CHAPTER - 5

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GEOMORPHOLOGY

INTRODUCTION

Physiographically the study area forms a part of the lower Sabarmati river basin and the central part of the Cambay structural basin. The Sabarmati river, forming the main trunk drainage, traverses through the center of the area. It originates in the southern Aravalli hills and passes through three geomorphic zones, namely the Aravalli structural hills, the Gujarat Alluvial Plains and the estuarine zone at the Gulf of Cambay. The study area being a part of the Gujarat alluvial plains derives its all detritus from the upland catchment of Aravallis and the adjoining pediment zone of Himmatnagar sandstones. The river finally debauches in the Gulf of Cambay. The general slope is towards southwest, i.e. the direction of the flow of the river. The basin generally forms a flat terrain with some minor undulations due to the presence of sand sheets and sand dunes.

The landforms are the product of combine Quaternary process of sedimentation, tectonism and erosion. The various landforms have been identified, mapped and classified based on their mode of origin. This classification helps in correlating the landforms formed at the different times during the Quaternary period. The different types of landforms formed due to these processes include structural plateau, denudational bad lands and slopes, pediment landscape, levees, terraces,

flood plains, channel sands, river bank deposits, fossilized sand dunes, recent sands etc. The present study of the geomorphic processes and the resultant landforms yielded data on the degree of influence of neotectonics on these landforms. The data not only helped in reconstructing the Quaternary history of the area, but also revealed the present and past geo-environmental factors and parameters.

PALAEOGEOMORPHIC PROCESSES

Zeuner (1950) described Sabarmati river sections wherein it was pointed out that basal conglomerate deposits represent a major fluvial phase whereas upper silt and clay beds represent drier phases with progressive aridity. It has been observed during the present course of study that these silt and clay beds with kanker at base, overlying the conglomerate phase, mark a persistent palaeosol zone. The present rivers have occupied their position recently (Late Holocene) but they frequently shifted their courses earlier as a result of which wide spread older levee deposits with intervening palaeochannels are present.

The basal conglomerates which are widespread along Sabarmati river are overlain by pelletic carbonate rich deposits in which chief mineral component is calcite. Their origin and sedimentary structures may indicate marine shelf/lagoonal facies.

LANDSCAPE ANALYSIS

The area under study exhibits a flat terrain dissected by the prominent channel of Sabarmati river. The topographic elevation range from 40-60 m above MSL. On

the whole, the general flatness of the area has been dotted with minor undulations and low relief features. It is observed that most part of the terrain is under category of very gentle to gentle slope with a gradient of 1:670. Slope is in general from NE to SW direction, which is almost parallel to the flow of the river Sabarmati. The major contours being of 60 m, 40 m and 20 m. Mostly the gradient is less than 3%, hence the area can be treated as flat area with very less significance of slopes. Sabarmati, the main trunk river, flowing NNE-SSW direction is conspicuously present in the center of the study area. The area is mainly composed of alluvial plain developed by shifting of the river during Pre-Holocene, over which aeolian landforms have developed due to variations in climate from time to time. The area, in general, shows evidences of progressive aridity as a result of which an older and dominantly fluvial surface is overlapped by aeolian landforms.

During Holocene, another cycle of younger fluvial deposition superimposed by a younger aeolian phase is recorded. At present, a semi-arid climate prevails in the region and as a result the rivers which drain the area are mainly ephemeral in nature. These rivers cut through the older alluvial plain and have restricted and smaller flood plains. Thus the area exhibits landforms evolved due to various geomorphic processes active during different phases of climatic changes. Therefore, the resultant landforms can be designated as climato-stratigraphic units, which are the result of structural denudation, fluvial and aeolian processes along the river course in the semi-arid region.

At places landforms derived by structural processes have been subjected to denudation and are covered by fluvial or aeolian deposits. This is also indicative of neotectonic movements and readjustment of structures within the recent past. These movements are clearly depicted by surface expressions, which are referred as 'morphostructures'.

The younger Quaternary sequence exposed on the surface have positive geomorphic expressions in the form of fluvial and aeolian deposits. Geomorphologically, these units can broadly be classified into three categories based on their mode of origin viz. marine, aeolian and fluvial as follows:

Marine landforms include old tidal flats and newer tidal flats. The old tidal flats have a gentle slope towards the Gulf of Cambay. Dendritic type of drainage pattern is developed on this unit by various ephemeral streams. The newer tidal flats are the areas of inter tidal deposits lying between the high and low water lines. Intensive gully erosion is caused by receding water of the high tides in this zone.

Fluvial landforms comprise distinct palaeochannels and flood plains of older and younger alluvium. The older flood plain of the Sabarmati river now constitutes a terrace. These older levee deposits have intervening depressions forming palaeochannels. The palaeochannels are characterised by low-lying linear depressions, which are covered by recent flood sediments. Presence of number of such palaeochannels in the area is suggestive of frequent shifting of older rivers resulting into drainage congestion and development of highly undulatory topography.

Low alluvial plains are formed in the lower reaches of fluvial regime. The older alluvium plains are degraded and are often cut across by present fluvial channels.

The younger alluvium is being deposited along the present Sabarmati river as the channel bar, natural levees, back swamps, flood plain deposits etc. The flood plain deposits occur as sheet flood deposits in the area. Various ephemeral streams are also depositing their load in the western part of the area due to check on the stream velocity, as the gradient is very low (Kumar R. et al., 1992).

Aeolian landforms comprise sandy hills, stabilised dunes, sand sheets, undulatory mounds etc. Winnowing of sand over degraded alluvial plain deposits has developed this landform. The older deposits occur in the form of obstacle dunes far north of the study area. The younger deposits occur as fossilised sand dunes and sand sheet over younger fluvial deposits or along the older alluvial plain or even sometimes in the wide dry riverbeds. The dunes are highly stabilised due to rich carbonate concentration (calcrete). The dunes are of different shapes viz. paraboles, longitudinal and transverse. They are made up of hard, compact and well-oxidised sand. They show a good amount of vegetation and gulling effect. These landform features overlie all other geomorphic features and have a tendency of burying fluvial landforms formed prior to its deposition. These features break the monotony of the flat alluvial plains and impart a distinct undulatory aspect to the topography of the area.

The entire Quaternary landforms have been fashioned by alternate periods of humid and arid cycles. These landforms have evolved in an alternating succession of fluvial and aeolian episodes operating during late Quaternary period (Iqbal Z., et al., 1992).

The different geomorphic surfaces identified are Bedland surface, Pediment surface, Old levee surface, Flood plain, Sand dune surface etc. as described under:

Bad land surface: It is identified along the Sabarmati river from Prantij to Ahmedabad. The topography is undulating due to the gully and ravine erosion. Gullies are very deep, steep sloped at places (Plate 5.1).

Pediment surface: It is developed over resisting granite rocks exposed far north of the study area, near Himmatnagar. Aeolian sands often thinly cover pediment surface (Plate 5.2).

Old Levee Surface: This covers a large part of the area under study. Remnants of levees, highlighted by their relief, shape and size in the otherwise monotonous flat alluvial soil constitute the old levee surface. The older levee deposits have intervening depressions forming palaeochannels. Presence of such palaeochannels in the area is suggestive of frequent shifting of older rivers (Plate 5.3).

Flood Plain Surface: The older alluvial plains (levee surface) are degraded and are often cut across by present fluvial channels. Thus, it is overlapped by recent flood plains (Plate 5.4).

Plate 5.1: Deep Ravines near Prantij.

Plate 5.2: Pediment Surface as Seen in the North of Himmatnagar.

Plate 5.3: Old Levee Surface near Sola.

Plate 5.4: Flood Plain Surface near Indroda.

Sand dune Surface: This landform has been developed by winnowing of sand over degraded alluvial plain surface. The older deposits occur in the form of obstacle dunes (stabilised dunes) along hill slopes in the north of the study area. This surface is also seen around Ahmedabad, Sanand, Bareja, Thor etc (Plate 5.5).

The area is totally devoid of any drainage. It is prominently covered by recent wind blown sand in form of sand sheet over younger fluvial deposits or along the older alluvial plains.

LAND FORM CHARACTERISTICS

REGIONAL LANDFORMS

The geomorphic evolution and development of present landscape is the result of dominent fluvial and aeolian activities in the semi-arid type of climate. The area shows evidences of progressive aridity as a result of which the fluvial landscape is partially overlapped by aeolian landforms. The ephemeral rivers play a part in the fluvial transportation during monsoons whereas during dry cycle fine material deposited by river is lifted by wind and redeposited in the form of sand dunes. The recent geomorphological phases are responsible for the formation of various landforms in the area. These landforms have positive geomorphic expression i.e. depositional characters. Specific landform, lithology and pedogenetic character define each such geomorphic expression. These different geomorphic expressions are identified as separate units. These units have been classified into degradational, fluvial and aeolian landforms based on time interval between each

Plate 5.5: Sand Dune Surface near Ahmedabad.

Plate 5.6: Older Alluvial Plain near Kalol.

geomorphologically active phase and resulting landform. They may also be separated from each other by a break in slope (as in the case of aeolian deposits) or transitional overlap relationship (as in the case of fluvial deposits) (Fig. 5.1, Table 5.1).

Table - 5.1: REGIONAL GEOMORPHIC UNITS:

Age	Environment of Deposition	Formation	Geomorphic Unit	Geomorphic Expression	Lithology	Sedimentary Structures
Holocene	Fluvial	Sabarmati	Recent flood plain	Point bars channel bars, back swamp	Fine to coarse sand and silt	Cross beds, current ripple lamination
	Aeolian	Jantral	Younger aeolian surface	Sand sheet	Light brown, fine to very fine sands	Fine cross bedding
	Fluvial	Vijapur	Younger flood plain	Older back swamp	Fine to medium sandy silt and clays with inceptisols	-
	Aeolian	Akhaj	Older aeolian surface	Obstacle dunes, stabilised and dissected	Aeolinites, well sorted fine sand	Large cross bedding, calcareous kankars
Late Pleistocene	Fluvial	Mehsana	Older alluvial plain	Older levee, low flat plain (peneplains)	Light brown fine to medium sands and silts	Convolute bedding
Mid Pleistocene	Fluvial Deltaic	Waghpur	-	(Paleo-geomorphic surface)	Pedogenised silts and fine sands	Rhizo concretionary structures
Early Pleistocene	Subaerial deltaic	Valasana	-	-	Marl stone gritty sandstone	Rough cross bedding, graded and current bedding

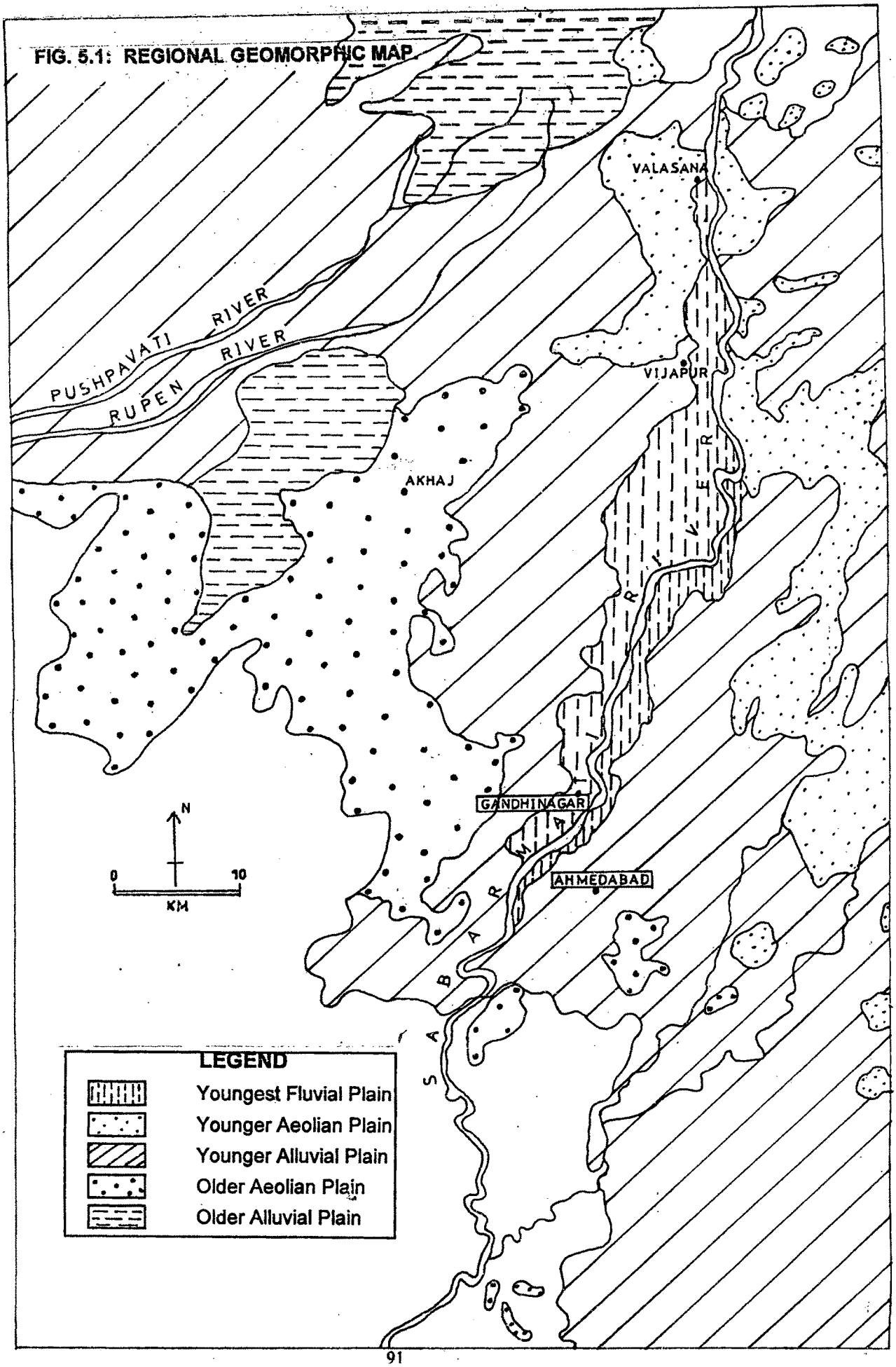


FIG. 5.1: REGIONAL GEOMORPHIC MAP
VALASANA
PUSHPAVATI RIVER
RUPEN RIVER
VIJAPUR
AKHAJ
SABARMATI RIVER
GANDHINAGAR
AHMEDABAD
N
0
10
KM
LEGEND
Youngest Fluvial Plain
Younger Aeolian Plain
Younger Alluvial Plain
Older Aeolian Plain
Older Alluvial Plain

OLDER ALLUVIAL PLAIN

This plain forms flat surface and exposed in the far northern part of the study area. This surface gently slopes towards SE direction and constitutes a thick alluvial cover, which has mostly been pedogenised forming aridsols. It is formed of older levee deposits. It forms a highly fertile ground and is being extensively cultivated due to deep pedocalcic pedogenesis (Plate 5.6).

OLDER AEOLIAN SURFACE

This surface overlies older alluvial plain and is represented by obstacle dunes forming along the hill slopes of Pre-Quaternary rocks, far north of the study area. Within the study area they are seen around Ahmedabad, Sanand, Bareja, Thor etc. These features comprise of sandy hills, dunes, undulatory mounds etc. These have been developed by winnowing of sand over degraded alluvial plain deposits. The dunes are stabilised and dissected as evidenced by the formation of soil over them. The surface is characterised by parabolic and longitudinal dunes and indicates that these deposits have been formed in an older aggraded river valley during a sub-humid climate (Plate 5.7).

YOUNGER ALLUVIAL PLAIN

This surface is encountered along the Sabarmati river. It is the widest and well developed along the western bank of the river, bordering the present flood plain. This is a flat surface formed of younger river alluvium and dips very gently towards the river. The unit narrows down in the width towards north and finally

Plate 5.7: Older Aeolian Surface near Chharodi.

Plate 5.8: Younger Alluvial Plain in the Background near Koba.

merges with youngest flood plain of the river. There is formation of inceptisols indicating a younger age of these deposits as compared to older alluvium deposits. It comprises of light brown, fine to medium sands and silty clays with kankar as well as with some quartzofelspathic material and some basaltic grains. The presence of channel fill deposits and coarse sands below this humus cover differentiates this surface from older alluvium plain. At places they also show channel fill deposits formed of coarse rounded pebbles occurring as remnants of older fluvial channel. It is likely that the unit forms an older back swamp of Sabarmati river but at present the river has been shifted to a new course and soil forming processes have been initiated leaving this as an isolated plain (Plate 5.8).

YOUNGEST AEOLIAN SURFACE

The surface is characterised by recent sand dunes and sheets covering both the present and the younger flood plain. The deposits occur mainly along the western bank of the river Sabarmati. These deposits consist of very fine to fine sands either as sheets or unstable undissected dunes mainly crescent shaped, covering the older deposits. The sands are derived from older flood plain (Plate 5.9).

YOUNGEST (PRESENT) FLOOD PLAIN

It is formed of youngest Quaternary alluvium deposited by the present Sabarmati flood waters. The river has U-shaped valley and exhibits a variety of geomorphic expressions. Three types of geomorphic feature development have taken place viz. Channel deposits, bank deposits and flood plain deposits.

Plate 5.9: Youngest Aeolian Surface near Gota.

Plate 5.10: Youngest (Present) Flood Plain from Indira Bridge.

Amongst channel deposits, development of point bars and channel bars is prominent. A study of exposed point bar section in the Sabarmati river showed development of irregular ripple beds, graded beds and climbing ripple laminations. The bank deposits have formed natural levees. They occur as small dome shaped ridges. Back swamp and a thin cover of silty clays represent the flood bank deposits over older alluvial deposits. The river has the widest flood plain. It extends on either side of the Sabarmati river up to a distance of 1 to 3 km and consists of deposits of light brown fine sands and silts. In the north part of the area, along the banks of the river, the flood plain has been developed into bad lands due to gully erosion. Chief constituents of the deposit include very light brown, medium to coarse grained, sub angular to sub rounded sands with silt and little clay (Plate 5.10).

This surface includes following geomorphic sub-units.

Abandoned Channel

Numbers of buried channels have been delineated in the area with the help of satellite imageries and field checks. These channels have been left due to lateral shifting of river courses and at places due to choking of the channels by aeolian sand accumulation. The channels are crescent shaped and slightly depressed. The abundance of these channels is seen in the NW and SW directions of Ahmedabad. These channels have been later on filled up with silty clay and sand. Some of these channels reactivate during rainy season and cause floods (fig. 5.2, Plate 5.11)

FIG. 5.2: PALAEOCHANNEL MAP.

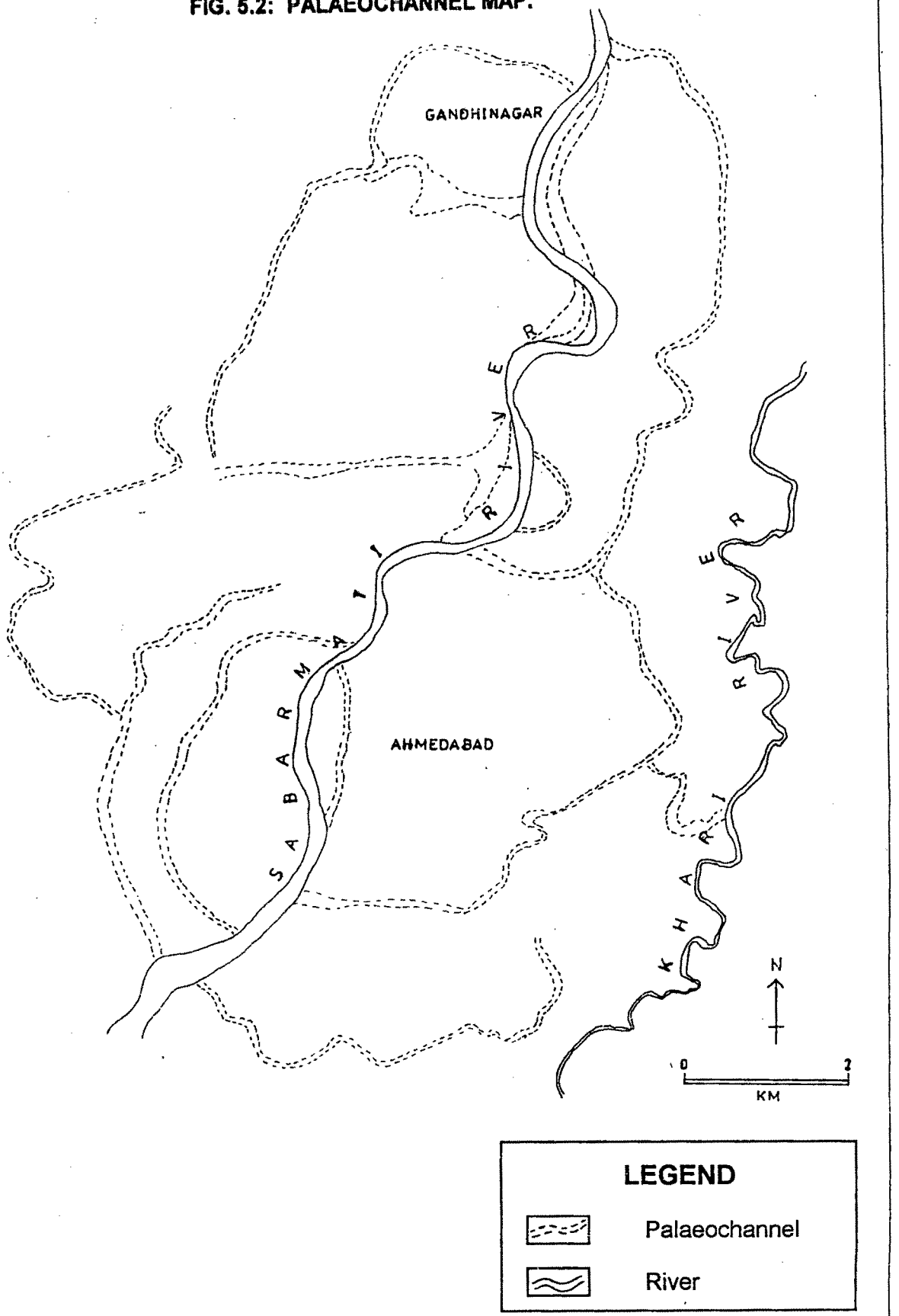


Plate 5.11: Abandoned Channel near Sarkhej.

Plate 5.12: Interdunal Surface near Khodiyar.

Cut off Meanders

These are few meandral loops present in the area that have been cut off and abandoned. These are arc shaped remnants of meandering river course, later filled with silty clay and act as back swamp areas.

Abandoned swampy land

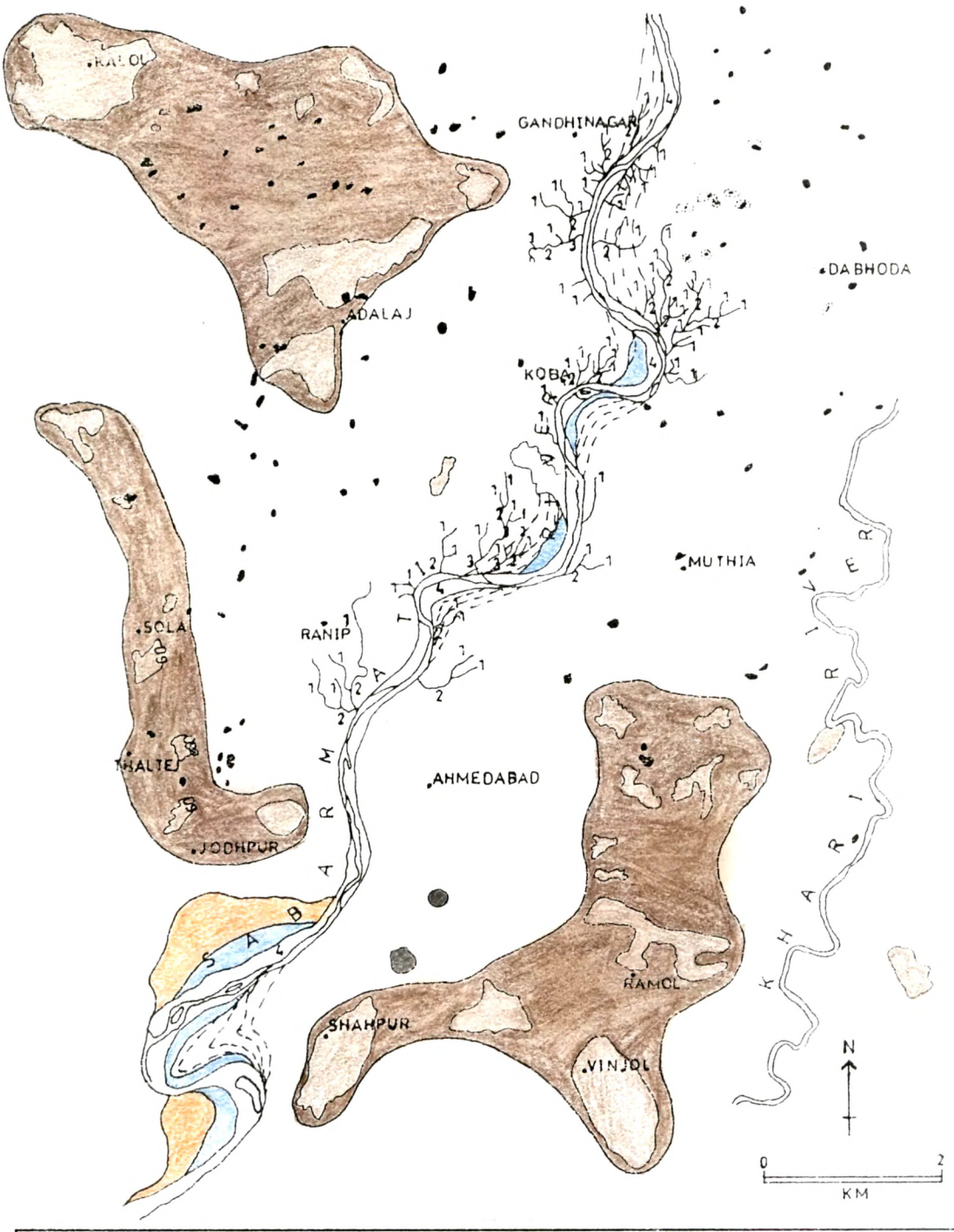
The area W and SW of Bavla town shows extensive deposition of black silty clay forming an abandoned swamy land. Number of abandoned meandering channel courses can be traced in the tract. Along these channel courses the silty sand deposit is more prominent forming the levees. Within sampy land saline patches are also present at places.

LOCAL GEOMORPHIC UNITS

In the study area at microlevel two major types of landforms can be identified depending upon the agencies responsible for their formation viz. Fluvial and aeolian (fig. 5.3).

In general, the area exhibits a flat aspect with minor undulations. The general slope of the area is towards SW. Geomorphic mapping of the area has been carried out on 1:50000 scale. Satellite imageries and topographical maps were used to decipher the macro landforms. They were then checked in the field and precise boundaries demarcated. The sediment characteristics comprising these landforms and their field relationships were also noted. All the landforms mapped in the area

FIG: 5.3 GEOMORPHIC MAP OF STUDY AREA



LEGEND

FLUVIAL FORMS	AEOLIAN FORMS	
Alluvial plain	Sand dune	River
Terrace - T1	Inter dunes	Meander Scar
Terrace - T2		Water Bodies
		Drainage Order

have been categorised into three main groups viz. aeolian, fluvial and degradational or erosional land forms.

I. Aeolian land forms

a. Older stabilised dunes

b. Younger stabilised dunes

c. Inter dunal areas.

II. Fluvial land forms

a. Levees

b. Terraces

c. Point bars

III. Degradational land forms

a. Bad lands or ravines

b. River cliffs

AEOLIAN LAND FORMS

The aeolian land forms encountered in the study area include-older stabilised dunes, younger stabilised dunes and interdunal areas. These landform features overlie all other geomorphic features and have a tendency of burying fluvial landforms formed prior to their deposition. These features break the monotony of the flat alluvial plains and impart a distinct undulatory aspect to the topography of the area.

Older Stabilised Sand Dunes

The older stabilised sand dunes occur in the form of obstacle dunes along hill slopes in the north of the study area. Within the study area, these are seen around

Ahmedabad, Sanad, Bareja, Thor etc. These features comprise sandy hills, dunes, undulatory mounds etc. These have developed by winnowing of sand over degraded alluvial plain deposits. The dunes are stabilised as evidenced by the formation of soil over them. The dune shape resembles parabolic, longitudinal and transverse dunes. They are made up of hard compact and well oxidised sand and contain abundant calcretes or kankars. They show a good amount of vegetation and gulling effect. The dunes provide evidence of progressively increasing aridity as a result of which the earlier fluvial landscape is partially overlapped by these features. These dunes were produced as a result of fine sediments deposited by river subsequently uplifted by wind and redeposit in the form of dunes. However, the stabilised nature of these dunes suggest a return to subhumid climate after the aeolian phase.

Younger Stabilised Sand Dunes

These features include recent sand dunes and sand sheets. They occur along the western bank of the Sabarmati river. The dune comprises of very fine to fine sands covering the older deposits and are crescent shaped. The sands have been derived from river deposited alluvium subsequently reworked by wind. The dune sand is invariably greyish yellow with lime concretions. The top 1m is oxidised sand, reddish brown and free of lime concretions. The height of the dune varies from place to place. The sand accumulation is more or less confined along or very close to the present day river system.

Inter Dunal Area

Well defined inter dunal areas are not distinctly identifiable. Vast sandy flats are however prominent. These sandy areas show small depressions. These strata comprise mainly of fine silty sands. Greyish silts show compaction due to salt encrustations.

The morphological features of the above described aeolian landforms have been distorted due to biotic interference and extensive dissection they have undergone. The flanks have been more degraded. In some of the areas they are preserved in linear shaped ridges and some in crescent shape. The leeward slope varies from 5°-10° and windward slope varies from 25°-30°. Zeuner (1950) and Allchin et al. (1978) have attributed these aeolian landforms to the extremely arid climate during last glacial maximum. The stabilisation of the dunes took place during a humid climate post-dating the end phase (Plate 5.12).

FLUVIAL LANDFORMS

The fluvial landforms in the study area are the result of fluvial activity of Sabarmati river. These include levees, depositional terraces and point bars.

Levees

These cover a large part of the area under study. Remnants of the levee are identified by their high relief, slope and size. The older levee deposits have intervening depressions marking back swamps and palaeochannels. Presence of such palaeochannels in the area is suggestive of frequent shifting of the river.

These levees are overlapped by recent flood plain deposits of the river. The levees are encountered all along the Sabarmati river. It is the widest and well developed along the western bank of the river. This is a gently dipping flat surface, which narrows down in width towards north. The top surface comprises silty sand and clays. Channel fill deposits and coarse sands are present below the humus cover. There is formation of inceptisols indicating a younger age of these deposits. It is likely that it represents a levee-back swamp complex of Sabarmati river. The river subsequently shifted to a new course leaving this as an isolated plain and allowing soil forming process to operate. The chief constituents of the levee sands include quartz, muscovite-biotite flakes and black grains of magnetite. These deposits exhibit sedimentary structures like current bedding, ripple marks, graded bedding, lenticular bedding and slump structures (Plate 5.13).

Depositional Terraces

Apart from the flood plain and river channels there are few fluvial terraces along the Sabarmati river. They can be identified and traced from the satellite imageries.

The Terrace (T_2) is developed very dominantly but in limited extend and in patches. It also occurs as gully fills within alluvial plain. It is formed of alteration deposits of sand, silt and clay. It is semi-consolidated and forms highly fertile land. The best development of these terraces is in the downstream direction from Ahmedabad. There are number of old courses within the terrace extent.

Plate 5.13: Levee Surface near Bhat.

Plate 5.14: Depositional Terraces near Motera.

The terrace (T_1) is more prominently developed in the downstream direction from Ahmedabad from where the rivers have started fringing laterally. It is composed of fine sand and silt with little clay (Plate 5.14).

Point Bars

The point bars are confined within the present flood plain of Sabarmati river. These are present within the existing meander loops of the course of the river. The point bars are the sites of active depositional processes where present flood sands are deposited (Plate 5.15).

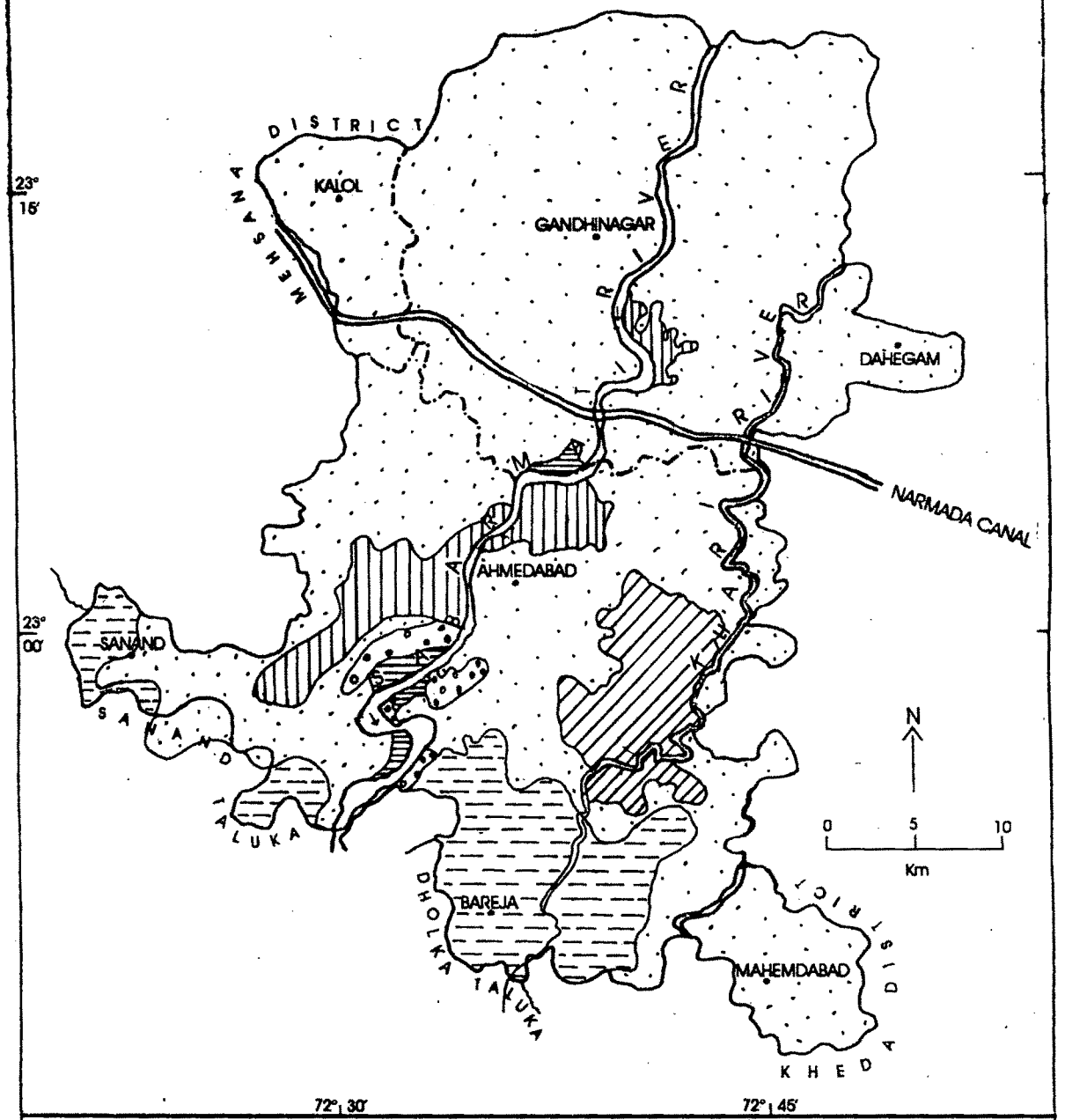
MORPHOSTRATIGRAPHIC STUDIES

Morphostratigraphic studies reveal geomorphic expressions of stratigraphic units in the form of surfaces. Surfaces are the landforms with definite evolutionary history, both under erosional and depositional environments.

A morphostratigraphic map (fig. 5.4) has been prepared from satellite imageries and ground checks which helps in depicting the geographical configuration of the land capabilities. It will help in proper land use planning. Different morphostratigraphic units have been identified in the filed by taking a number of traverses and through the geological sections and profiles along the Sabarmati and the Khari rivers. The evolutionary imprints of the Sabarmati through the Quaternary period from Pleistocene up to the Recent are well recognised in the form of buried channels, meandering loops, meander scars etc.

Plate 5.15: Point Bar near Koba.

FIG. 5.4 MORPHOSTRATIGRAPHIC MAP



LEGEND

- FLUVIAL TERRACE
- SABARMATI SURFACE
- BAVLA SURFACE
- GANDHINAGAR SURFACE
- VINJHOL SURFACE
- AHMEDABAD SURFACE

Repeated fluvial phases followed by aeolian interference are responsible for the formation of different surfaces of different magnitude. Study of these surfaces in the field and from satellite data suggests a deltaic origin of the entire tract. The dunes are parabolic in nature, typical of coastal tracts. It contains good amount of foraminifers. The Sabarmati system, which formed delta in the earlier stages, was disorganised and concealed under the cover of aeolian sediments. Fluvial activities of the later stages have established their imprints on the aeolian terrain. The morphostratigraphic sequence has been established from the Sabarmati and Khari river sections by GSI and followed here with modification. This sequence is given in Table 5.2.

Table – 5.2: Morphostratigraphic Units of the Study Area.

SURFACE	LANDFORM	LITHOLOGY
Sabarmati Surface	Present river channels and flood plains.	Unoxidised river sand – fine to medium grained.
Fluvial Terraces T1 and T2	Terraces along present river channels.	Unoxidised terrace fills silt, sand and clay.
Bavla Surface	Mainly flat plain area with few buried channels, low lying areas forming palaeodeltaic plain.	Gray silt and clay in the low lying areas (mud flats) reddish gray, brownish gray fine sand.
Gandhinagar Surface	Mainly flat plain at places undulating.	Highly oxidised sand-coarse grained, sub-rounded to rounded, lime free, dark reddish brown sand.
Vinjhol Surface	Parabolic dunes and interdunes.	Upper part is composed of fine to coarse grained well rounded reddish brown coloured sand. Lower part composed of grayish yellow with calcareous material and pedocalcic pedogenesis and presence of foraminifers.
Ahmedabad Surface	Highly dissected exhumed surface along the river channels.	Concretionary conglomerate at the base, fine to coarse grained yellow, white and gray sand. Full of lime concretions due to pedocalcic pedogenesis.
Koba Surface	Exhumed terraces in the sabarmati sections along its upstream banks.	Highly oxidised with lime leaching red, greenish gray coloured clay, silt and sand. Concretionary conglomerate with quartz pebbles at the base.
Mehmadabad Surface	Older palaeosol horizon.	Brown and gray mottled clay, sand, silt, intercalated concretionary conglomerate.