Chapter III

GEOMORPHOLOGY

3.0 INTRODUCTION

This chapter is mainly concerned with the systematic description and interpretation of the present day as well as the past geomorphic features in the study area, taking into account the field observations aided with remote sensing techniques, and ground checks. According to Davis (1909), the geomorphic processes and the prevailing litho-tectonic framework along with the climate, plays a significant role in controlling the successive sculpturing of the landscape configuration of that region, with increasing time.

The south Gujarat area in general and the study area in particular aptly represents an assemblage of diverse geomorphological features exhibiting a complex interplay of various erosional as well as tectonic processes (Scheidegger & Padale, 1982; Vyas, 1984). Earlier workers (Radhakrishna, 1965; Scheidegger & Padale, 1982; Ollier & Powar, 1985; Alavi, 1990) have attempted to describe the various geomorphic attributes of south Gujarat terrain; however, no specific studies have been made so far as the study area is concerned. The present study is aimed to bring out systematic analyses of these features and the factors responsible for their genesis with the help of field observations and satellite data (IRS-1C LISS III, 1998) (Fig. 3.1).

3.1 PHYSIOGRAPHY

Physiographically, the study area is characterized by a moderate relief, beginning from almost at the mean sea level in the west with highest positive value of 300m in the east, within an average lateral distance of 70 – 80 km. Based on the present day altimetric variations and the various geomorphic attributes such as relief, drainage, land use pattern and surficial sediment nature, the study area has been divided into four physiographic units (Fig. 3.2) viz.

A Trappean Highland Zone (>100m Above Mean Sea Level)

B Upper Pediment Zone (50-100m Above Mean Sea Level)

C Middle Alluvial Zone (10-50m Above Mean Sea Level)

D Lower Coastal Zone (<10m Above Mean Sea Level)

3.1.1 Trappean Highland Zone

The trappean highland zone, covering around 1600 sq. km., comprises the northernmost extension of the Western Ghat escarpments, the Sahyadri ranges and forms as N – S extending high plateau. A NNE – SSW fault (Babu, 1984; Rao 1987) appears to delineate these trappean highlands from the uplands (Alavi, 1990).

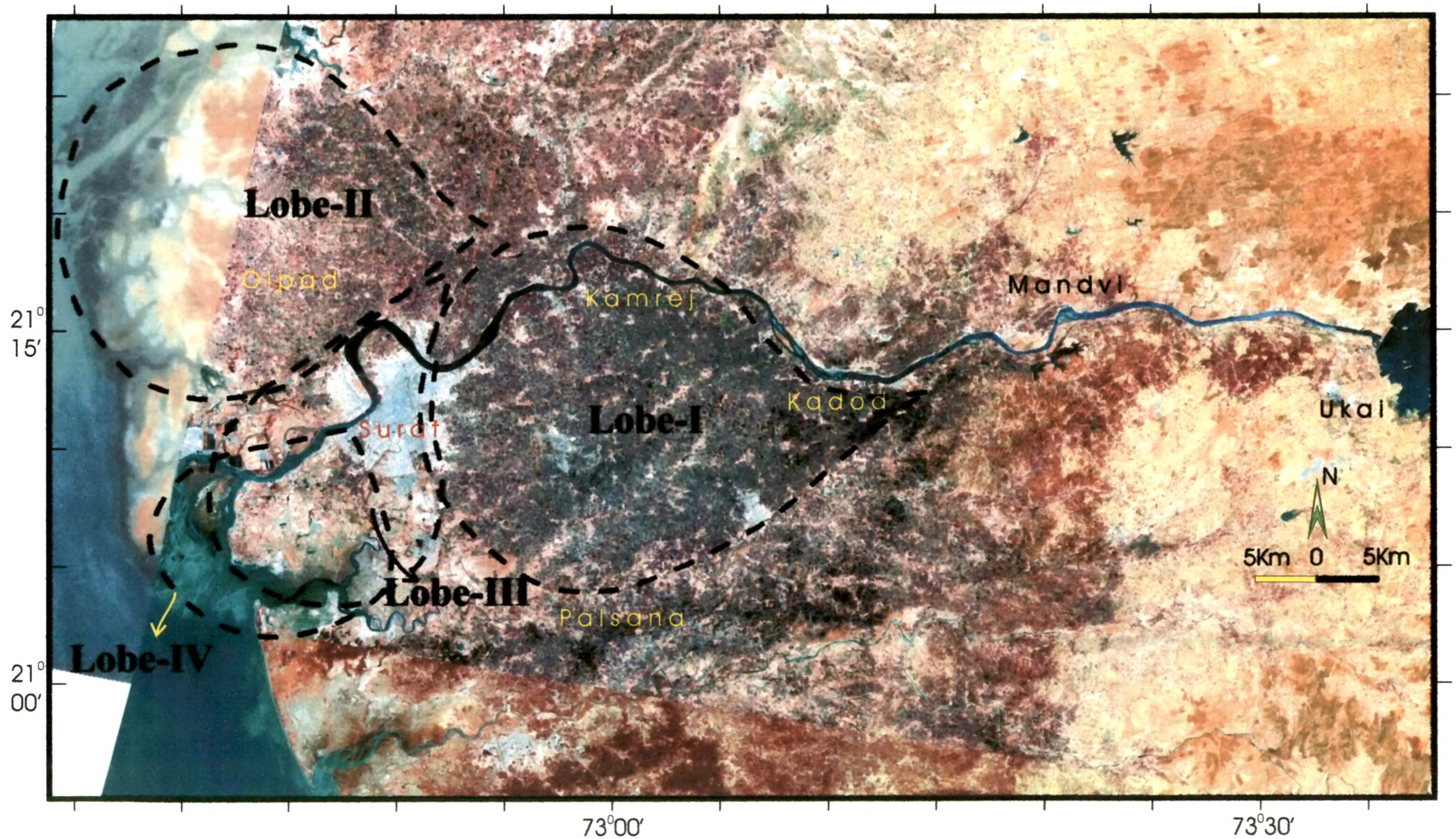

Fig. 3.1 - Satellite Imagery (IRS-1C LISS III, 1998) Of The Study Area.

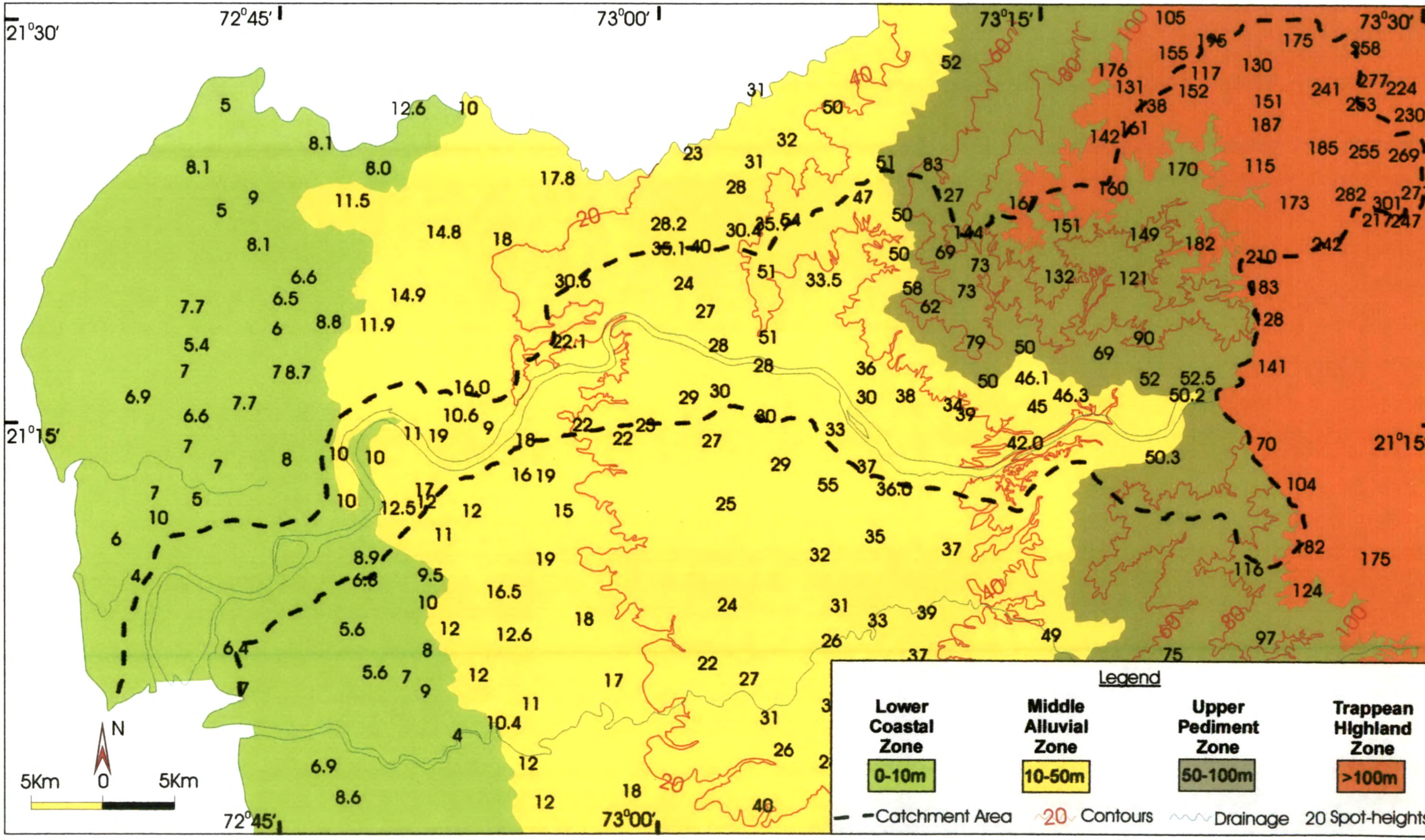

Fig. 3.2 - Physiographic Map Of The Study Area.

The spot heights and contour patterns of this zone, demonstrates a general slope towards west to northwest. The topography of this zone is highly rugged, marked by steeply sloping landforms and narrow inter-mountain valleys. The steeply sloping landforms and the chains of hills are intensely dissected by large number of E – W and NE – SW trending regional dykes. The inter-mountain valley flats are featured with pockets of alluvium, derived under fluvial action. The high rainfall coupled with the intense residual and mechanical weathering has enriched this trappean highland zone with a considerable thickness of soils and subsequently contributing in the development of middle alluvial and lower coastal zone.

3.1.2 Upper Pediment Zone

The upper pediment zone is distributed within the altitudinal range of 50 to 100m and covers 1010 sq. km. This zone acts as a transition zone sandwiched between the middle alluvium zone in the west and trappean highland zone in the east, and is characterized by low relief and rolling topography. This zone with a general slope due west, is occupied by a considerable thickness of colluvial material, essentially accumulated under gravity action and is conspicuously marked by triangular facets and colluvial fans near the hill piedmont. This zone is thinly covered with alluvium but at places bedrocks are exposed in the form of ridges.

3.1.3 Middle Alluvial Zone

This physiographic unit, covering an area of 1796 sq. km., is characterized by a vast planation surface, with a gentle westward slope and is bounded by the upper pediment zone in the east and narrow coastal plain in the west. This zone comprises of thick accumulation of riverine sediments (alluvium plains) and a well knitted westerly flowing active drainage system. This unit spreads for almost eighty kilometers width in the northern portion and tends to decrease towards south.

3.1.4 Lower Coastal Zone

This zone, with an aerial extent of 1142 sq. km., is distinguished by a gentle planation surface, delimited by the alluvium plains in the east and the Arabian sea in the west. This zone shows gradual decrease in its width southward and comprises of unconsolidated sediments, contributed by marine, fluvial and aeolian processes. According to Merh (1986), the south Gujarat coastal zone in general, is characterized by the presence of more than one generation of landform features developed on account of Late Quaternary sea level fluctuations.

3.2 LANDFORMS

Landforms are characterized by distinctive surface expressions, internal structures, or both (Howard, 1967), and their analysis involves the critical appraisal of their geometry and attributes. The south Gujarat terrain in general represents an interesting assemblage of erosional as well as depositional landforms developed on account of fluvial, marine and aeolian processes, which have been described by the earlier workers (Vashi & Ganapathi, 1982; Joottun et al., 1982; Vyas, 1984; Mukherjee, 1985; Vashi et al., 1988; Alavi, 1990; Rai, 1991; Alavi & Merh, 1991; Deota, 1991). The nature of occurrence and distribution of these landforms indicate a strong influence of various pre-dominating complex factors, related to tectonism and eustatic changes, in their sequential evolution.

Landforms developed in the study area (Fig. 3.3), were identified and demarcated (Table 3.1), with the help of Survey of India (SOI) topographic maps and satellite data

(IRS-1C LISS III, 1998), and duly ground-checked by field observations. It is observed that these landform features are distinctly distributed with respect to the four physiographic units and their genesis is attributed to the unit-specific prevailing processes of that time. The detail description of various landform features of the study area is as follows.

Sl. No.	*Category*	*Tone*	*Shape*	*Texture*	*Remark*
1.	Trappean Highland Zone	Yellow to buff	Irregular	Mottled	Distinctly characterized by its tonal variation, highly criss-crossed by dykes and ridges.
2.	Upper Pediment Zone	Light brown / pale red	Irregular	Mottled	Sandwiched between trappean highland and middle alluvium zone.
3.	Alluvial Plains	Pale red / light brown	Irregular	Mottled	Occupies vast stretch of Middle Alluvium Zones; formed due to fluvial process.
4.	Flood plains	Light brown / dark brown	Irregular	Mottled	Occurs adjacent to present-day river channel, formed on account of fluvial process.
5.	Point and channel bars	Pale red	Irregular	Medium	Develops within the river channel on account of fluvial process.
6.	Ravines	Dark brown	Linear	Smooth	Occurs as small & narrow valleys with steep slopes.
7.	Barrier ridge complex	Yellow / red	Linear	Medium	Occurs as multiple ridges, red tone denotes vegetation.
8.	High tidal flats	Bluish green / yellowish red	Irregular	Smooth	Occurs above high water line, deprived of inundation by daily tides.
9.	Inter-tidal flats	Bluish green / brown	Irregular	Smooth	Occupies the portion between high water line and low water line, dissected with creeks.
10.	Sub-tidal flats	Black	Irregular	Smooth	Occupy their position below low water line.
11.	Beaches	Brown	Linear	Medium	Seen south of Mindhola river mouth only, developed due to marine process.
12.	Mouth bars	Dark brown	Irregular	Medium	Highly dissected by tidal channels.
13.	Salt pans	White / dark blue	Rectangular	Smooth	Shows white tone when dry and blue when wet.

Table 3.1 – A Landform Interpretation Key Of The Study Area.

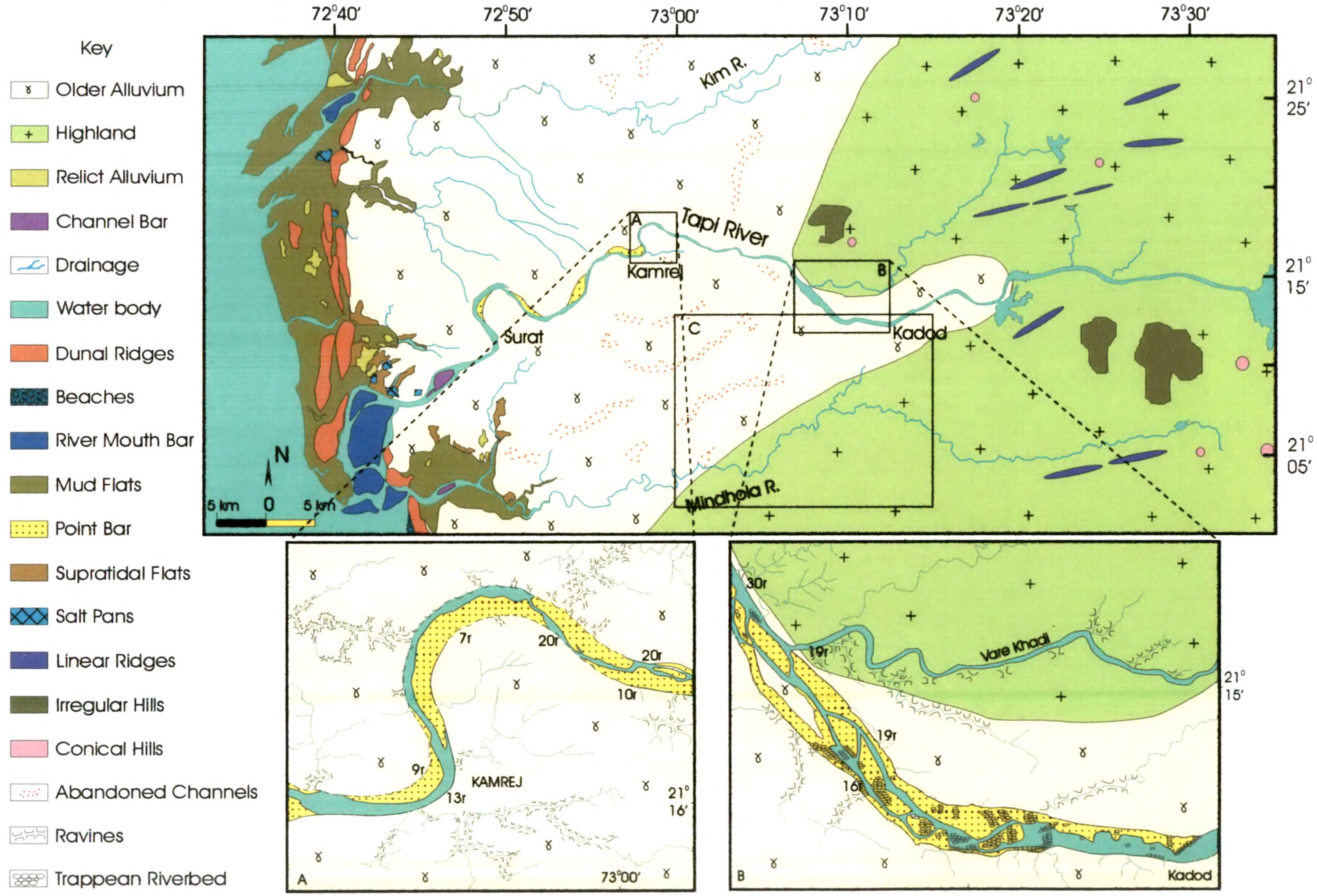

Fig. 3.3 - Geomorphological Map Of The Study Area. Inset Figures Depicting The Presence Of Ravines Near (A) Kamrej And (B) Mandvi.

3.2.1 Landforms in Upper Pediment and Trappean Highland Zone

The trappean highlands as well as the pediment zones, owing to the presence of basaltic outcrops and fracture systems, predominantly show the presence of erosional landforms. They include linear ridges, irregular hills, conical hills, plateaus, escarpments and valleys.

3.2.1.1 Linear ridges – The linear ridges have varying dimensions with length measuring few hundred meters to several kilometers and are aligned in ENE – WSW and NNE – SSW directions. These ridges show an average elevation of 100m and are characterized by flat-tops with steep slopes on either side. The orientation of these ridges represents strong control of fractures which are sympathetic to the regional fracture trends.

It is interesting to note that the area between Tapi and Mindhola rivers is riddled with linear ridges trending NNW – SSE directions. One such example of the linear ridge is well observed south of Mindhola river (Fig. 3.3), which extends about 25km in length having maximum elevation of 213m, which gradually decreases towards westward.

3.2.1.2 Irregular hills – The irregular hills, with the summit elevations ranging between 200 and 300m, have been observed dominantly occupying the NE and SW part of the LTRB. These irregular hills are believed to have formed on account of the dissection of initially horizontal plateaus.

3.2.1.3 Conical hills – The conical hills represent their formation on account of the erosion of basaltic flows and are characterized by pointed tops with steep slopes on all sides. These conical hills exhibit variable heights and are predominantly seen in the trappean highland zone.

3.2.1.4 ***Plateaus*** – These features occupy areas of several square kilometers and extend in N – S directions. They exhibit flat tableland topography with occasional presence of isolated mounds and comprises of steep slopes with thin cover of residual soils.

3.2.1.5 ***Valleys*** – The extensive jointing and fracturing of the basaltic lava flows has given rise to week zones along which broad, flat-bottomed, inter-mountain valleys have developed. These valleys occur in the eastern and northeastern portion of the study area and are seen to be covered with thin alluvium deposits.

3.2.2 Landforms in Middle Alluvium Zone

The middle alluvium zone, unlike the earlier described zones, is dominantly characterized by depositional landforms, pre-dominantly formed on account of fluvial processes. The details of various landforms observed in this zone are furnished in the following paragraphs.

3.2.2.1 ***Alluvial Plains*** – The alluvial plains which are commonly referred in the literature as 'Older Alluvium', covers a comparatively vast area of this physiographic unit and are considered to be of middle to late Pleistocene in age (Krishnan, 1982; Vashi & Ganapathi, 1982). They are characterized by a gentle westward slope and a well-developed soil profile. These alluvial plains represent a vast accumulation of riverine deposits, thought to have formed during the earlier aggradational phases of fluvial agencies. At places, they occur in the form of inliers (Relict Alluvium) within the coastal plain unit. These isolated outcrops of relict alluvium have been considered to be the extension of alluvial plains far into the continental shelf during a low sea level phase (Vashi & Ganapathi, 1982), that were left untouched during the rising sea (Joottun, 1982).

3.2.2.2 Floodplains – These depositional landforms occur as over-bank deposits adjacent to the existing river channels and are the manifestations of the present day seasonal flooding. They are extensively developed in the study area and represent the alluvium, deposited during the aggradational phase of the river channel.

3.2.2.3 Terraces – The middle alluvium zone is characterized by the presence of three distinct planation surfaces in the form of erosional terraces (T_0, T_1 & T_2) that occur at varying heights from the river beds.

The Terrace – T_0 is the oldest, paired in nature, and is seen extending all along the Tapi river channel from Kakrapar weir in the east, to the mouth in the west. The elevation of this terrace varies from 14 – 15m in the upper reaches (near Kakrapar), to 6 – 8m in the lower reaches near Umra village. The Terrace – T_1 is dominantly unpaired and is restricted along the right bank of Tapi river, particularly between Mandvi and Kamrej localities, having elevation ranging between 5 – 10m from the river bed. The youngest Terrace – T_2 is observed at lower elevations, ranging between 2 – 3m, particularly between Puna and Utran villages and is unpaired in nature. The present day accretion and simultaneous down cutting of the sediments near the river channel has given rise to the development of this youngest terrace. According to Vashi and Ganapathi (1982), the terrace T_1 reflects a major aggradational phase probably during the upper Pleistocene times, whereas the T_2 terrace represents the post-Flandrian degradation process. The Mindhola and Kim river channels also display development of two distinct terraces.

3.2.2.4 Point bars and shoals – These depositional features are the manifestation of meandering channels and are conspicuously developed within the river channels. Point bars (also known as meander bars), are the low, crescent shaped, sand and gravel ridges that develops inside the growing meander by gradual addition through lateral accretion. Examples of point bars are noticed in the study area, particularly near Surat, Utran, Mota Warachha in Tapi river, near Tajpura in Mindhola river and near Kathodra in Kim river, varying in size from 10 to 100 meters and display cycles of fining upward nature.

Shoals are the submerged mid-channel bars that rise from the bed of a shallow body of water and normally develops due to sudden check in energy conditions. They comprises of unconsolidated sediments that accumulate within the channel, finally leading to bifurcation of the channel. Shoals of impressive dimensions are observed near Sarthana, Rander, Magdalla and other areas, in the lower reaches of Mindhola and Tapi rivers. The present-day channel bars are also noticed in the study area, near Magdalla in Tapi river.

3.2.2.5 Meandering loops – The natural course of any river attains sinuosity mainly due to turbulence in the flow of water and irregularities in river channel. The increase in the sinuosity leads to the further development of meander loops that migrates laterally, giving rise to the formation of ox-bow lakes. Several such meander loops and ox-bow lakes are observed at various places in the interfluve region of Tapi and Mindhola rivers.

3.2.2.6 Ravines – These small and narrow valleys with steep slopes are prominently observed along Tapi and Mindhola rivers. Along the Tapi river, ravines are dominantly seen developed on the northern bank particularly between Kamrej and Mandvi (Fig. 3.3 A & B), and are oriented in N – S directions, however the southern bank show less concentration of these features. Similarly, along the Mindhola river also, they occur prominently on the northern banks between Karchaka and Palsana (Fig. 3.3 C).

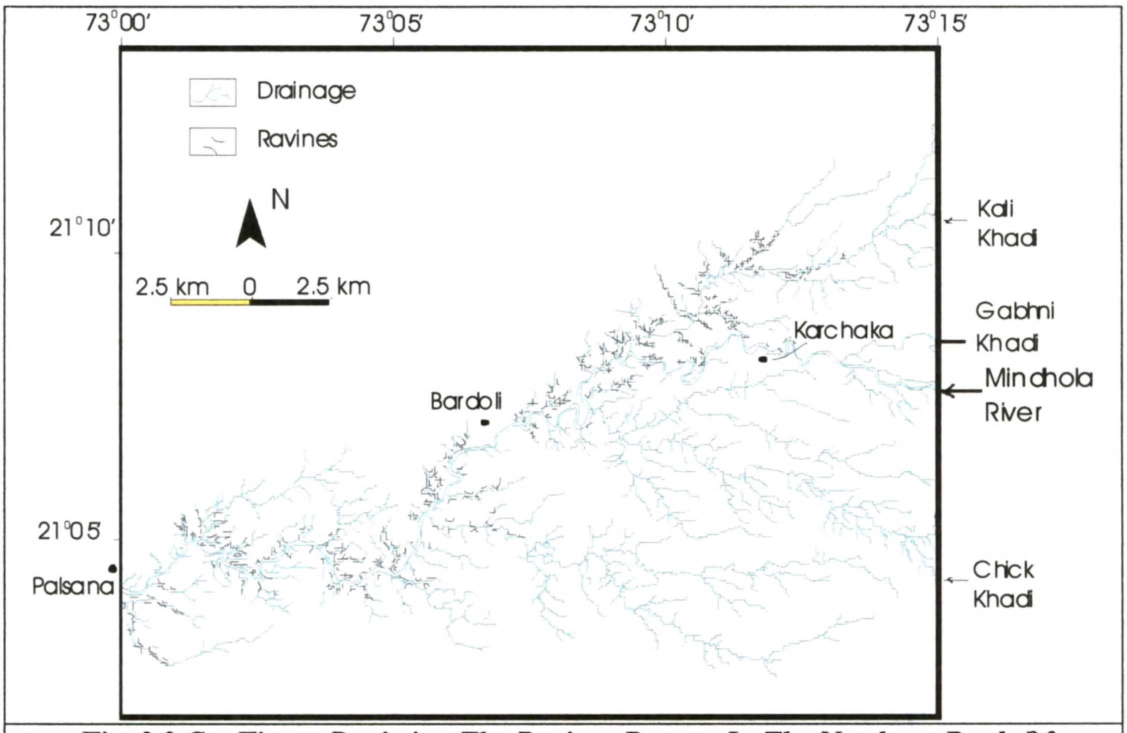

Fig. 3.3 C – Figure Depicting The Ravines Present In The Northern Bank Of Mindhola River, Between Palsana And Karchaka.

3.2.3 Landforms in Lower Coastal Zone

The lower coastal zone displays a complex assemblage of landform features, representing the active role of erosional as well depositional processes. According to

Vashi and Ganapathi (1982), the south Gujarat coast in general, typically represents a "drowned alluvial coast", and its present configuration is on account of the last marine transgression, which is believed to have got stable around 6000yrs BP.

A detail account of the various landform features observed in this zone are given in the following paragraphs:

3.2.3.1 Barrier Ridge Complex – These landform features are observed in the study area in the form of ridges with their crest parallel to the shore and dominantly comprises of sand-sized particles. Examples of such features are noticed near Hazira, Suwali, Damka and Dumas area having a maximum elevation of about 10m. These multiple ridges are subsequently followed by the presence of older dunal ridges towards the inland portions and have acquired stability owing to the presence of vegetation. This barrier ridge complex is considered to have developed during the upper Pleistocene to Holocene times in front of former bays and estuaries (Vashi and Ganapathi, 1982).

3.2.3.2 Mudflats – Mudflats represent one of the most important landform features of the lower coastal zone as they have been extensively developed and occupy vast stretch of inland area behind the barrier ridge complex. The mudflats have been classified into high-tidal flats, inter-tidal flats and sub-tidal flats based on their position of occurrence with respect to the high water line as well as the low water line. These mudflats seem to have developed on account of the negligible influence of competent long shore drifts, aided with the substantial influx of sediments load, mainly contributed by Kim, Tapi and Mindhola rivers and their tributary streams. These mudflats have been categorized as high marshes (raised mudflats) and low marshes (present day mudflats), based on their occurrences at different altitudes with respect to the present sea level. The present day mudflats (0 – 4m AMSL) occupy the inter-tidal zone and gets inundated during high tides. They show a gentle seaward slope and are highly dissected; wherein the tidal inlets show a characteristic dendritic drainage pattern developed on account of the homogeneity of the sediments, occurring between high tide and low tide. According to Merh (1987), the raised mudflats (5 – 6m AMSL), represents the higher strandline position during the Flandrian transgression. The raised mudflats occur in the form of isolated patches above the High Water Line (HWL), in the estuarine regions of Tena creek and Mindhola river (near Abhwa village).

3.2.3.3. Beaches – In the study area, these landform features have been developed in the south of Mindhola river mouth. These sandy beaches are straight and linear in nature and attain a maximum width of 500m near Umbhrat village. Compositionally, they comprises of trappean clasts and shell fragments. It is necessary to note here the marked absence of these landform features in the areas north of Tapi river. This could be on account of the absence of effective long-shore currents along with the influence of appreciable influx from the Gulf of Cambay.

3.2.3.4 Mouth bars – These landform features are developed along the Tapi and Mindhola river mouths and are highly dissected by the tidal channels. They show varying dimensions, with their maximum elevation of 5m AMSL. The largest mouth bar, i.e., Kedia bet, with a dimension of 3km X 5km, hook shaped in nature, is developed in the Tapi river. Mouth bars of smaller dimensions have also been noticed in the Mindhola river. These bars comprise of coarser sediments, mainly sands with less proportions of silts and clays.

3.3 PALAEO-GEOMORPHIC FEATURES

The palaeo-geomorphic features reflect the phases of changes of a fluvial system within an area, with respect to the nature of their flow patterns, induced by combined effects of various geological processes. These features are conspicuously noticed for the first time in the study area, which are identified and delineated on the basis of topographic maps (SOI) as well as digital satellite data (IRS-1C LISS III, 1998), supplemented with appropriate ground checking. A detail study of these features is carried out in the present work to establish the chronology of their evolution, with a view to understand the past and present dynamics of Tapi river vis-à-vis the role of tectonism and eustasy during Quaternary times in the study area.

3.3.1 Palaeo-channels, Palaeo-mouth bars and Raised mudflats – The critical analyses of the satellite data has reflected the presence of palaeo-channels, palaeo-mouth bars and raised mudflats, particularly in the middle alluvial and coastal zones of the study area. Palaeo-channels occur in the form of abandoned channels and buried channels, showing their maximum development within the interfluve region of Tapi and Mindhola rivers. The abandoned channels form one of the most fascinating features that reflect the nature of earlier drainage network. Based on the field observations and satellite data (IRS-1C LISS III, 1998), such abandoned channels are demarcated in the study area as remnants of earlier drainage system. These features, which reflect the nature of the earlier drainage courses, are well observed on the northern and southern sides of the existing Tapi river channel and are filled with younger sediments. The presence of oxbow lakes and linearly oriented ponds with steep embankments noticed in the area between Tapi and Mindhola rivers aptly corroborates the presence of abandoned channels.

The palaeo-mouth bars are observed at Sena and Tena creek, between the present-day mouth portions of Tapi and Kim rivers, and near Dumas and Bhimpur, between Tapi and Mindhola river mouths.

The raised mudflats are seen occurring at 6 – 8m above mean sea level and are highly dissected by the tidal inlets. Some of the illustrative locations of these features have been encountered along the estuarine areas of Kim, Tapi and Mindhola rivers.

3.3.2 Palaeo-lobatic features – The study of satellite data (IRS-1C LISS III, 1998) has revealed the presence of interesting features in the form of lobes distributed in the study area in the inland portion as well as towards the present day shoreline. Four distinct lobatic features have been identified for the first time in the study area (Fig. 3.1). The presence of these features is quite significant from the point of view of understanding the land-sea boundary position during the Quaternary times.

The geometry of these lobes indicate that their proximal portions are narrow, steep and show concavity, whereas the distal portions are broad, fanning out with gentle convexity. The nature of occurrence of these lobatic features and their present positions, strongly suggest their sequential development at various times during the Quaternary period. In order to understand the surface morphology and sedimentation pattern of these lobes, several cross-sectional profiles (transverse and longitudinal), have been prepared, based on the topographic maps and available bore-hole records.

The following paragraphs furnish the details of the geometry and sedimentation pattern of individual lobes:

(i) **Tapi lobe – I (72° 52' E, 73° 13' E & 21° 03' N, 21° 19' N):** This lobe forms a part of middle alluvial physiographic division and occurs at a mean elevation range between 12m and 41m AMSL. On the satellite imagery, this lobatic feature is characterized by dense brownish tone, medium to coarse texture and marked with number of palaeo-distributory channels. This lobe is the largest of all the lobes with an approximate dimension of around 21km X 29km, located in the southern proximity of present-day Tapi river channel. The central long axis of this lobe shows an orientation of 247° N. Taking into account the present day position and the three dimensional morphology (Fig. 3.4), it appears that this lobe is the oldest and first to develop.

The various transverse as well as longitudinal profiles (Fig. 3.5), prepared on the basis of bore-hole records, depict the presence of alternating clay and sand units. The transverse profile AA' reveals that the clay members occur as lensoidal bodies within the sand layers, whereas, the longitudinal profiles BB', CC' and DD', represents a linear and continuous nature of the clay members, with a gentle inclination towards the distal end of this lobe. The presence of Deccan traps in the sub-surface, particularly towards the apex portion of this lobe and their conspicuous absence in the middle and distal portions could be attributed to the displacement, along the Eastern Cambay Basin Marginal Fault.

(ii) **Tapi lobe – II (72° 30' E, 73° 00' E & 21° 14' N, 21° 27' N):** This lobe is associated with the lower coastal and middle alluvial physiographic zones and appears to be slightly smaller in dimension as compared to Tapi lobe – I.

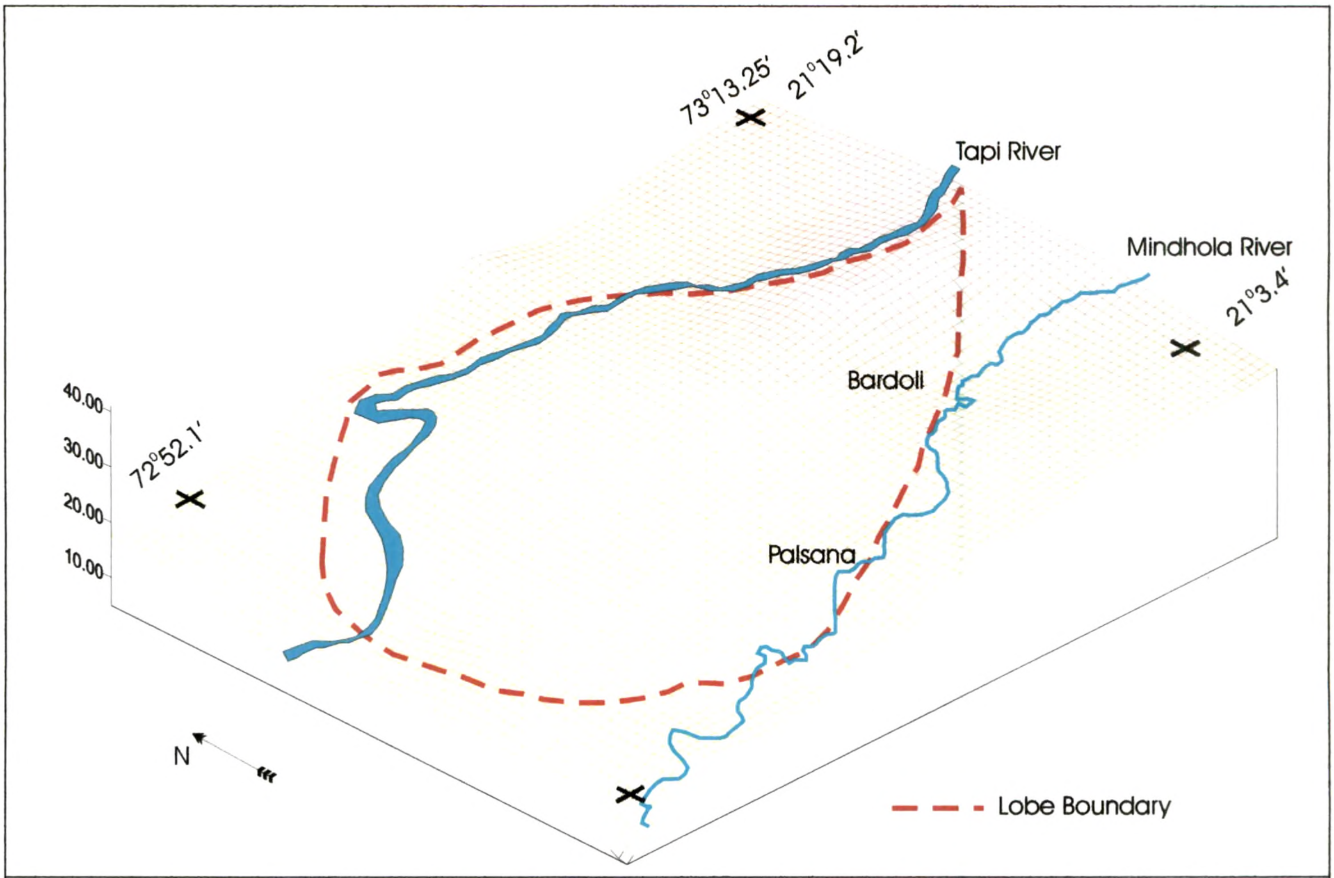

Fig. 3.4 - Diagram Showing 3D Morphology Of Tapi Lobe - I.

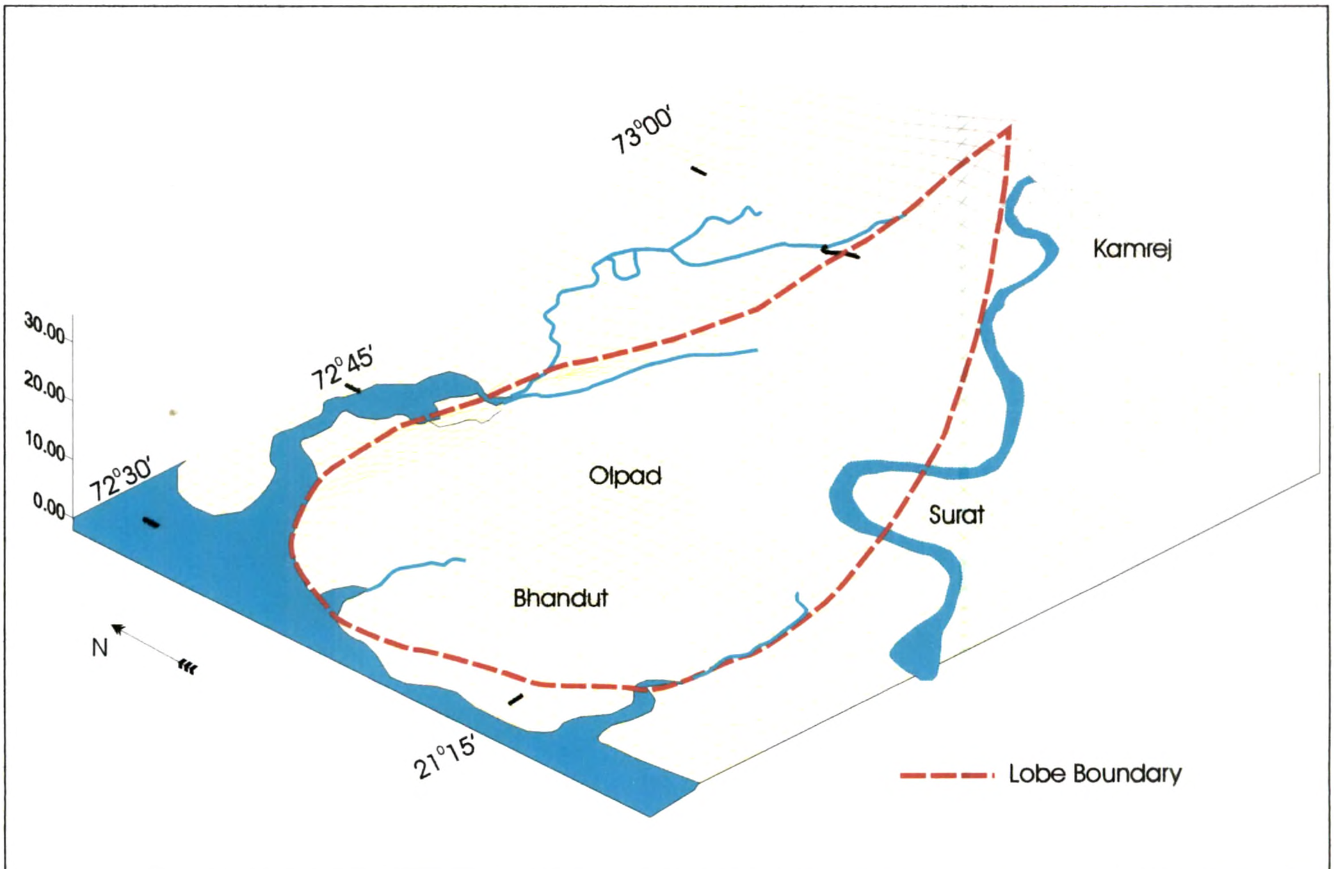

Fig. 3.6 - Diagram Showing 3D Morphology Of Tapi Lobe - II.

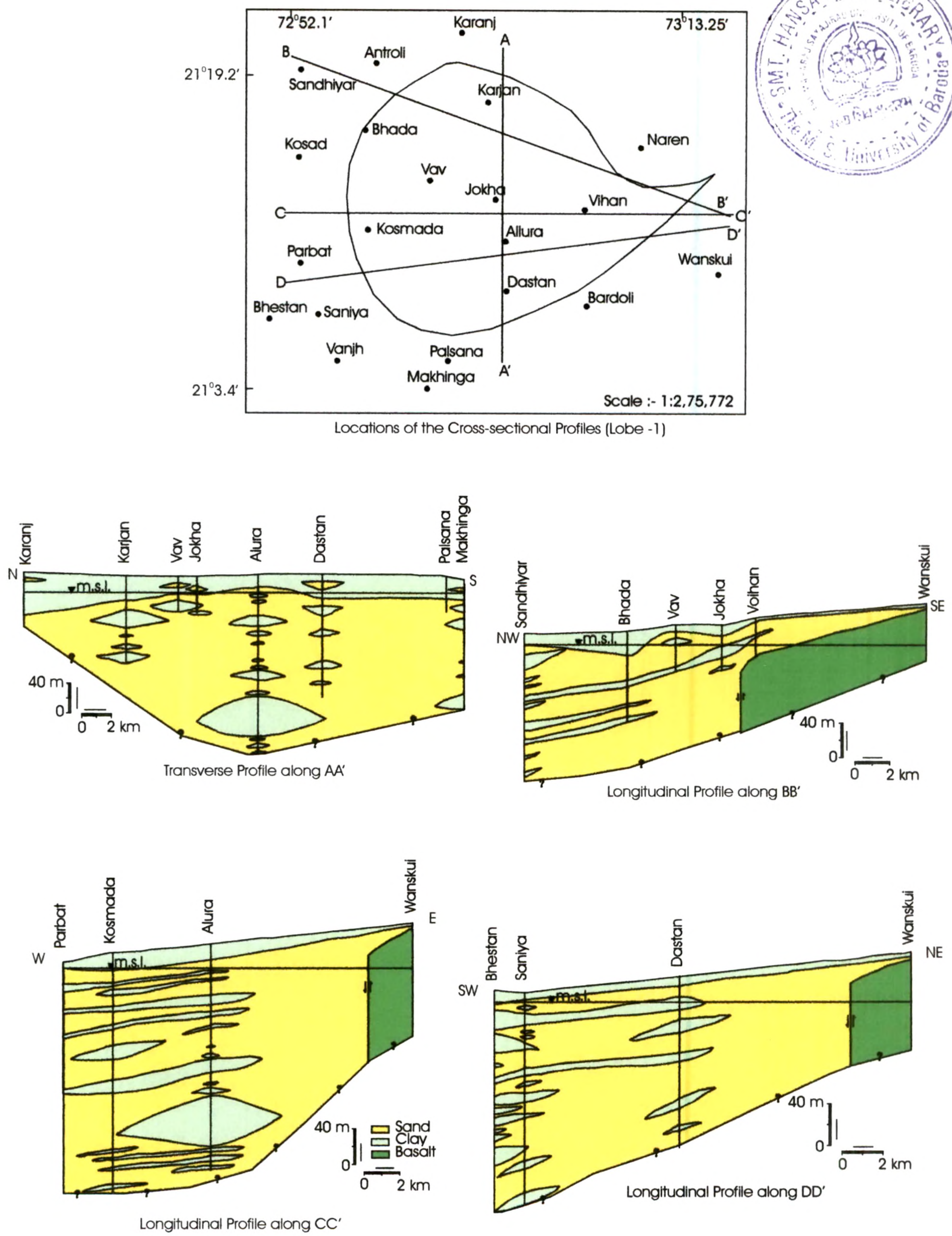

Fig. 3.5 - Diagram Showing The Sub-Surface Transverse (A - A′) And Longitudinal (B - B′, C - C′ And D - D′) Profiles Along Tapi Lobe - I.

Unlike Tapi lobe – I, it occurs in the northern proximity of present-day Tapi river channel and range in elevation between 7m and 35m AMSL. On satellite imagery this lobe is characterized by a light brownish tone with medium to rough texture and numerous traces of palaeo-distributory channels. The three dimensional pattern of this palaeo-lobe (Fig. 3.6), points to its E – W orientation (263^0) with an aerial extent of 17km X 22km. Taking into account the present day position and the morphology, it appears that this lobe is of second generation and younger to Lobe-I.

The cross-sectional profiles of this lobe (Fig. 3.7) show a gentle decrease in the ground elevation towards the middle and distal portions. The longitudinal profiles AA', BB' and CC', indicate that the clay members occur as long, continuous layers inclined towards the distal part of the lobe, with a gradual decrease in their thickness from proximal to the distal end of this lobe. The transverse profile DD' represents the clay members in the form of lenses within the sand units.

(iii) **Tapi lobe – III (72^0 40' E, 72^0 55' E & 21^0 01' N, 21^0 16' N):** This lobe is restricted in the lower coastal and middle alluvial zones and is comparatively smaller in dimension with respect to Lobe-I and Lobe-II, having altitudinal range between 6.5 – 20m AMSL, with an aerial extent of 12.5 X 17km. This lobe is oriented in NE – SW direction with its longest axis showing an azimuth of 217^0 N. This lobe is also characterized by the presence of numerous palaeo-distributory channels and occurs in the close proximity of the present day Tapi and Mindhola river mouths.

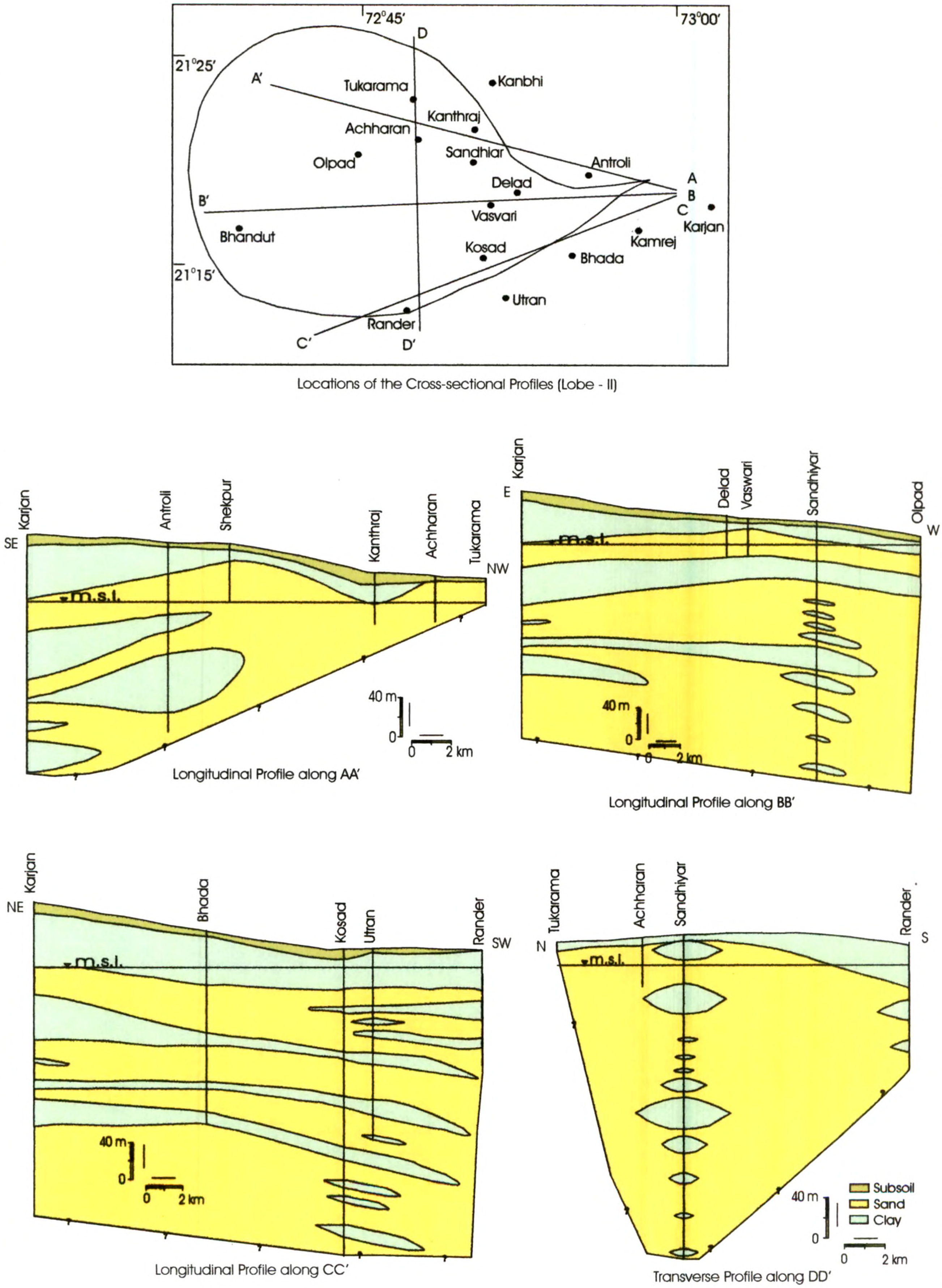

Fig. 3.7 - Diagram Showing The Sub-Surface Transverse (D - D') And Longitudinal (A - A', B - B' And C - C') Profiles Along Tapi Lobe - II.

The satellite imagery shows that the proximal portion of this lobe is covered under the present day settlements; however, the distal portions show yellowish to light brown tone with medium to rough texture. Owing to the position of this lobe and its morphology (Fig. 3.8), it appears that it must have developed after the formation of Lobe-II.

The sub-surface longitudinal profiles, AA' and BB' (Fig. 3.9), show the dominance of sand members with alternating clay units in the form of long and continuous layers. The clay layers show a gradual increase in their inclination in the distal portion of the lobe, towards SW direction. The transverse sections CC', DD', EE' and FF', like the earlier lobes, represents the lensoidal nature of the clay layers.

(iv) Tapi lobe – IV (72^0 39' E, 72^0 50' E & 21^0 1.5' N, 21^0 10.7' N): This lobe occurs in the lower coastal zone, having N – S orientation (173^0), with mean elevation less than 10m. This is the smallest and probably the youngest of all the four lobes, representing the present day river mouths of Tapi and Mindhola rivers (Fig. 3.10). On satellite imagery, this lobe shows the presence of number of abandoned channels and is characterized by yellowish brown tone, having medium to coarse texture towards the proximal portion and a finer texture, towards the distal portion.

The sub-surface longitudinal profiles AA' and BB' (Fig. 3.11) shows a dominance of sand members encompassing long and continuous layers of clay members, whereas the transverse section CC' shows the clay members as lensoidal bodies within the sand units.

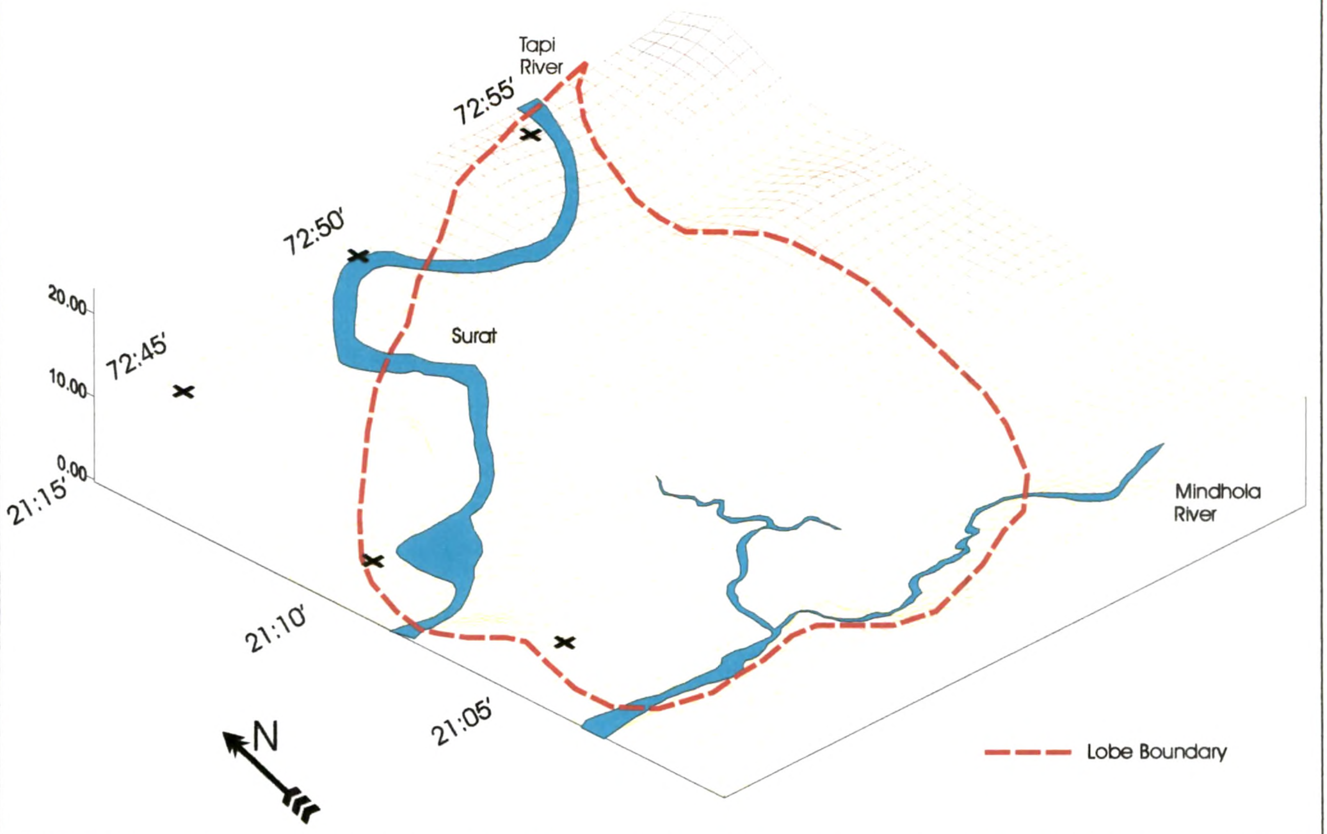

Fig. 3.8 - Diagram Showing 3D Morphology Of Tapi Lobe - III.

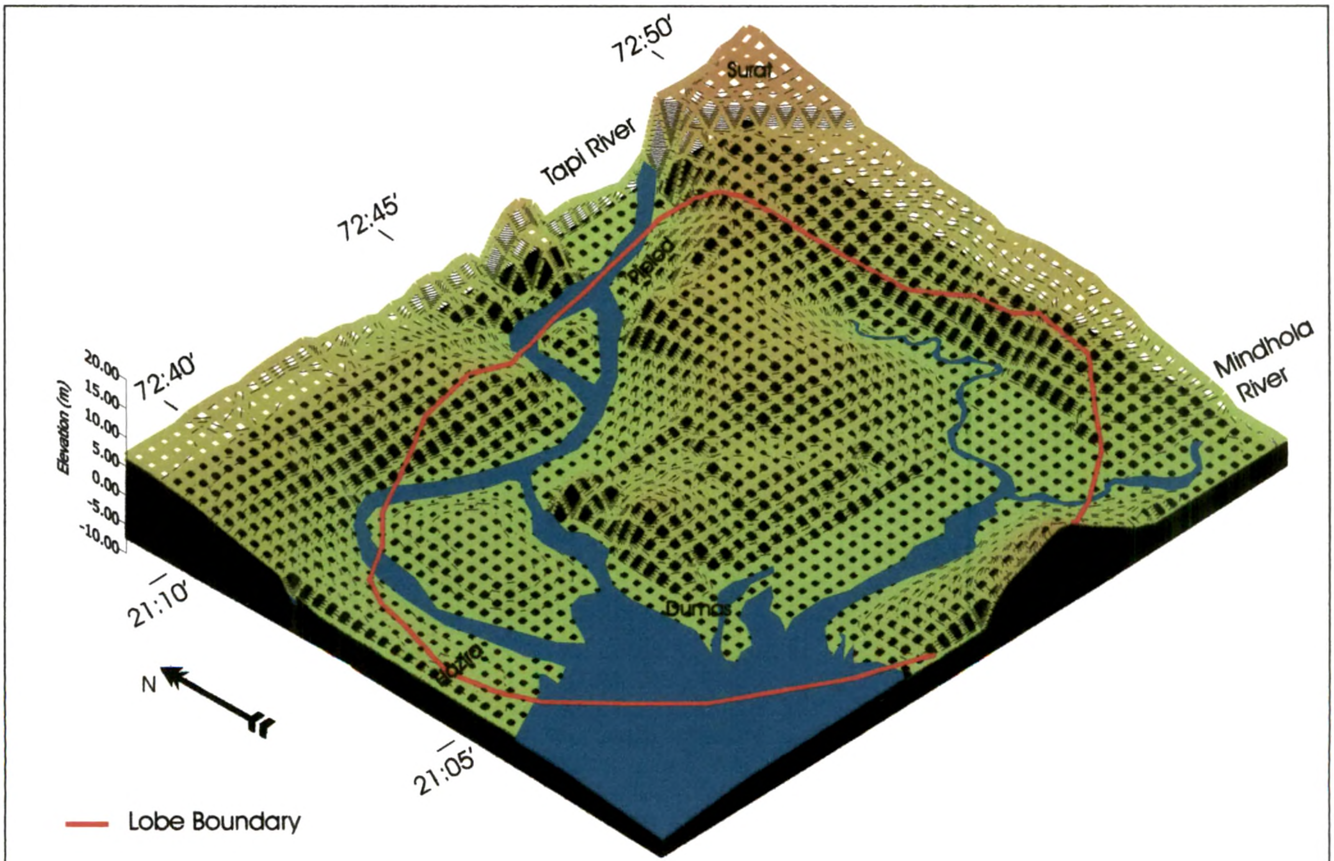

Fig. 3.10' - Diagram Showing 3D Morphology Of Tapi Lobe - IV.

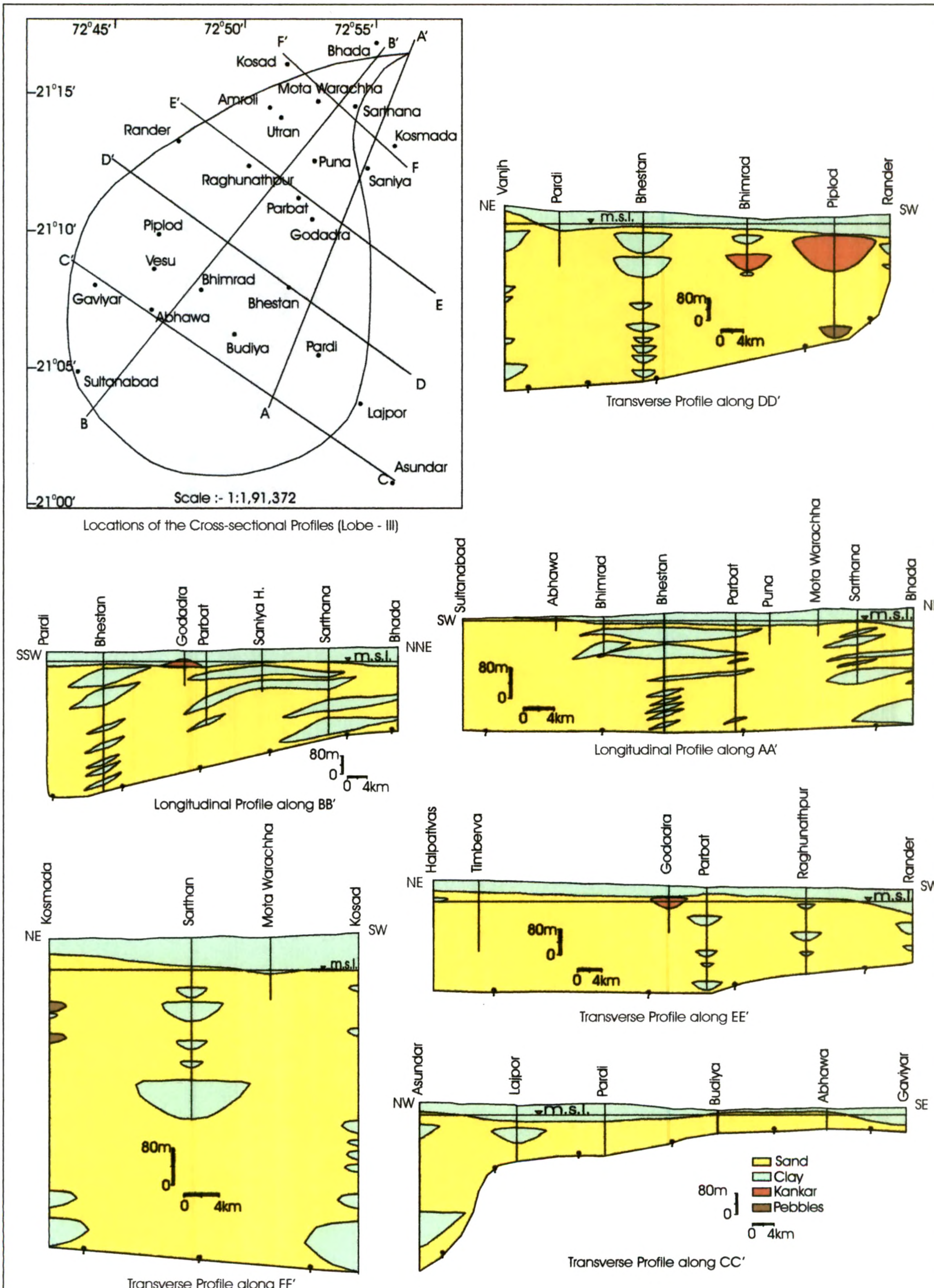

Fig. 3.9 - Diagram Showing The Sub-Surface Transverse (C - C', D - D', E - E' And F - F') And Longitudinal (A - A' And B - B') Profiles Along Tapi Lobe - III.

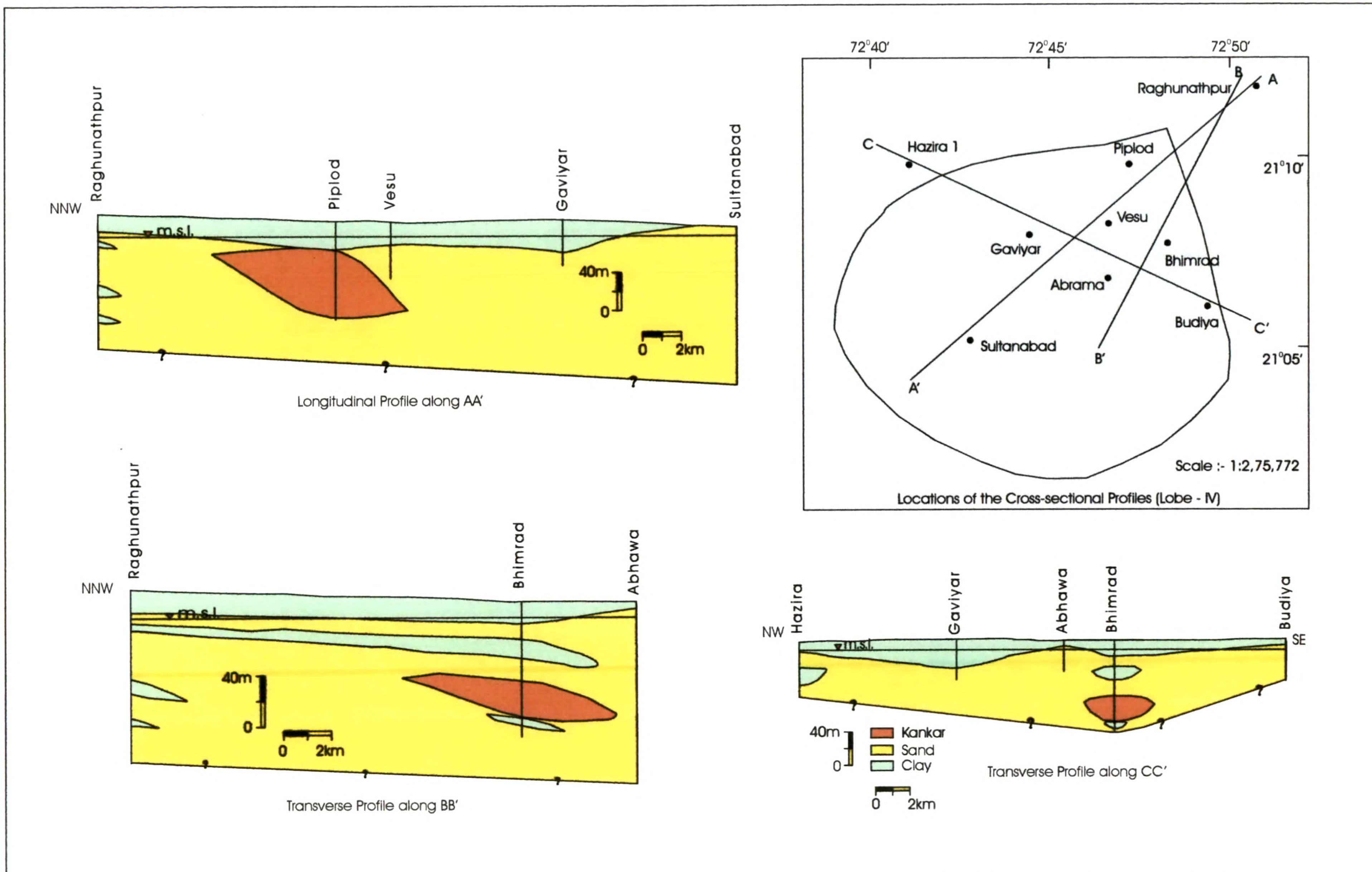

Fig. 3.11 - Diagram Showing The Sub-Surface Transverse (C - C') And Longitudinal (A - A' And B - B') Profiles Along Tapi Lobe - IV.

Taking into account the geometry of the palaeo-lobatic features, they have been identified as the river dominated fan-shaped deltas, which are normally produced when heavy load of sediments is discharged by stream on a plain of low-gradient (Sengupta, 1994). Examples of such lobatic features have been cited by earlier workers along the Mississippi delta on the Louisiana coastal area. According to Sengupta (Op. cit.), these lobatic features are preserved even though at times the distributory channels abandon their earlier courses. He has further opined that in such cases, the fluvial sediments are deposited in stream channels, natural levees, point bars and abandoned stream courses. As suggested by Einsele (1992), the fluvial dominated deltas results on account of high sediment input and low counter-action by coastal processes, indicating low energy conditions.

The sub-surface transverse as well as longitudinal profiles (Fig. 3.8, 3.9, 3.10 and 3.11) clearly show alternating sand and clay layers. It is very much likely that the continuous sands encountered in the sub-surface data represents the delta-front sands with a linearly oriented alternating clay units.

3.4 DRAINAGE

The drainage system of an area is mainly controlled by the prevailing structure, lithology and hydro-climatic processes and helps to understand the evolution of landscapes therein. The study area represents the dominance of two contrasting lithological domains i.e., the Deccan Traps and alluvium that covers vast areas over which the existing drainage network is developed. In addition to the lithological contrast, the drainage system of the study area has been influenced by the prevailing structural elements. The nature of the drainage system and their pattern of development convincingly reflect the control of both lithology and structure.

The study area is drained by the westerly flowing rivers such as the Kim, Tapi and Mindhola along with their tributary streams. The Tapi river originates from Betul district of central Madhya Pradesh and represents a mega fluvial system, whereas the rivers such as Kim and Mindhola, originates from the inner trappean highlands in the east and finally enters the Arabian sea in the west. The Tapi river, although shows a general ENE – WSW orientation, however towards the lower reaches it shows NW – SE orientation (between Kadod – Kamrej), NE – SW orientation (between Kamrej – Bhada) and N – S orientation (between Bhada – Dumas), before entering into the Arabian sea. The Mindhola river also follows ENE – WSW orientation, however the presence of right-angled swings, tight windings, loops and contortions are not uncommon. The Kim river, although exhibits an NE – SW orientation in its upper reaches, however further downstream it follows the ENE – WSW orientation.

3.4.1 Drainage Pattern:-

A drainage pattern, as defined by Howard (1967) is the design formed by aggregate of drainage ways in an area, regardless of whether they are occupied by permanent streams. According to him, the drainage analyses constituting the study of drainage patterns, drainage texture, individual stream pattern and drainage anomalies, is useful in structural interpretation, particularly in areas of low relief. Earlier Zernitz (1932), had postulated that the pattern, which streams form are determined by inequalities of surface slope and rock resistance and the drainage patterns may reflect original slope and original structure or the successive episodes by which the surface has been modified, including uplift, depression, tilting, warping, folding, faulting and jointing, as well as deposition by the sea, glaciers, volcanoes, winds and rivers. According to Schumm et al. (1987), the geological history of an area, including information on structure and surficial conditions, can be deciphered from the study of drainage pattern.

The drainage network observed within the study area using the satellite data (IRS-1C LISS III, 1998), along with the topographic maps and field observations, has clearly pointed out a strong control of the prevailing fractures and joint systems, oriented in the ENE – WSW, NW – SE & NE – SW and N – S directions. It is observed that the trunk streams of Tapi and Mindhola rivers and the overall drainage shows westerly flow and that their trends is controlled by the ENE – WSW fractures i.e., the basement fracture trends (Powar, 1983). The tributary streams as well as the middle order streams, particularly of Tapi and Mindhola rivers, show abrupt swings and are aligned along the conjugate sets (NW – SE & NE – SW) of fractures, whereas the lower order streams are oriented along the N- S fractures. Although the drainage pattern in the study area displays the significant control of the prevailing fracture systems however, the role of the lithology is equally important and cannot be ruled out. The presence of two distinct lithological domains, i.e., the Deccan traps, demarcating the hilly terrain and pediment zone and the alluvium, marking the peneplain and the coastal areas have equally controlled the drainage pattern.

The drainage pattern of the study area has been described based on the characteristics exhibited by river Tapi and its tributary streams, representing the Lower Tapi Drainage

System (LTDS) and river Mindhola and its tributary streams, representing the Mindhola River Drainage System (MRDS).

The LTDS in general shows a dendritic to sub-dendritic pattern, however, in the NE portion, trellis, rectangular and pinnate patterns are also observed (Fig. 3.12). The dendritic drainage pattern is the result of the uniform resistance offered by the sub-stratum (basaltic terrain) indicating a dominant lithological control, however, at places, on account of the prevailing fracture systems, this dendritic drainage is gradually transformed into sub-dendritic to trellis pattern. The pinnate drainage pattern is characterized by many closely spaced, more or less parallel tributary streams meeting the larger streams at acute angles, giving rise to a featherlike appearance. The presence of rectangular drainage pattern, characterized by right-angle bends in both the main stream as well as the tributary streams, is attributed to the effect of conjugate set of fractures. In the NE part of LTDS, owing to the presence of N – S to NNE – SSW oriented branching faults, some of the tributary streams of lower order, shows fault trellis pattern also.

The overall observation of the LTDS suggests that the north-eastern portion is characterized by the drainage texture with dense network of streams; however the south west portion shows coarse drainage texture with widely separated valley segments.

The Mindhola river along with its tributary streams, represent a well-knitted drainage network (Fig. 3.13). In the upper reaches of MRDS, dendritic to sub-dendritic pattern is observed owing to the uniform resistance offered by the highly dissected Deccan traps. At places, particularly in the north-eastern portions of the upland region, fault trellis as well as directional trellis pattern is also observed (Fig. 3.13 A&B). Overall, the upper reaches of this drainage system show a fine texture with a dense network of streams.

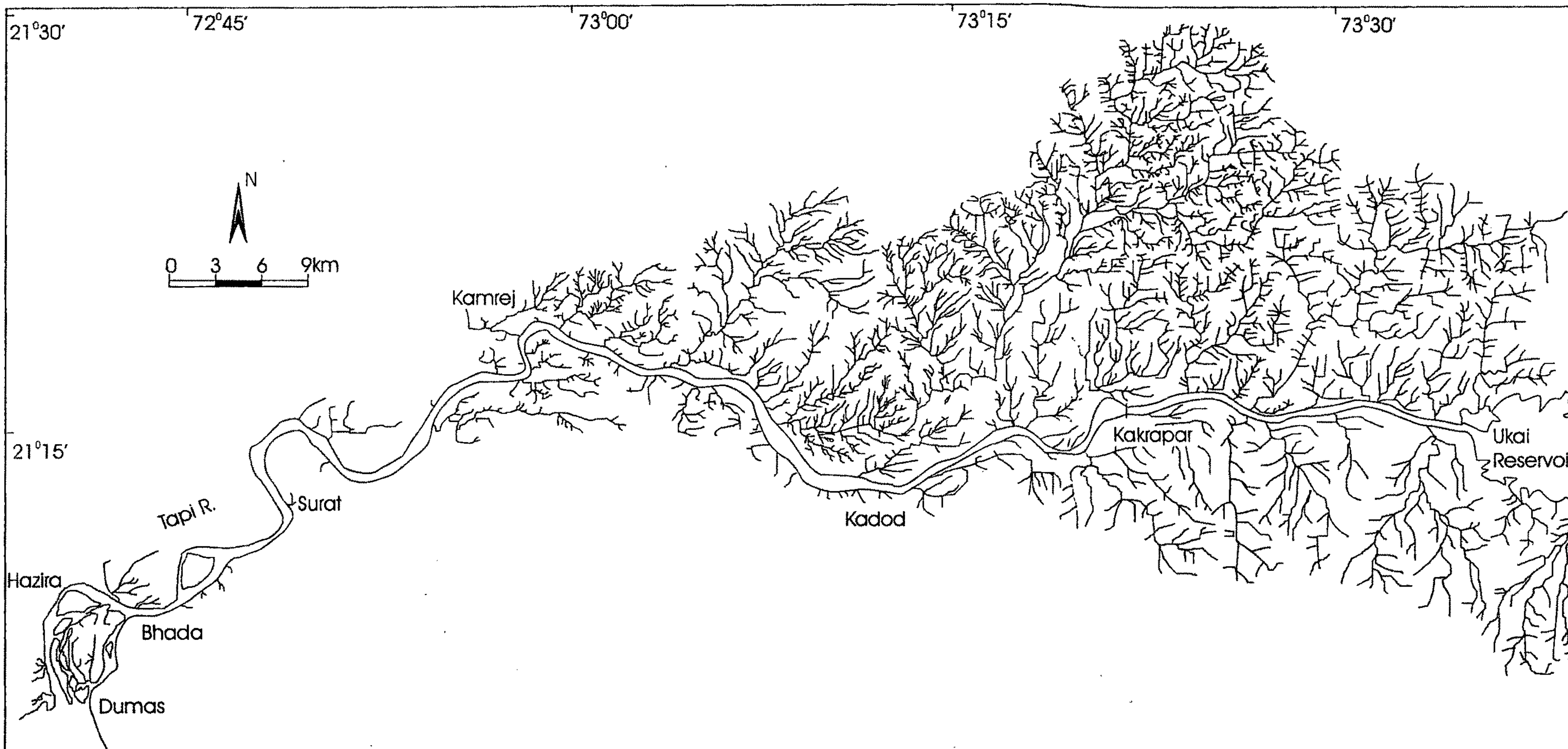

Fig. 3.12 - Drainage Map Of The Lower Tapi Drainage System (LTDS)

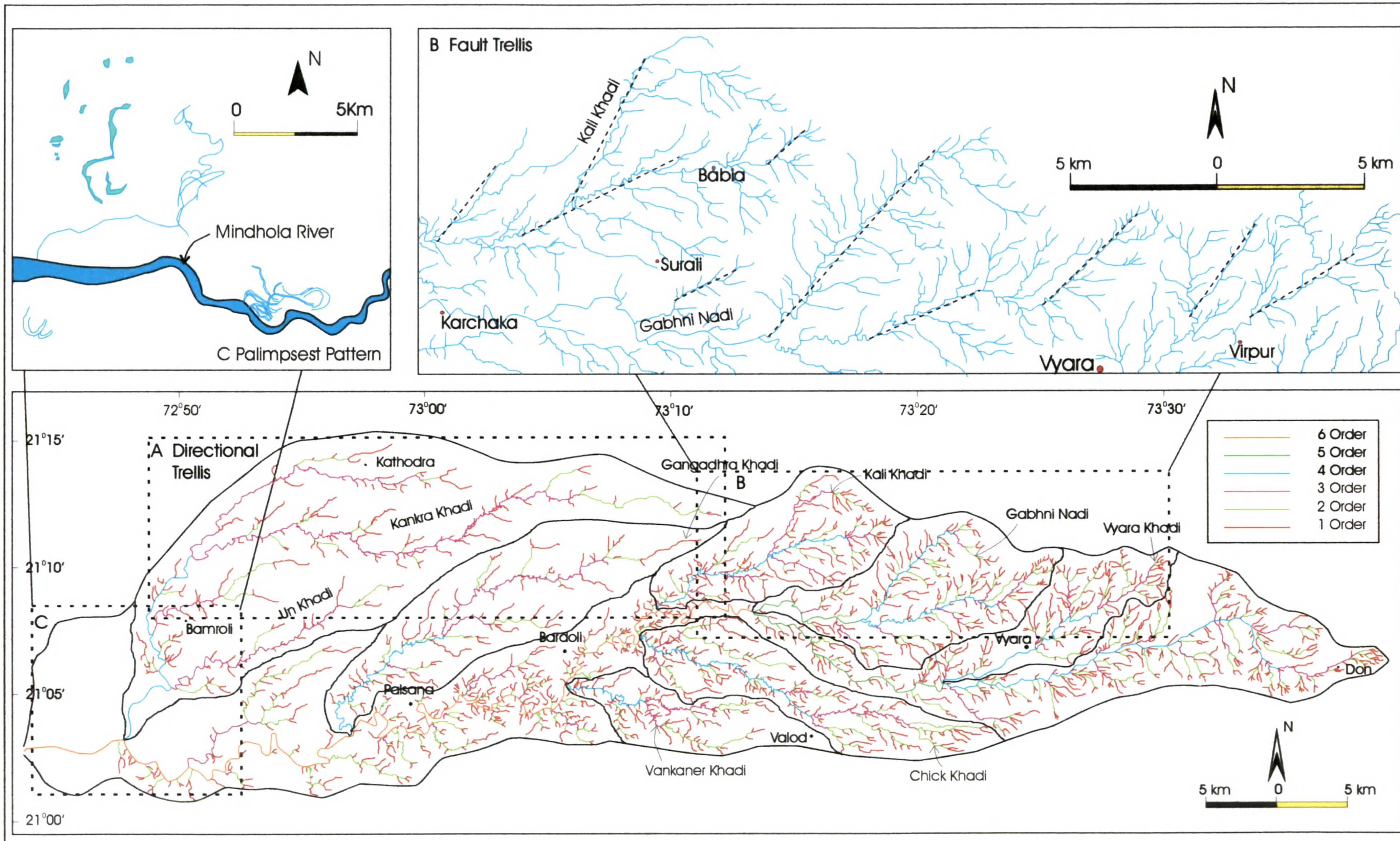

Fig. 3.13 - Map Showing Drainage Pattern Within The Mindhola River Drainage System (MRDS). Inset Figures Show The Presence Of (A) Directional Trellis, (B) Fault Trellis And (C) Palimpsest Patterns Within The MRDS.

In the lower reaches, the trellis drainage pattern is dominantly observed with occasional presence of palimpsest pattern at places (Fig. 3.13 C). Overall drainage network shows coarse texture with widely separated valley segments. Based on the drainage patterns displayed by Tapi and Mindhola rivers, in the study area, it is very clear that the lithology and structure have played a significant role in shaping the overall drainage characteristics. Some of the illustrative examples reflecting the role of these two factors are cited in the following paragraphs.

(i) The LTDS in general, exhibits the dendritic drainage pattern, particularly in the domain occupied by the basaltic outcrops of Deccan traps. This is clearly pointing to the influence of lithology, forming the sub-stratum and offering a uniform resistance.

(ii) The variation in the drainage texture within LTDS, wherein the upper highland and pediment zones are dominated by fine texture as compared to the middle alluvial and coastal zones, showing a coarser texture; is attributed to the local changes in the rock characteristics and the presence of contrasting lithological domains.

(iii) The presence of tight winding loops and contortions in the trunk streams as well as the tributary streams of Tapi and Mindhola rivers, particularly in the upper pediment and highland zones, is perhaps ascribed to the strong control exercised by the criss-cross fracture as well as dyke ridges. However, the meandering nature of these streams particularly in the middle alluvial and lower coastal zone is ascribed to their sluggish nature in porous and permeable sub-stratum.

(iv) The role of structure and its control on the drainage within the study area, is further justified by the abrupt SW swing in the course of Tapi river near

Kamrej, attaining a straight nature further downstream. This is very well attributed to the presence of Tapi fault with its up-throw on the southern bank of Tapi river (Kaila et al., 1981).

(v) The abrupt southerly swing of Tapi river near its mouth portion (Bhada – Dumas area), giving rise to a hook-shaped geometry also indicate a strong structural control. This is probably on account of the influence of NNW – SSE oriented West Coast Fault that delimits the western boundary of the study area.

3.4.2 Longitudinal Profiles:-

The longitudinal profile of a river is defined by a graph of its length, from the source to its mouth, following the winding of the valley versus elevation, and contains unique information about the past and present geomorphic and geological records.

According to Leopold et al. (1969), the development of a longitudinal profile of any river is controlled by (i) channel discharge, (ii) load delivered to the channel, (iii) size of the load/debris, (iv) flow resistance, (v) velocity, (vi) width and depth of the channel, (vii) gradient and (viii) tectonism. The inter-relationship of these variables provides the relation of fall in elevation to the distance along the channel. The longitudinal profiles of Tapi as well as Mindhola rivers (Fig. 3.14) show a smooth concave curve without any significant break in the profile however; the field observations reveal several rapids, nick points and cascades, such as near Kadod, Khanjroli, Vareli in Tapi river, near Utara and Tajpura in Mindhola river. The concavity of the profiles is attributed to the gradual decrease in the gradients of the streambeds and the uniformity in the bedrock, offering little change in flow resistance. On the other hand, the longitudinal profile of Kim river shows a convexity, particularly between Limbara and Panjroli, which seems to be on account of the presence of hard sub-stratum.

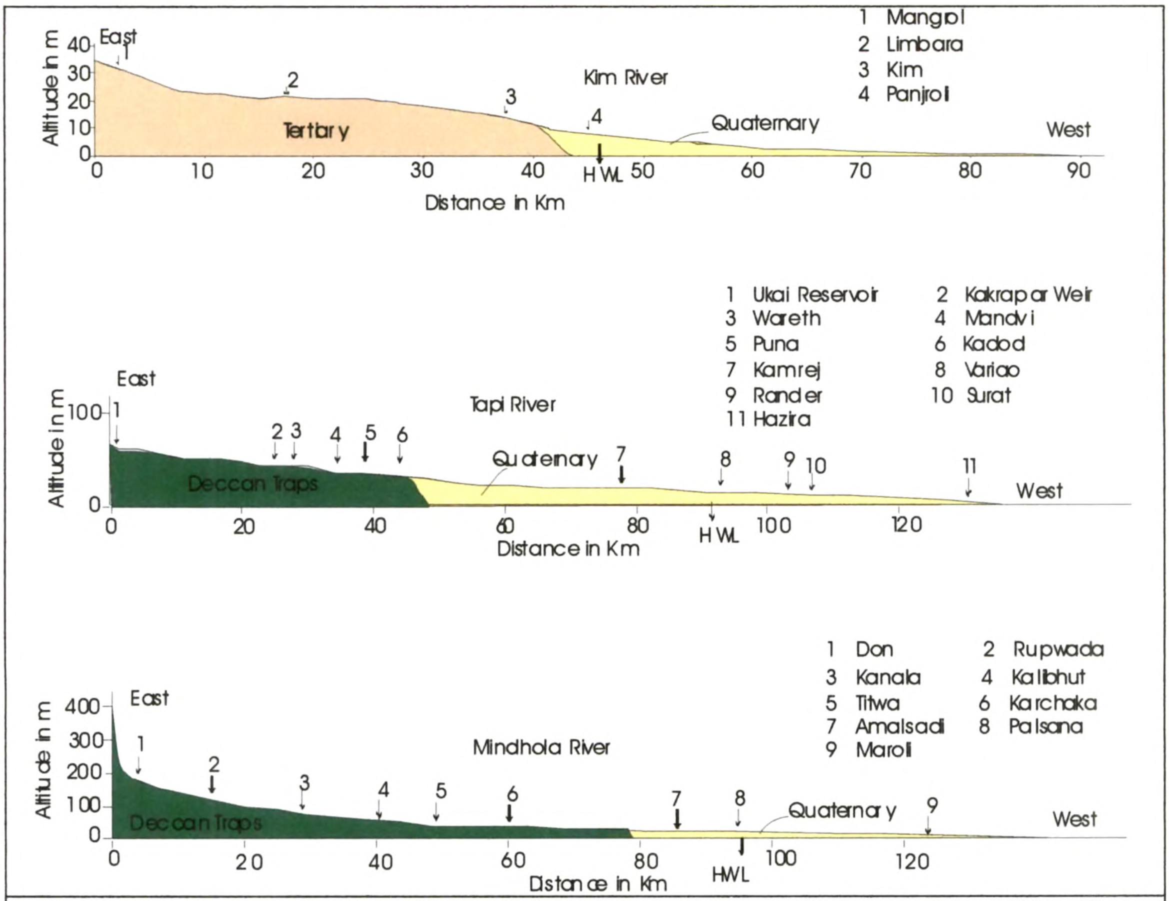

Fig. 3.14 – Longitudinal Profiles Of Kim, Tapi And Mindhola Rivers Along With The Position Of High Water Line (HWL) And The Inferred Lithology.