CHAPTER II

G E O L O G Y

II.1 INTRODUCTION

The author has given here only a few salient features of the geological setting of the area because the present study has more bias towards the geomorphic aspects.

Geologically, the study area comprises a terrain made up of Deccan Trap lava flows and the overlying Tertiary and Quaternary sediments.

The lava flows of Deccan Trap make up the dominant rocks, and it is observed that the subsequent

deposition of marine rocks was variable in the east and west. While the area to the east of the Okha Rann contains only restricted outcrops of Tertiary rocks, the Okha Mandal block shows a profuse development of these Tertiary rocks. On the other hand the late Pleistocene and Holocene sediments are less developed as compared to their thick accumulation over the trap basement and Tertiaries in the southwestern and southern parts of Saurashtra (Fig. II.1).

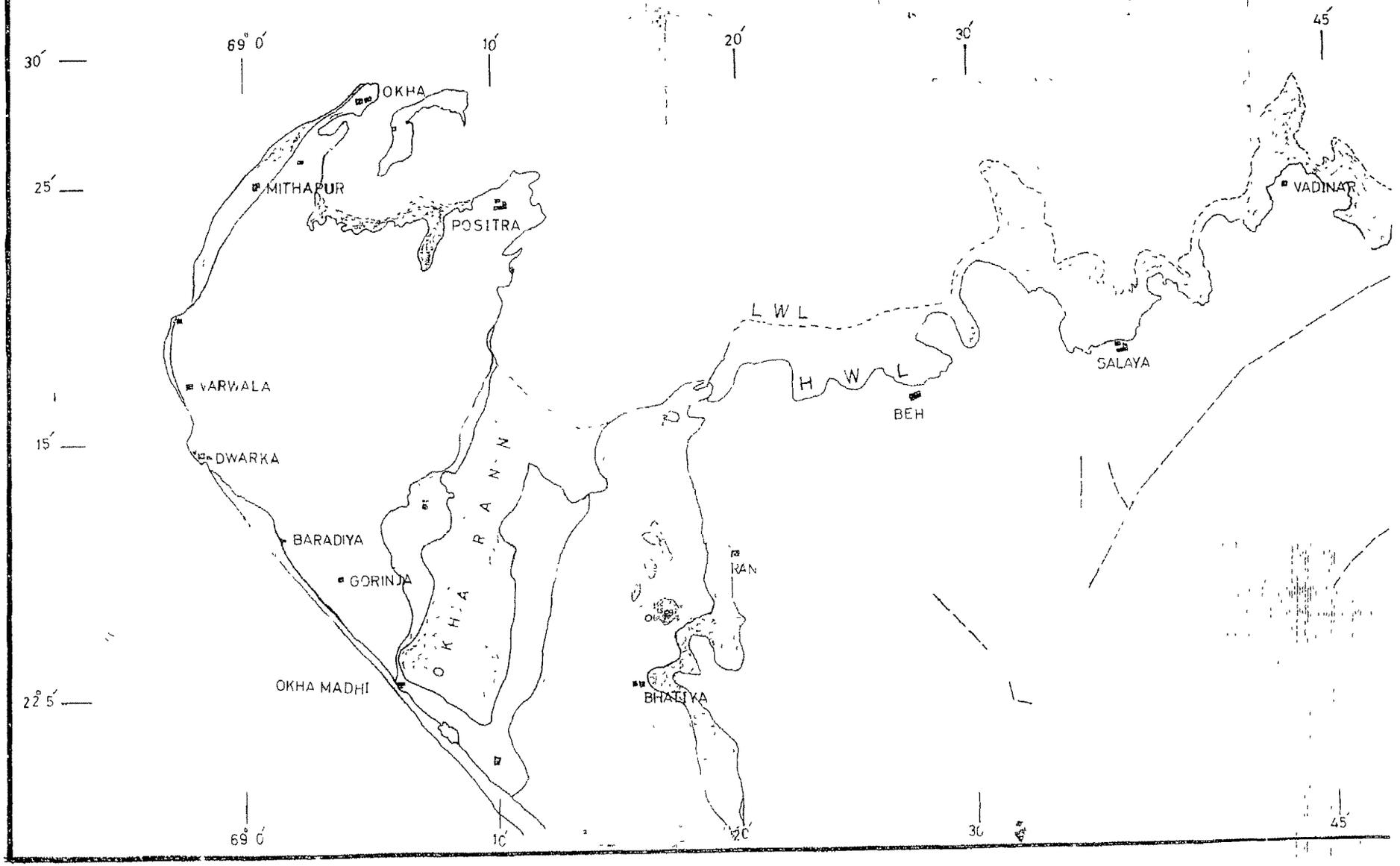
The Quaternary and Tertiary sequence for this part of Saurashtra has been given by Mathur et al (1975) as under :

Table II.1 : Quaternary and Tertiary sequence of Saurashtra

	Stratigraphic unit	Lithology	Age
QUATERNARY	Alluvium and Coastal Deposits	Freshwater alluvium (sands, clays), coastal deposits (Lime Mud; Rann clays with carbonaceous material/ marine shells; Unconsolidated calcareous sands)	Holocene

Contd...

GEOLOGY OF THE STUDY AREA



PHYSIOGRAPHIC MAP OF THE STUDY

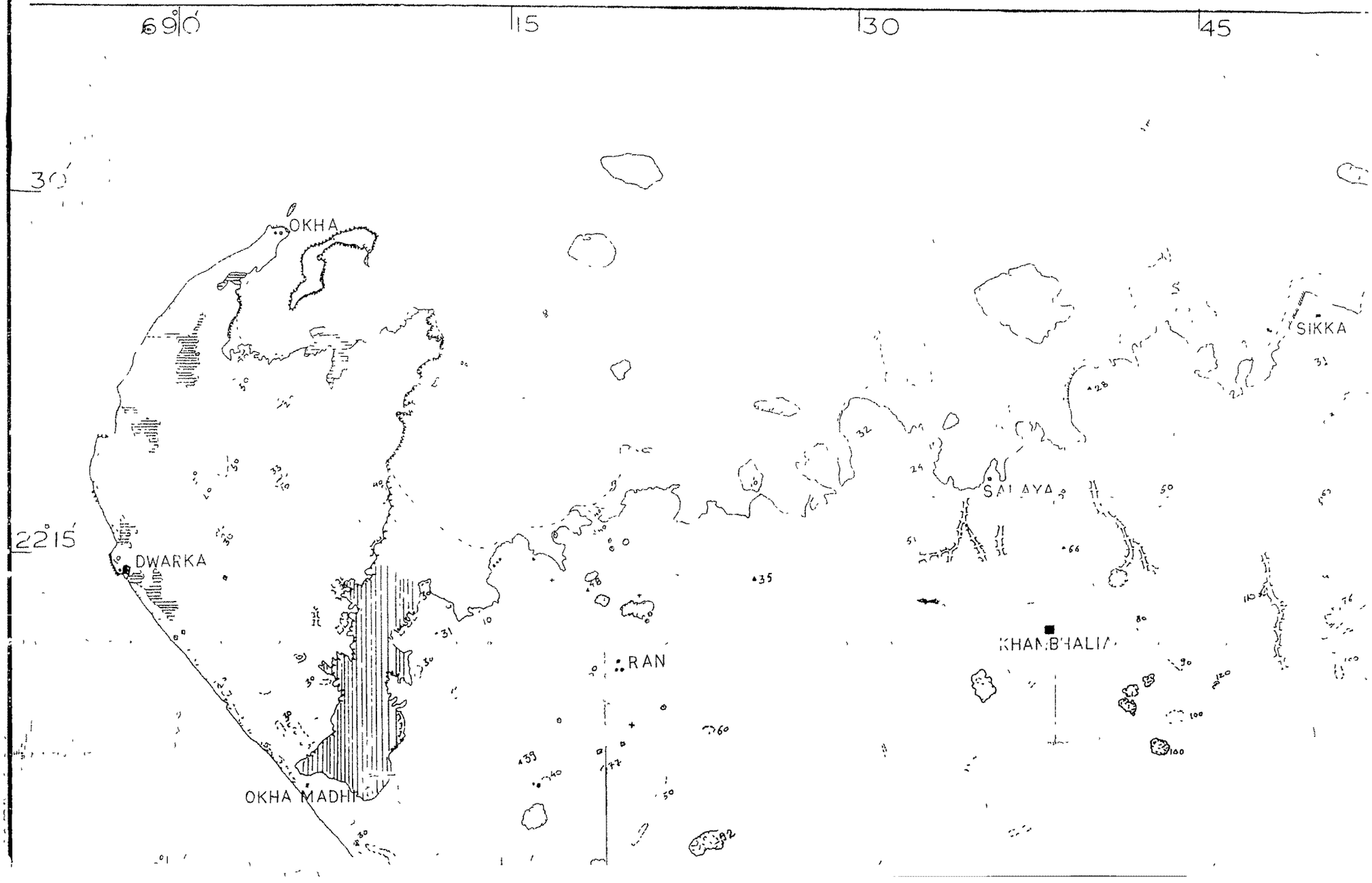


FIG. II.1

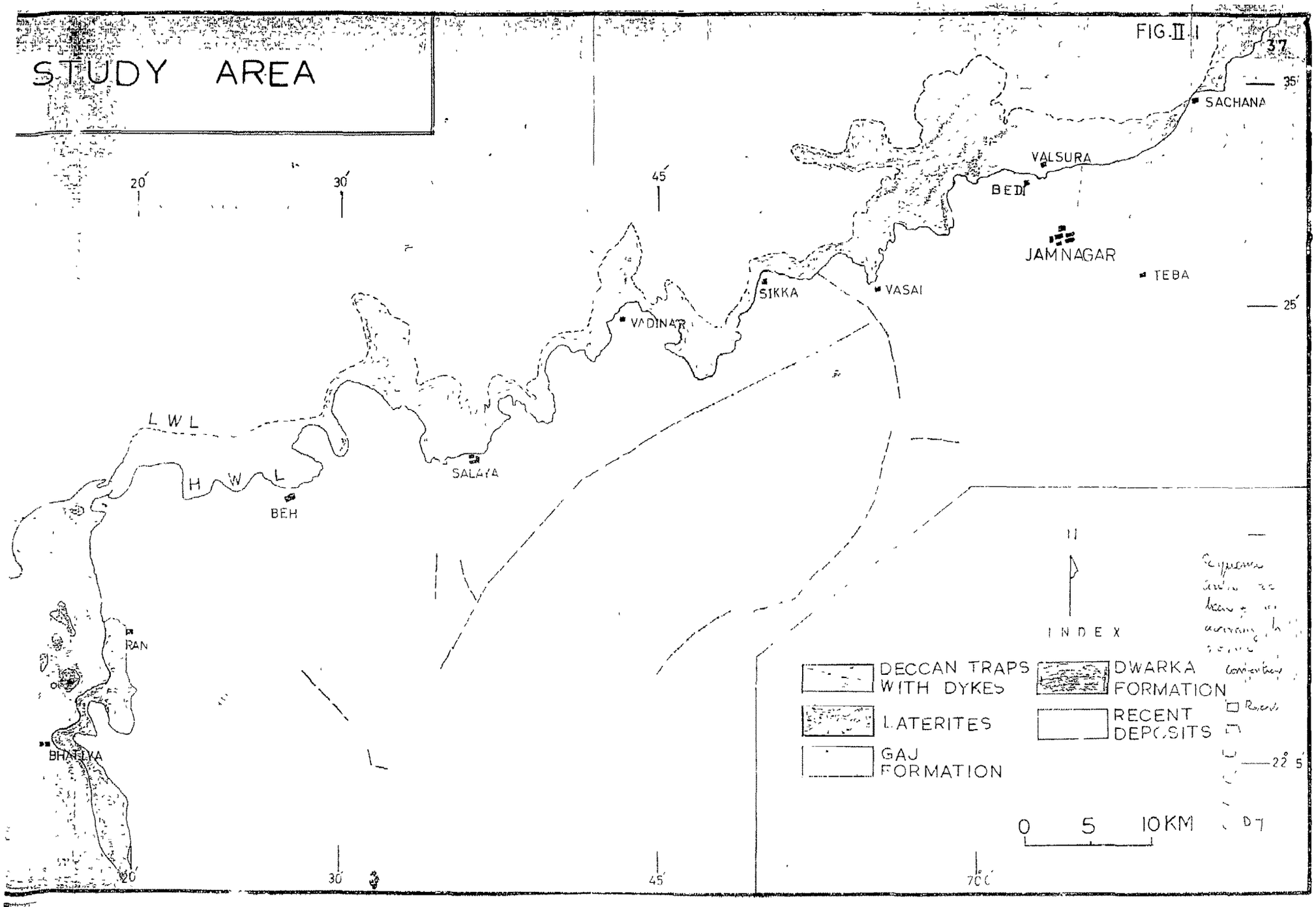

STUDY AREA
20'
30'
45'
35'
25'
SACHANA
VALSURA
BEDI
JAMNAGAR
TEBA
VASAI
SIKKA
VADINAR
SALAYA
L W L
H W L
BEH
RAN
BHATIYA
INDEX
DECCAN TRAPS WITH DYKES
LATERITES
GAJ FORMATION
DWARKA FORMATION
RECENT DEPOSITS
0 5 10 KM
22° 5'
70° 0'

Table II.1 : Contd.

	Stratigraphic unit	Lithology	Age
QUATERNARY	Chaya Formation	Semiconsolidated to consolidated limestones (calcirudites); shell limestones coral reefs and oyster beds	Holocene to Late Pleistocene
	Adatiana member	Pelletoid limestones (Calcarenites)	Early Pleistocene
	Dhobaliya Talav member	Alternating sequence of pelletoid limestones and fine grained limestone (Micrites)	
TERTIARY	Dwarka Formation	Flaggy arenaceous limestones with recrystallised shells; clays	Middle Miocene to Lower Miocene
	Gaj Formation	Hard, compact, fine grained limestone with abundant foraminifera; Variegated clays	Lower Miocene
		Laterite and Deccan Trap	

Within the limits of the area investigated by the author, only following formations are encountered :

Alluvium and coastal deposits

Chaya Formation

Dwarka Formation

Gaj Formation

Deccan Trap

II.2 DECCAN TRAP

This formation is the most dominant and widespread. To the east of Okha Rann, from the north-south line joining the villages Virpur, Mowasa and Ran, the trap extends almost uninterruptedly eastward, forms a fairly elevated ground in the southern part of the area, which progressively slopes down towards the Gulf of Kutch. In the south, the trap forms almost an E-W ridge while in the coastal plains, it is exposed as small hillocks and mounds with wide convex slopes. The rock consists of almost horizontal lava flows, frequently interbedded with red clays and ash beds of light grey colour. The individual flows also show variations, and in addition to the most common grey massive basalt, cavitous, amygdaloidal and scoriaceous varieties are also observed. Generally these make up the top portions of individual flows.

An overall trap thickness of about 200 m is observed. The individual flows range in thickness from 10 m to 15 m. The ash or red bole beds are 1 to 2 m thick. These do not show straight contacts with the traps, and usually form very undulating and irregular surfaces.

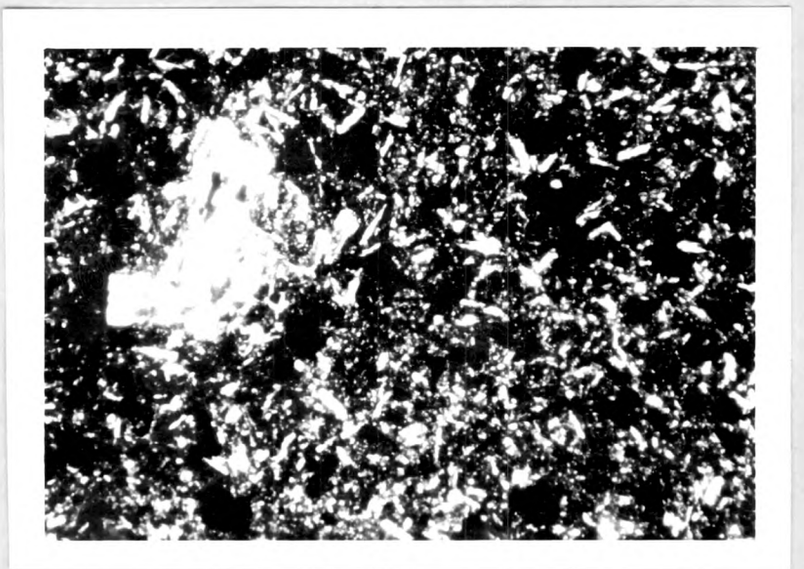
Petrographically, the traps have been found to consist of usual Tholeiitic basalts made up of plagioclase laths with occasional olivine grains embedded in a microcrystalline groundmass (Plate II.1). The coarser varieties show sub-ophitic textures. The grain size variation is also observed from fine to medium grained. Plagioclase is a labradorite, while the pyroxenes are augite, diopside and enstatite. Olivine is seen as an accessory mineral altered to serpentine. Phenocrysts of plagioclase and occasionally of augite are quite common. Amygdules are those of zeolites and chalcedony (Plate II.2).

The uppermost portions of the trap are considerably lateritised, overlying the basalts is a thickness of laterite rock, scattered and sporadic. Restricted to the western limit of the traps around Bhatia and Ran, laterite is seen below the Tertiaries.

PLATE II.1

The texture of tholetic basalt
(x 80, crossed nicols)

PLATE II.2



Basalt with a phenocryst of plagioclase
(x 80 crossed nicols)

Its contact with the underlying trap is characterised by a layer (1 to 2 ft thick) of bentonitic clays. These clays comprise decomposed brecciated ash or tuff consisting of white and faintly mottled soft clay enclosing lumps and lapilli of similar rock, richly coloured and fairly earthy.

The laterite when rich in ferruginous content, typically shows a mottled brick red colour and is easily recognised by its porous and concretionary structure. The aluminous laterites are more nearer to bauxite showing light red or pink colour with white patches and a pisolitic structure. On the whole this aluminous variety is dominant and is extensively mined for industrial purposes. The contacts of the lateritic formation with the overlying Tertiaries and the underlying traps clearly point to the fact that these laterites were formed from the traps and the volcanoclastic materials under intensely hot humid conditions. A good example of gradual lateritisation of trap was observed in a nala near the village Bhatia. On the hillocks south-west of the village Ran, it was noted that the Tertiary limestones contained abundant fragments of laterites. Evidently, the laterites must have been subjected to considerable denudation prior to the deposition of the Gaj Formation above.

II.3 GAJ FORMATION

These comprise the oldest of the Tertiary rocks of Saurashtra and are extensively developed in the southwestern and southern Saurashtra coastal areas, representing the marine transgression during Miocene period. Earlier Tertiaries viz Oligocene beds are nowhere exposed, and they have been reported to occur sub-surface in Bhavnagar and Ghogha area. In the study area, the rocks of Gaj Formation are restricted to the western half. Here these form a narrow fringe along the western margin of the Okha Rann and form good exposures to the east of this Rann, in the Kalyanpur Taluka of Jamnagar. These overlie the laterites and trap, and form almost horizontal beds of calcareous sandstone, clayey marls and limestone, highly fossiliferous. Resting with a distinct unconformity above the older laterites and trap, these Miocene rocks show a succession which progressively increases in calcareous content upward. The lowermost layers are sandy, while the middle portions are marly. The upper part is almost a limestone.

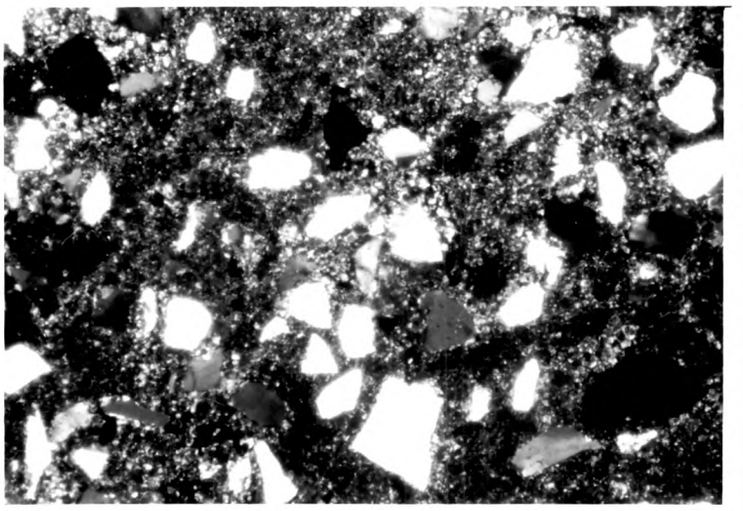
Total thickness of this formation is difficult to ascertain because in no section, both the top and

bottom, are clearly observed. However, a maximum thickness of about 40 m is observed at the village Khatumba on the west bank of the Okha Rann. Nowhere, the present author came across low northerly dips mentioned by Fedden (1884). On the other hand, it is seen that the dips could be due west, as younger rocks are exposed westward.

Petrographically, the lowermost beds are made up of fine to very fine angular quartz grains with argillaceous matrix (Plate II.3). This sandstone is feebly calcareous. The fossils are absent. It is fairly rich in ferruginous matter, and the rock could be considered as a friable sandstone. This horizon probably indicates a slight change in the depositional environment. The higher proportion of quartz sand indicates slightly turbulent environment which resulted in the breakdown of this quartz component. The absence of fossils could be explained by the turbulence of water during its deposition. This horizon could indicate a sort of stratigraphic break between the depositional environment of the rocks above and below it.

As regards the more calcareous layers that overlie the sandstones, they show quite interesting

PLATE II.3



Friable sandstone with angular quartz grains cemented in argillaceous matrix (x 80 crossed nicols)

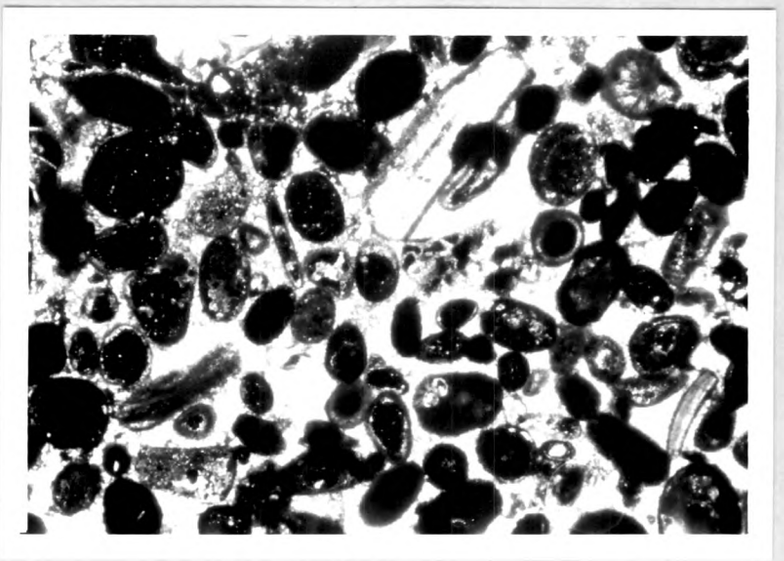
petrography and origin. The yellow clayey marls have been found to be essentially calcareous mud, i.e. micrites containing high percentage of pellets and fossils; and thus have been classified as biopelmicrites (Plate II.4). On the other hand the upper compact limestone layers are sparites, having been made up of sparry calcite (Plate II.5).

Taking into account the petrographic characters of the various thin sections, the author has found the entire Gaj formation to show a variation between sparite and micrite with varying percentages of fossils and pellets. Locally, terrigeneous quartz grains are also present. In a general way the Gaj Formation shows the following sequence :

Biopelsparite (Fossiliferous Limestone)	Lightbrown with violet tinge
Micrite, Pelmicrite and Biopelmicrite (Clayey marls)	Yellow and reddish yellow
Biosparite and Biopelsparite	Fossiliferous Limestone

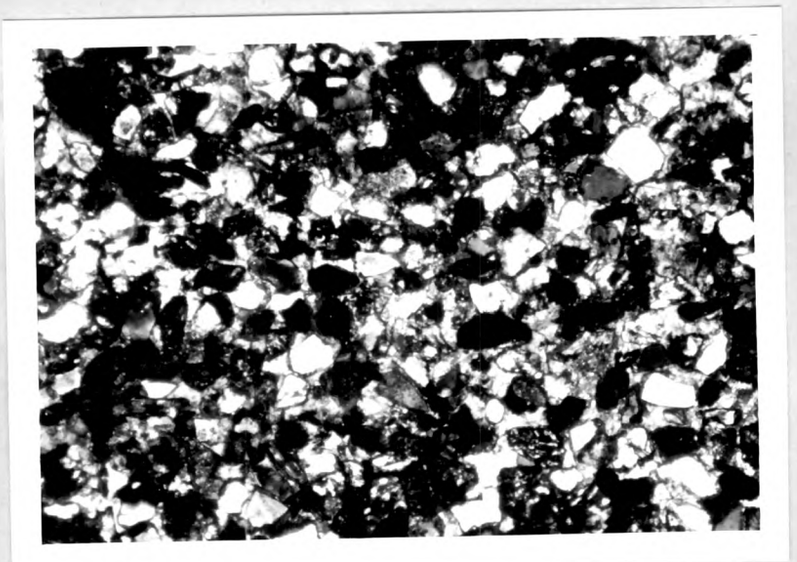
Laterite/Bentonite/Trap

PLATE II.4



Photomicrograph of biopelmicrite showing microfossils and pellets (x 80 crossed nicols)

PLATE II.5



Photomicrograph of sparite showing sparry calcite (x 80 crossed nicols)

From above, it is seen that the Gaj beds show considerable variation in terms of their carbonate content, pellets and fossils. This variation, points to the change in the depositional conditions vertically as well as laterally.

The lower-most biosparites indicate a shallow offshore environment pointing to a fall of sea level and increase in the activities of currents and waves. Biosparite with poorly sorted shells and shell fragments and fragments of coral reefs indicate shallow offshore environment while biopelsparite indicates more faunal activities with abundance of organic matter. In the upper successions, gradually a deepening of the sea-floor is indicated. Biopelmicrite and micrite indicate the increasing depth of sea-floor. This depth is a little more than the earlier one, where species could survive and carry out their vital activities, the fine material being deposited without disturbance of currents and tidal waves. This implies both a rapid rate of precipitation of microcrystalline carbonate mud and deposition of pellets together with lack of strong currents.

As regards the fossil content of the Gaj Formation, it is very rich in molluscan shells and microfossils. Though Fedden (1884) has given quite an exhaustive list, the present author could record and identify only the following :

Megafossils

GASTEROPODA

Natica, sp.
Cypraea sp.
Eburna sp.
Turritella angulata, C. Sow.
Phasianella ? comp. oweni d'A. & H

PELECYPODA

Placuna sp.
Dosinia pseudoargus, d'A. & H.
Astarte hyderabadensis, d'A. & H.
Venus non-scripta, C. Sow.
Cardium triforme, C. Sow.
Pecten bouei, Var d'Arch.
" favrei, d'Arch.
" Soomr owensis, C. Sow.
" (Vola) Sub-Cornieus, d'Arch & H.
Scapula ? indet (or modiola ?)
Pullastra virgata ? (or Verus Subvingata)
Ostrea multicostata (small)

ECHINODERMATA

Schizaster granti, Dun & Sla.
Cidaris halaensis, d'Arch. & Haim
Clypeaster sp. indet.
Temnechinus sp.

COELENTERA

Grammechinus regularis Duncan & Salden
Brissopsis sp.

Microfossils

FORAMINIFERA

Triloculina sp.
Quinqueloculina sp.
Ammonia sp.
Spirolocalina sp.
Bolivinita sp.
Globigerinita sp.
? Bigenerina sp.

On the basis of the above fossil content and the presence of foraminifers Globigerinita sp., Ammonia sp. and Bolivinita sp., it is clear that the rocks belong to a Lower Miocene age.

II.4 DWARKA FORMATION

The rocks of Gaj formation pass upward into the Dwarka with a disconformity only. The rock types

continue to be calcareous, though different in nature from the underlying Gaj beds, and also show a sudden drop in the fossil content. The constituent rocks are different varieties of limestones.

Extensive outcrops of Dwarkas are encountered all over the Okha Mandal block, and also along a narrow NNE-SSW strip restricted between the Okha Rann and the Gaj beds in the eastern part.

Good sections are exposed at :

1) Ranjitpur (east of Okha Rann)
2) Aramda
3) Bet Dwarka
4) Dwarka

At Ranjitpur, the base of the Dwarka beds is exposed, where the Gaj are seen overlain by a light brown compact limestone with a disconformity. The sudden disappearance of fossils is so characteristic. The overall dip of the beds is a few degrees due west.

Considering all the exposures and the dip directions at the various sections, the following stratigraphic sequence has been worked out :

Dwarka Formation	Current-bedded compact light brown limestone	Dwarka cliffs
	Hard spongy grey limestone	
	Red shaly limestone	
	Light grey coarse compact limestone	
	Compact, hard, violet coloured limestone	Aramda and Bet cliffs
	Crystalline buff coloured, current bedded limestone	
	Dark grey friable sandstone	
	Pink marls	Ranjitpur
	Yellow marls	
	Light brown compact limestone	
	---- Disconformity ----	
Gaj Formation	Reddish hard compact fossiliferous limestone	East of Ranjitpur

Petrographically, the Dwarka beds have been found to comprise biosparites and micrites. Pellets are almost absent. Fossil content is also negligible. However, sporadically the following foraminifers have been identified :

Triloculina sp.
Ammonia sp.
Spiroloculina sp.
Bolivinitia sp.
Globigerinita sp.
Cellanthus sp.
Podolia sp.

along with some molluscs like :

Pelecypoda : Pecten cf. pyxidatus, Cephalopoda : Balanus sp.

Of these, the fossils Podolia sp. and Cellanthus sp. point to the Upper Miocene to Lower Pliocene age.

Depositional structures mainly comprise cross-bedding in almost all layers and these point to variations in the current directions and in amount of dips of the foreset beds.

The Dwarka beds show quite interesting neotectonic structure in the form of conspicuous ENE-WSW flexures. A number of anticlinal ridges marking these folds are encountered in the Okha Mandal block. When traversing from Okha to Okha Madhi, it is further observed that the intensity and amplitude

of folds gradually decrease southward. Although no related faulting was observed but the likelihood of the flexures being bordered by longitudinal faults along their northern flanks cannot be ruled out.

II.5 CHAYA FORMATION

These carbonate rocks, taken as younger to the 'Miliolite formations' (Mathur et al, 1975) are the next formation encountered in a restricted manner on the west coast near Shivrajpur (north of Dwarka). Miliolites are nowhere recorded, and the Chaya Formation is seen resting directly on the Dwarka with an unconformity. About 20-25 m thick sequence is observed in quarry faces. Obviously, these exposures are the northern limit of the Chaya beds, which have been reported to occur extensively all along the coast from Jafrabad north-westward. According to B. Roy and some other workers at the Geology Department, M.S. University of Baroda (Personal Communication), the so-called Chaya rocks do not represent a distinct formation, younger to the Miliolite rocks, but comprise only a facies variant within the Miliolite Formation. These are essentially calci-rudites, devoid of pellets, and identical to the dead oyster beds and coast-fringing rocks of Fedden.

The constituent rock is a dirty white consolidated to semiconsolidated porous highly fossiliferous limestone. At places the limestone is so full of fossil corals that it can be aptly called "coralline limestone" or dead coral reef. In fact, the three variants of Chaya limestones viz. shelly limestone, coralline limestone and oyster bed form a part of the calcirudite limestone. Some of the fossils identified from the Chaya rocks are as under :

PELECYPODS

Tellina sp.
Venus sp.
Pecten sp.
Ostraea sp.

GASTROPODS

Turritella sp.
Conus sp.
Cypraea sp.

CORALS

Astroconis sp.
Septastrea sp.

In addition to the abovementioned megafossils these limestones contain a rich assemblage of microfossils, specially foraminifers, a few of which that were identified are as under :

Benthonic forms

Textularia conica d' Orbigny

T. foliacea Heron Allen and Earland

Spiroloculina excavata d' Orbigny

S. indica Cushman

Quinqueloculina cf. lamarckiana d' Orbigny

Criloculina cf. tricarinata d' Orbigny

Discorbis sp. indet

Gyroidina sp.

Bolivina cf. variabilis (Williamson)

Planktonic forms

Globigerina bulloides d' Orbigny

Globigerinoides triloba (Rauss)

Petrographically, the Chaya limestone has been found to show a high percentage of fragments of pelsparite and biopelsparite in a sparry calcite. Faunistically, these rocks are characterised by abundant broken and/or complete semi-fossilised shells of variety of gasteropods, lamellibranchs, corals and algae.

II.6 RECENT AND SUB-RECENT DEPOSITS

These consist of :

1) Coastal mudlfats,
2) Sand-dunes,
3) Residual soils.

1) Coastal mudflats

These are confined to the northern coast fringing it all along; the Okha Rann is also a mudflat.

All along the coast, these flats have a variable width of 1 to 10 km, this width is seen decreasing from east to west, the thickness is progressively increasing toward the offshore from a few cm to as much as 20 m. Okha Mandal Block has no mudflats.

The mudflats are dissected by creeks, nars and tidal channels. These deposits of mixed environment are formed by the deposition of fine clay and silt particles carried either from sea or landward side. Near the river mouths, the mud is seen mixed with medium to coarse sand. The mud

overlying the trap is dark grey while that resting over the Tertiary limestone, is of light brown colour. Extensive mangroves flourish on these mudflats.

2) Sand dunes

Coastal sand dunes are developed along the west coast from Okha to Okha Madhi. In fact, they extend further upto Kodinar. The dunes, comprise a continuous ridge dissected by creeks at Shivarajpur, Rupen Bandar and Dwarka. The height of the ridge varies from 8 to 10 m, and width is between 100-300m. The landward slope of the ridge is 4°-6°. At places like Mithapur a number of parallel ridges are seen. The sand is mainly calcareous, medium to fine grained white in colour, and is mixed with pieces of molluscan shells and corals. A seasonal growth of small flowering plants and grass takes place on this ridge which dries out in summer.

3) Residual soils

The inland area is covered by a blanket of soil, 4 cm to 30 cm locally a greater thickness is also seen. The soil is mainly derived from the underlying rock itself by the action of agents of

denudation. Soils overlying the Deccan Trap are black and fine-grained and very fertile. The soils derived from Tertiary rock are fine grained, of light brown to reddish brown colour, mixed with sand particles and are comparatively less fertile.

The black cotton soil supports a rich growth of Acacia Arabica, Nim, etc. and a dense forest, while on Tertiary soils mainly grows cactus, a typical arid zone flora.