PART - II

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GEOLOGICAL SETTING

PREVIOUS WORK

The study area is largely covered by Quaternary alluvium and forms a part of the petroliferous Tertiary Cambay basin. Earlier studies have mainly been concentrated on Tertiary sequences for their oil and gas contents and in recent years a lot of data have been generated on the Quaternary geology of the area as well. However, an integrated study of the geological history, geomorphic set up, hydrogeological conditions and their impact on the geo-environmental system in the area is lacking.

The Cambay basin is one of the three major marginal rift basins of the Indian craton (Fig. 3.1) which developed subsequently during India's drift after the break up of Gondwanaland (Biswas, 1987). The architecture of the basin is controlled by three Precambrian orogenic trends viz. the ENE-WSW Satpura trend paralleling the Narmada-Son lineament, the NE-SW Aravalli trend and the NNW-SSE Dharwar trend (Fig. 3.2). Within the Cambay basin, the Deccan basalt form the basin floor over which Tertiary and Quaternary sediments have been deposited. The combined thickness of these sediments in most parts of the basin varies from 3000 to 5500 m. The Tertiary stratigraphy and structural styles have been worked

FIG. 3.1: INDIAN CRATON.

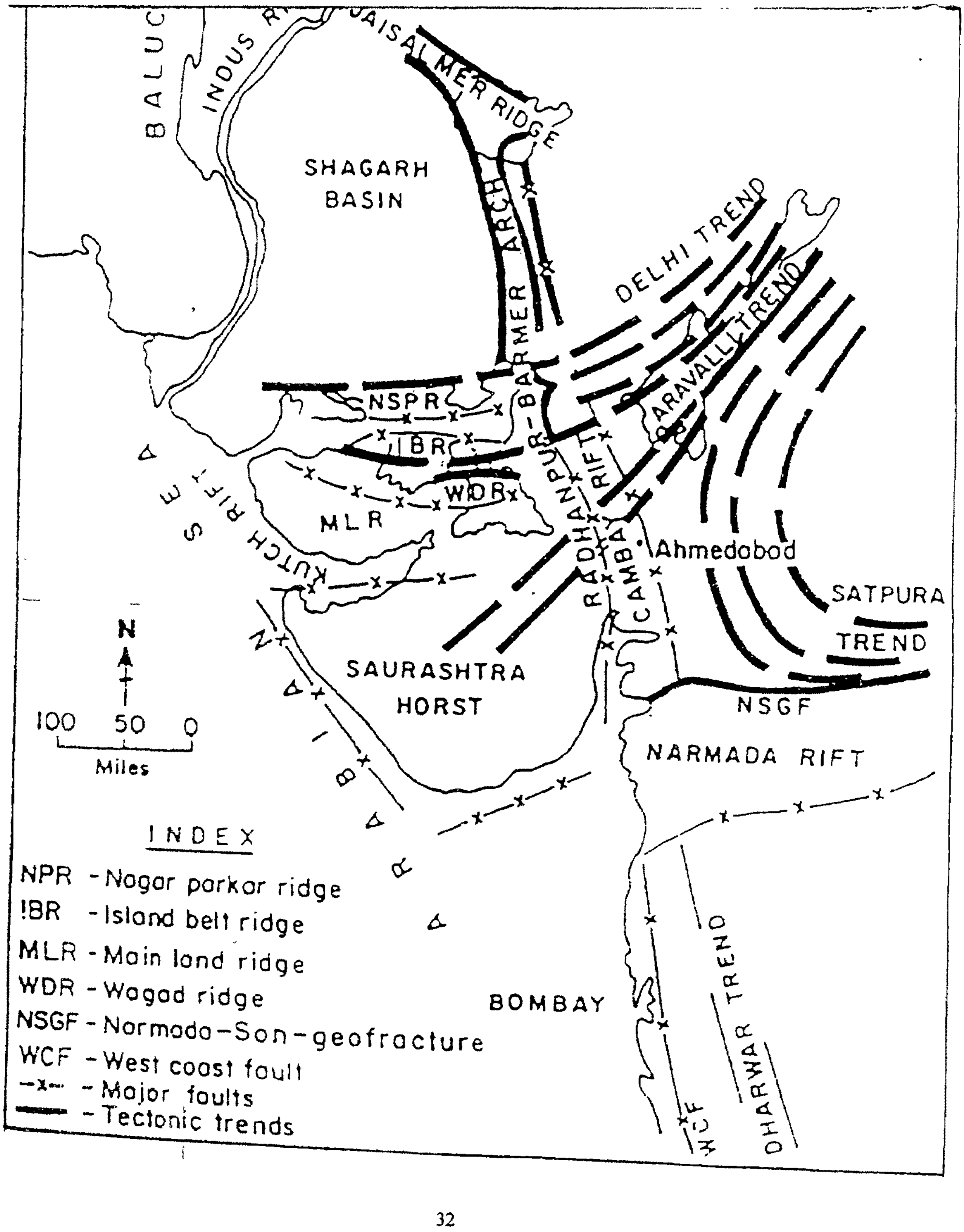
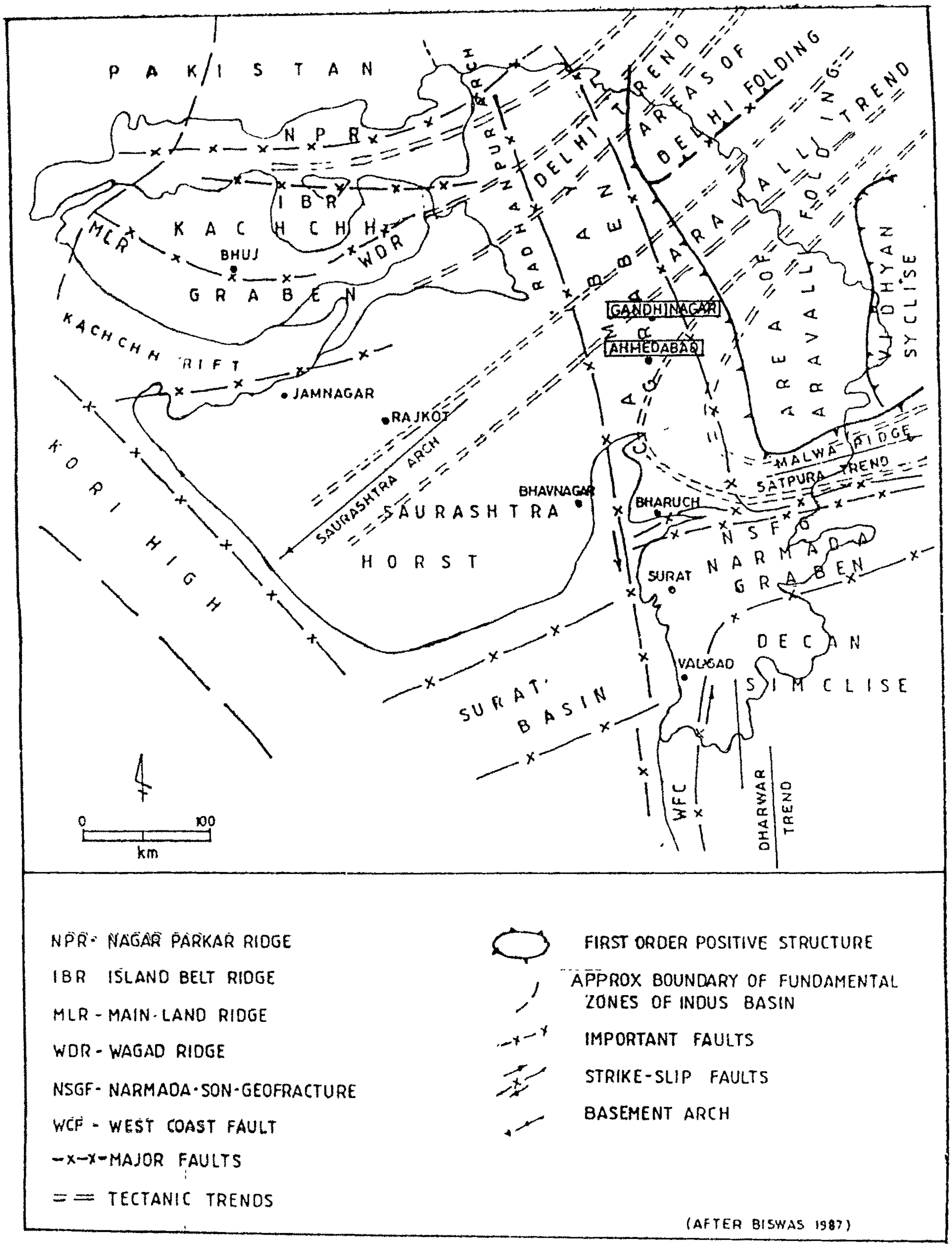


FIG. 3.2: REGIONAL STRUCTURAL TRENDS.

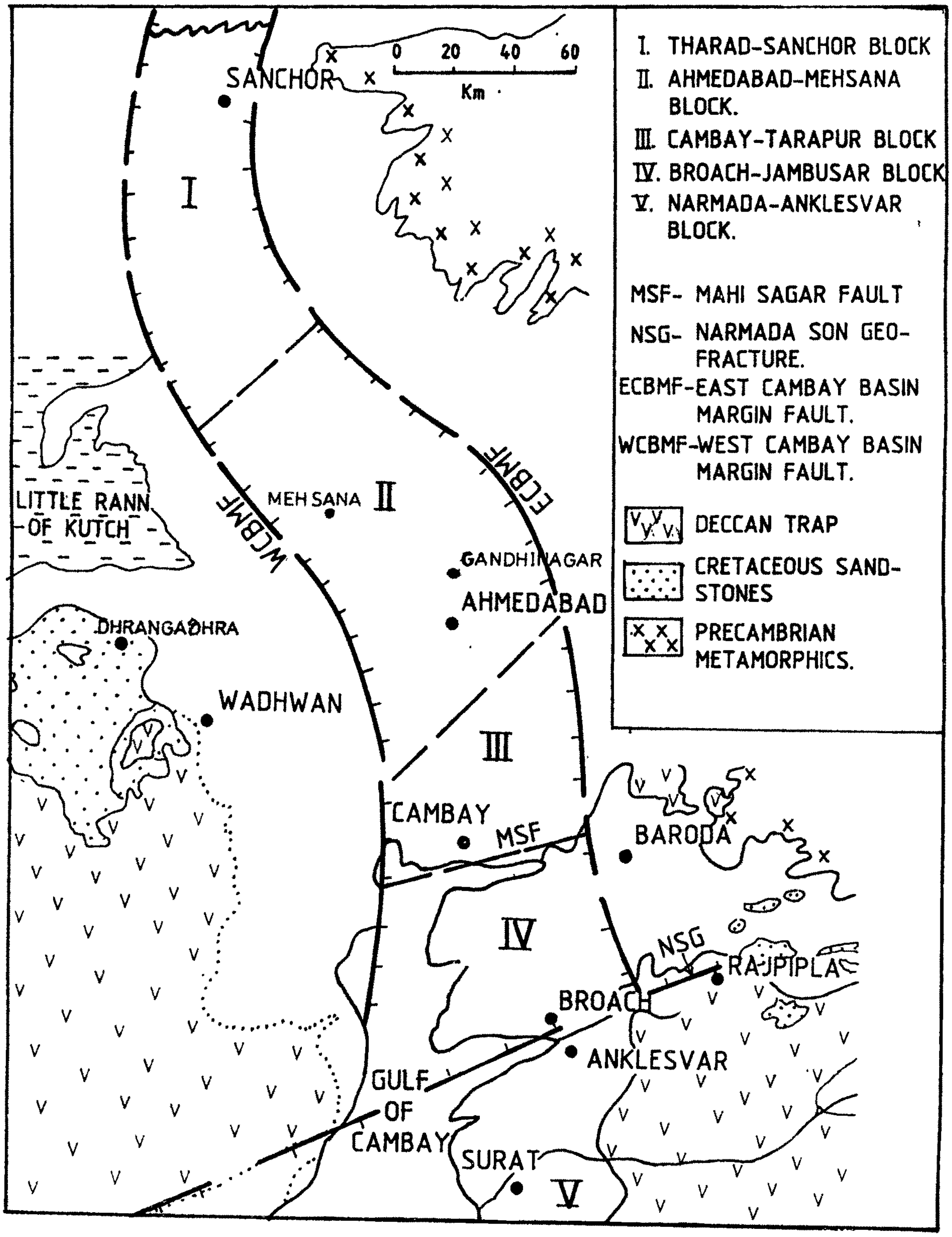


by several authors (Mathur et al., 1968; Zubov et al., 1966; Raju 1983; Biswas, 1982, 1987). The steep en-echelon boundary faults delimiting the basin width, simultaneous shoulder uplift of the basin with concomitant sedimentation etc. are some of the major features of the basin (Raju and Srinivasan, 1983). The block structures of the basin controlled by basement faults have been clearly brought out by Mathur et al. (1968). Based on structural styles, such as fault pattern, symmetry, size and orientation of the depression, the Cambay basin is divided into five tectonic blocks, namely, (1) Tharad-Sanchor block, (2) Ahmedabad-Mehsana block, (3) Cambay-Tarapur block, (4) Broach-Jambusar block and (5) Narmada-Ankleshwar block (Fig. 3.3).

The northern part of the Cambay structural basin is entirely devoid of any surface hard rock exposures except in the vicinity of Himmatnagar where outcrops of volcanic rocks of late Palaeocene age, sedimentary rocks of Jurassic age and the Precambrian shield are well known. The palaeocurrent direction of the Dhangdhra sandstone of Mesozoic age is prominent from east to west, indicating that the drainage carrying sediments was from the crystalline complex of Aravalli mountain range towards gulf of Cambay.

The study area lies within the Ahmedabad-Mehsana block of the Cambay basin. The block lies between the Khari river in the north to Watrak river in the south. Area wise this is the largest block extending over a wider area from Dholka and Navagam in the south up to the Unhawa ridge in the north of Mehsana.

FIG. 3.3: TECTONIC BLOCKS OF THE STUDY AREA.



The Mehsana horst divides the block into eastern and western depressions. The marginal faults are more pronounced in this block than in any other block. The structural elements have differentiated the block into uplifts and depressions. The geological succession of the Ahmedabad-Mehsana block is given in Table- 3.1.

Table - 3.1: Generalised stratigraphic sequence of Ahmedabad – Mehsana block

AGE	FORMATION	LITHOLOGY	THICKNESS(m)
Recent / Holocene	Gujarat Alluvium	Sand, Clay, Gravel and Kankar	0 - 400
Middle / Upper Pliocene	Jambusar	Silt, Sand, Sandstone	400 – 500
Lower Pliocene	Broach	Sand, Siltstone, Sandstone	500 – 575
Upper Miocene	Jagadia	Sand with intercalated clay	575 – 650
Miocene	Kand	Claystone,Siltstone with shaley intercalations	650 – 900
Lower / Middle Oligocene	Babaguru	Sand with few intercalations of claystone and sand	900 – 1200
Lower Oligocene	Tarapur	Shale with few streaks of sand and silt	1200 – 1375
Middle Eocene	Kalol	Arenaceous section consisting of sand, sandstone with coal (Cap rocks)	1375 – 1600
Lower / Middle Eocene	Kadi	Argillaceous shale, siltstone and coal (oil reservoirs)	1600 – 1800
Lower Eocene	Cambay Shale	Moderately hard shale and siltstone (Source rock for oil)	1800 – 2100
Lower Palaeocene	Olpad	Silty shale, siltstone with calcareous sandstone	2100 – 2500
Upper Cretaceous	Deccan Trap	Dark greenish, weathered trap	2500 +

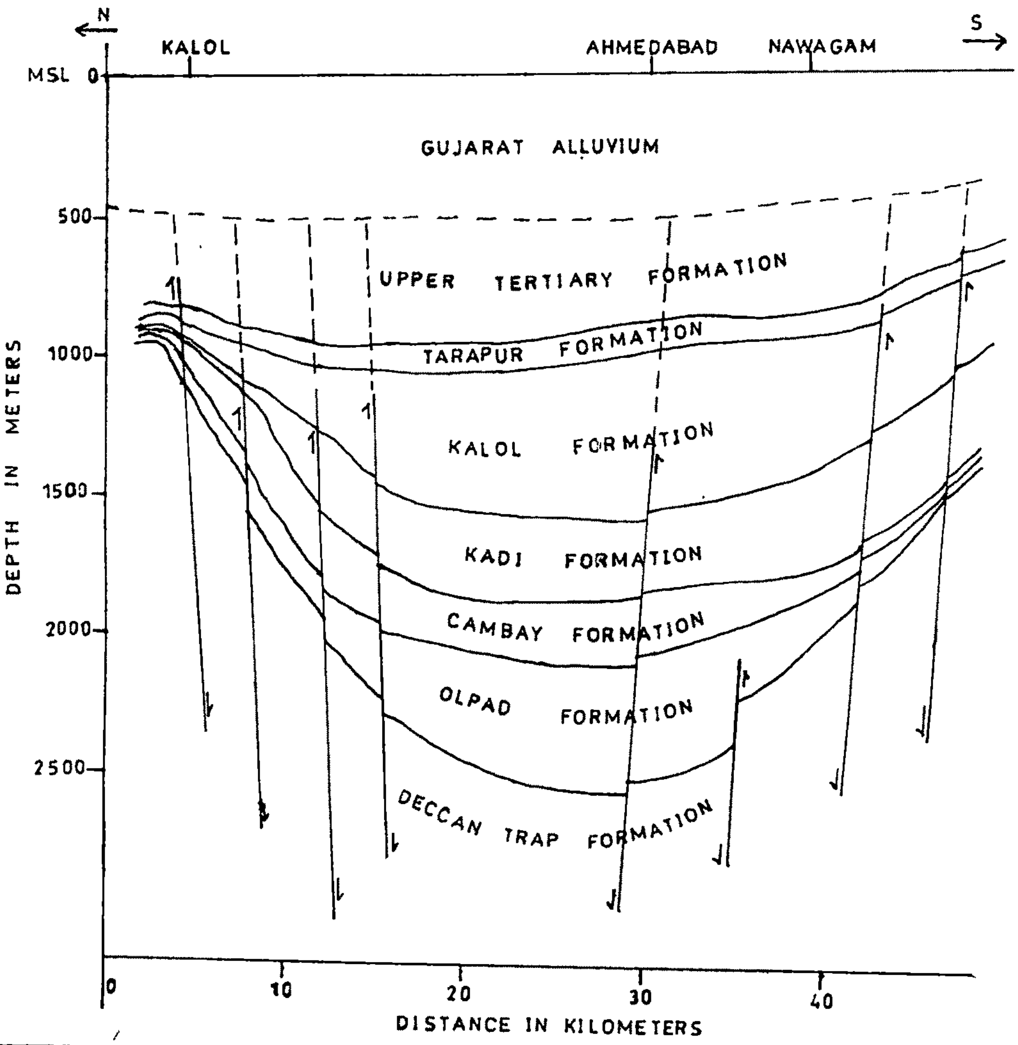
(Source: Oil Well, ONGC, 1991)

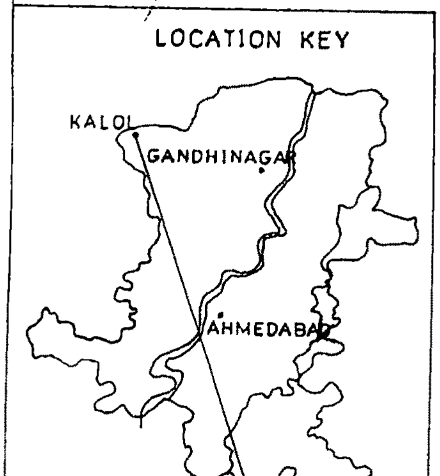
The structures near Sanand, Nawagam and Mehsana are associated with trappean faults. These faults have given rise to horsts. The anticline at Kalol has formed due to a single fault. The fault near Mehsana has a deep downthrow to the east, causing a depression to the north of Kalol. The variation in lithology and structural characteristics is believed to be the result of differential movement along these faults (Fig. 3.4).

Foote (1898) in his book, "Geology of Baroda State" has described the exposed alluvial successions of Sabarmati and Mahi rivers. He has noted that the present day rivers were erosional rather than depositional and recorded the first prehistoric findings at Sadolia and Pedhamli. He observed the capping of loessic deposits and calcretes contained in them.

Zeuner (1950, 1963) gave a detailed account of the exposed Quaternary sediments in a regional context. He studied the alluvial sediments of Narmada, Orsang, Mahi and Sabarmati in particular and noted their similarity. Envisaging the role of changing palaeoclimatic conditions in the deposition of the Quaternary sediments, he interpreted the coarser deposits as indicative of seasonally dry climates with occasional heavy floods whereas the fluvial silts represented a drying up phase. The mottled clay according to him were formed through intense weathering in a warm humid climate while the red soil was formed in a dry climate with about 20-40 inches rainfall. Merh (1992) considered these clays to be equivalent of Miliolite deposits of Saurashtra and correlated it with the Middle Pleistocene transgression. Of particular relevance is the work carried out by Pant and Chamyal, 1990; Merh and Chamyal, 1993; Chamyal and Merh, 1992. They have described the

FIG. 3.4 VERTICAL CROSS SECTION ALONG KALOL - NAWAGAM (N-S)





Quaternary sediments of various cliff sections of Sabarmati, Mahi and Narmada valleys and provided a detailed lithostratigraphy. The entire Quaternary geological history of the Gujarat Alluvial Plains have been elaborately described for the first time by Merh and Chamyal (1997). They have provided detailed account of lithostratigraphy, depositional environments, sedimentary facies and the sequence of palaeoclimatic events. The generalised description of the classification is given in table 3.2. Sridhar et al. (1994) have proposed a Super Fluvial System which deposited the Quaternary sediments in the northern alluvial plains. Sareen et al. (1993) attributed the present slope deviatory course of the Sabarmati to neotectonic adjustments related to the structural elements of Cambay basin. Maurya et al. (1995) emphasised the influence of Cambay basin tectonics in the evolution of Gujarat Alluvial Plains. Tandon et al. (1997) described the Late Quaternary aggradational history of the Sabarmati river and provided absolute dates to some of the key horizons. They suggested that the present drainage adjustment is younger than 39 ka. They have attempted to provide a detailed chronology of these sediments and related palaeoclimate. They have emphasised the role played by neotectonic activity during Middle to Late Quaternary in shaping the basin.

REGIONAL GEOLOGY AND TECTONICS

The Ahmedabad-Gandhinagar area forms a part of the Cambay basin. The entire surface of the area is covered by thick sequence of Quaternary sediments.

EVENTS	ENVIRONMENT	ENERGY CONDITIONS	LITHOLOGY	PEDOGENESIS	CLIMATE
Deposition of present day unconsolidated sand-sheets and dunes		Moderate to low	Sand and silt		Semi-arid to arid
Deposition of dunal sands	Aeolian environment	High velocity winds	Sand and silt		Arid
Period of non deposition	Sub-aerial weathering	-		Stabilization and pedogenisation of silts Palaeosol formation and calcretization	Sub-humid to semi-arid
Sudden deposition of sediments of silt and fine sand	Aeolian environment	High velocity winds	Fine to medium grained silts and coarse sand		Arid
Deposition of third fluvial cycle	Fluvial environment	Reduced energy conditions Deposition in the form of intermittent flash floods	Mud, coarse sand and lenses of gravel, chiefly composed of quartz grains feldspars and micas		Sub-humid to humid
Period of non deposition	Sub-aerial weathering			Pedogenetic changes including rubification of silts and development of calcrete nodules at the base	Sub-humid to semi-arid
Continuing deposition of second fluvial cycle Deposition of second fluvial cycle	Fluvial environment	Moderate to low energy conditions High to shallow energy conditions	Silts and sands Gravel comprising clasts of varying sizes of quartzite, rock fragments capped by mud		· Humid
Period of non deposition	Weak sub-aerial weathering			Weak pedogenesis of the top part (mud)	Sub-humid to semi-arid
Deposition of first fluvial cycle	Fluvial environment	High to shallow energy conditions	Gravels comprising clasts of quartzite, granite, chert jasper and rock fragments overlain by mud		Humid
Period of non deposition	Sub-aerial weathering			Pedogenetic changes in basal clay	Semi-arid
Marine conditions (High sea)	Tidal environment	Low energy	Clay rich in illite, smectite, montmorillonite and silt comprising mainly quartz, feldspar and micas		Humid

(After Merh and Chamyal, 1997).

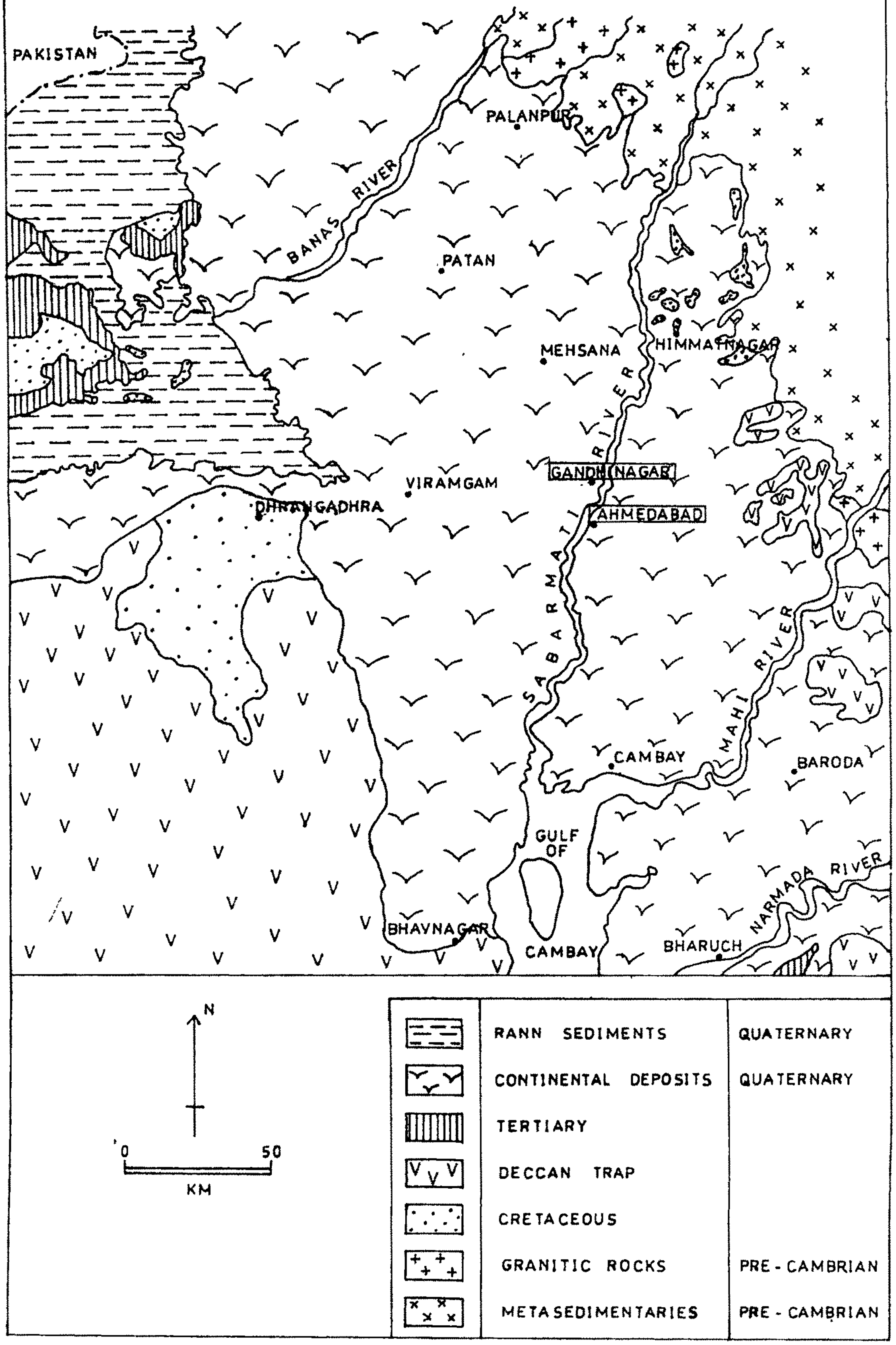
TABLE - 3.2: SYNOPTIC VIEW OF QUATERNARY GEOLOGICAL HISTORY OF THE GUJARAT ALLUVIAL PLAIN.

This sequence is called Gujarat Alluvium Formation. The thickness of these sediments increases from NE to SW. To the N and NE of this formation, lie the Aravalli mountains which are composed of Precambrians. Deccan traps cover the western part i.e. Saurastra with a patch of Mesozoic (Cretaceous) in NW near Dhangadhra. Himmatnagar sandstone of Cretaceous age is exposed along the Sabarmati river near Himmatnagar and Vijapur (Fig. 3.5).

The evolution of Cambay basin which is described variously as intracratonic rift graben or half graben is attributed to large scale basement faulting (Raju, 1968). The basic tectonic framework of the western continental margin was established in Late Cretaceous (Biswas, 1982, 1987). The present understanding of the stratigraphy of the Cambay basin owes much to the massive exploratory efforts of ONGC in search of hydrocarbon accumulations. The basin as a whole is being largely concealed under the Quaternary alluvial sediments. Strips of Cretaceous, Tertiary and the Deccan traps occur on the eastern and western fringes of the basin as isolated outcrops.

The Mesozoic sediments are directly overlain by Deccan traps, which form the floor of the Tertiary sediments. It is believed that the Cenomanian transgression brought the Tethys southwards from the Indus valley to cover a depression, which was possibly the forerunner of the Cambay basin. This depression was completely filled up by the deposition of sediments constituting the Bagh beds and later on covered by basic igneous lava flows before being uplifted and subjected to

FIG. 3.5: REGIONAL GEOLOGICAL SET UP



erosion, followed by another depression. The Tertiary sediments were deposited in this trough, the deposition keeping pace with the sinking of the trough. By the end of the Oligocene times the basin was probably filled up, for the deposits underwent some erosion before the renewal of submergence which brought about more widespread sedimentation of Miocene, Pleistocene and Recent times.

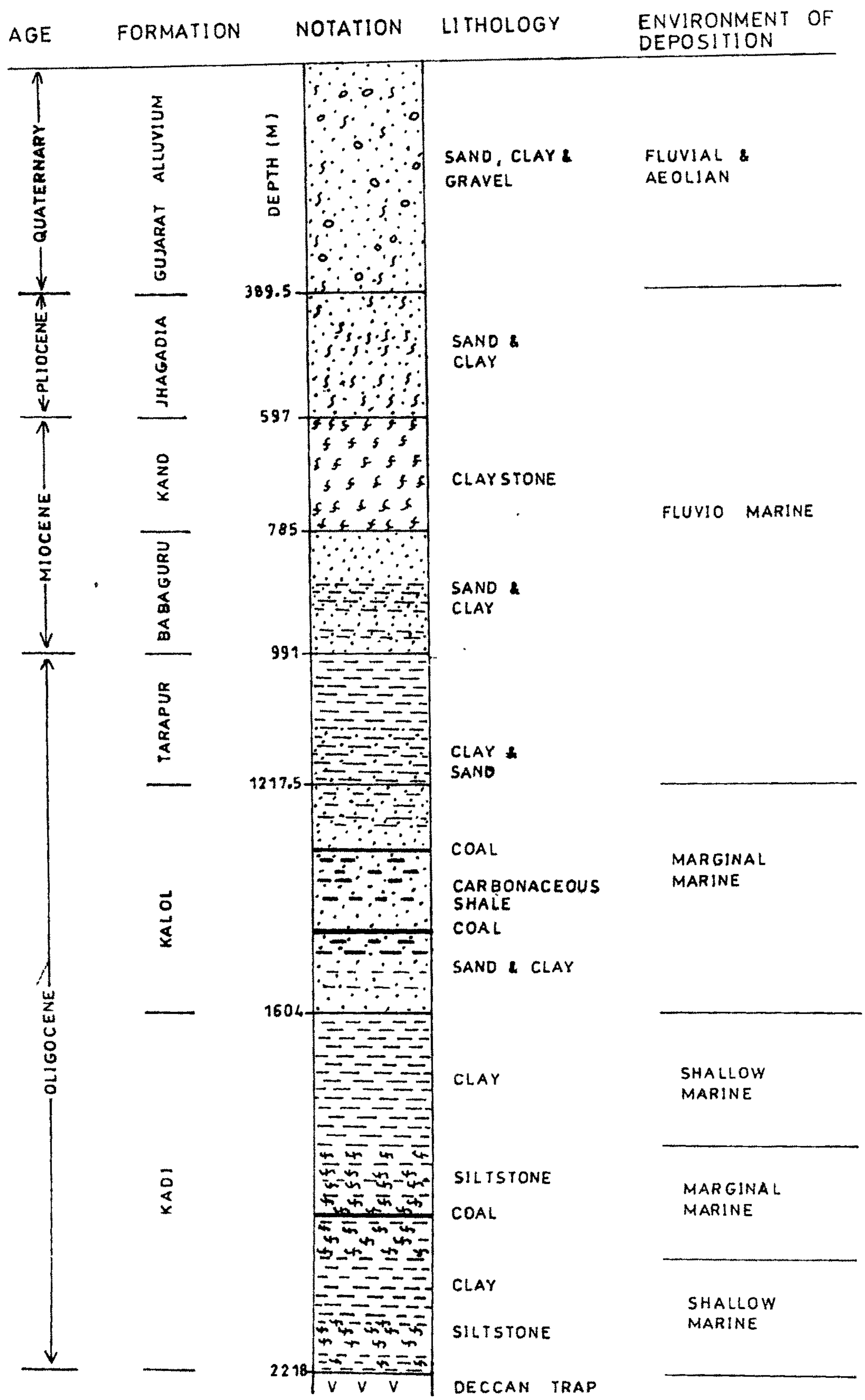
Cretaceous

The Cretaceous beds include thick sandstone, known in different outcrops as Wadhwan, Himmatnagar and Nimar sandstone. This is a continental deposit of Lower Cretaceous age. The Bagh beds were deposited during upper Cretaceous times and include thin limestone and marls with an upper Cretaceous fauna having mainly Tethyan affinities. Cores of the Deccan traps show that three basaltic rocks were subaerial flows. They are at places overlain by thin laterites, clays and tuffs.

Tertiary

The oldest member of the Tertiary group is the Eocene bed. They include pyritic shales and siltstones with minor sandstone and limestone intercalations. Structural contours of the Cambay basin show that the top of the Eocene beds at Ahmedabad is touched at a depth of 1200 m below the surface (Chandra et al., 1969). The Oligocene is thin, which is only 160 m thick and consists of shale and sandstone. The Miocene beds include alternating shale and sandstone with locally developed carbonaceous shale. The Tertiary include Kadi formation, Kalol formation, Tarapur formation etc. The typical litholog showing these formations is given in the fig. 3.6.

FIG. 3.6 LITHOLOGY SHOWING GEOLOGICAL SUCCESSION AT SALADI ONGC WELL SITE



Quaternary

The thick alluvial deposits in and around Ahmedabad-Gandhinagar are the result of fluvial activity during Quaternary. The thickness of these Quaternary sediments at Ahmedabad is around 400 m. The Precambrian rocks and to some extent the Mesozoic rocks are the sources of detritus brought by Sabarmati river. Sareen et al. (1995) have divided the Quaternary sediments of the Sabarmati basin into four formations as given in table- 3.3.

Table - 3.3: Major Lithofacies of the Sabarmati Basin

Formation	Lithology	Major Depositional Climate	Description
Sabarmati	Aeolian sand	Semi-arid	Fine sands, sand sheets overlying fluvial sediments.
	Fluvial sand	Semi-arid	Coarse sand to fine silty sand forming river channel and flood plain deposits.
Akhaj	Fine sand	Semi-arid (dry phase)	Aeolian sand, fine, well sorted, indistinct stratification, large cross beds.
Mehsana	Upper Sand	Fluvial	Silty sand, poorly sorted, unlaminated fine sand and silt.
	Lower Sand	Semi-arid	Poorly cemented, carbonate concretions in silty matrix. Fine silty sand, very thinly bedded, poorly sorted.
Waghpur	Conglomerate	Semi-arid	Unconsolidated, matrix supported conglomerate grading in to cross-stratified gritty sand.
	Sand		Red silty sand; unconsolidated, sub-angular quartz grains

From the mineralogical analysis of coarse clastic sediments, they concluded that the sediments have been derived from the pediment or piedmont zone and Aravalli hills. They have further envisaged that the presence of red sand and clay minerals such as smectite and kaolinite indicate pedogenic modification. From the grain size distribution, they have suggested aeolian reworking of the predominantly fluvial phases. The Quaternary sediments of the Central Gujarat plains have preserved within them three major Quaternary events and combination of these events such as glacio-eustasy, neotectonism and palaeoclimatic. The Quaternary deposits of Gujarat are represented by deposits belonging to all the three major depositional environments - fluvial, marine and aeolian. They reveal the influence of at least two marine transgressions during the Middle Pleistocene and Holocene with an intervening period of major regression. Similarly the climatic fluctuations point to two distinct phases of aridity. The one that followed the Middle Pleistocene gave rise to aeolian miliolite deposits and the other is related to the loessic sand dunes of terminal Pleistocene. These loessic silts occupying vast areas in central and north Gujarat represent the younger aeolian deposits. Loess is recorded in the river sections of Sabarmati. These sections reveal evidence pointing to significant climatic changes during the accumulation of these wind blown silts (Merh and Chamyal, 1997).

Large areas of central and north Gujarat are occupied by thick Quaternary alluvial deposits indicating the existence of an earlier Super Fluvial system. The present day rivers have only exposed the fluvial sequences deposited by this earlier drainage system on a very large scale in the form of a continuous spread in the structural depression i.e. Cambay graben (Sridhar et al., 1994). The thick alluvial deposits in and around Ahmedabad and Gandhinagar area thus constitute a part of the thick continental Quaternary sediments reported from Gujarat. In the study area they are about 400 m thick as revealed by the borehole records. The bore holes drilled by the Ahmedabad Municipal Corporation (AMC) reveal that the alluvium comprises of alternating beds of sand, silt, clay and gravel.

SEDIMENTATION HISTORY

A detailed study of subsurface geology in the area is possible to carry out from the data available through river sections; oil well logs and bore well sections. The thickness of Quaternary sediments increases from northeast to southwest. Hard rock basement is not touched even in deep bore wells. Zeuner (1950) indicated probable occurrence of a deep basin, which may be controlled by faults. Mathur et al., (1968) defined a major fault running NNW-SSE and cutting across Sabarmati basin. This fault probably defines a deep basin in which thick Quaternary sedimentation has taken place over Tertiary rocks.

During the early sedimentation of the basin till the end of Eocene period, the basin floor was sloping towards north as revealed by a larger thickness of this sedimentary unit near Kalol in comparison to the same near Bareja in the south.

The Ahmedabad Mehsana block, within which the study area lies has a characteristic feature of the thick Palaeocene sedimentary section on the Deccan trap basement, in the middle of the basin.

In building the depositional models, Raju (1968,1983) considered geotectonic environments as a basis for the reconstruction of sedimentation history. As to him the geotectonic environment can be deemed to confirm the changes in basin evolution with each lithological unit representing a tectonic stage or cycle. The stages are discussed as under:

1) During the late Cretaceous or early Tertiary initial rift phase, a few hundred to over 2000 m thick sedimentary facies ranging from conglomerates, sands, silts, claystone and shale were deposited. Carbonaceous shale succeeds this suit.

2) The next lower to middle Eocene phase coincides with regional westward basinal tilt, leading to widespread marine transgression and deposition of dark grey to black shale which is pyritic and rich in organic matter.

3) The uplift of hinterland areas and establishment of new drainage systems during middle Eocene succeeded this stage. Among them proto-Sabarmati in north was instrumental in initiation of delta building activities.

4) The last stage of tectonic evolution marked a period of significant disturbance and onset of regression cycle in late Oligocene to early Miocene. This was followed by early to middle Miocene transgression phase.

Continental fluvial trough filled with lagoonal, intertidal to holomarine sequences from north to south make up the reminder of Late Tertiary - Quaternary basinal fill stage.

GEOLOGY OF THE STUDY AREA

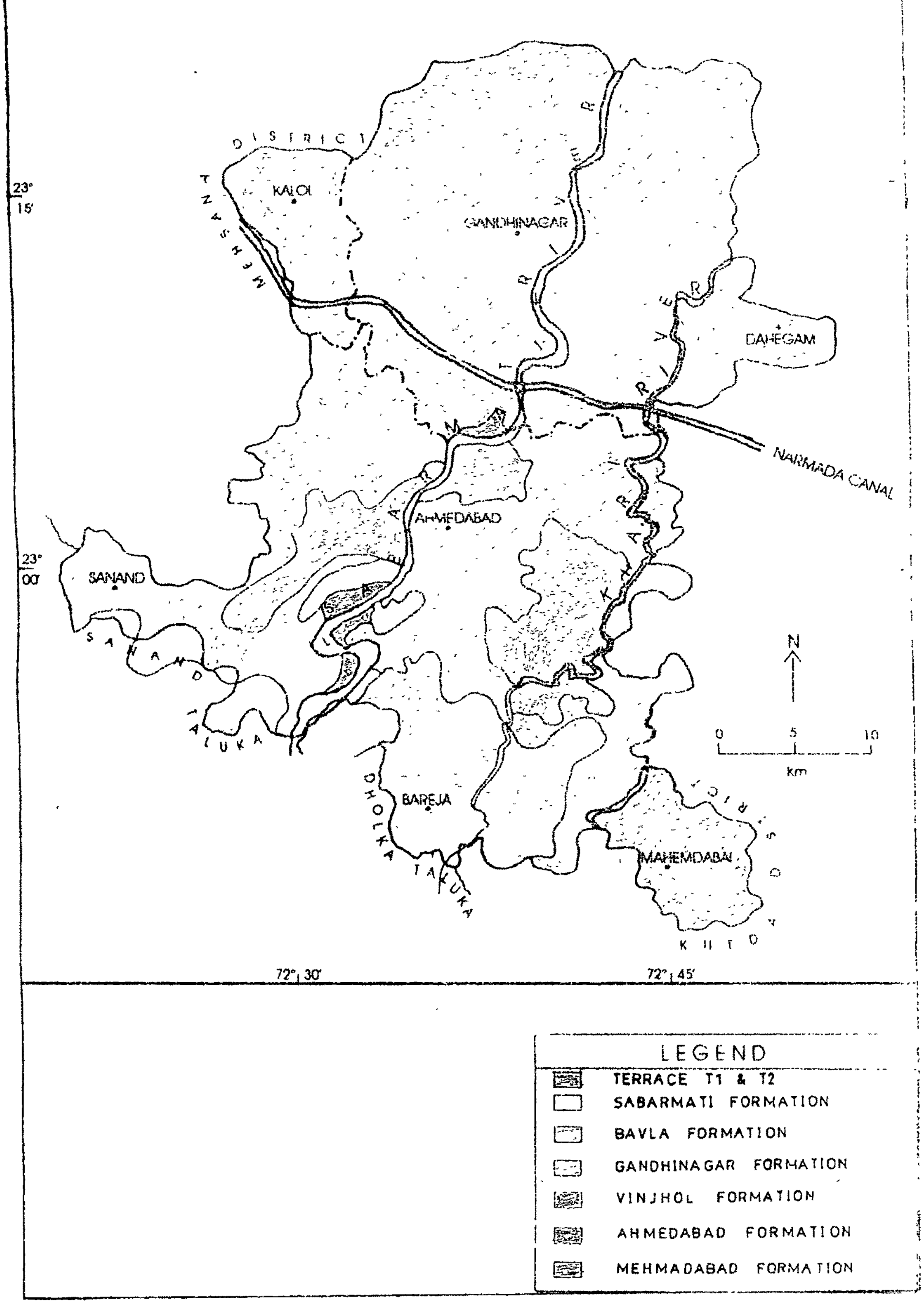
The upper part of the Quaternary sequence, involved in land use system, has been studied from river sections and bore hole logs. Various lithological types of sediments have been identified and mapped and shown in fig. 3.7. The identification is based on the physico-chemical properties such as colour, texture, degree of oxidation, degree of compaction, pedogenesis and stratigraphic positions. A lithostratigraphic sequence proposed for the study area is as under following the work of GSI (Dasgupta et al., 1984).

Recent fluvial sediments
Terrace fill sediments along present river
Bavla-Sanand Formation
Gandhinagar Formation
Vinjhol Formation
Ahmedabad Formation
Koba Formation
Mehmadabad Formation

MEHMADABAD FORMATION

The sediments of this formation are semi-consolidated reddish brown or buff coloured sand, silt and clay with lime concretions and a few intercalated concretionary conglomerate layers. This forms a part of the older palaeosol

FIG. 3.7: GEOLOGICAL MAP OF THE STUDY AREA.



horizon, sections of which are well preserved in the Sabarmati river section near Koteshwar and in the Vatrak river section near Mehmadabad (Plate 3.1).

KOBA FORMATION

It is composed of highly oxidised red and greenish grey coloured clay, silt and fine sand, at places with coarse grained sand and lime concretions. This formation is typically exposed along the Sabarmati river section near Koba and Koteshwar. It shows definite stratigraphic relation with the overlying Ahmedabad and underlying Mehmadabad formations. Koba formation has undergone strong pedogenesis to form a palaeosol. The complete soil section is not preserved due to erosion.

AHMEDABAD FORMATION

This forms the stable base of the Ahmedabad city and its surrounding areas. This formation can be well studied in river sections of Sabarmati. Along the river banks this formation is highly dissected and eroded to form gullies and badlands. Lithologically, it consists of a concretionary conglomerate at the base, coarse to fine grained loose sand layer in the middle and unoxidised to moderately oxidised fine to coarse grained concretionary sand horizon towards the top. This entire sequence can be studied in many sections along the banks of the Sabarmati in its upstream course, beyond Ahmedabad. The Ahmedabad formation is the product of older fluvial activities, i.e. sand aggradation phase. It has undergone intensive pedocalcic pedogenesis. Concretionary conglomerate does occur in all sections.

Plate 3.1: Mehmadabad and Koba Formation at Koteshwar.

Plate 3.2: Ahmedabad Formation near Sabarmati Ashram.

Different buried channels observed within the area are possibly the remnants of old river courses of this sand aggradation phase (Plate 3.2).

VINJHOL FORMATION

This is an aeolian deposit occuring as sand dune and sandy flats towards W, SW, S, SE, and E of the Ahmedabad city. Lithologically this unit consists of brown grey to light yellowish, fine to very fine grained sand. This formation is moderately oxidised and contains few lime concretions. These calcareous concretions are products of pedogenesis. Aeolian bedding laminations are prominent in some sections. The name Vinjhol Formation is given to this aeolian sand formation as good sections are exposed near Vinjhol village, SE of Ahmedabad city. Considering the morphostratigraphic position, it can be interpreted that aeolian sands of this formation probably were derived from the preceding fluvial deposits of the sand aggradation phase (Plate 3.3).

GANDHINAGAR FORMATION

This formation is wide and extensive covering northern and northwestern parts of the study area. It consists of highly oxidised red coloured fine to coarse grained sand, highly oxidised red coloured clay, above it fine sand and greyish black clay, silt, sand with little lime concretions. This forms the most stable surface of the area. It is mainly flat low-lying tract, which may be remnants of buried channels. The sandy clay and silts of this unit are used for brick manufacture. Gandhinagar formation is characterised by two lithological assemblages. Towards lower

Plate 3.3: Vinjhol Formation near Bidaj.

Plate 3.4: Gandhinagar Formation near Indroda.

southwestern part of the area, it is characterised by greyish black silty clay and in the rest of the area it is fine to coarse grained, sub-rounded oxidised sand (Plate 3.4).

BAVLA-SANAND FORMATION

Unoxidised or feebly oxidised sand with or with incipient pedognesis forming the younger deltaic plain has been grouped under Bavla-Sanad formation. Earlier fluvial systems which have formed the younger deltaic plain have deposited reddish and brownish grey and grey coloured fine sand as levee and channel fill sediments within mudflats. The mud flat deposits consist of grey and greyish black clay and silt (Plate 3.5).

TERRACE FILL SEDIMENTS

Along the present river channels of the Sabarmati, the Khari and, the Vatrak; two generations of fluvial terraces one older (T2) and another younger (T1) are well developed. The younger terrace comprises grey coloured silty sand and the older one comprises brownish grey clay and silty sand with fine to very fine-grained sand and occasional coarse sand.

SABARMATI FORMATION (Recent fluvial sediments)

This is the youngest Quaternary unit, which is still under the process of formation, as channel fill deposit. It consists of mainly fine to coarse-grained sand and at places gravels. They occur as channel fill and over bank deposits along the present

Plate 3.5: Bavla-Sanand Formation near Bareja.

Plate 3.6: Sabarmati Formation (Recent Flood Deposit) near Bhat.

day rivers of the area. The sediments of this unit are loose, unconsolidated and immature and comprise mainly of sand and silt. These deposits exhibit sedimentary structures like current bedding, ripple marks, graded bedding, lenticular bedding etc. The over bank deposits which occur on either side of the river, comprise fine to very fine micaceous sand and silt with a little clay (Plate 3.6).

The Quaternary continental deposits of the area consist of a succession of layered sediments of marine, aeolian and fluvial origins.

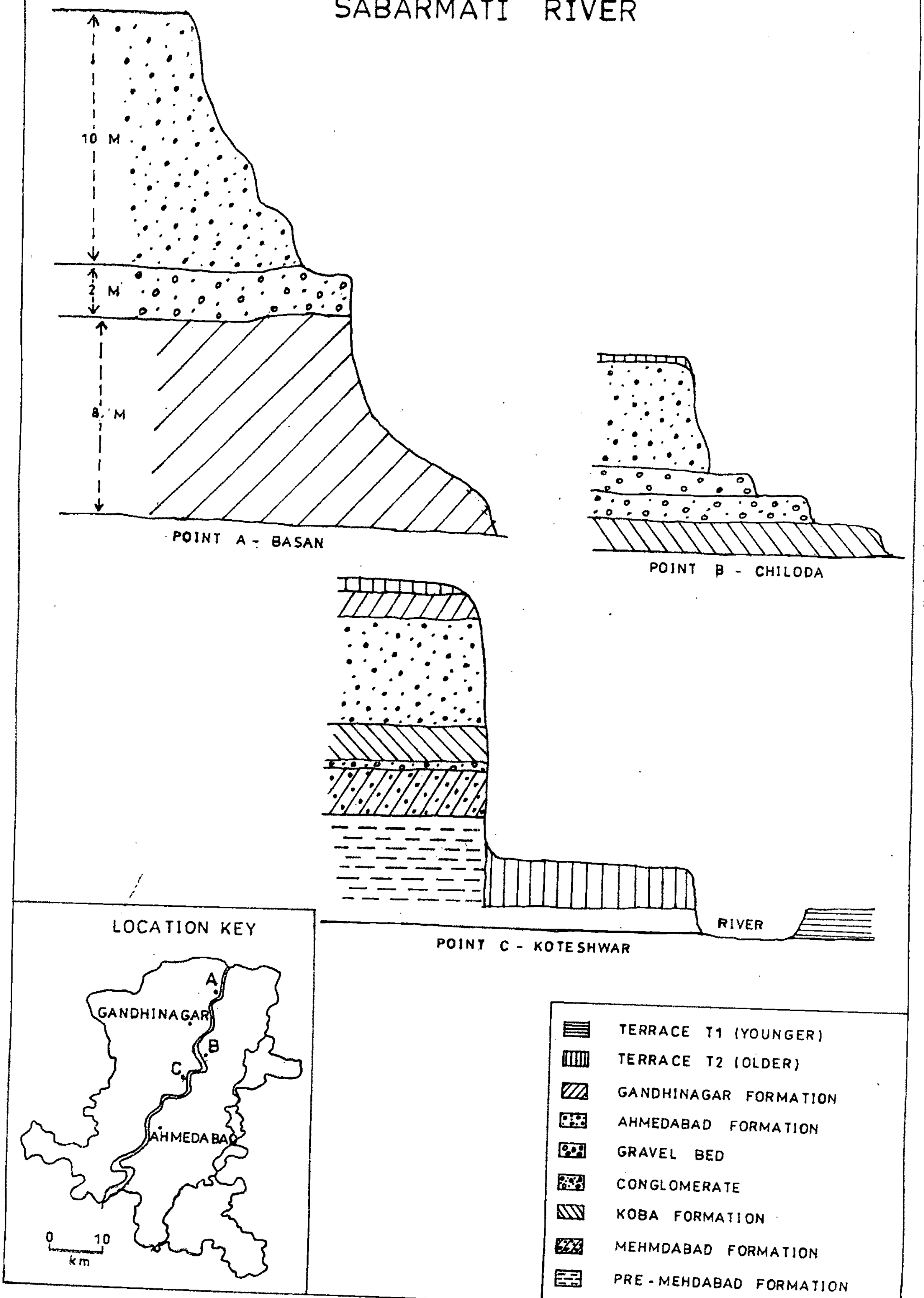
On the basis of exposed sequences and subsurface bore hole data, it is possible to establish lithostratigraphy of the area. The lower part of the Quaternary sequence has not been investigated.

The Sabarmati river provides very good cliff sections revealing almost entire exposed sequence. Examining three well exposed sections along Sabarmati river, a composite lithostratigraphic succession has been prepared and presented in fig. 3.8.

SUBSURFACE GEOLOGY

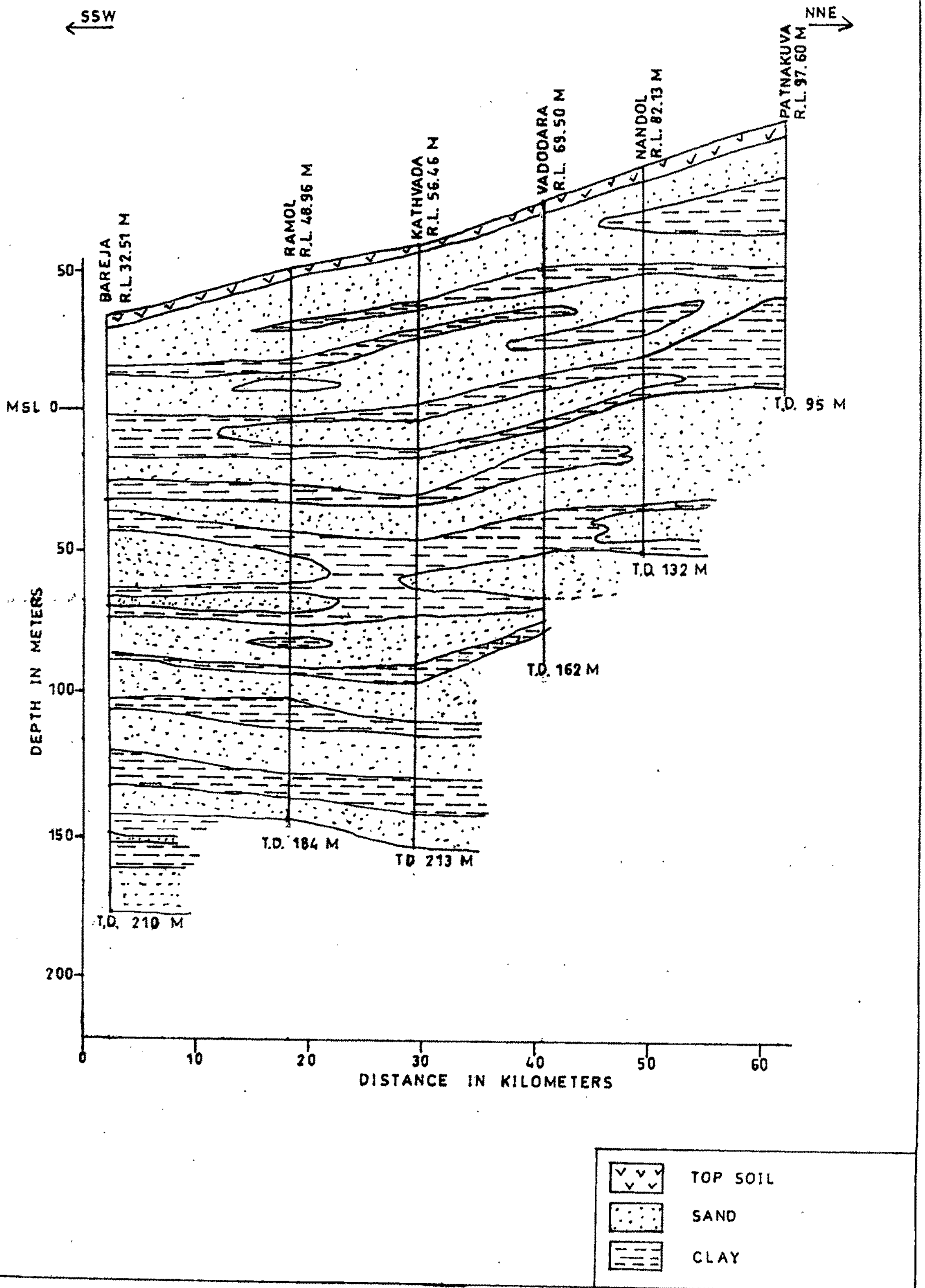
A considerable thickness of Quaternary deposits is present in the area. A thickness of 125 m to 400 m, increasing from NE to SW can be inferred from the examination of bore wells drilled by GWRDC and AMC for groundwater exploration. It may be noted from the bore hole section studied in the area that there are alternate deposits of gravel, sands and clays. The deposition is not uniform and their thickness and extent vary within small horizontal distances. The thickness of these deposits varies considerably in different bore holes.

FIG. 3.8 LITHOSTRATIGRAPHIC SECTIONS ALONG SABARMATI RIVER



In general the sandy horizons vary in thickness from 5 to 25 m and consists of fine to medium sands with subangular quartz grains and pinkish felspathic grains with some opaques. The sands also become gravely at places. The clayey horizons vary in thickness from 2 to 15 m and consist of yellow, brown sticky clays. Blue clays are also noted in one of the bore holes at a depth of 125 m to 132 m. The extensive thickness of sandy deposits with minor clay beds act as good aquifers. The clay beds act as aquicludes. The subsurface section from Bareja to Patankuva (Fig. 3.9) is drawn to understand the geology and aquifer characters in north-south direction. Topography of the area is plain with a very gentle slope towards south. The elevation of Bareja is 32.51 m and that of Patankuva is 97.6 m from MSL. Top soil has almost equal thickness of 4 to 6 m. This is followed by alternate layers of sand and clay with Kankar beds. It is seen that there are several sand layers down to a depth of 50 to 60 m. They are separated from one another by lenses of clay bands. Therefore, these sand layers form a single unconfined aquifer. Below the depth of 70 to 90 m deeper aquifers have large areal extent. It is found that the thickness of sandy layers decrease from north to south direction. Static water level trend follows the topography. A study of the Sabarmati river section indicates presence of pebbly conglomerate at a depth of about 15 m. This conglomerate bed shows current and graded bedding.

FIG. 3.9 GEOLOGICAL CROSS SECTION ALONG BAREJA TO PATANKUVA (SSW - NNE)



The riverbank of Sabarmati at north of Gandhinagar exposes about 15m thick section. In general it can be described as under:

2m-5m	Reddish brown and brown, fine sands with kankar, channel deposits and graded bed deposits. Semi-consolidated with subangular quartz grains, felspar, sandstone.
1m-1.5m	Thin kankar zone (conglomerate when semi-consolidated) transformed to red and white clay patches at places.
2m-3m	variegated clays with red and grey fine sands.
1.5m	Red fine clayey sands with subrounded to subangular quartz. This part shows fluvial activity e.g. graded beds, current beds etc.
4m+	Conglomerate with clayey matrix at top, which becomes sandy at bottom, contains pebbles of sandstone and basalt.

SEDIMENTARY STRUCTURES

A number of sedimentary structures have been recorded in the river sections, nala cutting, deep pits etc. Depending upon the process of formation and structures, they may be divided into four classes such as current structures, deformational structures, biogenic structures and chemical structures.

CURRENT STRUCTURES

The section at Prantij exposes 10-15 m thick section of conglomerate (polymictic) pebbly sand, silty sand and clay. The beds are of unequal thickness, which also vary laterally with discontinuities at places. The conglomerate also shows an internal imbrication pattern where elongated pebbles are oriented normal to flow direction. The pebble size also decreases laterally in southerly direction indicating fanning out of the deposits. Current ripples, current lamination and small - scale cross beds are prominent in present flood plain deposits (Plate 3.7).

CROSS BEDDING

Channel fill cross beds are commonly seen along the banks of Sabarmati. They are produced by filling up of small erosional channels with sets of thin laminae. Cross beds are also present in sand dunes and natural levees. The cross beds are superimposed on each other in lower strata (Plate 3.8).

GRADED BEDDING

Graded bedding is also seen at places where sediments become finer upwards. It indicates decaying and revival of fluvial currents. Grading, in general, takes place from gravel to fine sands in individual beds.

DEFORMATIONAL STRUCTURES

The main deformational structure in the river section is slump structure. Slump structure is formed by penecontemporaneous deformation. These are very

Plate 3.7: Exposed Section Along Sabarmati near Prantij Showing Conglomerate Layers.

Plate 3.8: Channel Fill Cross Bedding Along Sabarmati River near Koteshwer.

common all along the course of the river and are produced by gravity sliding of fluvial sediments forming gullies and their subsequent refilling in the form of channel fills (Plate 3.9).

CHEMICAL STRUCTURES

Pedocalcic pedogenesis is very well defined in older alluvial as well as aeolian deposits. Developing of 'C' horizon of soil which is a result of precipitation and solution. The calcareous concretions formed by leaching, range in size from a few mm to 2 cm. They are normally spherical or ellipsoidal in shape. In aeolian deposits, they show preferred shapes. They are rod shaped, extended tube like etc (Plate 3.10).

QUATERNARY DEPOSITIONAL ENVIRONMENTS

The Sabarmati riverbank sections exposes well developed sediments where sedimentation pattern can be studied. Basal conglomerate is the lower most unit in the area. The conglomerate and overlying gritty bed are deposited by an active fluvial phase. Consolidated to semi-consolidated material containing calcareous concretions represents a marine transgressive phase where shelf / lagoonal conditions were created. In the shallower parts of the delta there is development of mottled clay phase representing subaerial swamps at the time of deposition. Red silty clays of deltaic origin overlie this. Development of palaeosols in this phase indicates that there was a long period of non-deposition in the north and northeastern parts.

Plate 3.9: Slump Structure Produced by Gravity Sliding, near Vadaj.

Plate 3.10: Calcrete in Gandhinagar Formation near Bhat Village.

The Holocene sedimentation depositing a fluvial phase and an arid phase has taken place after a long break.

In the southwestern part of the area the Quaternary sedimentation was very extensive as it took place in a graben. The subsurface section indicates an alteration of coarse sand, calcareous silty sand with yellow clay deposits.

Longitudinal profile of the Sabarmati river shown in fig. 3.10 is much significant in understanding the Quaternary depositional environments. The figure indicates that the slope of the river is uniformly gentle from Pedhamali to Vadgam. This is agradational zone where the deposition is taking place. From the section it is seen that early Quaternary pebbly formation indicate fluvial phase, which was followed by fluvio-aeolian deposition under semi-arid climate. This is represented by medium to coarse sandy sediments forming Mehsana formation. Near Navapura there is a break in the slope which suggests that the deposition took place under estuarine condition. This may be due to regression of the gulf or elevation of the area due to neotectonic activity. It also indicates degrading nature of the river in this part.

FIG. 3.10: A LONGITUDINAL PROFILE ALONG SABARMATI RIVER FROM PEDHAMALI TO VADGAM (N – S)