# CHAPTER 5

## SUMMARY, SYNTHESIS AND FUTURE PERSPECTIVES

This study was carried out with the dual objectives of understanding the evolution of Nal region, in terms of an interplay of regional tectonism and eustatic sea level changes, and to decipher its Holocene palaeoclimatic history. The Nal region is important because it lies within the palaeo-Thar margin and is a potential site for palaeoclimatic investigations. Owing to its low elevation, proximity to the Gulfs of Kachchh and Khambhat, and also to the tectonically active Cambay Graben, it is likely that both eustatic sea level changes and tectonism have played a role in the evolution of this region. It was, therefore, essential to reconstruct the evolutionary history of this region to provide a framework for any future study.

As described in the previous chapters, a variety of techniques including remote sensing, subsurface lithological correlation, sedimentological and mineralogical analyses, radiocarbon and luminescence dating, were used to decipher the evolutionary history of the region. For palaeoclimatic reconstruction, $\delta^{13}C$ and C/N ratio analyses on organic matter were also carried out.

In the following, the salient results of various studies are first summarised. This is followed by a synthesis of all the data to reconstruct an evolutionary model for the Nal region. Within this framework, palaeoclimatic reconstruction for the past ~7ka, using $\delta^{13}C$ and C/N, is also presented.

## 5.1 Summary

The salient results of this study, using various techniques, are summarised below,

### *5.1.1 Remote sensing and field studies*

1. Rivers on western, Saurashtra side, have large valleys though the present flow through them is seasonal.
2. On Saurashtra side, evidence of last major interglacial transgression was found in the form of inland deltas. The palaeo-strandline is, presently, at ~+15m msl.
3. There is no evidence of any major uplift, in the delta region, subsequent to their formation.
4. Several abandoned river channels were found to the east of Nal region.
5. Evidence of Holocene transgression was found as older mud flats on both western (Saurashtra) and eastern (Ahmedabad) side of Gulf of Khambhat.
6. Deranged drainage pattern was found in older mud flats.

### *5.1.2 Sub surface lithological studies*

1. The lithology on the eastern side of Nal region was dominated by sand with intercalations of clay/silty clay.
2. In the vicinity of Nal Sarovar, and in the N-S direction, extending from Little Rann of Kachchh to Dholera near Gulf of Khambhat, a change in lithology to a layer of sand (5-35m) underlain by thick sequence (40-55m) of clay/silty clay was seen.
3. In the Nal region, RL of the top and bottom of sand layer varies from +14 to -30m, while that of the underlying silty clay layer is +3m to -75m.

### *5.1.3 Core studies*

1. The core raised from Nal Sarovar comprised of three horizons: Horizon-3 (54-18m), Horizon-2 (18-3m) and Horizon-1 (3-0m). The base of Horizon-3 was not reached in the core.
2. Horizon-3 comprised of silty clay/clayey silt, Horizon-2 was dominantly sand and Horizon-1 comprised silty clay/clay.
3. Mineralogical studies indicated the source of sediments in Horizon-3 to be from south and/or west; Horizon-2 and Horizon-1 to be dominantly from east.
4. Radiocarbon dating on organic matter indicated the age, of the base of Horizon-1, to be ~7ka. Carbonate nodules from 16m depth and below gave $^{14}C$ date of >38ka. IRSL dating indicated that Horizon-2 was deposited between 7-~65 ka. Based on IRSL dating and other studies, the deposition of Horizon-3 was assigned to oxygen isotope stage 5.
5. Stable isotope ($\delta^{13}C$) and C/N studies indicated the climate to be drier than present between ~6.6-6ka. From 6-4.8ka, while the overall climate was dry, the rainfall was inferred to be more evenly distributed. The climate was wetter than present in the period 4.8-3ka. From 3ka, the trend towards aridity began and present day conditions were established around 2ka.

## 5.2 Synthesis

Based on the results of various investigations carried out, as described in previous chapters and summarised above, it is possible to develop a model for the geomorphic evolution of the region covering the entire low lying tract between the Gulf of Khambhat and the Gulf of Kachchh including the Nal Sarovar.

### *5.2.1 Geomorphic evolution of Nal region*

**STAGE 1**

During the last major interglacial when the sea level was higher, a shallow sea linked the Gulf of Khambhat with the Gulf of Kachchh. The palaeo-deltas and the palaeo-strandline observed to the west of Nal Sarovar (upto 30km inland, at ~+15m msl respectively) were formed during the period of last major interglacial transgression (isotope stage 5e, ~125ka). At that time, and also during the entire isotope stage 5 (127-73ka), the low lying Nal region was covered with a shallow sea having a dominant input of sediments from the Saurashtra peninsula and/or Gulf of Khambhat. The presence of smectite as a dominant (>70%) mineral phase in the sediments of Horizon-3 implies that the sediment input, at the present location of the Nal Sarovar, from the eastern side was small. This, probably, was due to the depositional front of the rivers draining the north and central Gujarat being farther east in the Cambay Graben. There may have been breaks in the sediment deposition, during the sub-stages of isotope stage 5, linked to the fall of the sea level. The IRSL dating, however, suggests that the deposition of the silty clay (Horizon-3) in this region ceased when the sea level finally dropped at the beginning of isotope stage 4. Owing to the limitations of the dating methods available, it has not been possible to give a more precise time of break up of this connection.

A schematic representation of the geography of the Nal region during last major interglacial transgression is given in Fig. 5.1.

**STAGE 2**

With the lowering of base level, the depositional front of fluvial input from the east, probably also aided by tectonic uplift in the region of Cambay Graben, could now advance westwards. This is suggested by the presence of a layer of sand (Horizon-2), with its source in the east, as confirmed by the characteristic

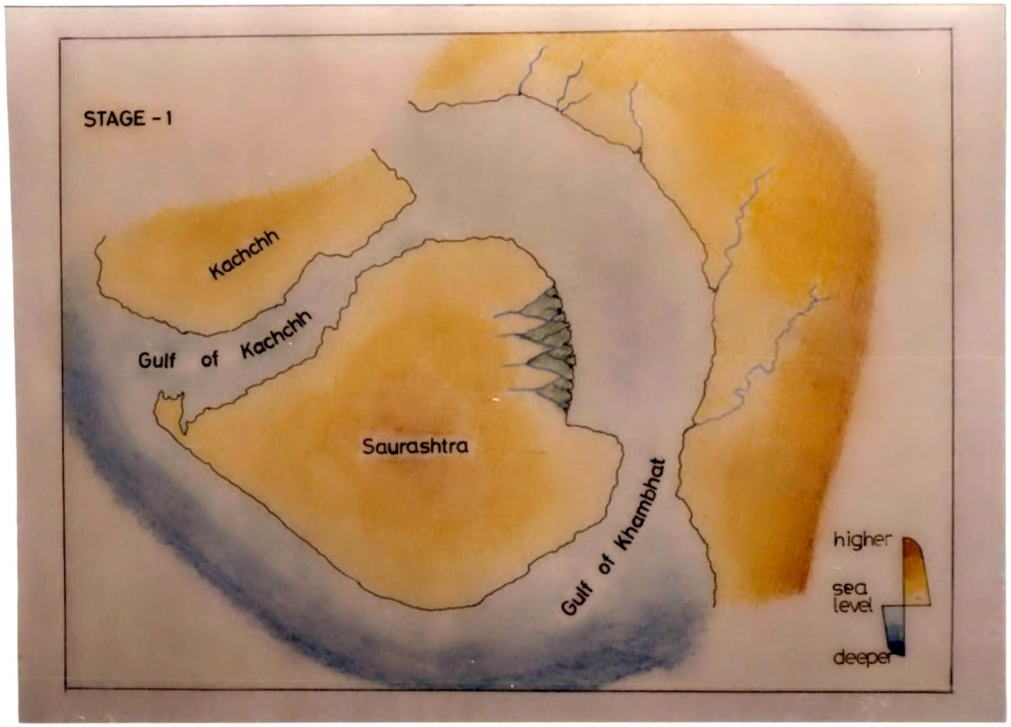


**Fig. 5.1** Schematic representation of the geography of the Nal and surrounding regions during the period (~125ka BP) of last major interglacial transgression (in Stage 1 of evolution of Nal region)

heavy mineral assemblage. The thickness of this layer varies from 5-35m, increasing towards the southern part of the Nal region. The deposition of sand was not continuous as is indicated by the presence of a red bed and evaporite minerals. This sedimentary material was most likely brought in by flash floods and had little sun exposure so that TL/OSL signal from the previous depositional history was not erased. Alternatively, it is possible that the region to the east of Nal Sarovar was tectonically uplifted some time subsequent to the deposition of Horizon-3 and pre-existing sediments from farther east were rapidly eroded and redeposited in the low level narrow land corridor, that still remained, linking the Little Rann of Kachchh and the Gulf of Khambhat. It may be noted that the Cambay Graben lying to the east of Nal Sarovar was topographically the lowest elevation and had acted as a sediment sink at least until Miocene. Presently, this area has a surface elevation of +80 m to +100 m and the low elevation area has shifted to Nal Sarovar which is +13 m to +16 m msl. Evidences of Late Quaternary tectonism in the Cambay Graben have been reported in the form of entrenched rivers, cliffy sections, fault controlled river courses.

The Stage 2 of evolution of Nal region spans the interval ~73-7ka. A schematic representation of the geography of Nal region, during LGM, is given in Fig. 5.2.

**STAGE 3**

As a result of the combined influence of (i) westward advance of the sedimentation front; (ii) tectonism and; (iii) the post glacial sea level rise, the Nal Sarovar came to within few metres of its present elevation at about 7ka when it became a closed basin. The present Nal Sarovar, therefore, originated as a result of westward advance of the sedimentation front until it could no longer advance due to the presence of high land of Saurashtra. At that time either due to sedimentation process alone or aided by tectonism, the west flowing rivers shifted their courses and presently only the abandoned channels remain. The present day rivers are entrenched in their courses indicating the role of tectonism. Other studies also indicate that the present river

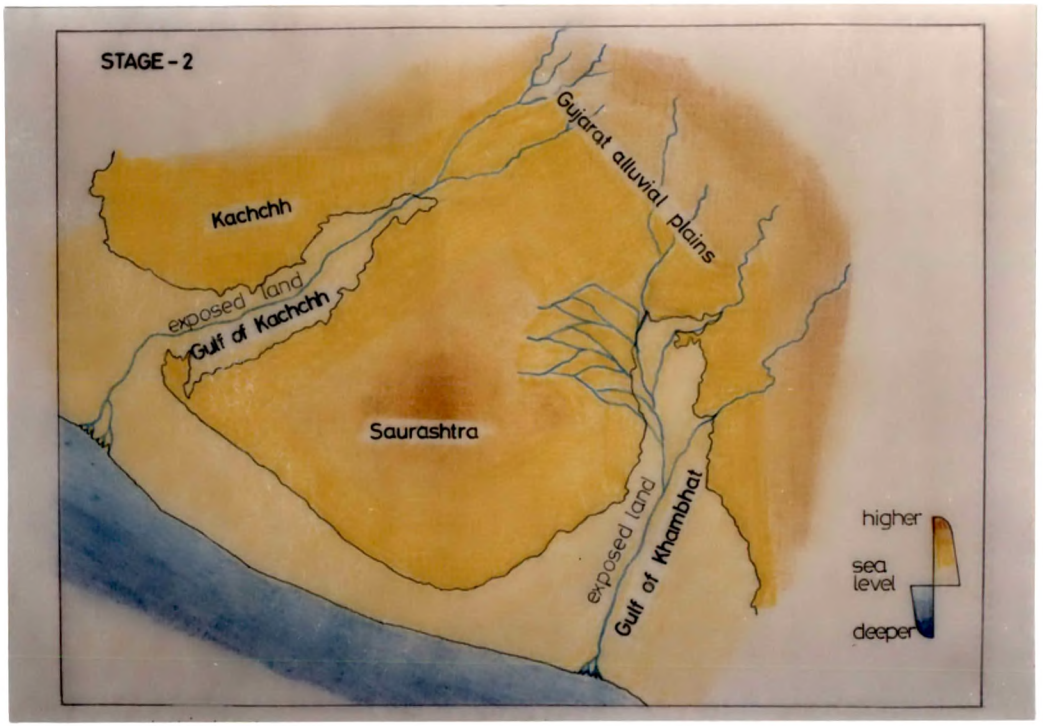


**Fig. 5.2** Schematic representation of the geography of the Nal and surrounding regions during the period (~18ka BP) of last glacial maximum (LGM) regression (in Stage 2 of evolution of Nal region)

courses may have been acquired during Late Quaternary. The mud flats, present to the south of Nal, represent Holocene transgressions in the area.

A schematic representation of the geography of the Nal region during Holocene transgression is given in Fig. 5.3.

In view of the distance, and elevation difference, that separates the Nal region from the reported exposed sections in Sabarmati, Mahi and Narmada rivers, as also the limitations of working with a core, it is difficult to establish correlation of these sections with the Nal region, particularly in view of limited chronological control. It was, however noted in Chapter 2 (Section 2.2.3.1), that red beds were encountered in the Nal core between 10-14m. The IRSL dating of a sample (N-143) at ~12m depth in the core gave a date of 47±8 ka. This is to be compared with the TL/OSL date, 58±5 ka, of a similar red bed found at Vijapur, near Ahmedabad. it is significant since this red bed has a regional occurrence and has been used as a marker horizon for Quaternary alluvial sediments. In view of the limited available chronological data, both from river sections and the Nal region, it maybe premature to attempt detailed correlation at this stage.

### *5.2.2 Palaeoclimate of Nal region during last 7ka*

The $\delta^{13}C$ and C/N ratio of the organic matter (Horizon-1), that was deposited in the Nal Sarovar basin, provide a qualitative picture of the palaeoclimatic variations in the region. The studies indicate that the period from ~6.6-6ka was generally drier than present with the exception of a short wet phase around 6.2ka. From 6-4.8ka the rainfall was lower than present but more evenly distributed, probably as a result of a slight increase in winter rainfall. From 4.8-3ka the climate was wetter than present. The trend towards aridity began around 3ka and present day conditions set in ~2ka BP. This picture is somewhat different to the one deciphered by earlier workers from Rajasthan lakes for the period 6.5-4.8ka when, in opposition to the wetter climate in Rajasthan, the climate here was drier. From 4.8ka to present however the climatic changes in this region are similar to those in Rajasthan. Also, a general agreement between periods of glacier expansion in Eurasia and drier periods in

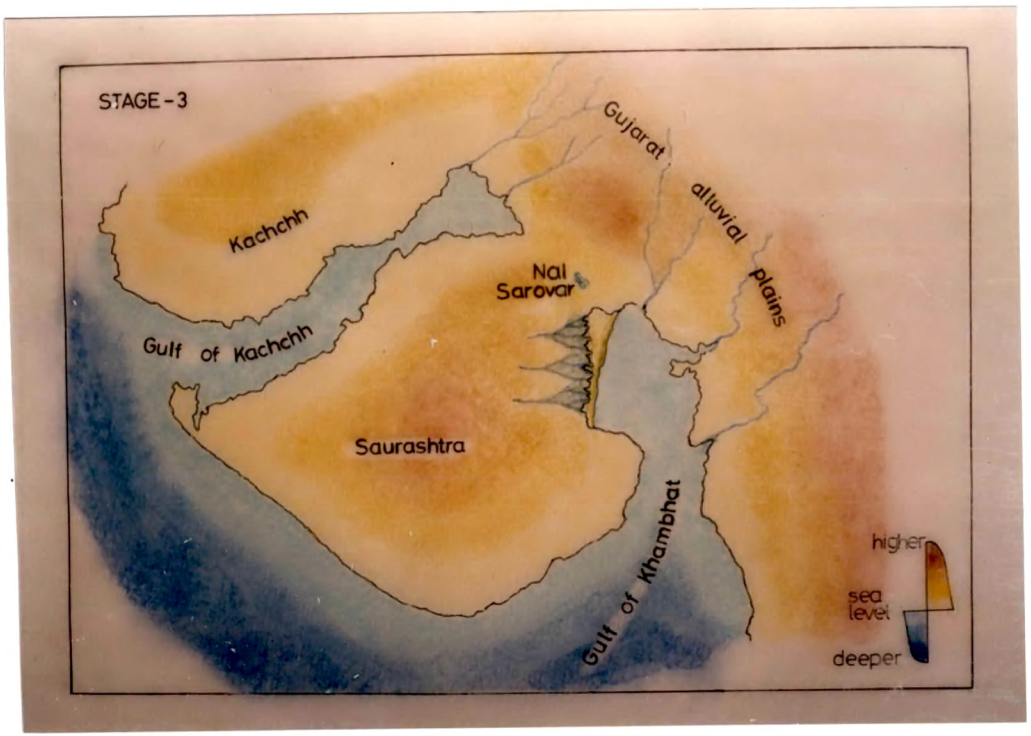


**Fig. 5.3** Schematic representation of the geography of the Nal and surrounding regions during the period (~5ka BP) of Holocene transgression (in Stage 3 of evolution of Nal region)

Nal Sarovar is observed. This suggests that the palaeoclimatic record from Nal is a regional feature.

### 5.3 Future perspectives

This thesis has yielded an understanding of the interplay of eustasy and tectonism in the evolution of Nal region and has provided a framework for further work in this region. Some of the studies were beyond the scope of the present work as they require extensive investigations, but need to be pursued later, are listed below:

* The amount of organic material in these sediments was small and obtained radiocarbon dates for much of the sequence were beyond the normal radiocarbon dating range. Therefore, recourse was taken to luminescence dating. In some samples, insufficient bleaching of sediments and in some others saturation effects were identified. The ages of different horizons and events in the evolutionary history of the region, therefore, had to be inferred through a combination of $^{14}C$, TL/OSL dating, geomorphological data and globally established chronology of sea level variations.

  More studies are required for further validating the chronology using a variety of approaches e.g., dating of different minerals, OSL partial bleach and TL partial bleach using restricted spectrum for bleaching.

* There is also a need to establish a more definitive chronology for the inland deltas. The limited field work undertaken during this study did not yield any suitable radiocarbon or uranium/thorium series dating material. TL/OSL was not attempted keeping in view the difficulties faced earlier.

* Additional drill cores, in the Little Rann of Kachchh through Nal Sarovar to Gulf of Khambhat corridor, have been raised to study the facies variation through grain size and mineralogical variations in this corridor. As expected, the lithological sequence is similar to the Nal Sarovar core. Detailed investigations on these cores are needed.

* No fossils have been found in the >63μ size fraction even in the Horizon-3 which, based on the considerations of sedimentology, mineralogy, eustatic sea level changes, chronology and stratigraphic correlation has been inferred to have been deposited in a shallow sea linking the Little Rann of Kachchh and the Gulf of Khambhat. The study of microfossils (<63μ) on this core as well as the others raised may prove useful.

* As the marine sediments have a higher concentration of boron in comparison to terrestrial sediments, such studies need to be carried out on the sediments from Horizon-3 to confirm their marine origin.