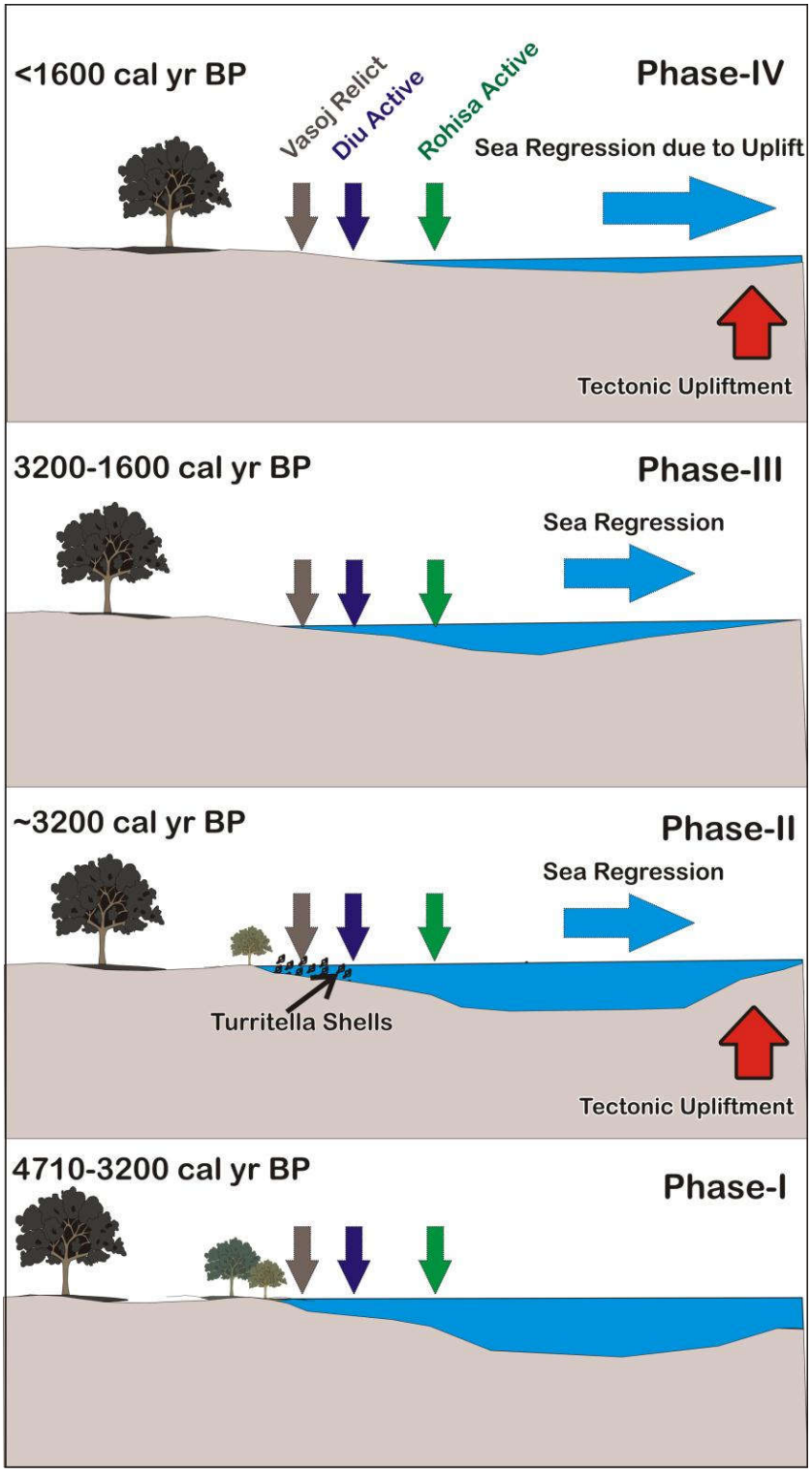

Figure 8-3. Schematic representation of sea level regression and tectonic upliftment during last 4710 cal yr BP deciphered for the three mudflats (active mudflat of Diu and Rohisa and relict mudflat of Vasoj) along the southern Saurashtra coast.

Tectonic interference uplifted the area and transformed the lagoon into a mudflat. The relict (VV) and active (DV) mudflat region experienced this tectonic upliftment after 3400 cal yr BP while Rohisa (RH) mudflat region witnessed an upliftment after 1500 cal yr BP.

8.1.4 Response of Mudflat towards Total Solar Irradiance

Various studies have invoked the sun–climate relationship using various archives such as marine sediment (Agnihotri et al., 2002; Ranasinghe et al., 2013), speleothems (Knudsen et al., 2009; Knudsen et al., 2011), peat (Hong et al., 2001) and others. However, till date none of the study has focused on the response of mudflat towards solar variability. Saurashtra peninsula being situated in the tropical region provides an opportunity to ascertain the mudflat response towards solar irradiance. In view of this, productivity, detrital flux and weathering proxies of the Rohisa sediment core were compared with TSI records. The comparison indicates that during the last 2000 yr, the productivity and weathering in the region have changed synchronously with changes in the TSI, implying that increased TSI increases the monsoonal activity in the region which in turn enhances the productivity and weathering.

The spectral analysis of various proxies was carried out to estimate the cyclicity in the data which ascertained periodicities such as 162, 296, 370, 415, 651 and 1037 yr. Similar to the present observations, the solar periodicities such as 162, 278, 389, 467, 834 and 1060 yr were recorded in a study of peat from NE China with the help of $\delta^{13}C$ (Hong et al., 2001).

8.2 Conclusion

Based on the geochemical, palynological and isotopic variations for the active and relict mudflat of southern Saurashtra coast, the climatic as well as sea level changes have been reconstructed for the past 5 ka.

- The present study indicates that the climate of the southern Saurashtra coast ameliorated between warm and humid condition to arid conditions.
- A gradual decrease in the monsoonal activity has been observed during last 5ka but an intense monsoon spill between 2800–3200 cal yr has been indicated by the proxy records.
- An arid climatic condition between 2800–1900 cal yr BP persisted in the region.
- The region recorded signatures of global climatic period of last 2000 yr i.e. RWP, MWP, LIA and MW. Moreover, it has also indicated DACP but due to its short duration, high resolution proxy is required to check the occurrence of DACP.
- The spectral analysis of the proxy data suggested solar periodicities (162, 296, 370, 415, 651 and 1037 yr) engrossed in the mudflats of southern Saurashtra coast. The insitu productivity and weathering for the last 2000 yr has followed a similar trend as of TSI.
- Along with sea level changes, tectonic component also played significant role in the present day coastal configuration.
- The present study also provides light on the usage of sulphur isotope as proxy to ascertain tectonic/ sea level changes. The tectonic upliftment probably took place after 3200 yr BP and after 1600 yr BP as indicated by the sulphur isotopes (–20 to +10 ‰). Due to such upliftment, the coastal lagoon was transformed into mudflat region.

- The sea level was nearly 2 m high than present during 5 ka which included nearly 1 m of tectonic component as indicated by the tidal notch. Fig.8–4 represents the coastal configuration during mid-Holocene period and the present coastal configuration

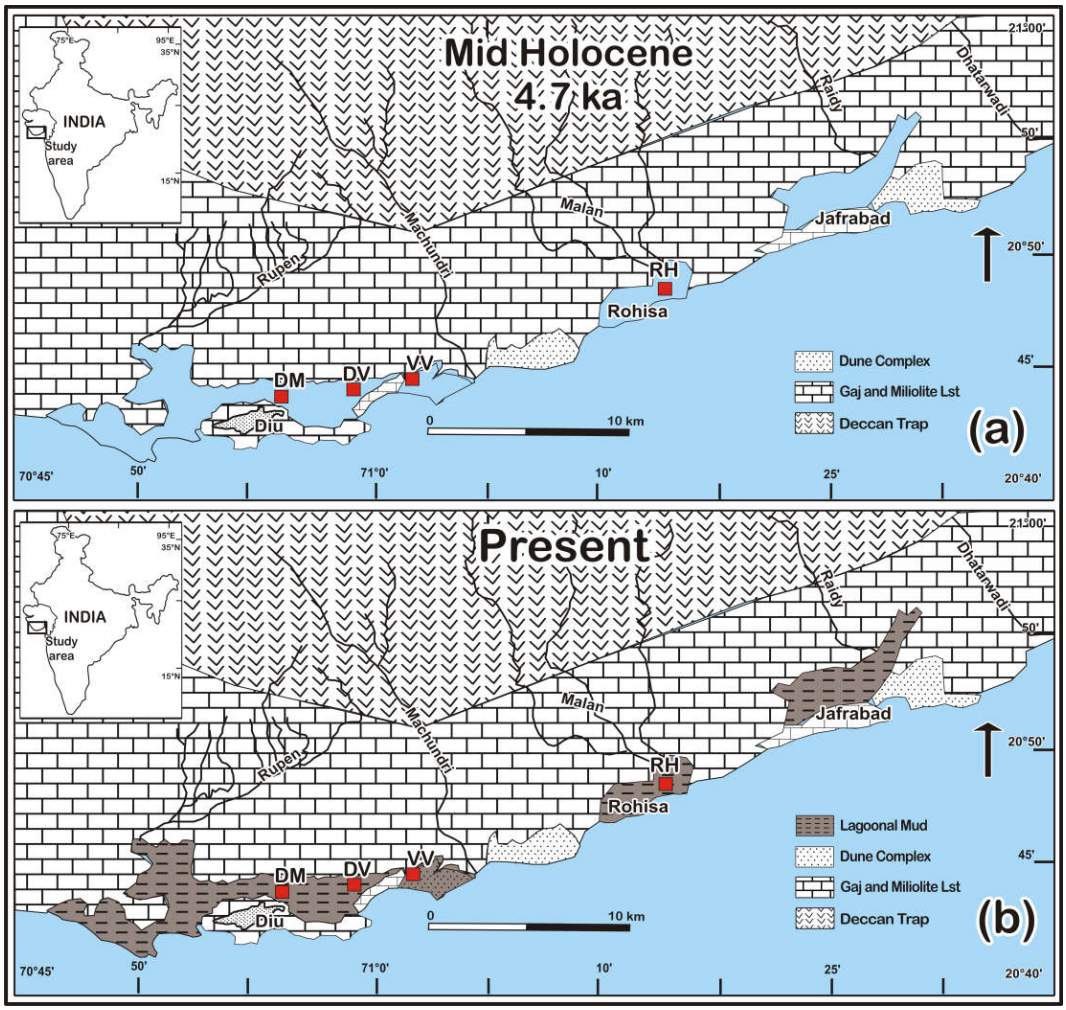

Figure 8-4. (a) Probable coastal configuration during Mid-Holocene period; (b) Present coastal configuration along southern Saurashtra coast

Nevertheless, further records of climatic and tectonic reconstruction for Gujarat with more emphasis on Saurashtra peninsula is required as the region is endowed with climatic as well as geomorphic records of Quaternary and Holocene period.