1
INTRODUCTION

PURPOSE AND SCOPE

Coastal zones are the repositories of evidence of changing land sea interface at various temporal scales; million to decadal and even annual. This may be with distinct trends indicating hemispheric climate change or imaging an abrupt event like a storm or tsunami.

A number of studies are available from various parts of the world, dealing with the palaeoclimate and sea level changes during the Holocene, based on mineralogical, geochemical and palaeontological proxies from coastal and marine environments. The laminated sediments of the tidal flats make it a good recorder of inter annual- to century-scale climate variability. The ability to construct palaeo-environmental time-series with near-annual resolution in the most recently deposited sediments allows the observations for calibration with historical instrumental records, and that can be extrapolated to the past to reconstruct the Holocene climate.

Signatures of environmental changes, taken in the past, are much clearly observed in the natural sinks. Estuaries are one such natural sink, where low energy conditions support deposition with minimum or nil erosion that leads to undisturbed and continuous sequence of sediments. The present study has been therefore, carried out to explore such type of high resolution record from the bottom of the Meda creek which is famous for the Harshad Mata temple on its right bank.

To understand changes in the past it is also essential to know present day setup and control of geological environment on the distribution of various species, or group of species that form proxies in the past record. Study of the relation and/or interactions between biota and other variants of geological environments are known as Geo-ecology. The present study tries to establish relation between geological variables and biota in the Meda creek.

With a purpose to understand the Late Quaternary history of the region the depositional and erosional features have been analysed at higher resolution. The middle to late Pleistocene deposits have been studied for their microfacies whereas, the Holocene record has been examined from the dried bed of the Meda creek.

Objectives

The basic objectives of the present study have remained as under;

(1) To evaluate the geological characteristics of the study area especially, that of the Late Quaternary age with reference to its bearings on the geo-ecology at local scale.

(2) To record a multi-proxy database on the Holocene sediments sampled at high resolution from the dry bed of the Meda Creek for their sedimentology, and palaeontology.

(3) To reconstruct the Holocene climate variability at fair resolution with multi-proxy approach.

Methodology

To achieve the above said objectives, the following methodology has been adopted.

- Various maps like drainage, geomorphology, geology and soil were prepared with the help of the satellite data, SOI topographic sheets (1: 50,000) and other authentic published data and field observations.
- The present day geo-environmental conditions viz., morphology, water quality and macro and microfauna of the Meda Creek and adjoining intertidal area were evaluated to prepare the baseline data.
- Exposed Late Quaternary sequences were studied for their mode of occurrences and petrographic details. For this samples were collected from open quarry and trench sections.
- To evaluate the Late Holocene sequence, total 2.9 meter profile was sampled that included 2 meter of trench section followed by a core of 90 cm that was taken at the base of the trench using 3" diameter PVC pipe.
- The samples sliced at 6 cm interval were analyzed for its sedimentological characteristics. Samples at 18 cm interval were studied for micropalaeontological and palynological content.
- The micropalaeontology was studied using standard techniques for foraminifera, ostracods, pteropod and charophyte population.

THE STUDY AREA

Meda creek is a sea-dominated estuary located on western Saurashtra coast between Porbandar and Dwarka. It remains as a creek (sea inlet) during winter when fresh water does not come from the inland areas, and turns into a lagoon during summer when the spit extends northward and closes the mouth. Only during monsoon it turns into an estuary having interplay of saline and fresh water. The estuary is situated between Latitudes N 21°49.25' to 21°51.75' and Longitudes E

69°22.15' to 69°24.00' (Figure 1.1). The creek marks the administrative boundary between Porbandar and Jamnagar Districts of the Gujarat State.

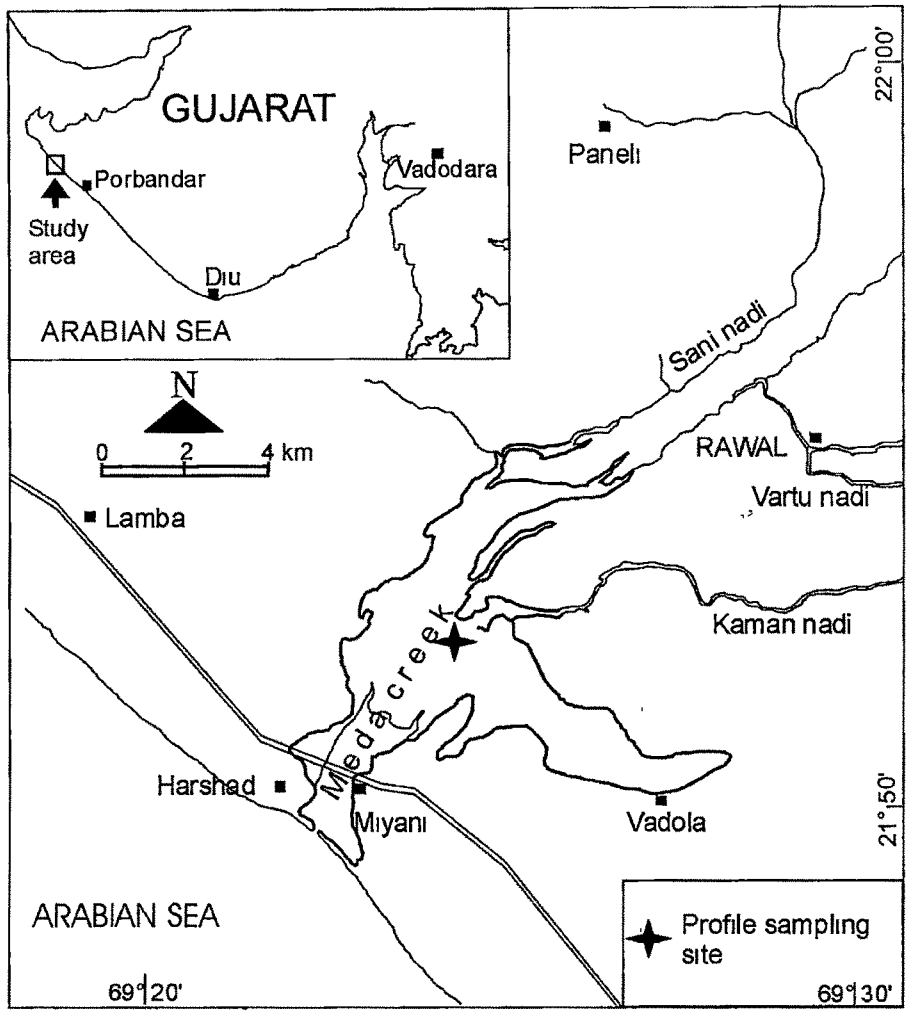

Figure 1 1 Map showing the geographical setup of the study area

Climate

The region is located on the margin of arid and semi arid climatic domains of the State (Figure 1.2) (Subramanyam 1983). Therefore, the study area experiences arid to semi arid climate; the April and May being the hottest months with a daily mean maximum and minimum temperatures of 32.1°C and 28°C respectively. Some time drop in temperature and closeness of sea leads to heavy formation of fog in winter. The highest temperature goes as high as 45°C during the peak of summer.

The December and January are the coldest months. The mean daily maximum temperature in January remains at 28.5°C and mean daily minimum temperature at 15.3°C. During winter nights mercury drops upto 4.5°C. Storms and depressions that form in the Arabian Sea during May and June cause heavy pre-monsoon showers associated with gusty winds.

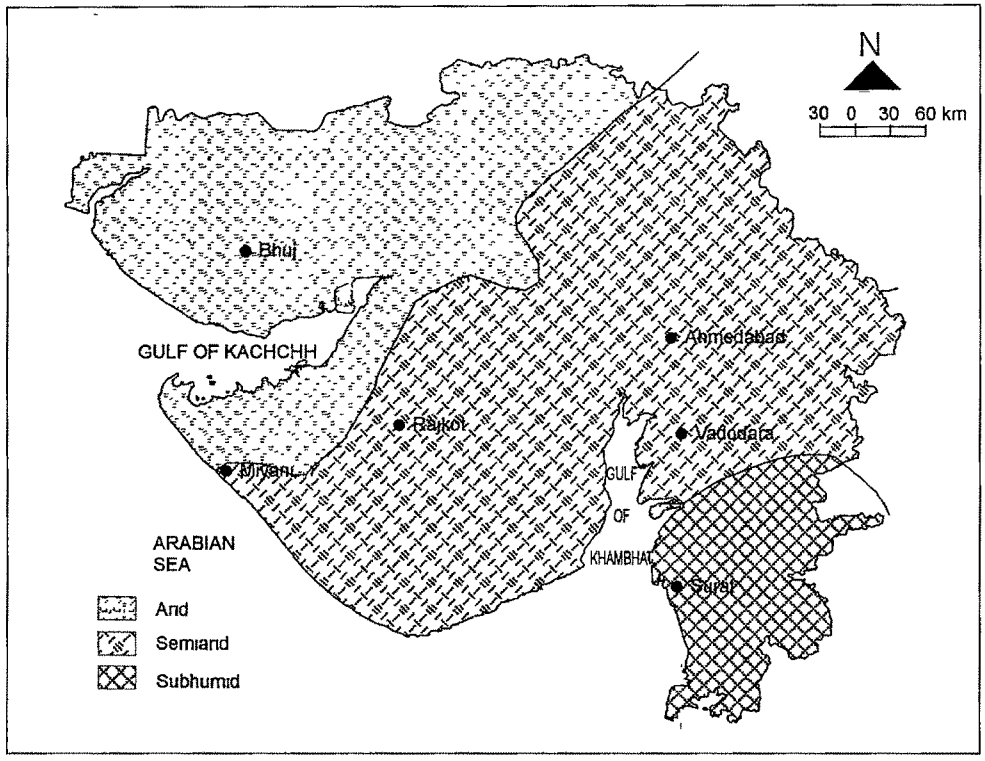

Figure 1.2 Climatic zones of Gujarat (Subramanyam 1983)

Prominent wind directions are NW in summer, SW in monsoon and NE in winter. Winds are light to moderate with annual average speed of 14.5 km/hr. There is some increase in force during the southwest monsoon season when mean wind speed increases to 19.1 km/hr in June and 23.1 km/hr in July.

Generally monsoon sets at the end of June and continues upto October. Maximum rainfall is received during the months of July and August. During the monsoon month relative humidity remains over 80%. The annual average rainfall remains in the range of 500 to 600 mm.

Bhanwad and Kalyanpur are the Taluk headquarters situated on the eastern and western side of the Meda creek, respectively. The Water Resource Investigation (WRI) rain gauge data shows average annual rainfall at Bhanwad is 627 mm and at Kalyanpur is 512 mm (Figure 1.3).

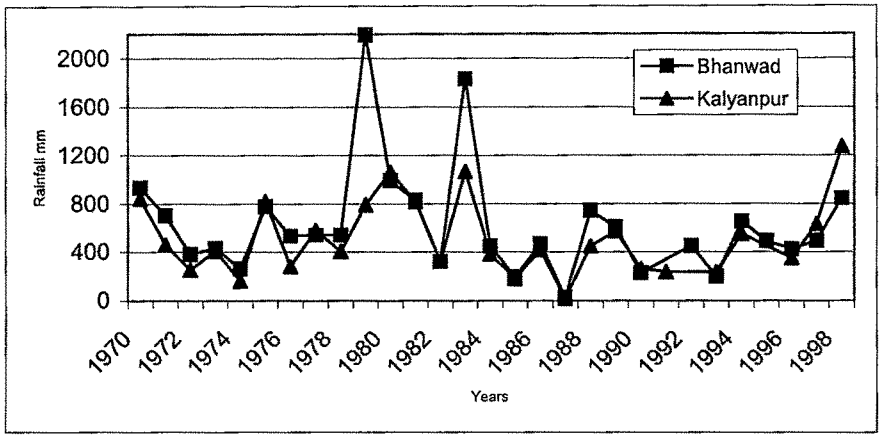

Figure 1 3 Rainfall in the catchments of Meda creek

Physiography

The study area forms a part of western Saurashtra which is marked by a large Deccan Trap plateau in the centre, fringed by a narrow strip of coastal plain, highly crenulated coastline in the north and relatively straight coast in the south.

The study area can be divided into three distinct units; (1) Barda hill complex, (2) highly dissected undulating mounds forming upper catchment and (3) coastal low lying area, with coast parallel linear ridges that reach upto 10 m AMSL. A prominent hill known as Kalio dunger (also known as Harshad hill) whereupon the famous temple of Harshad mata is situated forms a physiographic high of about 65 m right on the coast. Terrain becomes more rugged in northeast and eastern side, mainly attributed to the Daccan Trap basalt flows and Barda Igneous Complex. The maximum altitude in the study area is attained by the Barda hill (627m) whereas the Gop dungar in the east makes another major high of 362 m. Figure 1.4

depicts the physiography of the area as can be appreciated from the DEM (Figure 1.4).

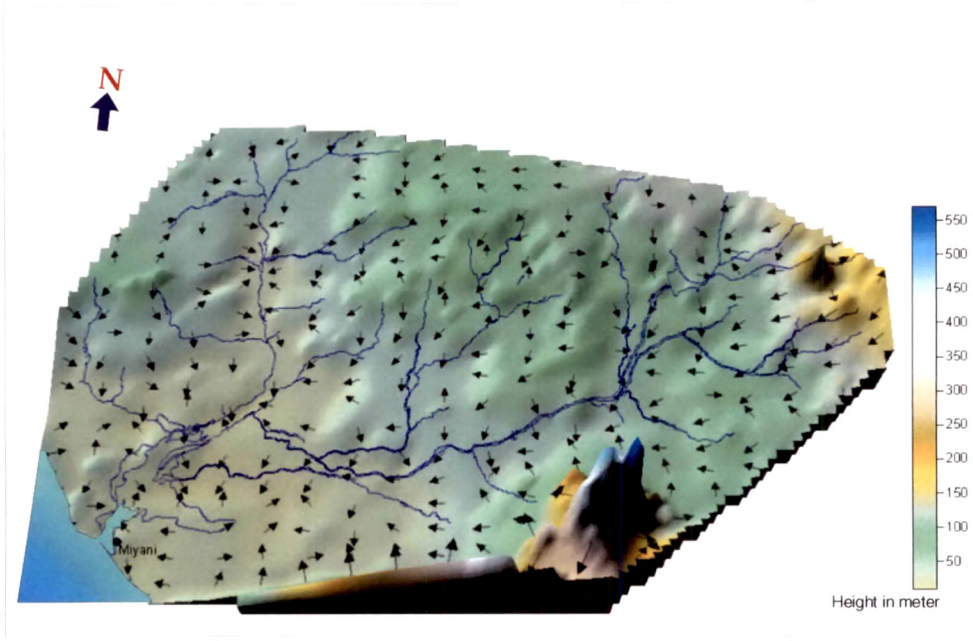

Figure 1.4 Digital Elevation Model (DEM) with slope vectors in the Meda creek catchment area.

Drainage

The central high land formed by Daccan Trap Formation makes the major water divide for the drainage of the western Saurashtra (Figure 1.5).

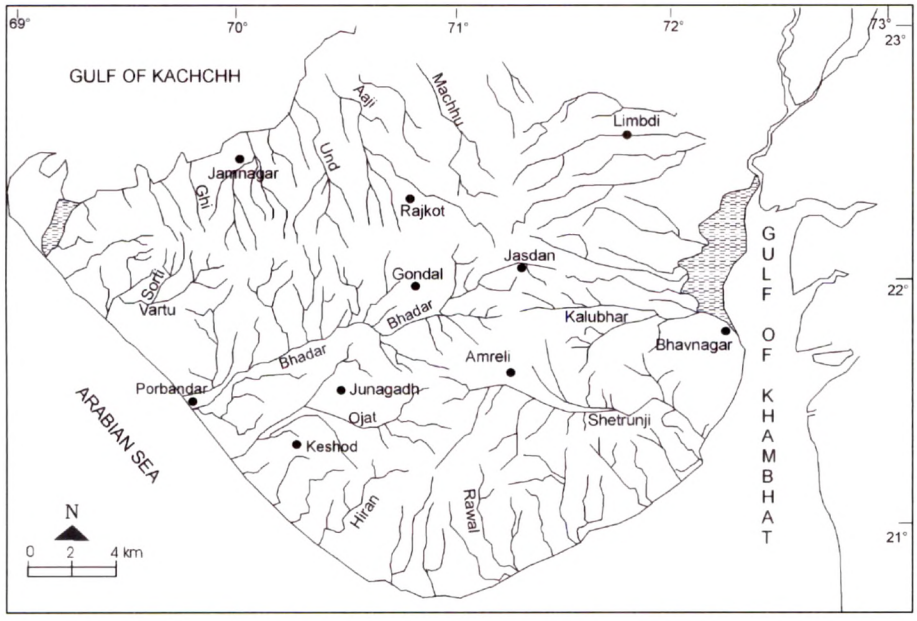

Figure 1.5 Drainage map of Saurashtra Peninsula

Bhadar is the major drainage system in Saurashtra that covers about 4143.75 sq. km area; originates from Jasdan plateau and meets the Arabian Sea at Navibandar. The catchment of Meda creek consists of two major rivers viz., Vartu nadi and Sani nadi. This covers an area of about 2457.24 sq. km. The basin extends in the SW direction to meet the Arabian Sea near Miyani. Towards the north of the study area, small rivers like Ghee, Sihan, Fuljhar and Sasoi flow north wards to meet the Gulf of Kachchh.

In the study area, the Vartu originating from the Barda Hills and Gop dungar flows in west direction to meet Meda creek near Rawal (Figure 1.6). Total catchment of Vartu is 1327.40 sq. km. The Vartu has two tributaries, Sorti and Kaman. Sorti, a major tributary of Vartu, originates from the hills in the northeast of the area at an altitude of 106 m AMSL. Its catchment dominantly consists of undulating terrain formed by the Daccan Trap rocks. Another tributary, Kaman is a very small river that originates from Barda hill at 456 m AMSL; most of its flow is through very gently sloping coastal plain manly consisting Quaternary and Tertiary Formations. Sani nadi occupies a catchment of about 929.84 sq. km and is located in northern part of the study area. This forms a gently slopping terrain mainly consisting of buried pediments and alluvial plain with contours hardly exceeding 60m level. A small tributary of Sani is Sindhni nadi that flows through highly weathered Deccan Trap basalts, laterite and younger alluvium.

These contrasting characters of the catchment area are clearly reflected in drainage density of these rivers (Table 1.1). The drainage density of Vartu is highest with 1.898 streams per sq. km than that of Sani, which is 1.748 streams per sq. km.

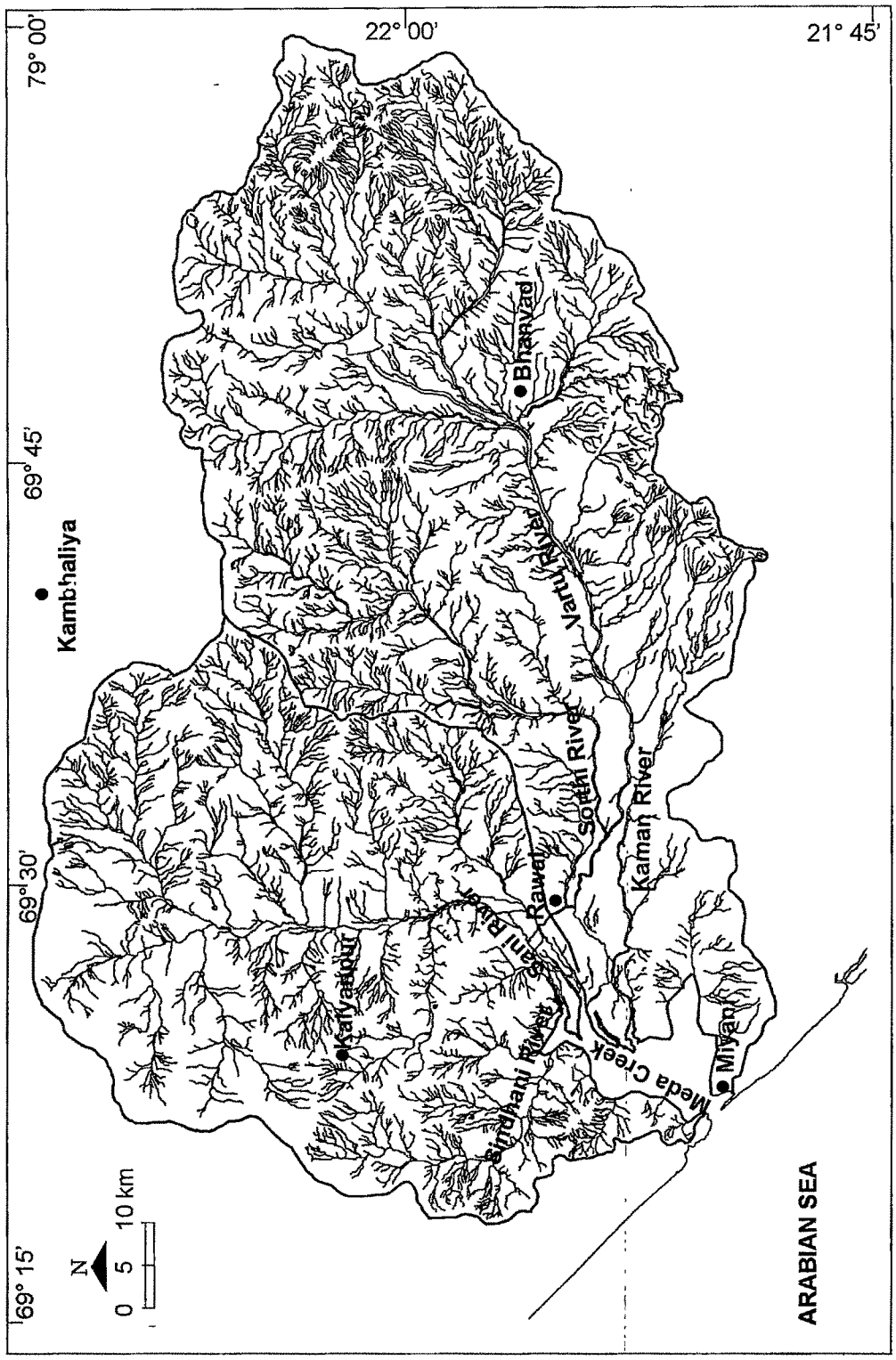

Figure 1.6 A detailed drainage map of the Meda creek and inflowing river basins

Table 1 1 Drainage characteristics of the Meda creek catchment

Stream order	Drainage Density number of stream per sq. km	
	Vartu nadi	Sani nadi
1st order	1.400	1.280
2nd order	0 383	0.364
3rd order	0.089	0.079
4th order	0.017	0.018
5th order	0.006	0.004
6th order	0.002	0.002
7th order	0.001	0.001
	1.898	1.748

Higher density of drainage in the Vartu basin could be a result of more steep terrain as compared to the Sani basin. However, primary factor that give rise to a drainage is rainfall which is also recorded higher in the Vartu basin (at Bhanvad) in comparison with the Sani basin (at Kalyanpur).

Geomorphology

The study area consists of a variety of geomorphic units (Figure 1.7) starting from hills to costal plains, beaches and intertidal areas. Barda hill igneous complex is a semicircular hill in the eastern side of the study area with very steep slopes that start rising from 80m contour and attains about 600 m height in the study area. The Barda hill is marked by steep escarpments in the north and western side of the hill. The pediment zone is partly covered by the aeolianites of Middle Pleistocene age that constitutes the miliolite deposits.

A group of hills viz, Gop dungar, Ekakheda dungar and Ketia dungar, makes another hill complex in the eastern side of the study area. These are hills made-up of basaltic flows and occur along N-S and NW-SE trends. Gop hill is the highest peak among them with 362 m height. Large part of the area located on the northern and western side of the Meda creek is marked by stony waste and volcanic dykes.

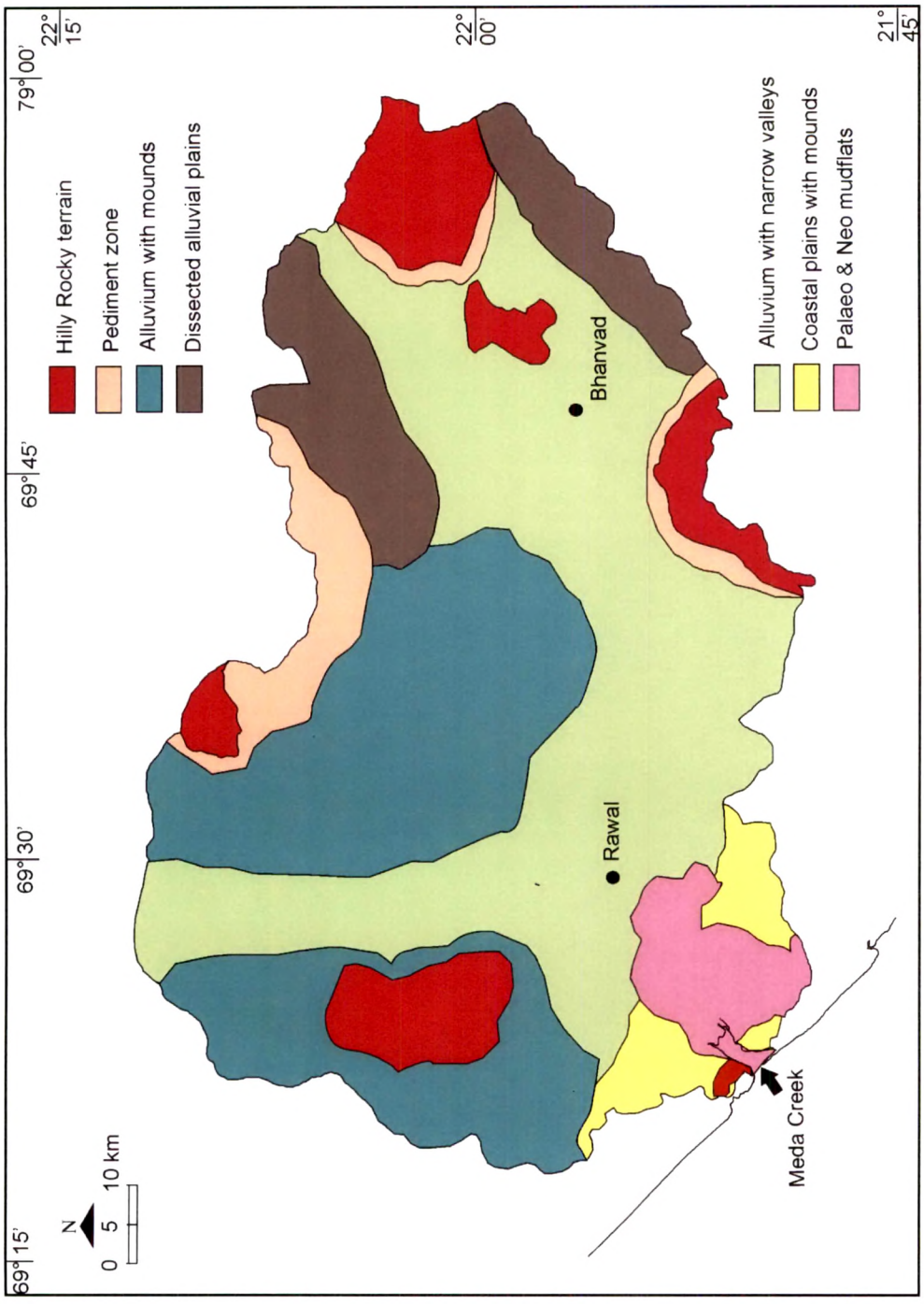

Figure 1.7 Geomorphology of the Meda creek and its catchment area

Barda hill contains narrow and steep pediment zone with excessively drained barren stony waste. Pediment zone is followed by gentle sea ward slopping plain marked by alluvium with narrow well dissected valleys and mounds. This unit

defines the coastal plain that separates active coastal landscape and the hills. Near the shore, successive beach ridges, swales, coastal dunes and beaches form the interesting geomorphic scenario. At many places hard rocks extends shoreward and form shore platforms.

Soils

The soils of the study area are fine and clayey in nature. Montmorillonite is the major clay mineral, derived from the weathering of basalt source rock. Almost all soil units are calcareous in nature, pointing towards Ca rich provenance and dry climate. Upper catchment is marked by very shallow to shallow well drained soil units, whereas costal soils are deep, poorly drained and suffers from salinity and sodisity problems. Soils of pediment zone and rock mounds are lithic and paralithic (dominated by rock fragments) in nature and are exposed in upper catchment of the Vartu and Sani river (Figure 1.8).

A large part of the study area contains soils formed due to insitu weathering and quick alteration of parent rock, known as Inceptisols. Soils occurring in catchments of Sorti River are light coloured and moisture deficient, with less organic matter (Ustochrepts grate group).

Soils that occur in upstream of Meda creek and in surrounding area of Rawal are deep dark colored soil (Chromusterts grate group, a Vertic type of soil) suffering from salinity and sodisity problem due to the lack of proper drainage and proximity with Meda creek.

Soils in the coastal dunes and adjacent area are coarse grained sandy in nature and show a negligible development of pedons (Ustipsammants grate group of Entisols). Soils in foot hill of Harshad are very shallow, dry, skeletal soil formed due to

results of rapid erosion of parent rock (Torriorthants grate group of Entisols)

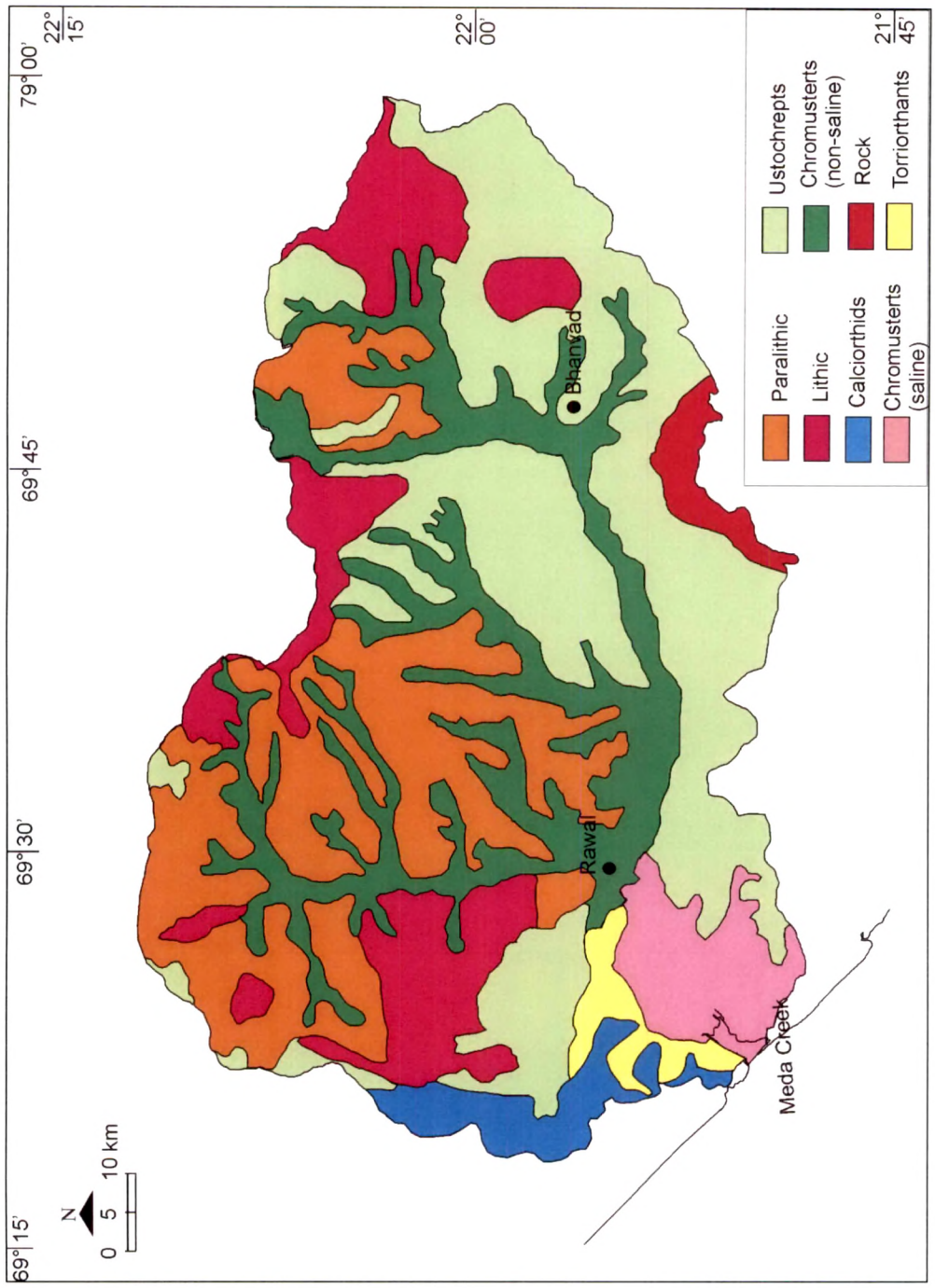

Figure 1.8 Soil map of the Meda creek and its catchment area (Sharma *et al* 1994)

In the western side of the Harshad, soil contains strongly leached surface horizon of oxides of aluminum and iron derived from weathering of laterites (calciorthids grate group of spodosols).

Terrestrial and coastal biota

Study area is has a variety of natural ecosystems like forests of Barda hill, grassland, scrublands, estuary, coastal dune and intertidal areas. Agricultural land has occupied large terrestrial area, except steep slopes of Barda and coastal saline tracts. Rain fed agriculture dominates with minimum irrigation. Major crop types of the area are groundnut, cotton, *bajri*, *jowar* and wheat.

The forests of Barda hills are rich in biodiversity, as there have been about 700 plant species are recorded (Singh 1998). The major tree species are *Acacia senegal* (Gorad), *A. nilotica* (Babul), *A leucophloea* (Hermo), *Anogeissus latifolia* (Dhav), *Manlikara hexandra* (Rayan), *Zizypus* sp. (Ber), *Syzigium cumini* (Jamun), *Tamarindus indica* (Amli), *Wrightia tinctoria* (Dudhlo) and *Dendrocalamus strictus* (Bamboo). About 20 mammalian species have been recorded, major of them are blue bull, wild boar, hyena, jackal, leopard, wolf and fox.

Scientists have recorded 83 invertebrate species, including 53 species of butterfly. 4 species of amphibians and 28 species of reptiles have also been recorded from the Barda hills. There are 166 of birds species recorded from the Barda hills.

Outside the forests, major tree species found include *Prosopis juliflora, Acacia nilotica, Salvadora* sp., *Azadirachta indica* and *ficus* sp. Vegetation around Meda creek consists of sparse mangrove, *Avicinia marina* occupying western bank of the estuary. Avian species like seagull and lesser flamingoes were observed in the creek. Meda creek is dominated by invertebrates like oysters, shrimps, gastropods and sponges. Several microfauna like ostracods, pteropod and foraminifera inhabit the creek. The rocky intertidal area facing the Arabian Sea has a variety of algal

and invertebrate species, including corals. During the study a control of geo-environmental factors on the distribution of invertebrates was clearly observed.

Geology

The Deccan Trap Formations of Upper Cretaceous age forms most widely occurring and the oldest Formation in the study area. It mostly occurs as dykes and flows of black and grey colored massive basalt and amygdaloidal basalt, extensively in the north and northeast part. Another major occurrence of this Formation is in the form of Barda igneous complex. Barda hill consists mainly of felsites and quartz-felsites. Daccan Trap Formation also constitutes many prominent hills like Gop and Harshad hills (Merh 1995). Laterites are exposed in western part of the study area as discontinues strip running from North to South. Quaternary sediments are found widely distributed in the form of aeolianites, beach rocks, coastal dunes, tidal flats, fluvial gravels and sands. The major exposures occur in coastal areas bordering the Meda creek. The foot hill of Barda hill and Gop hill host obstacle deposits of Miliolite Formation of Middle to Upper Pleistocene age. The Holocene deposits are mainly found occurring as raised mudflats and stabilized costal dunes. The geological setup of the region in general and that of the study area in particular, is described in the successive chapter.