CHAPTER - II

STRUCTURAL EVOLUTION

AND

QUATERNARY GEOLOGY

Regional Geological Set-up
Regional Tectonic Framework
Structural and Evolution of Cambay Basin
Quaternary Geology

CHAPTER - II

STRUCTURAL EVOLUTION AND QUATERNARY GEOLOGY

REGIONAL GEOLOGICAL SET-UP

As overview of the geological and geomorphic framework of Gujarat State can provide a better picture of the geological setting of the study area in its appropriate regional perspective. The Gujarat region can be divided into four major geomorphic units as under :

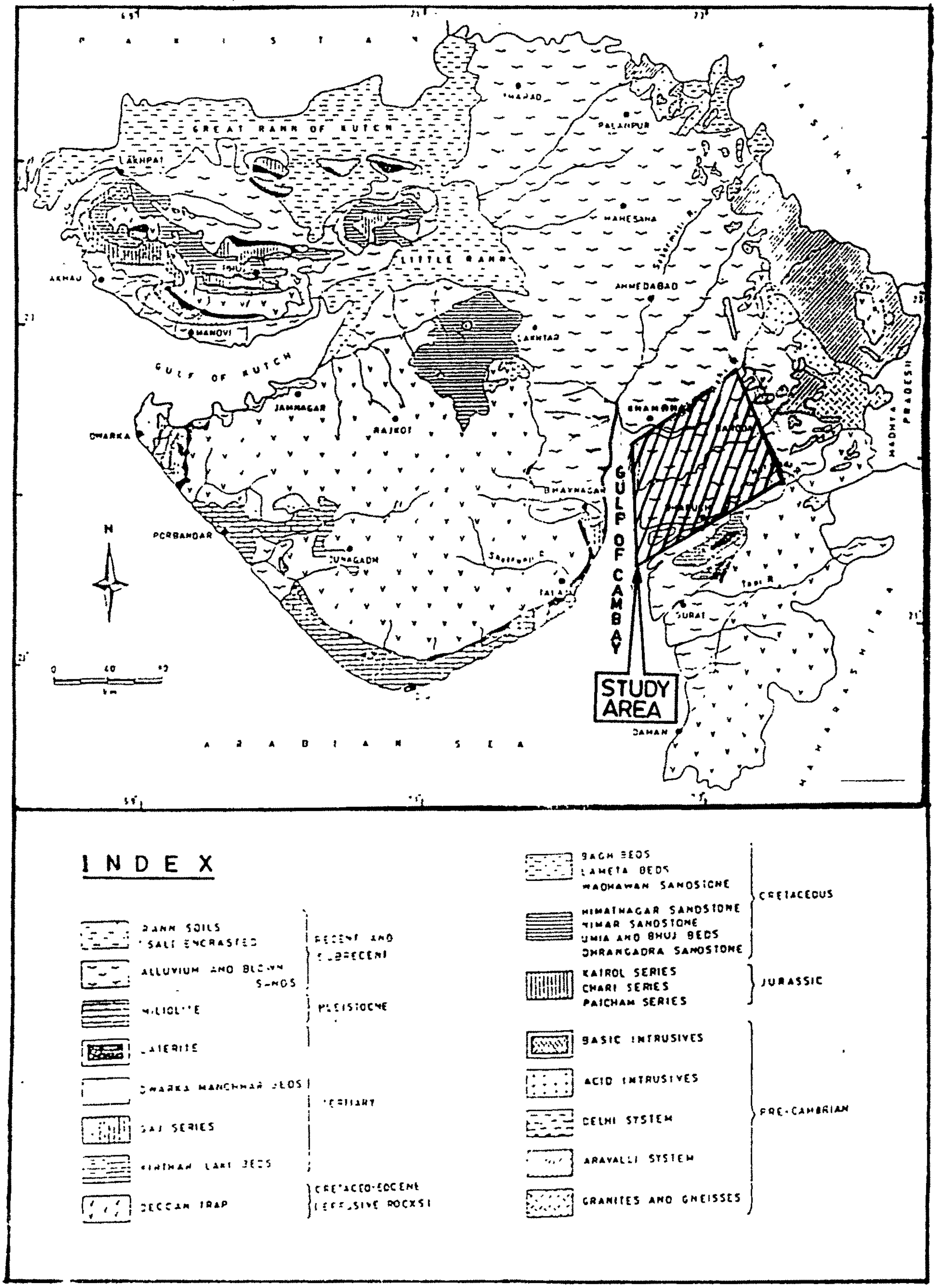
i) The Eastern Hilly Tract
ii) The Central Alluvial Plains
iii) The Saurashtra Peninsula
iv) The Kutch Peninsula

The Eastern Hilly Tract, about 50 km wide and 500 km long, runs all along the Gujarat border from north to south comprises the terminal hills of the Aravalli ranges, Satpura and Sahyadri. The hills comprise the rocks of Precambrian, Mesozoic and Deccan Traps. The Central Alluvial plains about 150 km wide and 350 km long are mainly covered by the Quaternary deposits. The Saurashtra Peninsula with circular shape of about 250 km diameter is surrounded by the Arabian sea on its three sides NW, W and SE, towards NE it merges in the central alluvium. It predominantly consists of extensive lava flows of Deccan Traps, and subordinate sedimentaries of Mesozoic, Tertiary and Quaternary. The Kutch peninsula having oval shape with E-W and N-S diameters of 250 km and 125 km respectively is surrounded by the Arabian sea and its great and little Ranns. It comprises Mesozoics, Deccan Traps, Tertiaries and Quaternaries.

The interesting geomorphic exposition of the state within a small geographical area of about 1,96,024, sq.km. is the manifestation of remarkable record of geologic and tectonic history evolved through Precambrian to Recent. The present study area is included in the central alluvial plains and located in its southern part. Distribution of various geological formations of the Gujarat state is shown in Fig. II.1, and their lithostratigraphic details are given in Table. II.1. The study area forms a part of Gujarat alluvial formations. Regional geological set up of the stüdy are is shown in Fig. II.2. It is seen that the Quaternaries of study area extend in the north beyond Mahi. In the west they are submerged in the Gulf of Khambhat. In the south west beyond Narmada they further extend along the sea coast while in the east and south east they merge in the pediment zones with Pre-cambrian Mesozoics and Deccan traps.

FIG- II- 1

GEOLOGICAL MAP OF GUJARAT

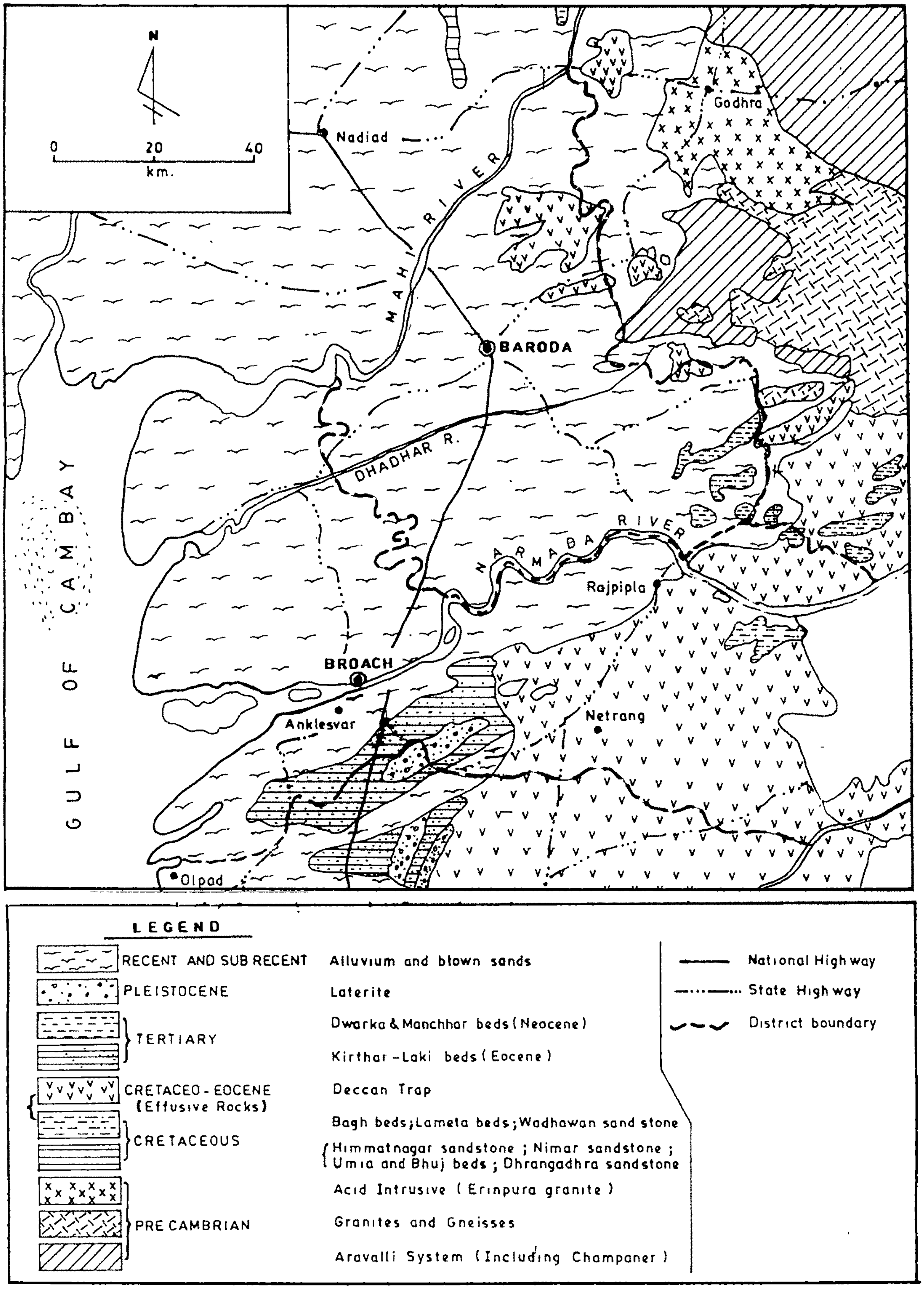


GEOCHRONOLOGIC UNIT		MAINLAND GUJARAT		SAURASHTRA		KUTCH	
PERIOD	EPOCH	FORMATION	LITHOLOGY	FORMATION	LITHOLOGY	FORMATION	LITHOLOGY
QUATERNARY	HOLOCENE	ALLUVIUM	Neo alluvium, Mudflats, Beaches Dune sands & Soils.	ALLUVIUM	Alluvium, Mud flats, Beaches and Dune sands soils	ALLUVIUM	Alluvium Sands and Clay Soils rannclays etc.
	PLEISTOCENE	OLDER ALLUVIUM & LATERITIC ROCKS	Sands & Clays, Alluvium, Laterites	AGATE; CONG. AND SANDSTONE MILIOLITE	Agate, Conglomerate and associated Sandstones, Calcarenite, Calc-Rudite with Intercalation of Clays	MILIOLITE FORMATION	Clay Arenite and Oomicrites
TERTIARY	PLIOCENE			DWARKA FORMATION	Silty clays, Gypsious, Calcareous clays & Marls, Arenaceous-limestone, Fossiliferous conglomerates	KANKAWATI SERIES	Sandstones Fossiliferous Calc Grits and Conglomerates with Shales
		JAGADIA FORMATION	Calcareous and Micaceous Sandstones and Sands	PIRAM BEDS	Grits and Sandyclays, Sandstone and Conglomerates		
	MIOCENE	KHAND FORMATION	Limestones and Ferruginous Agate, Conglomerates	GAJ FORMATION	Fossiliferous Grits, Gypseous clays with Thin bands of Limestone	KHARI SERIES	Gray clay with Fossiliferous marl variated Siltstones
		TARKESWAR FORMATION	Silty clays with lenses of Laterites				
	OLIGOCENE					BERMOTI SERIES	Silty shale Marl Sands Limestones Calc clays Shales
	EOCENE	NUMMULITE FORMATION	Ferruginous clays & Limestone with Bentonitic bands			BERWALI SERIES	Limestones Clays Laterites Lignite and Black shale
		VAGAD-KHOL FORMATION	Trap wash, Ferruginos sandstone	LATERITIC ROCKS	Red brown Laterites, Bauxite, Tuffacious material	MAD SERIES	Laterites Tuffacious shales Bentonitic clays Volcanic ashes
	PALEOCENE	DECCAN TRAP	Basalts with all alkaline varieties & Dykes	DECCAN TRAP	Basalts, Plutonic masses and Dykes, Thin Intertrappean bands	DECCANTRAP	Massive basalts & Amygdaloidal basalts with Inter trappean beds
CRETACEOUS		INFRATRAPPEAN LAMETA BEDS	Sandstone	WADHWAN SANDSTONE	Sandstones with Intercalation of clays		
		BAGH BEDS	Limestones & Sandstones				
		HIMATNAGAR SANDSTONE	Sandstones	DHRANGADHRA FORMATION	Sandstone, Grits, Carbonaceous Shales with Coal & Plant remains	BHUJ FORMATION	Sandstones Conglomerates and Shales
JURASSIC						JHURAN F.M.	Sandstones and Shales
						JUMARA F.M.	Shales and Limestones with Oolitic bands
						JHURIO F.M.	Limestones
PRE-CAMBRIAN		ERINPURA GRANITE	Ultra basic, Basic and Acidic intrusives				
		DELHI SYSTEM	Quartzites, Phyllites and Schists				
ARCHEAN		CHAMPANER SERIES (ARAVALLI SYSTEM)	Granites, Phyllites, Schists Dolomites, Quartzites				
		BANDED GNEISSIC COMPLEX	Granitic gneisses and Mica schists				

(Compiled after Krishnan, 1968; Shrivastava, 1968; Biswas, 1971.)

TABLE: II-1 GENERALISED STRATIGRAPHIC SUCCESSION OF GUJARAT

FIG- II-2 **REGIONAL GEOLOGICAL SETTING MAP OF STUDY AREA**



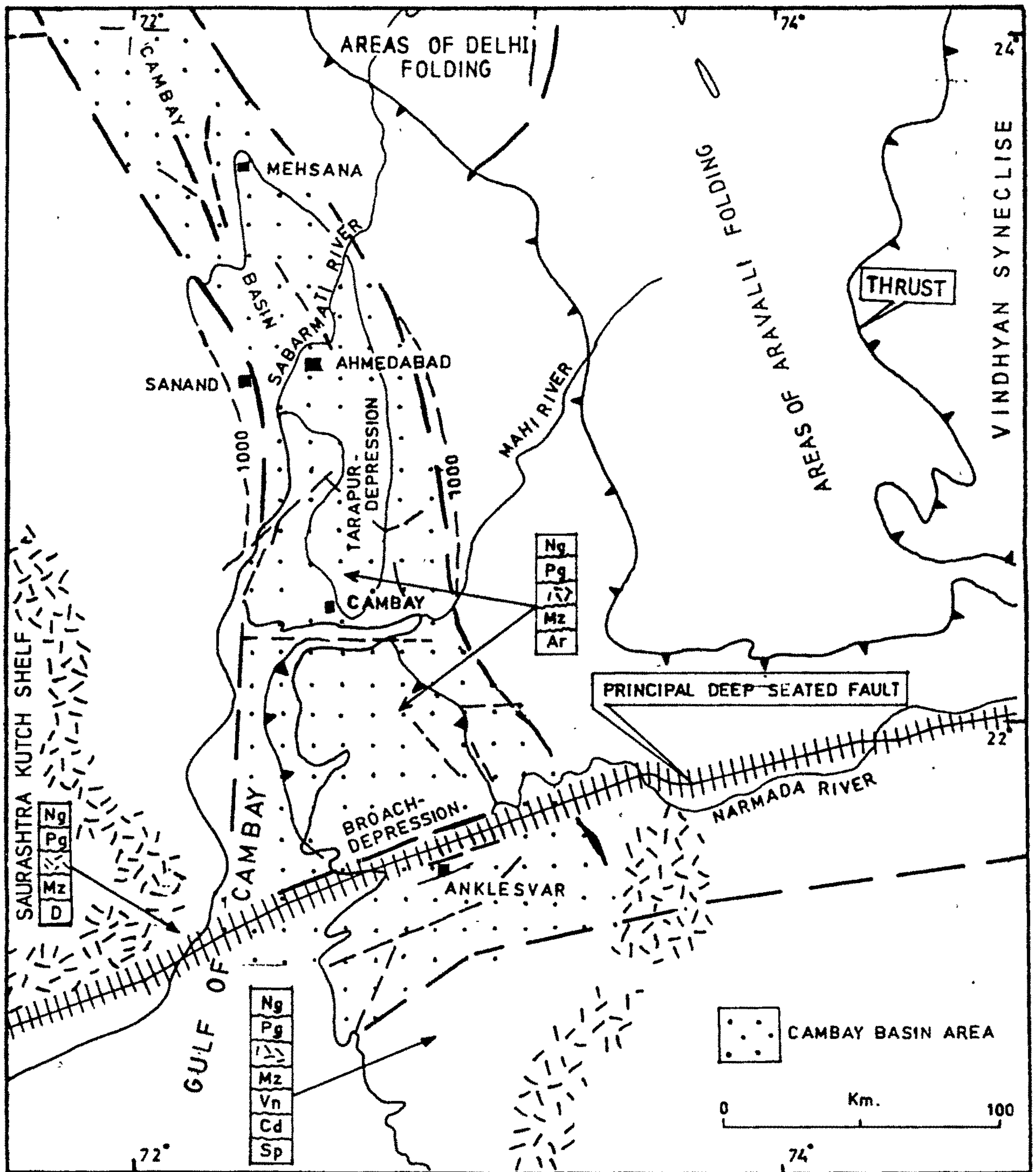
REGIONAL TECTONIC FRAMEWORK

The formation of Gujarat alluvium is structurally controlled by the Cambay basin. The basin derives its importance by virtue of its oil bearing province. The entire basin has been explored in great depth and finer details about its structural fabric have been studied by the scientists of the Oil and Natural Gas Commission (ONGC), and National Geophysical Research Institute (NGRI) and several others. The important works to mention here include Biswas (1982, 1987), Biswas and Despande (1983), Chaubey (1968), Eremenko et al (1968), Kaila et al (1985), Raju (1968), Raju and Srinivasan (1983), Rao and Talukdar (1980), Sudhakar et al. (1973), Mathur et al (1968), Agrawal (1985), Sychanthavong (1985) etc. The studies have provided a quite clear picture about the regional tectonic evolution of the basin. The structure and tectonics of the basin have played a crucial role in the evolutionary history of the Quaternary geology of the region.

The western marginal basins of India viz. Cambay, Narmada and Kutch have been described in detail by Biswas (1987) giving regional tectonics, structure and their evolutionary history. The Cambay basin alongwith Narmada and Kutch have been developed by rifting along the Pre-Cambrian tectonic trends as pericontinental basins (Fig. II.3). The structural style of the basins have been controlled by the interplay of the three major tectonic trends of Aravalli, Satpura and Dharwar. The tectonic evolution of the basin is indication of sequential reactivation

TECTONIC SET UP OF CAMBAY BASIN

FIG-II-4



LEGEND

Ng - NEOGENE

Pg - PALEOGENE

DECCAN TRAP

Mz - MESOZOIC

Vn - VINDHYAN

Cd - CUDDAPAH

Sp - SATPURA FOLDING

MAJOR FAULTS

of primordial faults. Formation of the basin initiated as early as late Triassic, as one of the major tectonic events in the evolution of Indian sub-continent was breaking up of Gondwana land. The Kutch basin opened up first, in the early Jurassic along Delhi trend followed by the Cambay Basin in early Cretaceous, along the Dharwar trend. The Narmada basin subsequently followed during late Cretaceous along the Satpura trend. A part of the Saurashtra was uplifted as a horst during the main tectonic phase in the late Cretaceous separating the Kutch Basin. A large part is now covered by the alluvium of Sabarmati, Mahi, Narmada and Tapi rivers.

STRUCTURE AND EVOLUTION OF CAMBAY BASIN

The Cambay basin is intracratonic type formed by discontinuous normal faults. The northern part of the basin is a graben, while the southern part is a half graben.

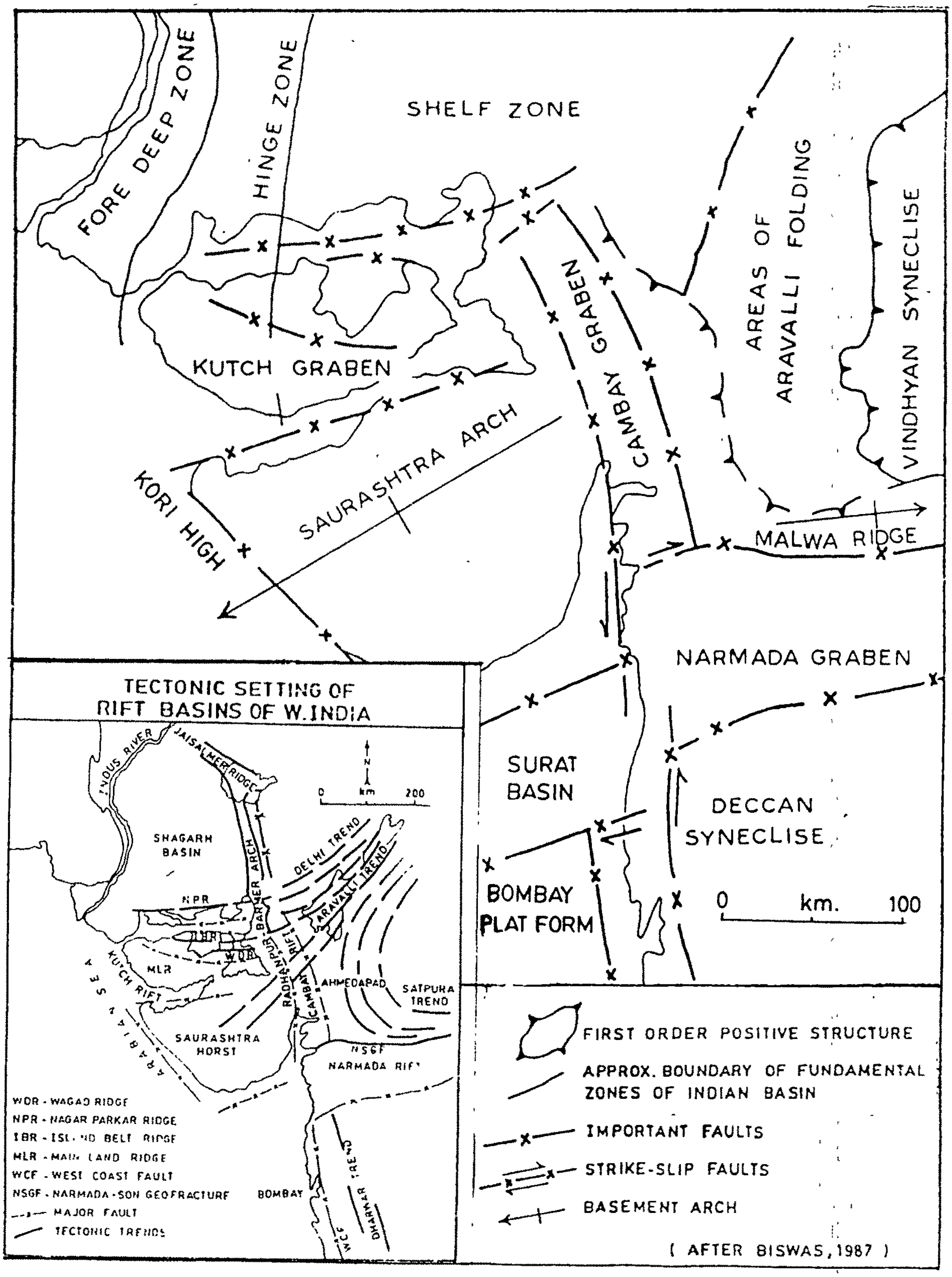
The Cambay Basin came into existence with down faulting along its margins which started during late Cretaceous. The dislocation along the eastern fault was more severe than the western. The subsidence continued during outpouring of lava flows, accommodating thicker lava sheets in the Cambay graben. During the Eocene, the Narmada faults continued to be a place of weakness but without any marked vertical movements, but the area in the north upto Mehsana experienced relative movements.

On the basis of the occurence of basement faults in the Cambay basin, Mathur, et al (1968) have structurally divided the basin into four blocks from south to north as (i) Ankleshwar block (ii) Jambusar - Broach block (iii) Cambay - Tarapur block and (iv) Ahmedabad - Mehsana block. Tectonic setting of these blocks is shwon in Fig. III.4.

The major part of the study area on western side comprises the Jambusar - Broach block. This block is bounded by the Narmada and Mahi river faults and main marginal faults of the basin. It is characterised by a deep syncline in which more than 5000 m of Cenozoic sediments have been deposited. In the lower reaches of the Mahi, a basement fault in Deccan traps has been infered which does not affect the overlying sediments. This fault is characterised by depth difference of more than 1300 m, in Deccan traps on either side of the river. A fault near Atali and another to its northeast joins up with the main Mahi river fault with a downthrough of 250 m to the south. These two faults and the marginal faults which brought about thick Eocene deposition north of Baroda.

The Oligocene period was characterised by the regression and development of tectonic horsts in the northern parts. The Tarapur-Jambusar blocks are relatively prominent area of subsidence and received a greater thickness of sediments. The Miocene period again witnessed widespread marine transgression and with further shift of depositional axis towards west caused maximum deposition in the Jambusar-Broach block. During late

Fig. II·3 TECTONIC FRAMEWORK OF MARGINAL BASINS OF WESTERN INDIA



Miocene - early Pliocene, the Narmada fault was reactivated with considerable downthrow of Broach-Jambusar block resulting the formation of a depositional sink of the post-Miocene sediments to the immediate North of Narmada river. The present tectonic configuration of the area north and south of Narmada river has been brought about largely during post-Miocene sediments appears to be the result of syn-sedimentary faulting along Narmada, the reactivation having commenced in the Pliocene. The secondary tilt of the basin continued during the post -Miocene. The basin floor ceased to be tectonically active and the basin was gradually silted up.

The prominent physiographic feature bordering the study area the Mahi and Narmada rivers along northern and southern limits, viz. the sea coast in west and foothill zone in the east are manifestation of the major structural elements of the Cambay Basin.

Structurally, the study area is divisible into two major blocks along the NNW-SSE trending eastern boundary of the Cambay graben. The western part of the area falls in the Cambay basin, while the eastern part lies in the up throw block of the southern most terminal portion of Aravalli geosynclinal belt. In regard to regional tectonic set-up, the study area lies close to the tri-junction of three major Precambrian tectonic trends of Aravalli (NE-SW), Satpura (ENE-WSW) and Dharwar (NNW-SSE). Schematic location of the junction is shown in Fig.II.3.

The study area is strategically located on the merger zone of the two right angled rift systems of Cambay and Narmada. The Narmada - Son lineament which marks the separation of the Pre-cambrian rocks to the North and Cretaceous to the south. This forms the northern limits of the composite Narmada-Tapi rift systems. The westernly flowing Narmada and Tapi are two prominent rivers in the Indian Peninsula. Presumably follow a series of enechelon faults. The N-S profile of deep seismic survey by Kaila et al. (1981) along Cambay graben from Nadiad to Navsari has indicated major deep seated faults going down to Moho are related to lineaments of Mahi and Narmada (Fig. IV.5). Besides, there are several other faults trending E-W and ENE-WSW ranging from 5 km to 20 km in length. E-W section, across the basin (Biswas, 1987) are shown in Fig. II.6.

NEOTECTONISM

The fault systems related to Narmada and Cambay graben has remained active during Quaternary period. Alongwith the factor of eustasy, the periodic movements along these faults have disturbed the sedimentation and morphologic configuration of the area. Ganapati et al (1985) have visualised two major movements during Quaternary history; one at the close of middle Miocene and other during the upper Pleistocene. The Narmada geofracture divides the Cenozoic sequence of Cambay basin into Narmada block and Jambusar-Broach block. The post-Miocene reactivation of Narmada fault uplifted the former and downthrown the latter resulting to deposition of Broach and Jambusar formations

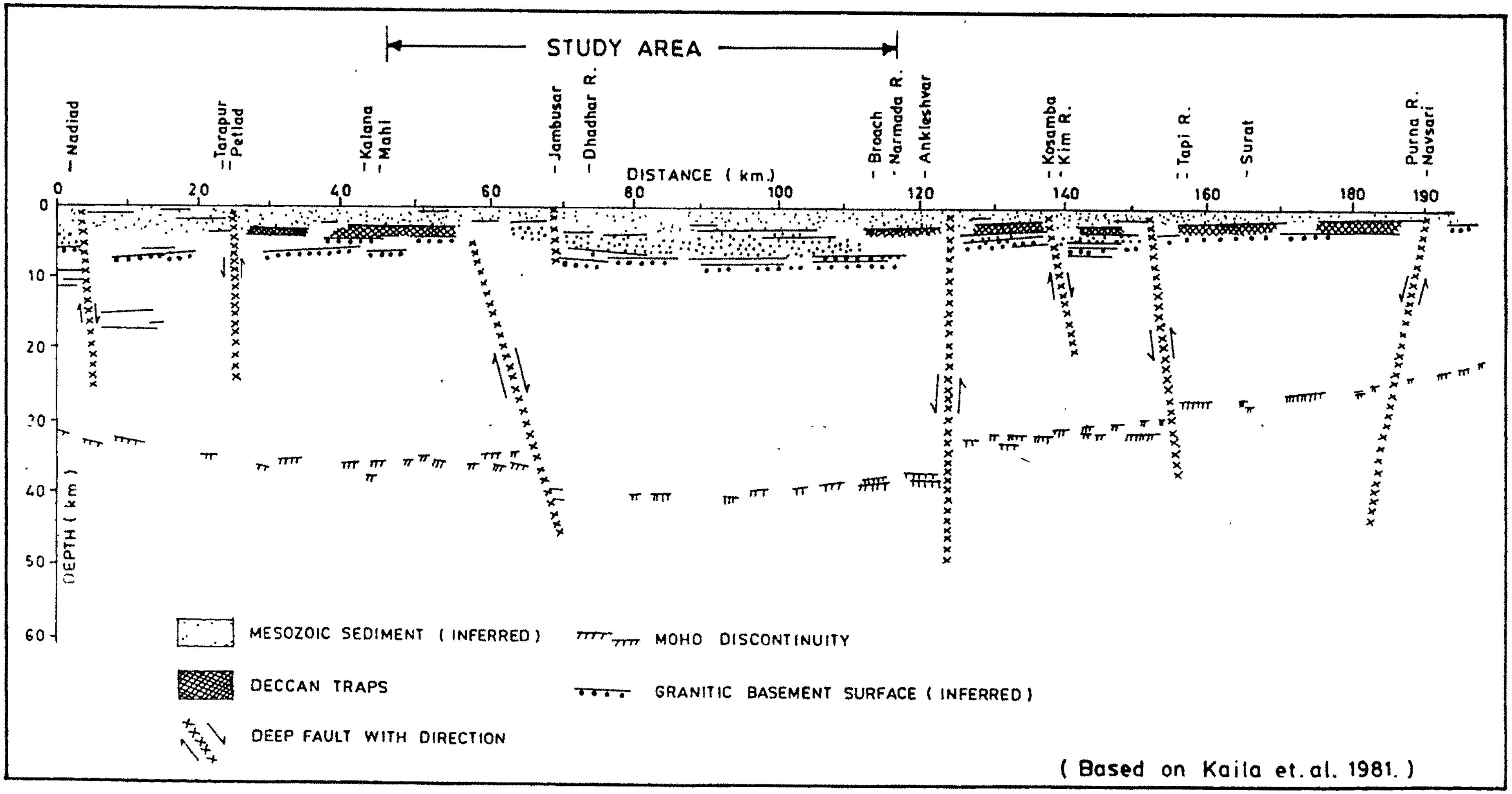


FIG-II-5 **MAJOR BASEMENT LINEAMENTS CUTTING MOHO BOUNDARY**

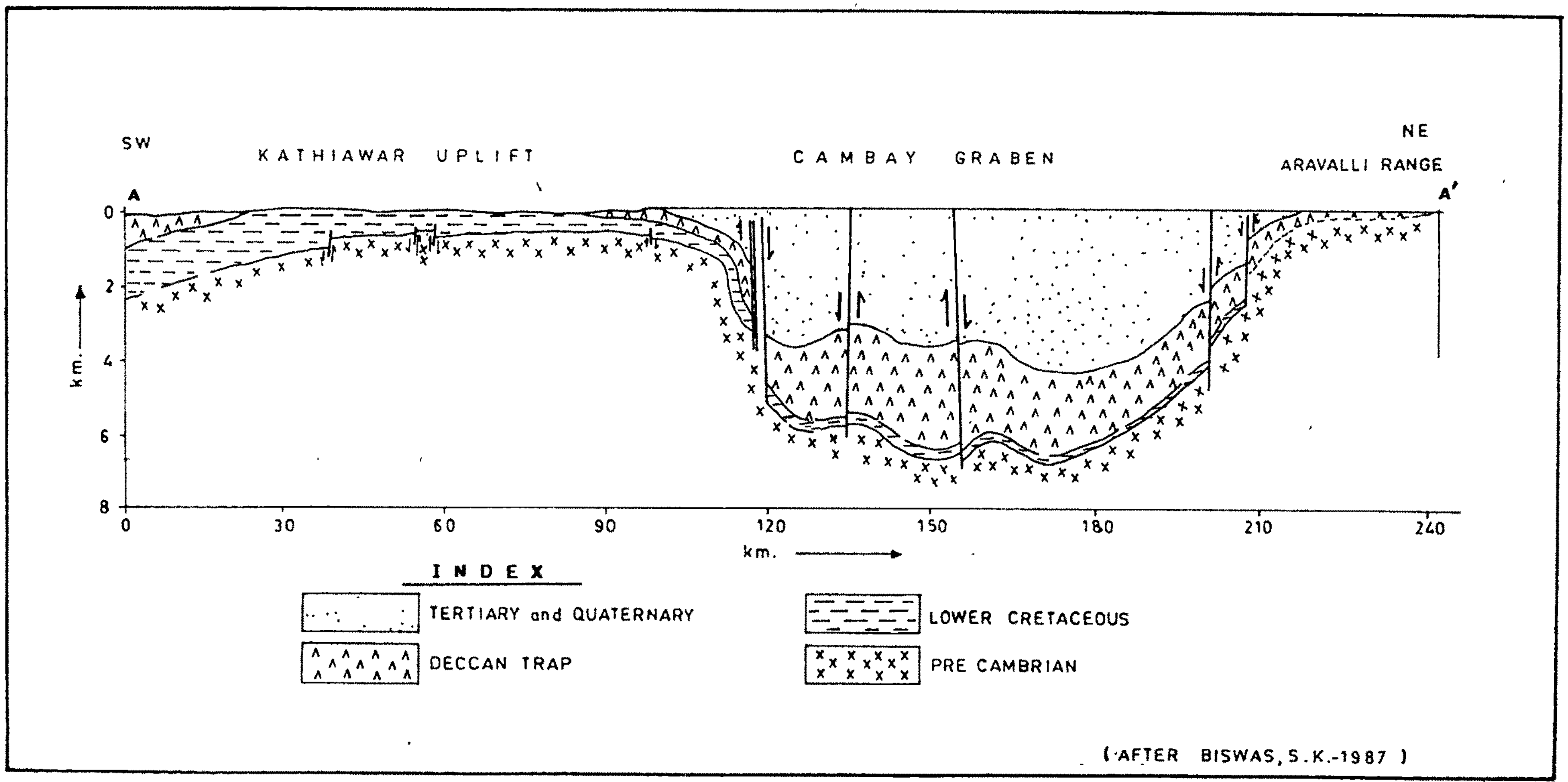


FIG-II-6 **GEOLOGICAL SECTION ACROSS THE CAMBAY BASIN ALONG LINE A—A'**

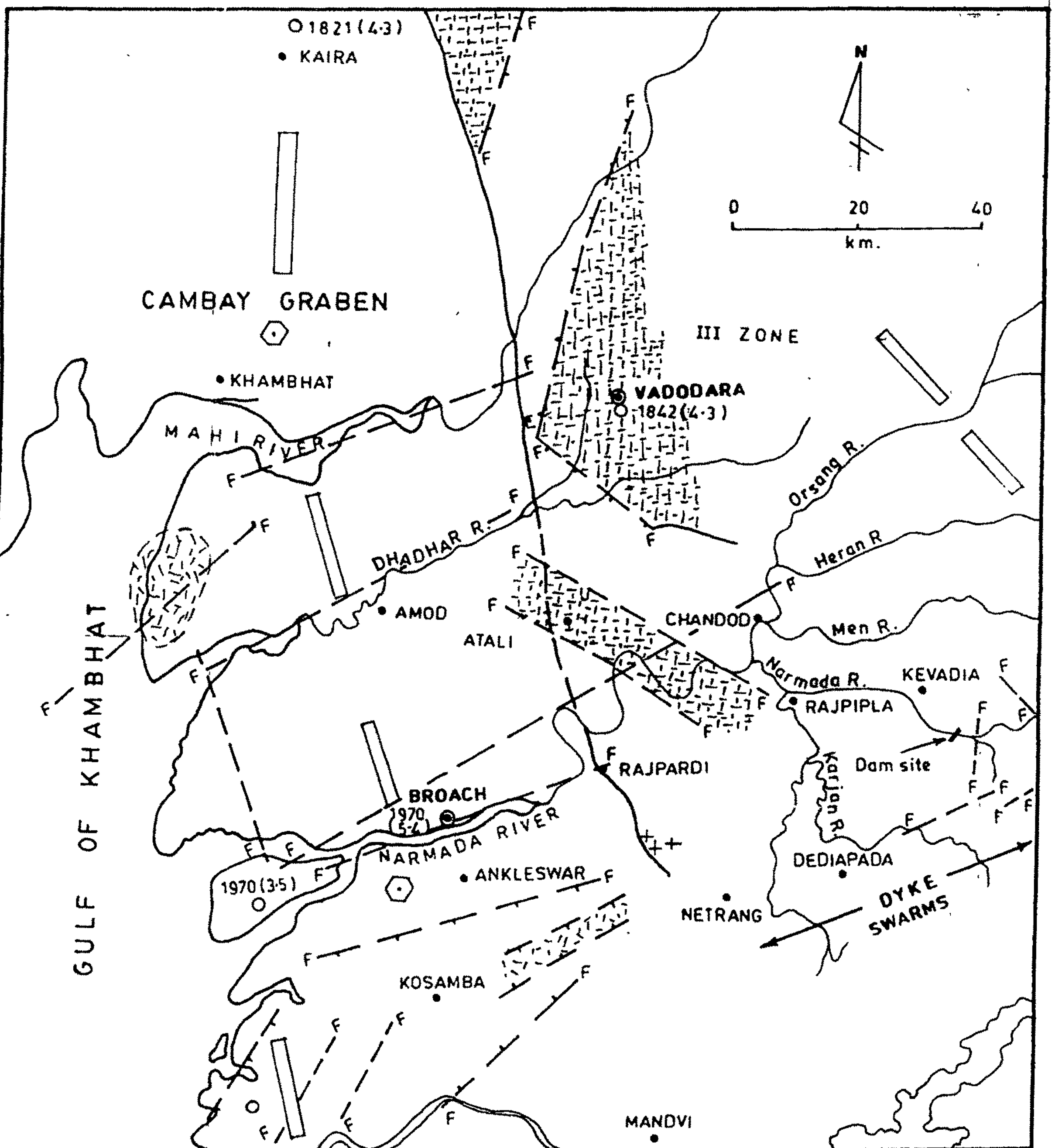
(Pilocene-Pleistocene) in Jambusar-Broach block only. The down faulting of Narmada block in upper Pliestocene times initiated the deposition of the alluvium. A 35 km long lineament trending NE-SW joining Rajpardi and Aliabet Island has been regarded as 'Palaeo-Bank' of Narmada, Agrawal, (1984) controlled by the Jagadia - Ankleshwar structural high. A map showing the seismo-tectonic status of the study area and adjoining region is shown in Fig. II.7.

Entrenchment of Narmada and Mahi rivers to a depth of more than 40m in their lower reaches cutting could be attributed to the neotectonic activities in the area. This is further evidenced by the offsetting of tributaries of Narmada and Mahi and the presence of two terrace levels and their tilting. Balasundaram (1970) considered development of alluvial scraps and frequent occurrence of earthquakes in this region due to tectonic activity of recent times. In this context, the recent earthquake of Broach, 1970 (Magnitude 5.4) could be cited.

QUATERNARY GEOLOGY

The Quaternary geological history of the area is quite complex but equally interesting because the sedimentation has taken place in an unstable structural basin under the compound influence of fluctuating sea levels, climatic variations and neotectonic acitivites.

FIG-II-7 SEISMOTECTONIC MAP OF THE STUDY AREA



REFERENCE :

O 1938(6·25)	EPICENTRE		BASEMENT UPLIFT
+	ERUPTIVE CENTRE		PLUTON
	THERMAL SPRING.		DYKE SWARMS
	MAJOR TREND LINE	F— — F	FAULT

SOURCE : (1) Jaikrishna, Chaturvedi R.S., Shrivastava L S.(1976) Geological and Seismological Investigations of the environs of Narmada valley around Navagam dam site in Gujarat state, University of Roorkee, Roorkee.

(2) Meteorological Dept. N.Delhi (1986)

STRATIGRAPHY

The Central alluvial plains of the Gujarat preserve a very rich record of the Quaternary geology in the western India but its detail documentation is yet to be made. Archeologists have explored the late Quaternary deposits from the point of view pre-historic civilisation. Hydrogeologists explored its upper sandy horizons limited to the depths of sweet water aquifers. Oil and gas exploration have pierced through the Quaternaries but details about stratigraphic history is generally recorded for the prospective horizons lying much below the Quaternary. Thus no details about the chrono-stratigraphic succession of the Quaternaries of this important area are available.

In the stratigraphic column of the Gujarat State, the Quaternary deposits of northern and central parts are generally described as Gujarat Alluvium. The sediments have general depositional strike direction of NNW-SSE and have very very gentle slope towards west. They have maximum thickness of about 700 m towards west and found to rest over Tertiaries. As they steeply tapper towards east, their thickness reduces to about 30m to 100m near the eastern border of the study area where they are found to rest on Deccan Traps, Mesozoics and Precambrians. The major portion of the Quaternaries of the study area are included into the Jambusar-Broach block of the Cambay Basin. Pre-Quaternary lithostratigraphy of the Cambay basin has been studied in detail by the scientists of ONGC. It mainly includes the works of Raju (1968), Chandra and Chaudhary (1969), Sudhakar and

Basu (1973), Raju and Srinivasan (1983), Biswas and Deshpande (1983), Agrawal (1984) etc. A generalised stratigraphic succession of the Cambay basin as worked out by Sastri et al. (1983) is given in Table II.2. Some information about Quaternary stratigraphy of area is available from the works of Alchin et al. (1971), Hegde et al (1969), Agrawal (1972), Patel et al (1985), Kale and Rajaguru (1985), etc.

Based on the available literature and subsruface exploration reports of several organisation and section (Plate II.1 and 2) and field studies by the author, a sequence of Quaternary stratigraphic formations for the study area has been tentatively constructed as given in Table II.3.

Table II.3 Quaternary Stratigraphy of the Study Area

Epoch/Age	Formation	Depositional Environment
HOLOCENE Recent 2000 yrs B.P. (10 to 25 m)	Surficial Deposits River sands, gravel, Coastal mud, Beach Sand, Modern Soils, etc.	Subaerial deposition under marine and fluvial conditions.
Sub-Recent 10,000 Yrs B.P. (50 to 450 m)	Newer Alluvium : Inter layering of thick sand gravel and thin clay silt with calcareous nodules.	Late semiarid to arid phase (fluvial and aeolian)and early wet phase predominently marine (post-glacial).
PLEISTOCENE 1.5 to 2 M.Y. (50 to 700 m)	Older Alluvium : Interbedding of thick silty clay and thin gravelly sands (4 major sets).	Fluvio-Marine (Glacial and Inter-glacial).
------- Unconformity -------		
Pre-Quaternary	Tertiaries, Deccan Traps, Mesozoics and Pre-Cambrians	

TABLE-II-2 GENERALISED STRATIGRAPHIC SUCCESSION OF CAMBAY BASIN

AGE \ AREA	SURFACE: WESTERN MARGIN	SUB SURFACE: THARAD	SUB SURFACE: AHMEDABAD MEHSANA	SUB SURFACE: TARAPUR	SUB SURFACE: BROACH	SUB SURFACE: NARMADA	SURFACE: EASTERN MARGIN
RECENT TO PLEISTOCENE	ALLUVIUM	GUJARAT ALLUVIUM	GUJARAT ALLUVIUM	GUJARAT ALLUVIUM	GUJARAT ALLUVIUM	GUJARAT ALLUVIUM	ALLUVIUM
RECENT TO PLEISTOCENE	AGATE CONGL.	BUDHANPUR FORMATION	JAMBUSAR FORMATION	JAMBUSAR FORMATION	JAMBUSAR FORMATION		
PLIOCENE		BUDHANPUR FORMATION	BROACH FORMATION	BROACH FORMATION	BROACH FORMATION		
U. MIOCENE	PIRAM BEDS	ANTROL FORMATION	JHAGHADIA FORMATION	JHAGHADIA FORMATION	JHAGHADIA FORMATION	JHAGHADIA FORMATION	JHAGHADIA FORMATION
M. MIOCENE	KUDA BHUMBALI	DHIMA FORMATION	KAND FORMATION	KAND FORMATION	KAND FORMATION	KAND FORMATION	KAND FORMATION
L. MIOCENE	RATANPUR	DEODAR FORMATION	KAND FORMATION BABAGURU FORMATION TARKESHWAR FORMATION	KAND FORMATION BABAGURU FORMATION TARKESHWAR FORMATION	KAND FORMATION BABAGURU FORMATION TARKESHWAR FORMATION	KAND FORMATION BABAGURU FORMATION TARKESHWAR FORMATION	KAND FORMATION BABAGURU FORMATION TARKESHWAR FORMATION
OLIGOCENE			TARAPUR SHALE	TARAPUR SHALE	DADHAR FORMATION	DADHAR FORMATION / HAZIRA SHALE	
U. EOCENE		WAV FORMATION	TARAPUR SHALE	TARAPUR SHALE	ANKLESHVAR FORMATION { TELWA SH., ARDOL MBR, KANWA SH.	HAZIRA SHALE	NUMULITICS
M. EOCENE		THARAD FORMATION	KALOL FORMATION	VASO FORMATION	ANKLESHVAR FORMATION { HAJAD MBR.	HAZIRA SHALE	
L. EOCENE		THARAD FORMATION	KADI FORMATION	UPPER CAMBAY SHALE	UPPER CAMBAY SHALE	HAZIRA SHALE	
PALEOCENE	LATERITIC ROCKS	BALUTRI FORMATION	LOWER CAMBAY SHALE VAGAD KHOL FORMATION	LOWER CAMBAY SHALE VAGAD KHOL FORMATION	LOWER CAMBAY SHALE VAGAD KHOL FORMATION	LOWER CAMBAY SHALE VAGAD KHOL FORMATION	LOWER CAMBAY SHALE VAGAD KHOL FORMATION
UPPER CRETACEOUS	DECCAN TRAP GROUP	DECCAN TRAP GROUP	DECCAN TRAP GROUP	DECCAN TRAP GROUP	DECCAN TRAP GROUP	DECCAN TRAP GROUP	DECCAN TRAP GROUP
L. CRETACEOUS TO JURASSIC	MESOZOIC SEDIMENTS	MESOZOIC SEDIMENTS	MESOZOIC SEDIMENTS	MESOZOIC SEDIMENTS	MESOZOIC SEDIMENTS	MESOZOIC SEDIMENTS	MESOZOIC SEDIMENTS
ARCHAEAN	GRANITE	GRANITE	GRANITE	GRANITE	GRANITE	GRANITE	GRANITE

(After Sashtry C.V.S. et.al.1984)

PLATE II.1 A veiw of Narmada river bank cliff showing section of alluvial flood deposits, Loc. near Nanda

PLATE II.2 A view of Mahi river bank cliff showing section of alluvial flood deposits, Loc. Singhrot

The Pleistocene deposits of the area form a part of the Narmada Alluvium and are characterised by the 2nd and 3rd glacial advent during mid-Pleistocene comprising interbedded clayey and sandy layers. The entire Quaternary depositional succession forms a system of coalescing alluvial fans of Mahi-Narmada drainage. The pattern is complicated by continued neotectonic activity. The progressively sinking Cambay basin facilitated the mass scale deposition of increasing thickness towards the Gulf of Khambhat. The load of sediments itself possibly contributed to the subsidence of the basin. The tappering depositional wedge merges into the foot hill zone in the east.

Mahi and Narmada rivers have exposed about 30m to 40m deep sections through the alluviual flood plains. Marine clay bed is extensively exposed at the bottom overlaine by the fluvial gravel and silts. Geological map, and section at the selected places where the rivers have cut deep through the alluvial deposits have been prepared and cross sections also constructed. These give idea about shallow depth depositional succession and also development of the related geomorphic features. The maps and sections prepared are as under :

A. Mahi River

i) Between Bhilod and Vadu, Fig. II.8

ii) Between Vasad and Raika, Fig II.9

B. Narmada River

i) Between Tavan and Goveri Fig. II.10

ii) Between Nand and Vankpur Fig. II.11

FIG-II-8 GEOLOGICAL MAP AND SECTION OF MAHI RIVER BETWEEN BHILOD AND VADU

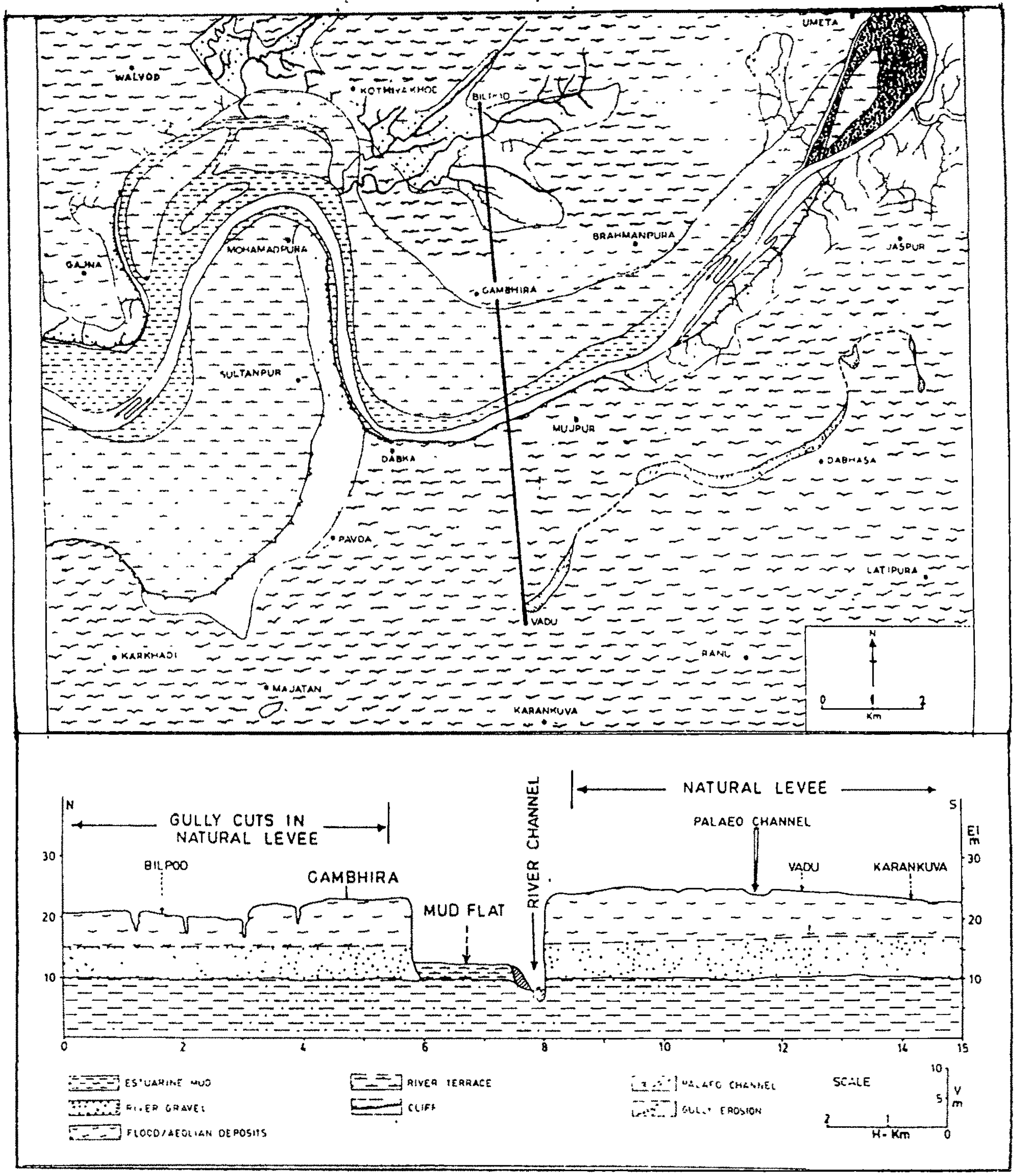
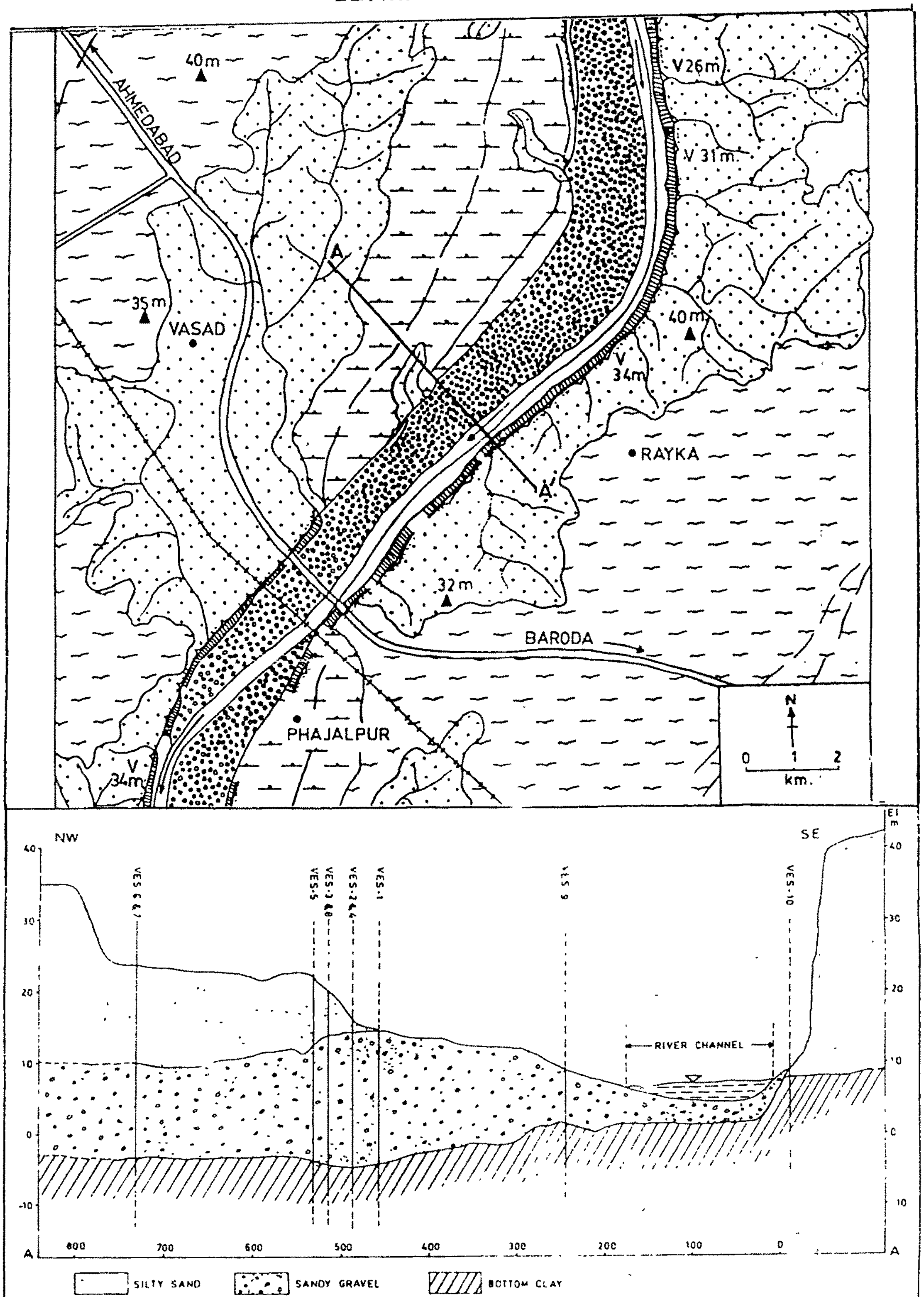
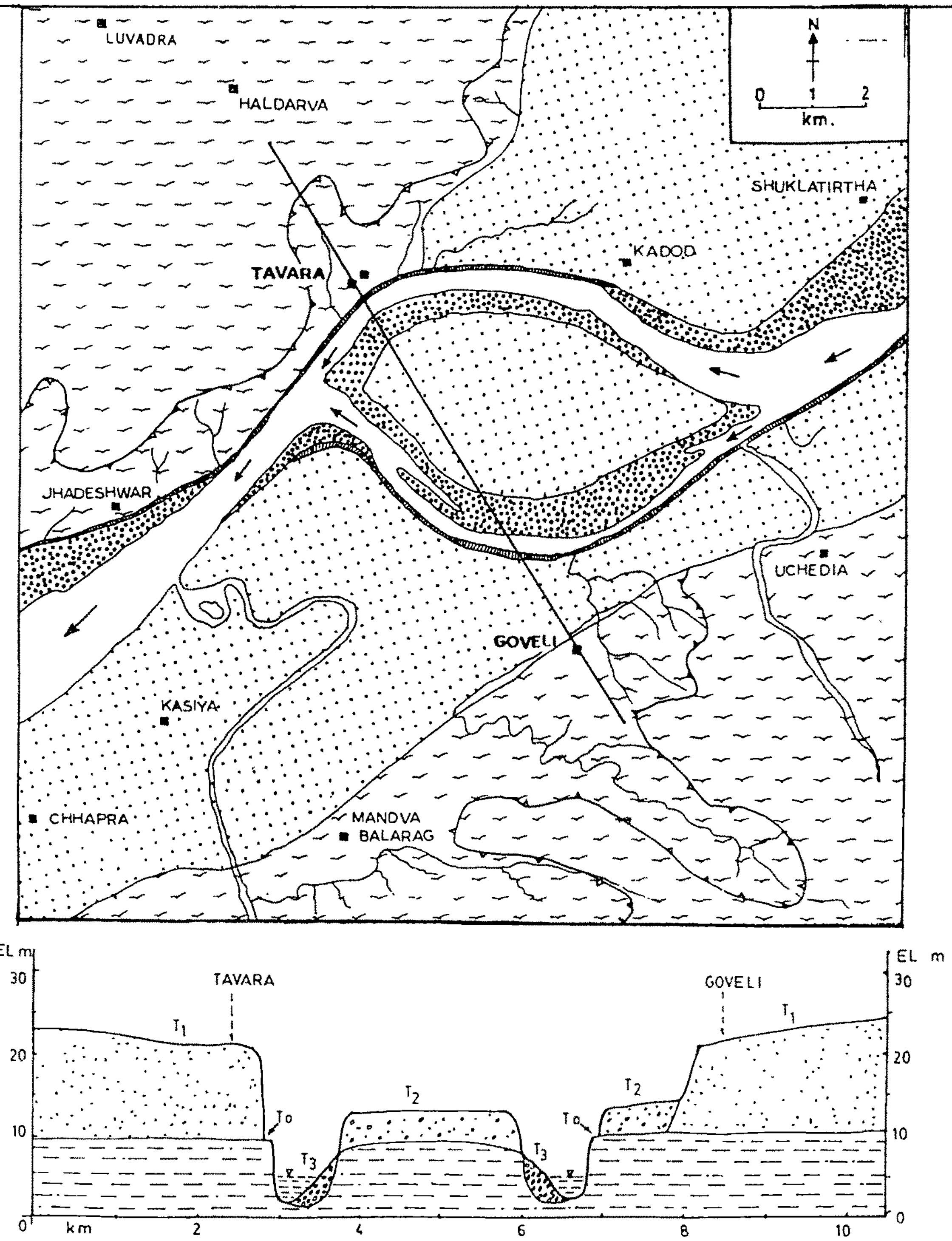


Fig. II·9 GEOLOGICAL MAP AND SECTION OF MAHI RIVER BETWEEN VASAD AND RAYKA



GEO ELECTRIC SECTION ALONG A—A'

FIG- II-10 **GEOLOGICAL MAP AND SECTION OF NARMADA RIVER BETWEEN TAWARA AND GOVERI**

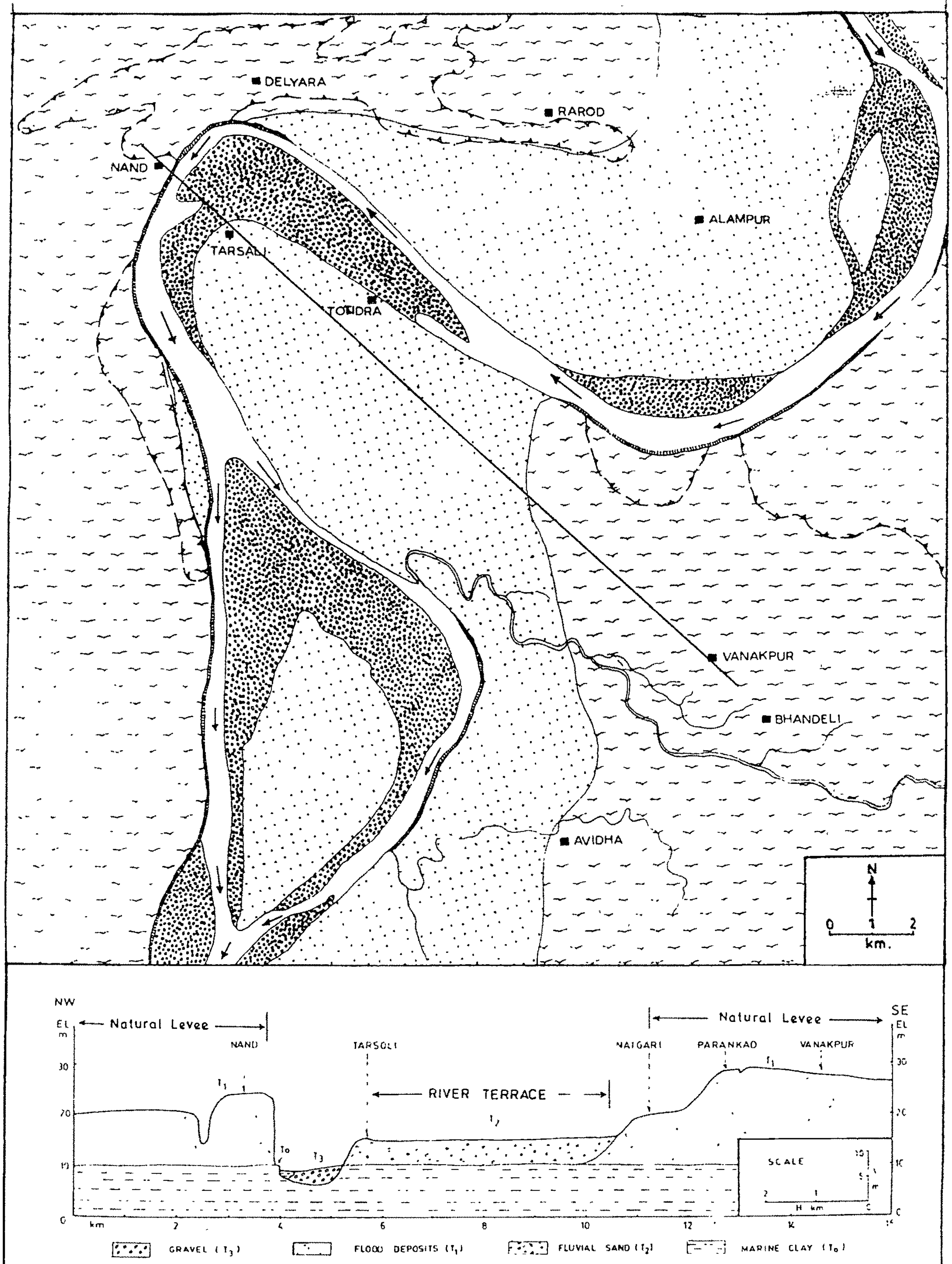


LEGEND

	EL RANGE	THICKNESS
FLOW CHANNEL	3 m to 6 m	3 m (depth)
GRAVEL	3 m to 9 m	6 m
FLUVIAL SANDS	10 m to 13 m	3 m
FLOOD DEPOSITS	10 m to 25 m	15 m
MARINE CLAY	Top at 10 m	-
LIMIT OF GULLY EROSION		

SCALE: V 10, 5 m, 0; H - km 2, 1, 0

FIG II-11 **GEOLOGICAL MAP AND SECTION OF NARMADA RIVER BETWEEN NAND AND VANAKPUR**



GEOMORPHIC SECTION ACROSS NARMADA BETWEEN NAND AND VANAKPUR

Electrical resistivity survey was carried out for Mahi section between Vasad and Raika and results incorporated in connection of the section. Based on the tubewell boring results, geological sections have been constructed. Map showing the locations of subsurface sectional profile is given in Fig. II.12. The subsurface geological sections along the four profiles lines are as follows :

i) A-A' line from Rann to Malod - Fig. II.13

ii) B-B' line from Kadodara to Karnet - Fig. II.14

iii) C-C line from Dariapur to Vankaner - Fig. II.15

iv) D-D' line from Devla to Dumad - Fig. II.16

The section revealed information upto the maximum depth of 184m. These sections indicate a prominence of arenaceous deposition towards east and argillaceous towards west. Sedimentation appears to have been influenced by continuous tectonic activity and fluctuations in climatic conditions.

SEDIMENTATION AND DEPOSITIONAL ENVIRONMENTS

The polygenic landscape of Mahi-Narmada alluvial plains has been developed by the interaction of endogenic and exogenic process during Quaternary. The differential tectonic movements and palaeoclimatic variations have affected the hydrodynamics of fluvio-marine regime. Various phases of fluvial rejuvenation can be attributed to dynamic, anatectic and static conditions. The Mahi-Narmada interstream area forms a part of the two major

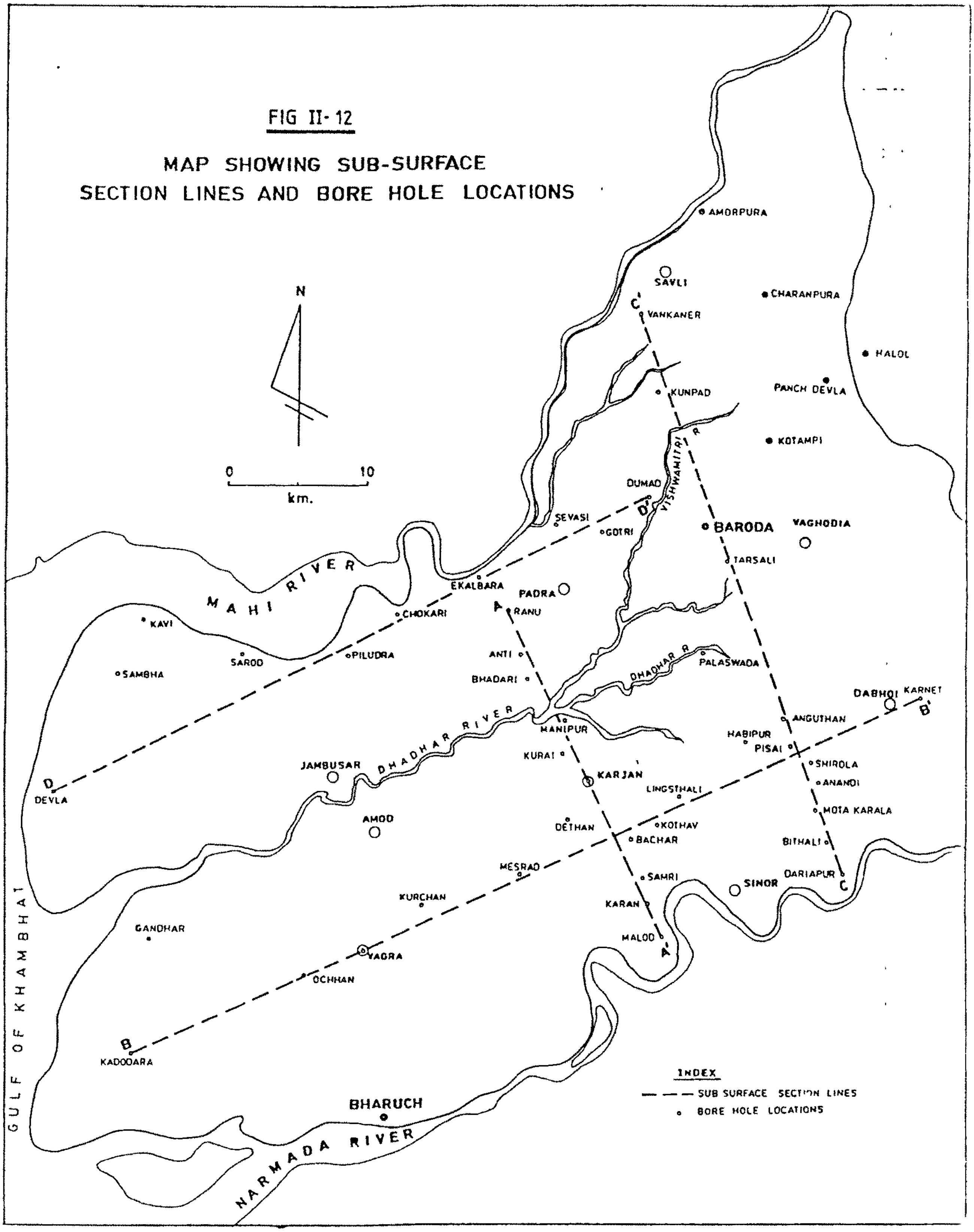


FIG II-12

MAP SHOWING SUB-SURFACE SECTION LINES AND BORE HOLE LOCATIONS

FIG- II- 13

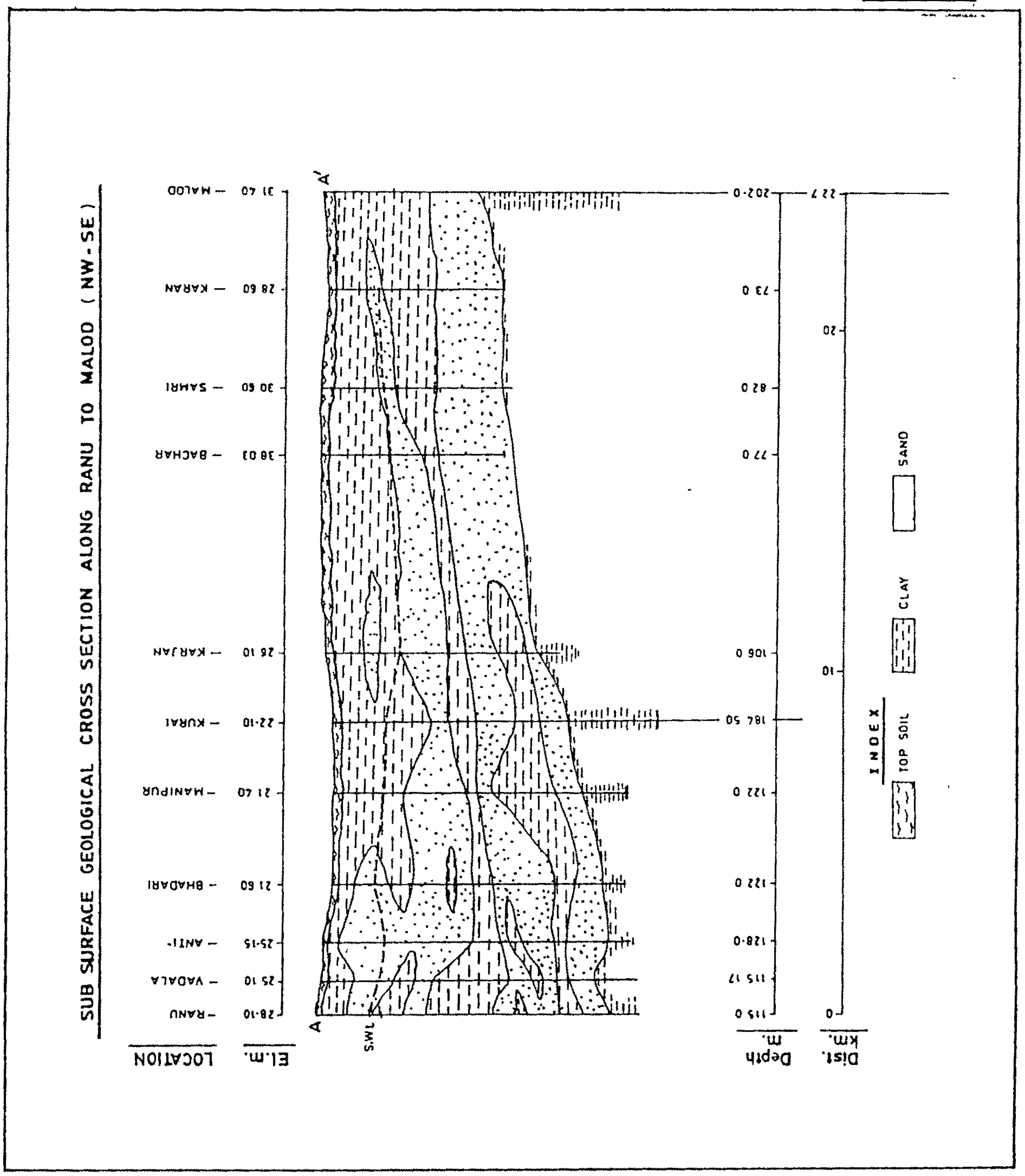

SUB SURFACE GEOLOGICAL CROSS SECTION ALONG RANU TO MALOD (NW-SE)
LOCATION
RANU
VADALA
ANTI
BHADARI
MANIPUR
KURAI
KARJAN
BACHAR
SAHRI
KARAN
MALOD
El.m.
28·10
25 10
25·15
21 60
21 40
22·10
26 10
38 03
30 60
28 60
31 40
A
A'
S.WL
Depth m.
115 0
115 17
128·0
122 0
122 0
184 50
106 0
77 0
82 0
73 0
202·0
Dist. km.
0
10
20
22 7
INDEX
TOP SOIL
CLAY
SAND

FIG II · 14

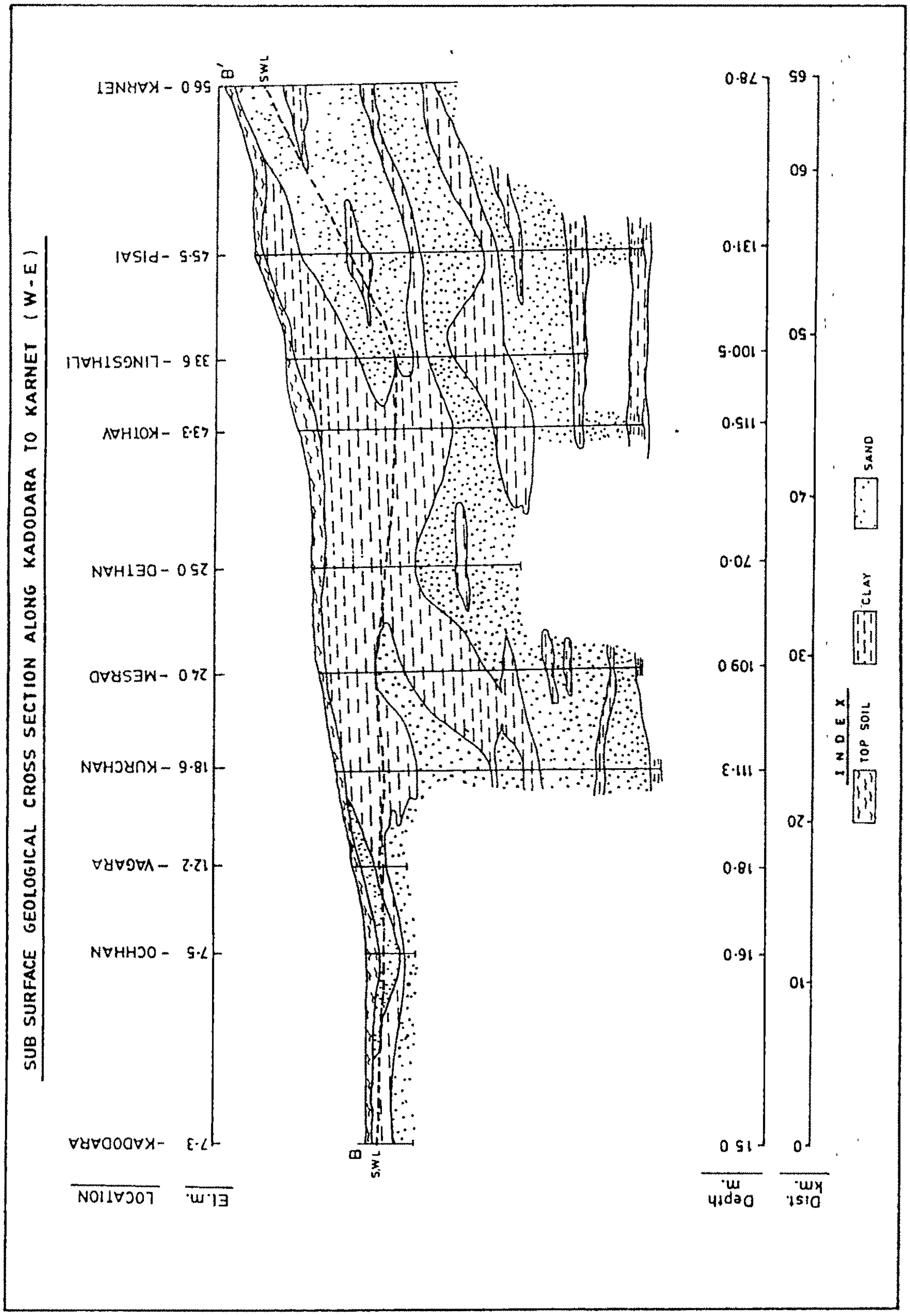

SUB SURFACE GEOLOGICAL CROSS SECTION ALONG KADODARA TO KARNET (W - E)
El.m.
LOCATION
7·3 - KADODARA
7·5 - OCHHAN
12·2 - VAGARA
18·6 - KURCHAN
24·0 - MESRAD
25·0 - DETHAN
43·3 - KOTHAV
33·6 - LINGSTHALI
45·5 - PISAI
56·0 - KARNET
B
B'
S.W.L
Depth m.
15·0
16·0
18·0
111·3
109·0
70·0
115·0
100·5
131·0
78·0
Dist. km.
0
10
20
30
40
50
60
65
INDEX
TOP SOIL
CLAY
SAND

FIG II-15

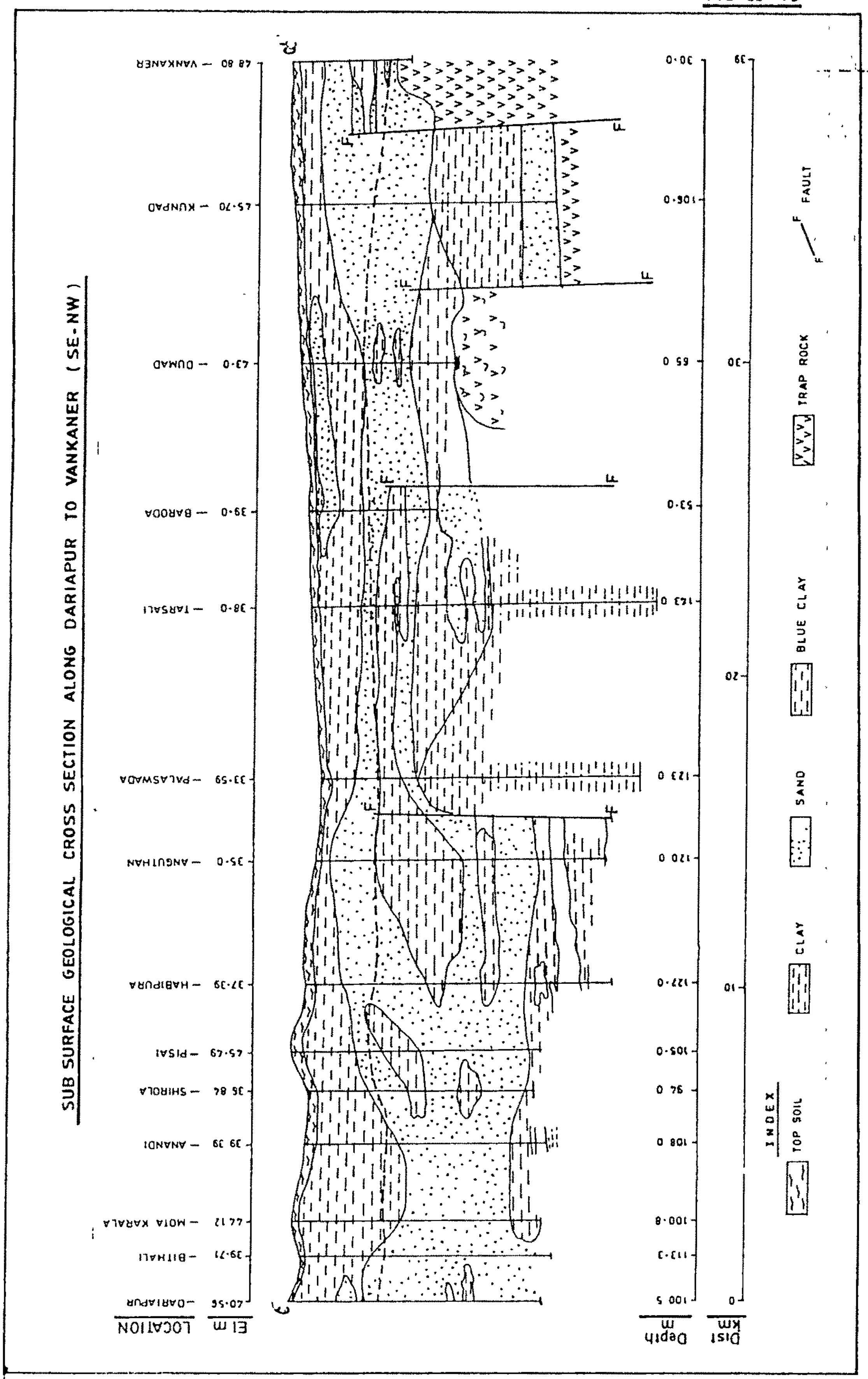
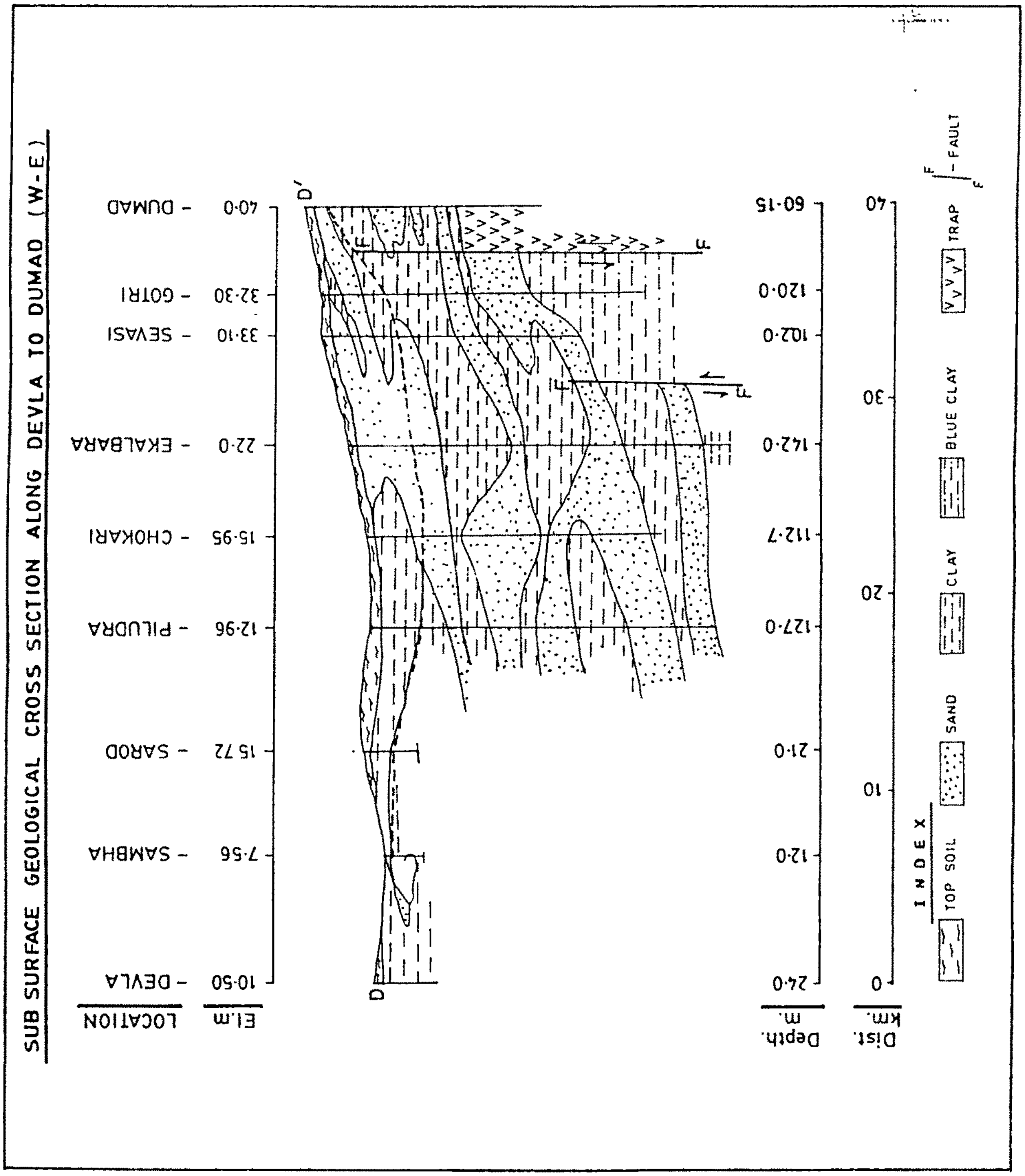

SUB SURFACE GEOLOGICAL CROSS SECTION ALONG DARIAPUR TO VANKANER (SE-NW)
LOCATION
El m
Depth m
Dist km
DARIAPUR
BITHALI
MOTA KARALA
ANANDI
SHIROLA
PISAI
HABIPURA
ANGUTHAN
PALASWADA
TARSALI
BARODA
DUMAD
KUNPAD
VANKANER
INDEX
TOP SOIL
CLAY
SAND
BLUE CLAY
TRAP ROCK
FAULT

FIG II-16



SUB SURFACE GEOLOGICAL CROSS SECTION ALONG DEVLA TO DUMAD (W-E) pericontinental rift basins (Cambay and Narmada) filled up with varigated sediments of Tertiary and Quaternary. A thick sequence of more than 6000m sediments have been deposited in these tectonic depressions whose basement comprised diverse rock formations. It has been found that the Narmada basin is of Mesozoic origin while the Cambay basin is mainly of Tertiary origin. The generalised stratigraphy and environments of deposition of Cambay and Narmada basin are given in Table II.4.

The pattern of Quaternary sedimentation appears to have been greatly influenced by climatic variations. Sea level fluctuations and tectonic events. The sedimentation process and the environment under which various lithological suites have been deposited are reflected in their lithology, facies variation, mineralogical compositions, textural changes, faunal and floral contents, etc. The variations in these characteristics are observed to have taken place laterally as well as vertically depending upon the basin configuration and phases of transgression and regressions that had taken place. The input of detritus reflect the geological characteristics of provenance. The lithogenic suite is a sequence of beds consisting of paragenetically inter-related lithofacies that are derived, deposited and buried in a particular geographic, geotectonic and physicochemical environment. The Quaternary, known as a period of Great Ice Age is characterised by strong climatic variations. The glacials and inter-glacials are adequately reflected in the comparable climatic conditions as cold and arid to warm and humid.

TABLE II-4

GENERALIZED STRATIGRAPHY ; ENVIRONMENTS OF DEPOSITIONS AND TECTONIC EVENTS OF CAMBAY AND NARMADA BASINS

AGE	CAMBAY BASIN			NARMADA BASIN		
	LITHOLOGY	ENVIRONMENT	EVENTS	LITHOLOGY	ENVIRONMENT	EVENTS
QUATERNARY	Gujarat alluvium Clays and Silts Sands and gravel	Fluvial Marines aeolian	Neo tectonics activity	Gujarat alluvium Clays and Silts Sands and gravel	Fluvial Marines aeolian	Neo tectonics activity
PLIOCENE	Sandstone Shale	Fluvio Deltaic to	Regression and			
E.MIOCENE	Conglomerate (3500 ft.)	Marine	Tectonic cycle			
OLIGOCENE	Shale Sandstone		Oscillatory Transgression			
L. EOCENE	Limestone (600 - 900 ft)		Regression cycle			
M. EOCENE	Sandstone Siltstone Shale Coal (600-900 ft.)	Marine Deltaic				
E. EOCENE	Black Shales (1500 -4500 ft.)	Marine Prodeltaic	Transgression			
PALEOCENE	Vol Congl/Trapwash/ Fe.Claystone(60'-4000')	Fluvial Lacustrine	Graben Formation	DeccanTrap (>3000 ft.)	Terrestrial	Regression Uplift Volcancity Maj Tect.Cy.
L. CRETACEOUS	Deccan Trap (3000 ft.)	Terrestrial	Uplift/Erosion/Volcanicity Maj.Tect. Cycle	L.st./Marl/Sd.st. (250 ft.)	Marine	Transgression
E. CRETACEOUS	Felds. sandstone (? 3000 ft.) ? ? ?	Fluvial / Deltaic	Rifting	Sand st. Shale(300 ft.)	Deltaic Continental	Rifting
U. JURASSIC						Uplift/Erosion
E-M. JURASSIC						
LATE TRIASSIC						
PRE-MESOZOIC				Sand st/Shale/L.st.	Marine	Transgression
PRECAMBRIAN BASEMENT				Metamorphics/Granitic		

ABBREVIATIONS : Maj = Major ; Tect.= Tectonic ; Vol.= Volcanic ; Fe = Ferruginous ; Felds = Feldspathic ; Congl.= Conglomerate ; Sd.st.= Sandstone ; L.st.= Limestone ; Cy.= Cycle.

(After Biswas S K. 1987)

Krishnan (1982) correlated Pleistocene sedimentation and environments of Narmada Valley with NW India as shown in TableII.5.

Table II.5 Pleistocene Correlation of the Narmada with NW India

Age		Narmada Valley	NW Punjab	Kashmir Valley
Pleistocene	Upper	Black Cotton Soil	Redeposited Potwar and Second loess	IV Glacial
		Erosional interval	Erosional interval	III Inter-glacial
		Upper zone	Potwar Silt	III Glacial
	Middle	Erosional interval	Long erosional interval	II Inter-glacial
		Lower zone	Boulder Conglomerate	Upper Karewa II Glacial (Karewa gravels)
	Lower	Narmada Laterite	Pinjor Stage Tatrot Stage	I Interglacial I Glacial
Pliocene		--	Dhock Pathan Stage.	--

A schematic section through Narmada Pleistocene is given in Fig. 17.

The studies of alluvial facies of Narmada-Mahi rivers vis-a-vis climatic variations have been carried out by several workers

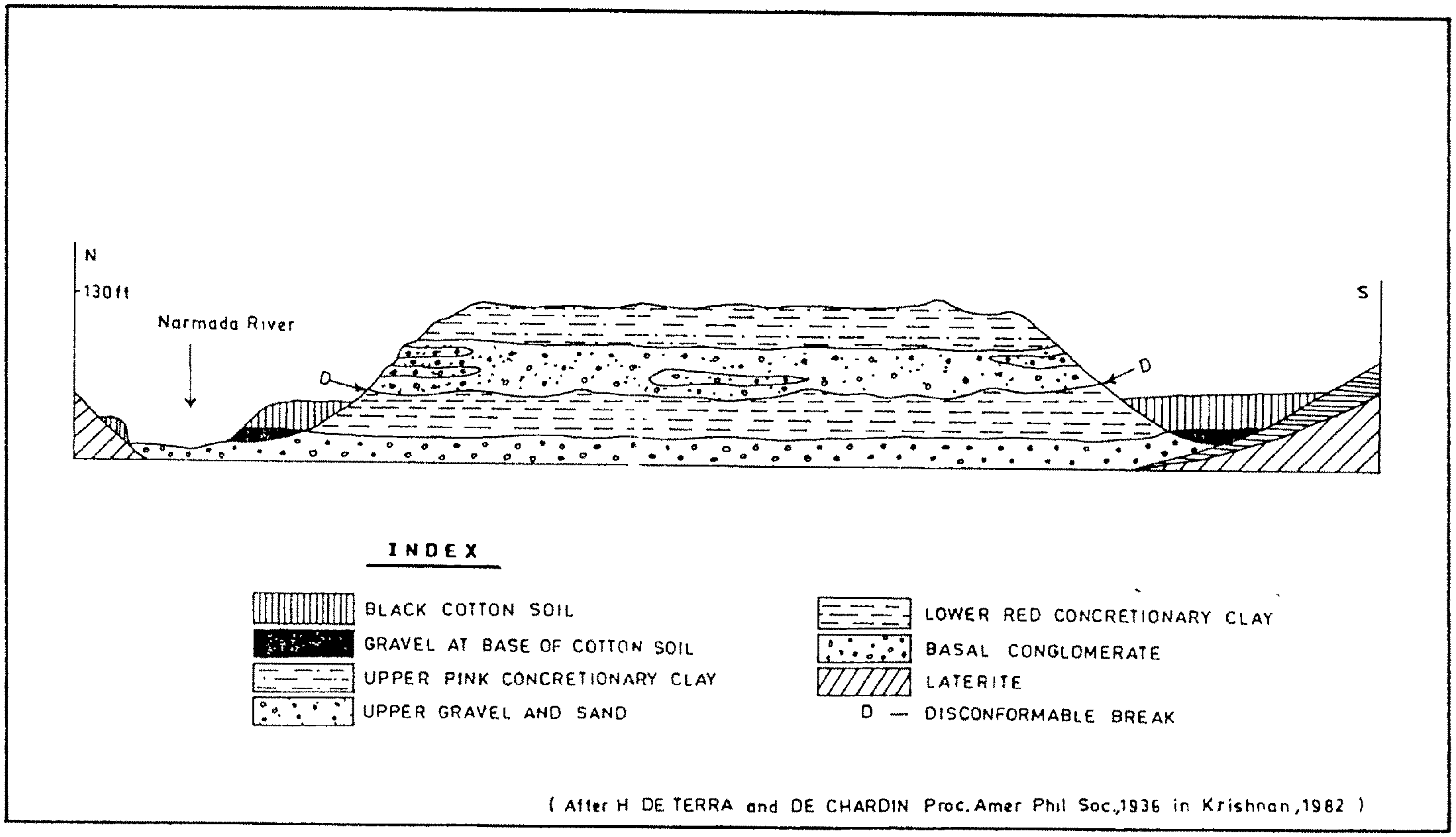


Fig. II 17 SECTION THROUGH NARMADA PLEISTOCENE viz. Zeuner (1950), Sankalia (1964), Dikshit (1970), Alchin et al (1970, 1971), Rajaguru (1973) Kale and Rajaguru (1985), Khan (1971), Merh (1987), etc. Based on palaeolithic tools, gravels, clays, dunal material as well as presence of palaeosol horizons exposed within the terraced horizons, these workers have postulated repeated oscillations of the climate between the arid and humid. This signify the aggradational and degradational phases detrital deposits. In these river valleys, the stratigraphy of the alluvium follows a uniform pattern exhibiting two major terrace systems. About 40m deep river sections have been cut by these rivers through the alluvium comrising compact concretionary clays at the bottom, overlained by sequence of alternate gravel and laminated silt. Within the silt an intermediate buried land surface of 10m to 12m below present ground level.

SEA LEVEL CHANGES

The climatic variations during the Quaternary glaciations have been reflected in relative sea level changes. Each interglacial stage marks sea level rise. On the global scale, six transgressive, cycles showing high strand line have been recognised by several workers from different parts of the world. A broad correlation between the changes in sea levels and climates (Holmes, 1975; Fairbridge, 1968) are given in Table II.6.

Table : II.6 Correlation between climatic stages and sea level Changes

Time	Transgression	Regression	Climatic Stage
Holocene	Flandrian	--	Post glacial
Up. Pleistocene	-- Monastrian	Wurm (W) R/W	Glacial Inter-glacial
Md. Pleistocene	-- Tyrrhenian --	Riss (R) M/R Mindel (M)	Glacial Inter-glacial Glacial
Lr.Pleistocene	Milazzian -- Sililian --	G/M Gunz (G) D/G Donav (D)	Inter-glacial Glacial Inter-glacial Glacial
Pre-Pleistocene	Calabrian	--	Preglacial

The estimates by different workers about the strand line fluctuation vary from maximum 220m rise (Calabrian) to 150m fall (Wurm). Alongwith the glacio-eustasy due role of tectono-eustasy, has also significant effects on sea level changes at local and regional scales.

West coast of India, especially the Gujarat region, is better investigated. Alongwith the field study of erosional and depositional features, some dependable radiometric dates are available, Nair (1974), the workers of O.N.G.C., G.S.I., P.R.L., Deccan College (Pune) and Geology Department, Baroda University have carried out extensive studies. Most of them have been referred in earlier sections of this chapter. Merh (1987) made a critical review and listed series of landform features as an evidence of the late Quaternary sea levels for the Gujarat Mainland. In the course of coastal zone geomorphic studies, author could observe the following features :

i) Eastuarine river mouths with bank scarps, and sets of river terraces.

ii) Offshore extension of river channels and drowining of river valleys.

iii) Entrenchment of river courses.

iv) Submergence of older alluvium under present day tidal mud.

v) Occurrence of mud flats above the H.W.L.

vi) Presence of older dunal ridges, older alluvium, etc.

Geomorphic studies of the Gulf of Khambhat by Nayak and Sahai (1985), Patel et al (1985) envisaged four different stages of strand lines in the range of - 40m to + 10m between Mahi-Tapi block along Mainland Gujarat coast as under :

i) Early upper Pleistocene transgression + 40m

ii) Late Upper Pleistocene regression -20 m

iii) Early Holocene transgression +8 to + 10 m

iv) Sub-Recent regression to present sea level.

They have postulated the heights of sea level on the basis of their studies on the Saurashtra coast and these strandlines cannot be recognised on the Gujarat Mainland due to vast alluvial accumulation together with the subsidence of the coastal block (Jambusar-Broach) north of Narmada during late Pleistocene. The author considers a very significant role of neotectonism and the sea level fluctuation, affecting the study area. On account of the tectonic subsidence the actual limits of Cambay basin could be visualised in the sub-surface covered under the late Quaternary alluvial deposits only. Today the Mahi-Narmada alluvium is seen to extend for several kilometres in the offshore region. The entrenchment of Mahi-Narmada channels have cut down this formation and revealed several features of Wurm regression. The indications of Holocene transgressive strandline as postulated by Merh (1987) to a height of about 10m above present sea level are well exhibited in the study area. The evidences of Holocene transgression are observed as submergence of fluvial landforms, extension of mudflats over coastal alluvium and development of estuarine creeks.