# CHAPTER 1

## INTRODUCTION

The Quaternary sediments of Gujarat preserve a record of a complex interplay of eustatic, climatic and tectonic changes through geological time. It is only in the past few decades that a concerted attempt has been made to decipher their evolutionary history through a study of various exposed sections. This, however, has resulted in leaving low lying areas, that lack exposed sections, remaining unstudied or receiving only cursory attention. The aim of present work is to decipher the evolutionary history, of the low lying Nal region, through a multidisciplinary study of sub-surface Quaternary sediments.

### 1.1 Study area

The Nal region is a low lying tract (average elevation ~+15m msl) which links the Gulf of Kachchh through the Little Rann to the Gulf of Khambhat (also known as the Gulf of Cambay) (Fig 1.1). The region lies between the Saurashtra highlands, to the west, and the Gujarat alluvial plains to the east. There are no major rivers draining into the region today. However, the region gets flooded during the summer monsoon months of June to September by the surface runoff from the surrounding districts of Ahmedabad and Surendranagar. In the following summer, the accumulated water dries up leaving behind a white salt crust covering large areas in the Nal region. Lying almost in the centre ($22^{\circ}48'$, $72^{\circ}E$) of this depression is a large (~120 sq km) shallow (average depth

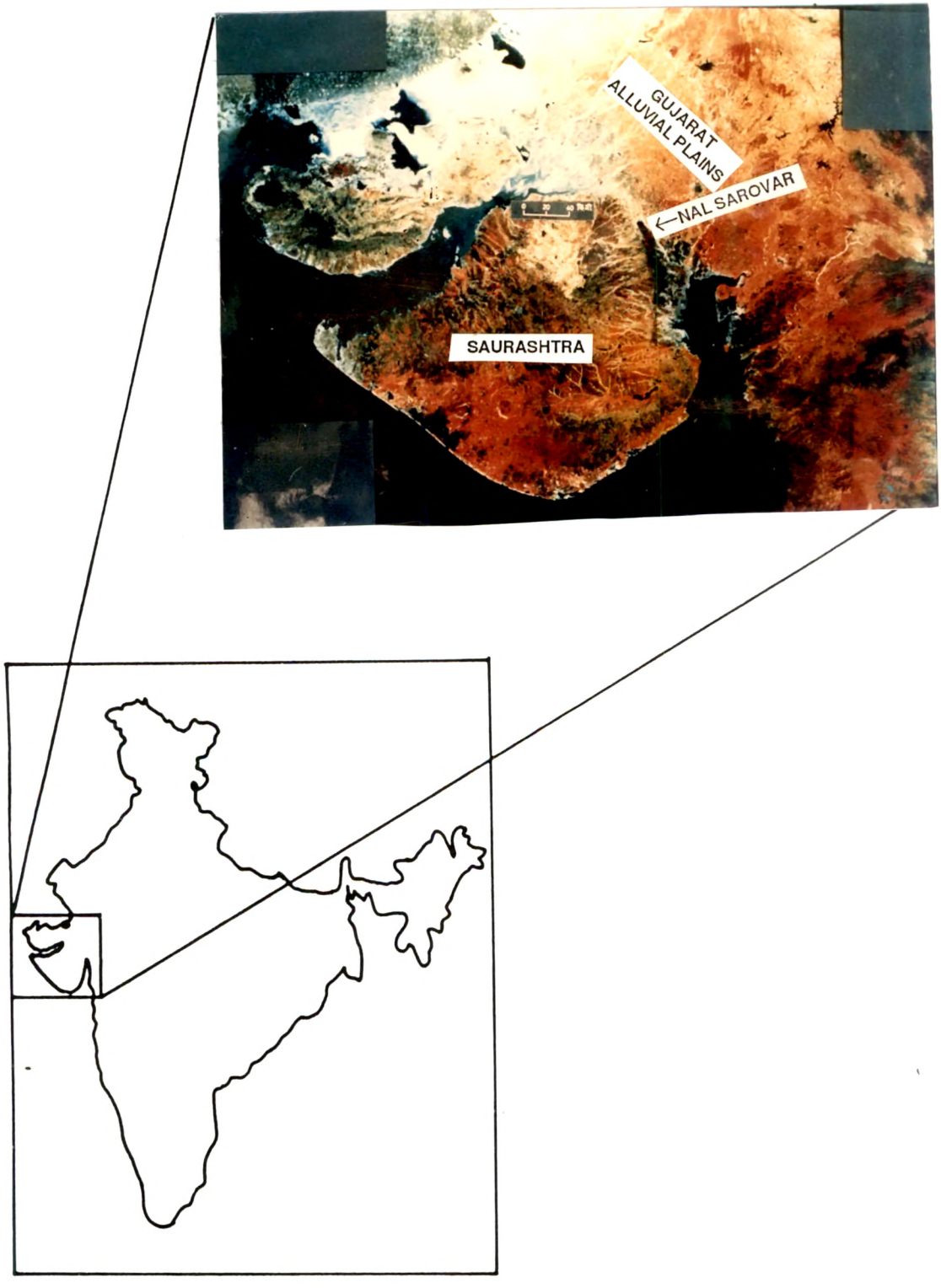


Fig. 1.1 Map of India and satellite imagery of Gujarat showing the location of Nal Sarovar and surrounding regions.

2m), brackish water lake, Nal Sarovar, (Sarovar in Hindi meaning lake) which is also a well known bird sanctuary of India. The entire region is easily accessible through a well laid network of roads. There are convenient bus services from Ahmedabad for reaching Nal Sarovar.

### 1.2 Climate

Presently, the region receives about 500mm of annual rainfall, mainly from the south-west monsoon in the months of July, August and September. During these months the lake is fresh and relatively deep. Winter temperatures range from a maximum of 22°C during daytime to 8°C at night. With the onset of summer, the lake becomes progressively saline and in some years dries up completely. Summer months are hot and dry with temperatures reaching a high of about 45°C during daytime and a low of 30°C during nights.

### 1.3 Flora and fauna

Common trees found in this area include Pilu (*Salvadora persica)*, Gando (*Prosopis juliflora*), Khijdo (*Prosopis spicijera)*, Babool (*Acacia nilotica*), Neem (*Azadirachta indica)* etc. Nal Sarovar is also rich in aquatic vegetation which includes *Typha, Potomogeton, Nelumbium, Aponogeton, Najas, Chara, Nitella.*

The region harbours mammalian species like Blue Bull, Wild Ass, Jackal, Hare and Hedgehog. Among the snakes found in this area are the common Cobra and the Rat Snake. The Nal region is especially rich in bird life. In fact, the economy of this area is chiefly based on the varied bird life found here which attracts a large number of tourists. The Nal supports some 250 bird species including Brahmini Maina, Ringed Plover, Cormorants, Koel, Oriole and Pelicans to name a few. In addition several species of migratory birds e.g. Flamingos visit the lake every year.

## 1.4 Geology

Nal depression, which constitutes the study area, is bounded by the Saurashtra basalts on the west and by the Juro-Cretaceous sandstones in the north-west. Alluvial plains are found to the east and north-east. To the extreme north-east are present the igneous and metamorphic rocks of the Aravallis comprising granites, dolerites, garnetiferous mica schist, hornblende schist and phyllites. Fig. 1.2 shows the geological map of the Nal and surrounding regions. The salt plains of Kachchh (the Little and the Great Ranns of Kachchh) are present in the northern vicinity of the Nal Sarovar while the mud flats are found towards the southern extremity.

## 1.5 Tectonics

The Nal study area is bounded by the following major faults (Fig 1.3):

a) Approximately 30km to the east of Nal region lies the western boundary of Cambay Graben (WCBF), where the Deccan trap rocks have been downthrown by nearly 2000m.

b) There is a fault (AA') to the west of Nal region which manifests itself as a prominent lithological boundary, trending N-S, beginning west of Nal Sarovar in the north and ending near the town of Palitana in the south. This is a contact between the Deccan volcanics in the west and alluvium in the east.

c) Another important fault (A'B') extends from near Bhavnagar in the east to Damnagar in the west and trends roughly E-W. This fault marks the boundary between an enormous thickness of the alluvium to the north and the Deccan Basalts to the south. This suggests that the fault block to the north may have been downthrown as there is no trace of basalts on the surface, the entire region being occupied by the alluvium in the north. However, basalts have been encountered at depths varying from 200-600m by Oil and Natural Gas Corporation (ONGC) during the course of drilling (Biswas, 1987).

d) Sridhar (1995), inferred a rotational fault (CC') passing through Nal Sarovar.

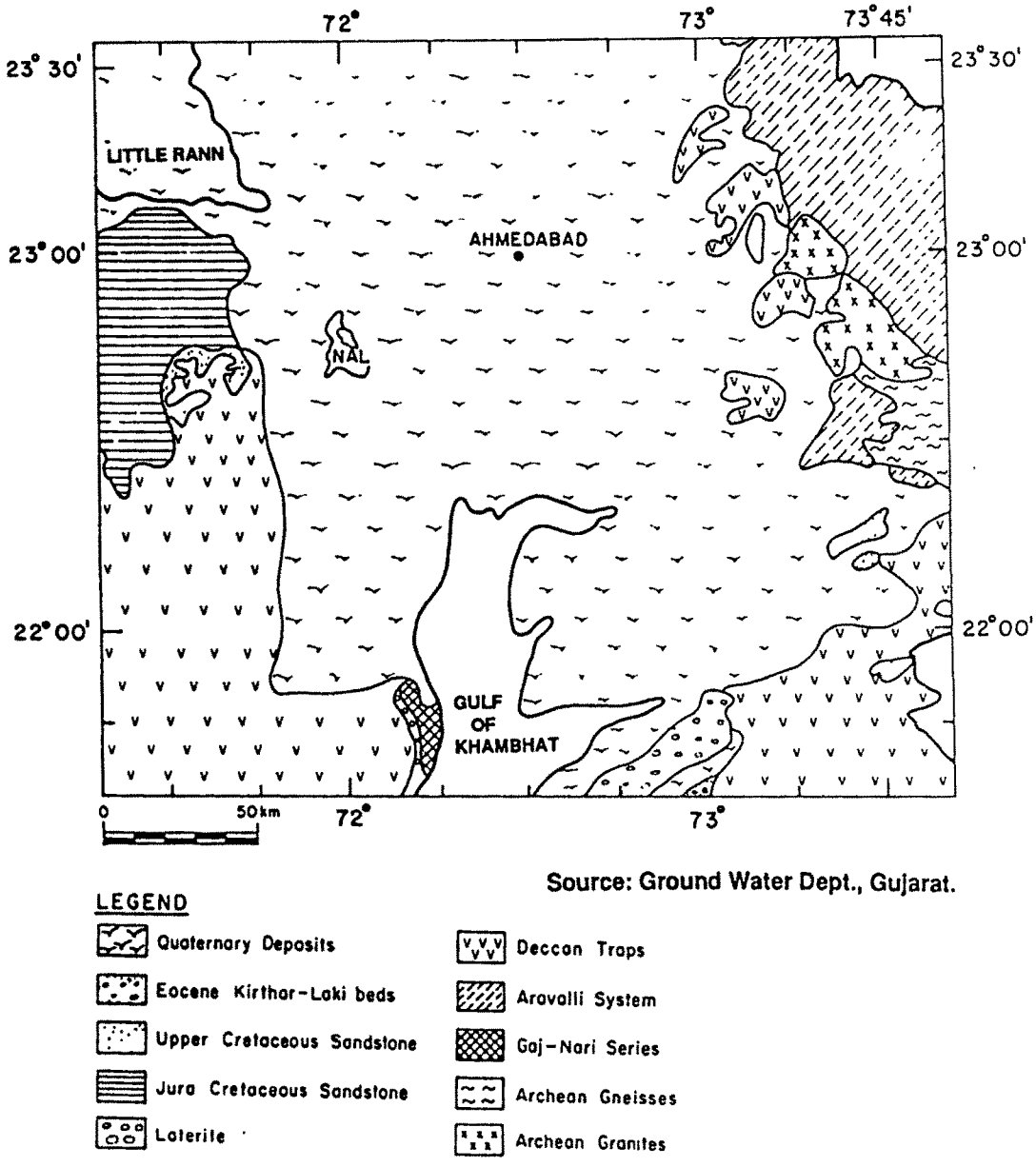


**Fig. 1.2** Geological map of Nal and surrounding regions.

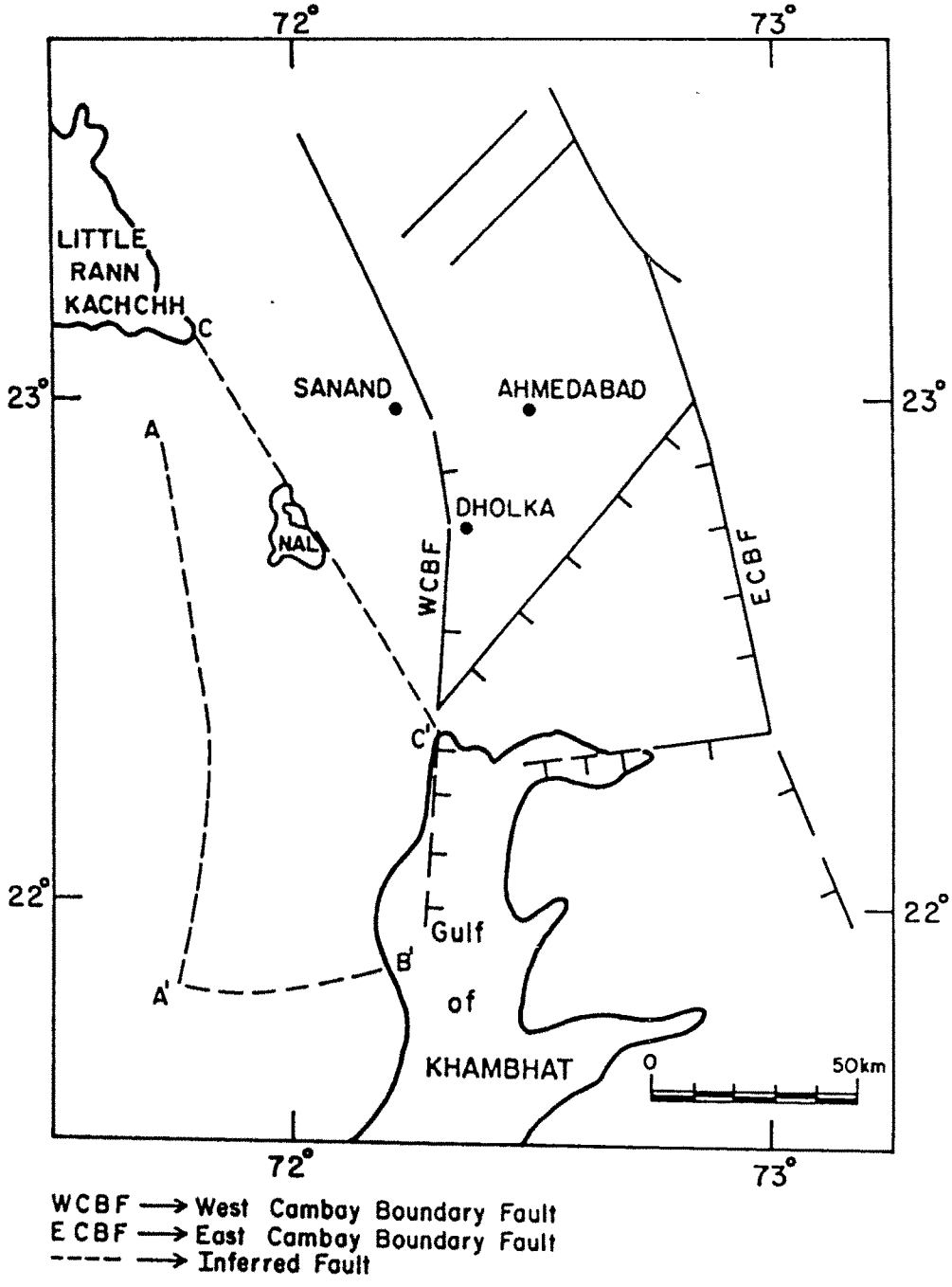


**Fig. 1.3** Tectonic map of Nal and surrounding regions.

(Modified after Chandra and Chaudhary, 1969).

## 1.6 Motivation and scope

Being located within the palaeo-Thar Desert margin (Goudie et al, 1973), the entire Nal region is a potential site for palaeoclimatic investigations. However, little is known about the evolution of this region. Based on its location in a low lying area, it had been surmised by earlier workers that the Nal lake is a remnant of a sea which linked the Little Rann of Kachchh and Gulf of Khambhat. This link was believed to have been progressively filled due to fluvial input from N-NE and west (Sukeshwala et al, 1948; Allchin et al, 1978). This proposed sea link was thought to have existed till ~2 ka and is believed to have been present at the time of the Holocene transgression (Merh, 1992). However, some questions remain:

1. Why does this topographic low not coincide with the Cambay Graben, located to the east of Nal, where the Deccan traps have been downthrown by more than 2000 m?
2. Based on radiocarbon dating, the elevation of Nal Sarovar was estimated to have been ~+10m, at the time of Holocene optimum (Gupta, 1973). Therefore, considering the magnitude of Holocene eustatic sea level rise on the west coast of India, variously quoted at +2 to +6m (Gupta, 1976), ~+3m (Pant and Juyal, 1993; Hashimi et al, 1995), and the absence of any reported evidence of uplift for the region, a sea link at the time of Holocene transgression seems unlikely.
3. In view of the fact that the global sea level was ~+7m msl during the last major interglacial (Ku et al, 1974; Cronin et al, 1981; Chappel and Shackleton, 1985; Pant and Juyal, 1993) and the low lying topography of the area, the existence of a sea link at some time during pre - Holocene cannot be ruled out. In such a case, if and when did the sea link exist?
4. The Nal region lies in close proximity to the Cambay Graben where evidences of Quaternary tectonism in the form of entrenched streams, cliffy sections and fault controlled drainage pattern have been

observed (Sridhar et al, 1994). What role was played by eustasy and regional tectonism in the evolution of Nal region?

The motivation for this work has therefore been to find answers to the questions posed above and to supplement the meagre palaeoclimatic data that is available from this semi arid region bordering the Thar Desert.

## 1.7 Objectives

The objectives of the thesis are two fold:

1. To decipher the evolutionary history of the Nal region in terms of eustasy and tectonism.
2. To reconstruct the Holocene palaeoclimatic history of the region.

## 1.8 Approach

### *1.8.1 Evolution of Nal region*

The study is based on the interpretation of remote sensing data and subsurface lithological correlation of bore hole data from regions around Nal Sarovar. In this connection, following studies were carried out.

1. Identification and mapping of drainage pattern and palaeochannels using toposheets and IRS FCC 1A imagery (1:250,000 and 1:50,000 scale) for studying past drainage patterns. This was necessary to identify the probable source of sediments in this region as also to study the changes in drainage pattern. The channels were identified on the imageries on the basis of colour, tone and linearity. Both pre- and post-monsoon imageries were studied and compared with the toposheets to identify the defunct channels.
2. Geomorphological features such as palaeo-deltas and mud flats which are indicative of sea level changes were also delineated and mapped using IRS FCC 1A imagery.
3. There are no surface exposures of Quaternary sediments in the Nal region. Hence, bore hole lithologs were collected from Central Ground Water Board

(CGWB), Gujarat Water Resources Development Corporation (GWRDC) and Gujarat Water Supply and Sewerage Board (GWSSB), for thirty stations spread over the Gujarat alluvial plains and Nal region. Three transects, two in NE-SW and one in NS direction were drawn, to enable subsurface lithological correlation as well as to study facies variation.

### *1.8.2 Palaeoenvironmental studies*

The basic framework was provided by

1. Sedimentological studies to obtain information about the environment of transport and deposition of sediments.
2. Mineralogical studies using X-ray diffraction (XRD) and heavy mineral analysis for provenance identification.
3. Study of stable isotopic ($\delta^{13}C$) and carbon/nitrogen (C/N) variations on organic matter for palaeoclimatic reconstruction.
4. Chronology, using radiocarbon and luminescence dating techniques, on the 54m long core raised from the bed of Nal Sarovar.

The results of these studies were synthesised with the available data on the eustatic sea level changes and a scenario for the evolution of entire Nal region was developed. Within the framework of this scenario, paleoclimatic reconstruction during Holocene was planned.

The thesis is structured as follows:

In **Chapter 2** is discussed the methodology and results of geological and geomorphological studies.

In **Chapter 3** are discussed the results of radiocarbon dating, stable isotope ($\delta^{13}C$) and C/N ratio analyses. Also discussed are the palaeoclimatic interpretation of these studies.

In **Chapter 4** are discussed the basic principles and results of luminescence dating of Nal core.

In **Chapter 5,** the results of various studies carried out are summarised and synthesised. A model for the evolution of Nal region is also presented.

Sampling procedures and experimental details of laboratory studies are discussed in the Appendixes.

In **Appendix A** the sampling procedures and details of Nal Sarovar core are presented.

In **Appendix B** the procedures employed in sedimentological and mineralogical studies are presented.

In **Appendix C** the details of procedures employed for radiocarbon dating are presented.

In **Appendix D** the procedures employed for stable isotope ($\delta^{13}C$) and %C, %N measurements are presented.

In **Appendix E** the details of procedures employed for luminescence dating are presented.