A panorama of Dwarka coast as viewed to the north
from the light house tower

CHAPTER I

I N T R O D U C T I O N

I.1 GENERAL

The state of Gujarat in western India is endowed with an extensive coastline, stretching for about 1450 km from Jakhau (Kutch) in the north to as far south as Umbargaon in the Valsad district. The coastline provides considerable diversity in its different segments, and is seen to have evolved during the Quaternary period on account of a variety of combination of eological and climatic factors.

Not only the coastlines of Kutch, Saurashtra and Mainland Gujarat, point to quite different evolutionary histories, but they also provide a wealth of data on the sequence of geological and geomorphological events that have operated during the last 2 million years or so.

Very little detailed work on the Gujarat coastline have been done in the past. In fact, almost all parts of this interesting coastal terrain are yet to be fully investigated. The coastal areas of Gujarat are not only of geologic and geomorphic interest, but they have considerable strategic and economic relevance.

The Department of Geology of the M.S. University of Baroda, has initiated a long term programme of coastal studies, and this investigation formed a part of the bigger programme.

The present study was restricted to the coastline from Jamnagar to Okha Madhi lying between Latitudes 22° N and $22^{\circ}30'$ N and Longitudes $68^{\circ}57'$ E and $70^{\circ}5'$ E comprising the westernmost part of the Saurashtra (Fig.I.1). The coastline includes port towns of Okha Madhi, Dwarka, Mithapur and Okha in the west and Bet Dwarka, Rajpura, Positra, Salaya, Sikka, Bed and Jamnagar in the north.

LOCATION MAP

FIG : I.1

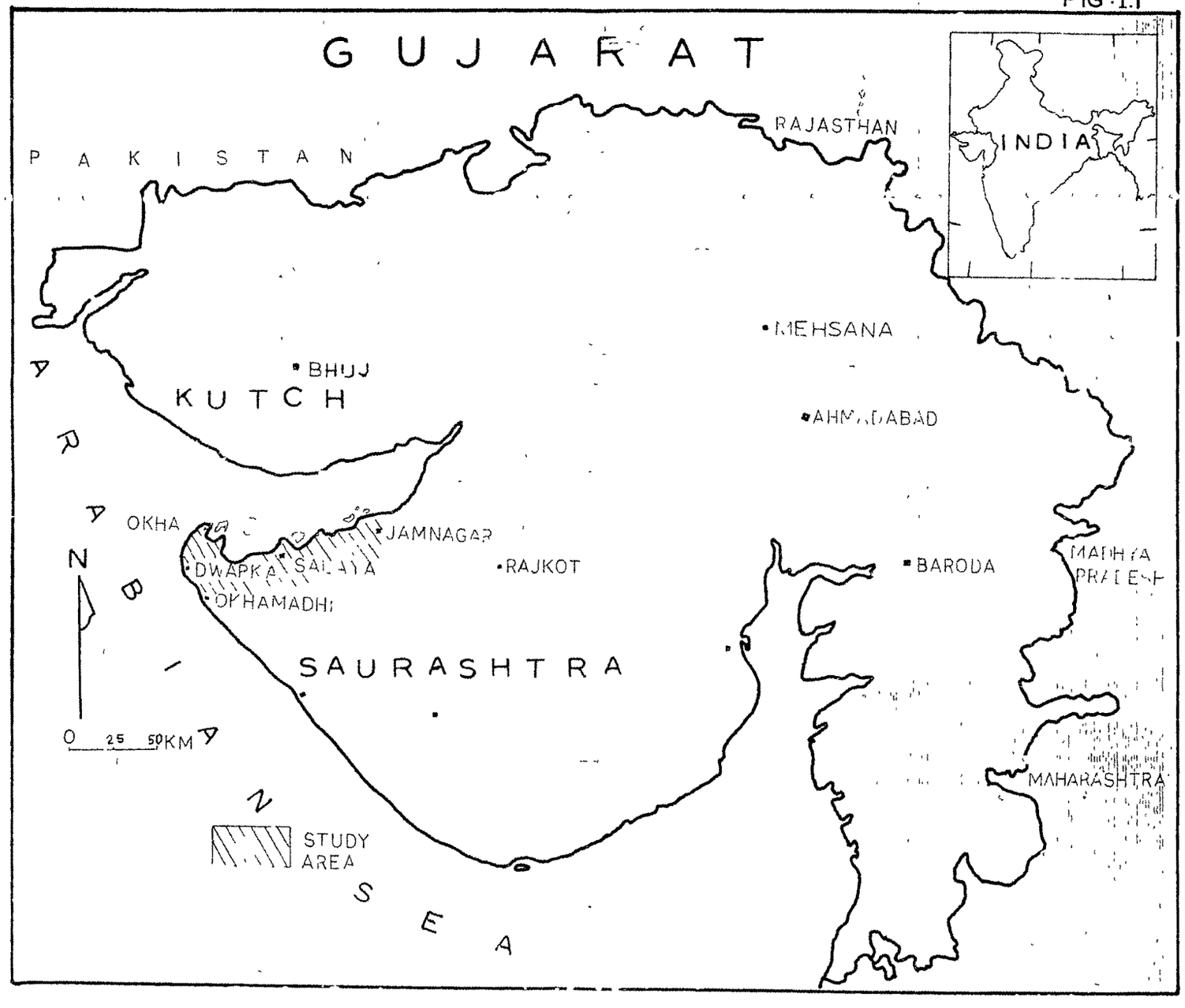
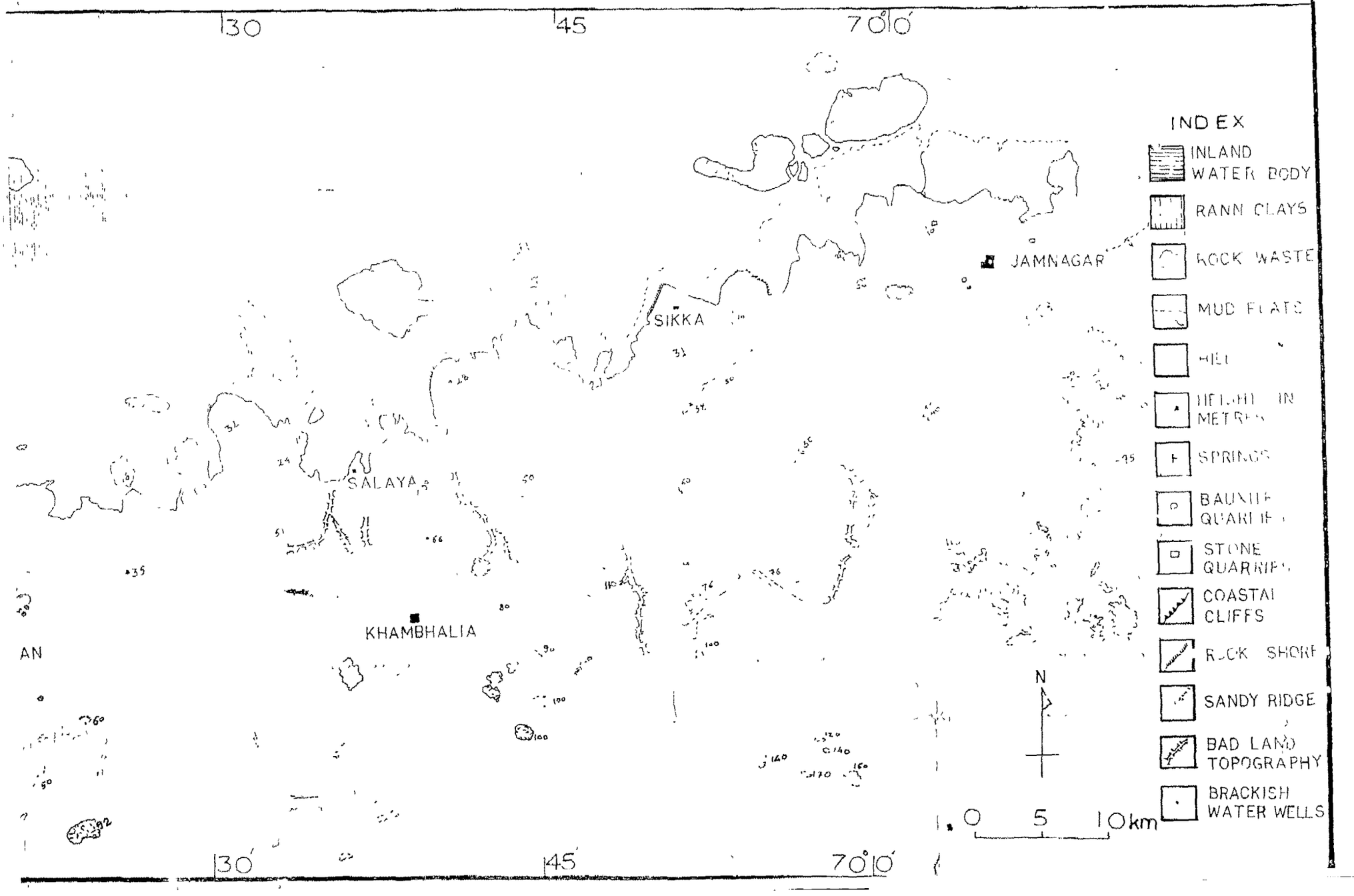


FIG 1.2

PHIC MAP OF THE STUDY AREA



2) South-eastern Deccan Trap hills

This physiographic division forms a central divide for the drainage of Saurashtra as a whole, rivers and streams flowing to north and south. This elevated terrain extending almost E-W, is dotted by hills and serrate mountain ridges of Deccan Trap. The prominent hills are the Barda (717 m), Alech (300 m), Delasa (300 m) and Gop (357 m). The hill range that extends parallel to the latitude $22^{\circ}5'$ N has a number of peaks of the height more than 200 m, it is from this range that the major rivers like Nagmati, Sasoi, Ghi, Phuljar etc. originate. Barda hill complex is a concentric group of hills and its conical shape indicating a volcanic origin of central type.

The trap hills are mainly of denudational type and are covered by patches of dense forest. Sloping down northwards from these hill ranges, the terrain gradually merges into the coastal plains. The elevation of this gently sloping plain varies from a few m to 75 m at the maximum. A major part of this plain is covered by agricultural land, but is dotted with small trap hillocks of 50 to 100 m height.

3) Elevated table land of Okha Mandal

This westernmost physiographic division is geographically separated from the Mainland by the Okha Rann. More or less semicircular in shape, it suddenly rises to a height of 10 to 40 m. The area adjoining the Arabian Sea around Dwarka is marked by a prominent shore cliff and rocky undulating coastal plain. The eastern border facing the Okha Rann is almost a straight line extending roughly NNE-SSW and is marked by cliffs ranging between 30 m to 40 m in height,

1.3 CLIMATE

The Jamnagar district has a semi-arid to arid climate. Though the area is close to the Tropic of Cancer, it being surrounded by waters of the Gulf of Kutch and Arabian sea, the temperature variation is slightly less than that of typical arid climate (Table I.1). Maximum temperature in May-June is about 35°-36°C which sometimes goes as high as 44°C. In winter months of December-January, the temperature ranges from 6° to 7°C, it may occasionally go down as low as 3°C. The month of May is the hottest and January is the coldest month of the year. Winter season lasts usually from the middle of November to the end

Table I.1 : Max. & Min. Temperature from 1961 to 197[illegible] at Dist. Head Quarters Statistics [illegible]

Month	1961		1962		1963		1964		1965		1966		1967		1968		1969		1970	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	[illegible]	7.2	[illegible]	4.1	[illegible]	[illegible]	[illegible]	[illegible]	32.5	[illegible]	[illegible]	[illegible]	[illegible]	2.1	[illegible]	4.4	32.0	4.6	[illegible]	[illegible]
February	[illegible]	[illegible]	[illegible]	10.0	32.5	[illegible]	[illegible]	[illegible]	34.5	[illegible]	[illegible]	11.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.4	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	11.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.5	36.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	17.6	39.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	24.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	36.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
October	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
November	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

of February and is not severe. Northerly and easterly cold winds blow over the region during winter season. Summer follows from March to the middle of June, when the winds blow, mainly from west and southwest. During summer, storms are uncommon. The period from mid. June to September constitutes the south-west monsoon (Table I.2). The average annual rainfall is around (Jamnagar 470 mm, Dwarka 370 mm, Okha 360 mm), 360 to 470 mm (Table I.3). Quite often insufficient rainfall causes famine conditions. July is the wettest month, while during the rest of the monsoon period, rains are scanty, the rainfall being about 40-60 mm. October and November months form the post monsoon transition period from rainy to cold season characterised by hot and oppressive days and cool night breezes after midnight.

So far as humidity is concerned, being a coastal area, it is rather high and averages beyond 60% throughout the year. During the south-west monsoon, it goes upto 85%. In winter when the air is dry the humidity is minimum, as low as 32% (Table I.4 a).

Table No. I.2 : Monthly Rainfall 1961 to 1970 at Dist. Headquarter Station
(in milimetres)

Month	YEAR									
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
January	-	-	-	2.5	12.0	-	-	3.6	-	-
February	-	-	-	-	-	-	-	2.2	-	-
March	-	-	-	-	-	-	33.3	0.8	-	-
April	-	-	-	-	-	-	-	-	-	-
May	-	-	-	-	-	59.8	-	-	-	21.6
June	168.3	3.9	4.3	123.3	-	139.4	180.8	10.7	72.2	68.4
July	283.2	88.9	29.2	183.2	202.7	-	502.7	98.5	236.0	213.2
August	344.5	119.0	34.2	227.9	101.6	2.3	41.6	265.5	18.8	278.5
September	151.2	68.9	69.7	30.0	-	59.1	2.2	5.5	0.3	96.5
October	5.1	-	83.9	-	-	-	-	1.3	-	56.6
November	-	2.5	56.4	-	3.0	-	-	-	3.6	-
December	-	-	-	-	-	-	12.0	-	-	-
Total	952.3	283.2	277.7	566.9	319.3	260.6	772.6	383.1	285.9	734.8

Table No. I.3 : Actual Annual Rainfall in the District.

Sr.No.	Year	Rainfall in mm
1.	1961	952.3
2.	1962	283.2
3.	1963	277.7
4.	1964	566.9
5.	1965	319.3
6.	1966	260.6
7.	1967	772.6
8.	1968	383.1
9.	1969	285.9
10.	1970	734.8
11.	1971	558.5
12.	1972	265.5
13.	1973	481.1
14.	1974	207.7
15.	1975	404.3
16.	1976	In Dwarka 240.0
17.	1977	346.6
18.	1978 upto October	399.0

Table No.I.4a : Monthly humidity percentage upto Oct. 1978

Location	Month									
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Jamnagar	75%	70%	80%	95%	85%	80%	90%	95%	80%	55%
Dwarka	80%	75%	84%	90%	95%	81%	84%	85%	80%	70%
Okha	70%	90%	90%	90%	90%	85%	85%	95%	80%	65%

Table No. I.4b : Temp. values in degree centrigrade January to Oct. 1978

Location	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.	
	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn	Mx	Mn
Jamnagar	28	6	28	13	34	17	35	22	38	-	35	25	32	26	28	23	31	22	37	17
Dwarka	26	16	27	18	27	20	31	24	34	27	32	27	30	27	29	26	30	25	34	24
Okha	25	19	25	19	27	22	31	23	33	-	33	27	-	-	29	25	30	25	31	25

Monthly rainfall in mm January to Oct. 1978

Jamnagar	-	-	-	Total = 500 mm	-	-	-	-	-	
Dwarka	-	-	2	-	-	236	57	-	75	12
Okha	-	-	5	-	-	218	45	-	65	-

I.4 VEGETATION

From the vegetation point of view, the study area can be divided into three subdivisions : the shore, the coastal belt and the arid and semiarid sub-coastal plain (including the hilly terrain)

1) Shore area

There are three main types of shores namely sandy, rocky and muddy. The sandy shore shows two main zones- foreshore and backshore. Lower foreshore area is occupied mainly by algae and certain marine angiosperms. Moist sandy upper foreshore is without any vegetation, while (Table I.5) drift-line area which is rich in organic matter is inhabited by Sisuvium portulacastrum. Sandy backshore shows Impmoea pes-carpae in abundance on elevated flats or steep beaches forming mats. Other plants noted in the area in order of abundance are Cyperus arenarius, Launaea sarmantosa, Borreria articularis and Boerhavia diffusa. In addition, following plant species are also noted: Psilostachys sericea, Hydrophylax maritima, Halopyrum mucronatum etc.

Table No. I.5 : Typical sandy coastal situation in Saurashtra (After Rao and Shanware, 1967)

Shore					Coast			Arid/Semi arid sub-coastal plain
Fore shore			Back shore		Extension of back shore conditions			
Lower Intertidal	Upper area	Drift line	Sandy flat and bar (Strand/ Dune habitat	Sand dunes	Sandy flat Extension	Slacks	Back dune	
Shallow Reef Sandy algae or Marine angiosperms	Moist sandy No vegetation	Rich in organic matter Sesuvium, Portulacastrum	Sandy bars/ dunelets	Dunelets		Saline or Fresh water mixed flora	Aerva javanica, Laptadenia pyrotechnica, Aristida funiculate	Gravelly sandy or Lateritic Euphorbia nivulua, Zizyphus nummularia, or Hypaene indica or crops.

A typical rocky shore consists of a wave-cut exposed rocks directly facing the sea and in such cases, the foreshore is free of sandy beaches and is mainly formed of limestone reef followed by rock pools and boulders of different shapes and sizes. This intertidal zone is full of algae and animals. Rocky slopes facing the sea are without any angiospermic vegetation. In the holes and crevices which are often filled with sandy soil are found to grow Atriplex stocksii, Fagonia cretica, Polycarpaea spicata and Statice stocksii exhibiting scattered distribution and rarely forming definite communities. The summit areas which are of limited width and composed of weathered rocky flats with numerous pot holes (holding sand) form a rocky strand zone, and support plants like Anaphalis cutchica, Enicostema hyssopifolium, Fagonia cretica, Kickxia ramosissima, Lindenbergia urticaefolia, Portulaca quadrifida, Pavonia patens, Pulicaria angustifolis, Sporobolus diander and Statice stockssi. Because of the increased accumulation of sand in the backshore area the vegetation in this part is a mixture of coastal and inland plants, and comprises shrubby plants like Capparis eartilaginea, Calotropis procera, Jatropha gossypifolia, Zizyphus nummularia

Tephrosia purpurea. A number of annual and perennial herbs like Alysicarpua monilifer, Convolvulus glomeratus, Glinus oppositifolia, appear in between these shrubby plants (Table I.6).

Muddy shores which are periodically flooded with tidal water are shallow, depressed regions protected from open sea currents. The foreshore of the muddy flats are exposed under low tide and completely submerged under high tide. In this area are found dominant thicket forming plants of Avicennia marina var. acutissima with innumerable pneumatophores. With the upwelling towards the land-side, the ground is covered by Aleuropus lagopoides, Cynodon dactylon, Atriplex stocksii, Salicornia brachiata, Suaeda fruticosa and Urochondra setulosa (Table I.7).

2) Coastal belt

The region just behind the shoreline forms the coastal belt and its physiography is influenced by the nature of the shore. Active sandy shores and marshes sometimes extend their influence beyond the shoreline and simulate the sandy or muddy shore conditions. Under these situations the flora is repetitive but less pronounced. The coastal belt is usually found to be occupied by Capparis decidua, Calotropis procera, Enicostema hyssopifolium, Senra incana and others.

Table No. I.6 : Typical rocky coastal situation in Saurashtra (After Rao and Shanware, 1967)

Shore			WAVE CUT COASTLINE	Coast			Sub-Coastal Plain			
Fore shore		Back shore		Seaward cliff with pot holes	Summit Rocky flat-Rocky strand	Rocky sandy strand	Arid		Subarid	
Shallow reef Algae or Marine angiosperms	Rock pools	Fallen boulders of varied size Algae		Polycarpaea, spicata, Statice stocksii, Kickxia ramosissima, Andrographis echiotides, Lindenfergia urtieaefolia		Capparis cartilaginea, Calotropis procera Aerva lanata, Polycarpaca corymbosa, Indigofera cordifolia, Latebrosa, Haylandia	Alluzum Saline Acacia nilotica	Gypsophilous Euphorbia nivulia	Alluvium Saline Hyphaene indica Acacia nlotica Butae monosperma	Lateritic Cotton millets

Table No. I.7 : Typical muddy coastline (after Rao and Shanware, 1967)

Shore	SINKING COAST	Coast				Sub coastal plain	
		Mangrove under protection	Salt pans	Muddy flats	Saline flats		
Shallow water under tidal influence		Avicennia marina var acutissima	Nil	Salicornia brachiata Urochondra setulosa	Suaeda fruticosa Alriplex stocksii	Arid or alluvial soil (saline) Acacia nilotica Euphorbia nivulia	Semi arid lateritic crops Cotton, Millets

3) Arid and semi-arid sub-coastal plain

This comprises the outermost inland area adjoining the coastal belt, which is away from direct marine influence. In this area, at certain places mixed scrub forests are developed. Components of such forests in the arid parts are Acacia nilotica var. indica, Commiphora weightii, Grewia tenax, Prosopis juliflora, Lycium europaecum, Maytenus emarginatus and Salvadora persica. While in semi-arid parts the landscape is covered at places by Borassus flabellifer and the other noteworthy shrubs are Aerva javanica, Butea monosperma, Solanum arundo, Zizyphus nummularia. In the arid zone Euphorbia nivulis thickets form the dominent plant community sheltering climbers like Canavalia gladiata, Luffa acutangula, Cayratia carnosa, and others. Trees like Azadirach indica, Streblus asper, Tamarindus indica, Ficus religiosa, Prosopis cineraria are found in and around the the vicinity of villages along sea coasts.

I.5 FAUNA

The area being arid, food and water supply in free state is rather scarce. Hence, the existence of wild amimals is very limited. Some animals like

fox, wild cats, etc. are seen in the south-eastern forest areas. Varieties of snakes, both poisonous and non-poisonous, are common along river sides and other reptiles like lizards, and crocodiles are encountered in the cactus forested coast.

Domestic animals like cows, buffaloes, oxen horses, goats, sheep, donkeys and camels are the major mammals used for agriculture purposes, transport and for milk production.

I.6 AGRICULTURE

The area receives a fairly low rainfall hence the agricultural production comprises mainly Kharif crops. Localised reservoirs and dug wells are the main source of water for irrigation. The potentiality of water is more in the eastern half of the area; while western half faces chronic water shortages. On this basis, cereals like jowar (Sorghum vulgaree), wheat (Triticus oostivum) bajra and ground nut, potato etc. are grown. Production of vegetables is mainly dependent on well and canal irrigation. Bajra and short living vegetables are the major productions from western arid/semi arid zones.

The concentration of villages is also higher in the eastern half of the area. Apart from agriculture, the main source of livelihood is the raising of cattle, sheep and rearing camels.

I.7 POPULATION

The total population of the Jamnagar District is round about 12,00,000 out of which 2/3 are rural habitants. Majority of them are Hindus, Mohammedans coming next. In the minorities are Christians, Buddhists and Sikhs etc. Density of the population decreases towards west, villages are less in number and widely scattered. Nomadic tribes are quite common in the eastern part of the area and these always keep on shifting in search of new pastures for cattles, sheep and camels.

I.8 COMMUNICATION

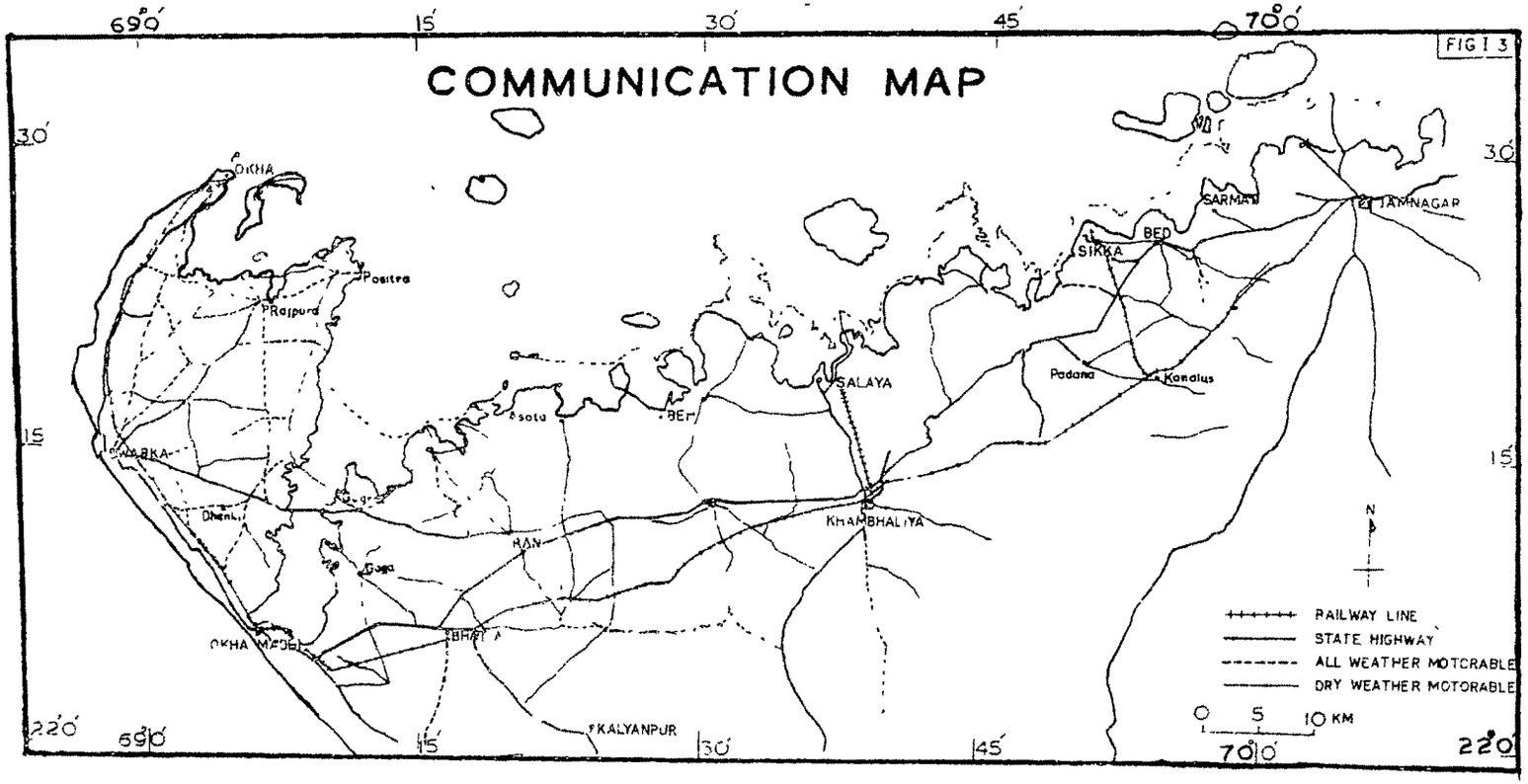
Jamnagar, the district headquarter is situated in the eastern part of the study area, quite close to the coast. It lies on the Western railway Meter-Gauge line of Mehsana-Rajkot-Okha section. Two junction stations on this line, provide branch lines to approach the coast are , 1) Kanalus to Sikka and 2) Khambhaliya to Salaya. Okha Madhi-Dwarka-Okha rail section is quite close and parallel to the coastline.

No National Highway passes through the area but a good State Highways aggregating about 578 km connect major towns and taluka places in the district. The various district roads and village roads are all-weather motorable roads and connect the various ports with the State Highway (Fig.1.3).

The Indian Airlines flights connect Jamnagar to Bhuj and Rajkot. At present following ports are in use : Jodiya, Bedi, Sikka, Salaya, Pindara, Dwarka (Rupen), Okha and Beyt. The ports are mainly used for transport of goods for internal as well as foreign markets.

I.9 SCOPE AND METHOD OF INVESTIGATION

The present study comprises a systematic investigation of the coastline geology and geomorphology and evaluation of terrain attributes like landforms, topographic features, water regime, trafficability, soil cover, vegetation etc. The investigation included 1) a precise geological mapping, 2) study of depositional environments of the coastal sediments, 3) drainage analysis, 4) comparison of morphometric parameters of the various drainage basins, 5) ground water conditions and 6) salinity affected areas.


COMMUNICATION MAP
FIG I 3
69°0'
15'
30'
45'
70°0'
30'
15'
22°0'
OKHA
Positra
Rajpura
SALAYA
Padana
Kanalus
SIKKA
BED
SARMAN
JAMNAGAR
KHAMBHALIYA
KALYANPUR
OKHA MADHI
N
RAILWAY LINE
STATE HIGHWAY
ALL WEATHER MOTORABLE
DRY WEATHER MOTORABLE
0 5 10 KM

Along a coastline of 250 km long, a large variety of geomorphic features in various stages of development were observed. The spot studies by actual field work were restricted upto the low water line, and offshore studies were mainly based on the bathymetric charts and by collecting information from other agencies like "Biological Research Station", Okha; Meteorological Department and personal discussions with the Kandla Port authorities.

Topographic features giving the evidences of tectonic activities on land and in the Gulf were also studied. The airphotos were used for marking these features. The observations made from airphotos were correlated with toposheets and checked in the field. Bathymetric studies were also conducted using airphotos, and inferences were checked in the field as well as correlated with Naval Hydrographic Chart.

Studies of creeks in relation to their depth during high tide and low tide, width, velocity and direction of currents, natural protection from winds, storms and rainfalls were also studied to locate suitable sites for all-weather sheltered ports along this coastline.

The knowledge of geology of the area has been utilised to study geological impact on distribution, orientation of channel segments, formation of drainage pattern and basin development. Evidences and effects of tectonic disturbances on the basins and topographic features were also studied.

The work was conducted mainly on the latest Survey of India Maps (1 : 50,000) and on airphotos of the same scale (1 : 50,000) (Lens with focal length 6 inches and flight height 25,400 - 25,500 feet). The inferences drawn were checked in the field by personal visits. Morphometric analyses were carried out in the laboratory. The investigations were carried during the winter months of the year 1976 to 1978, the aggregate time spent was 12 weeks. The various steps of investigation comprised the following :

The author divided the entire area into two zones each corresponding to a distinct lithologic unit, and also showing distinct morphometric characters. The author carried out, morphometric analysis for the two basins.

Collection of maps and aerial photos of the study area; reference work on different aspects of this study including collection of background information.

Study of drainage from 1:50,000 Survey of India (1970 Edition) maps; measuring gradient and length of channels, marking different orders of channels, calculating relative relief; measurement of areas by graphical methods for different order channel basins and plotting these values on single log paper against stream order on horizontal abscissa.

Interpretation of airphotos through mirror stereoscope; different features on land; tracing underwater stream channels on the basis of tonal variation; measuring of actual length of these channels and the depth of channel ends in the gulf; marking the thickly forested and vegetated areas on the land; finding out water table condition in that particular area and location of the area marking the presence of springs north of Ran., indicated by dark toned vegetation around it; mud flats and Rann clays with smooth plain surfaces having uniform tone. These geomorphic features were checked in the field. Detailed stereoscopic study of aerial photos before and after every field check was done to mark additional details; preparing typical stereopairs for illustrations.

Field work was done mainly to collect all geological details and to check and confirm the inferences and observations, based on stereoscopic studies of aerial photos, and was aimed at studying geomorphic and tectonic processes operating in the area, particularly 1) uplifts and subsidences, 2) faulting and folding, 3) the effects of river erosion, 4) effects of coastal erosion and deposition, 5) features developed on the coast, 6) action of waves and tidal currents, 7) type of vegetation and forests, 8) coastal cliffs and 9) tidal channels. Karst topography, wave cut caves, blow holes, natural bridges and stacks are the features that cannot be seen on airphotos, hence they were located and studied in the field itself. The nature of the coastline has been evaluated.

I.10 PREVIOUS WORK

The geological studies on the peninsula of Saurashtra have been carried out by several workers over a period of more than hundred years. Most of them have worked mainly on geology with some economic aspects. Very few of them have described geomorphology and its related aspects.

Some of the earliest workers were Huge (1836), Falconer (1845), Theobald (1857), and Blanford (1869), who made sporadic observations on the geology of the Saurashtra peninsula. Carter (1849) described the fossil Echinoidea from the formations of Okha Mandal. Fedden (1884) carried out intensive field work and studied the Saurashtra peninsula in detail and his work was published as a Memoir of the Geological Survey of India. He clearly recognised and described the major stratigraphic units of the Saurashtra peninsula. From the Teritary formations he described a large number of fossils and fixed the position of Gaj and Dwarka formations. He gave the following table describing the rock formations and their approximate ages :

Formation	Approximate Geological Age
Alluvium, tidal flats sand dunes, Rann clays raised beaches etc. and Miliolites	Holocene, Recent and sub Recent
Dwarks Beds	?Higher Tertiary or post Pliocene
Gaj Beds	Upper Pliocene (Lower Manchar in part and Gaj of Sind)
Lateritic Rocks	?Lower Eocene (Subnumulitic of Kutch and? high level laterite of Deccan).
Traps	Cretaceous, Eocene (Deccan traps).

Oldham (1893) described some Mesozoic (Dhrangadhra) rocks of Saurashtra as Kathiawar beds. Evans and Chapman (1900) gave an extensive account of the Miliolites and their microfossil content. Adye (1914) published his geological report as a memoir on the "Economic geology of Navanagar (Jamnagar) State". Sinor (1927) described the petrology of the igneous and sedimentary rocks of Bhavnagar territory, and this account was included by Vinayak Rao (1930) in his report to the Geological Survey of India. This led to various geological investigations by Ghosh (1936), Crookshank (1940) and Dunn (1942) in the Gogha area.

Fox (1931) suggested Upper Gondwana age to Kathiawar beds and Cretaceous age to Wadhawan formation. Pascoe (1959) gave a detailed account of the Mesozoic rocks of Saurashtra.

Several workers have studied the Deccan Trap rocks of the Saurashtra peninsula. The main credit goes to Blanford (1867), Fedden (1884), Chatterjee (1932), Krishnan (1962), Auden (1949) and West (1958).

Bruce Foote (1938) gave a rather brief account of the geomorphology and geology of the rocks of Okha Mandal Taluka. The fossil studies of the Gaj were done by Duncan and Sladen (1938). They also carried out chemical

analysis of some of the limestones and physical properties of rocks. Mohan & Chatterjee (1956) described the Miocene beds in the coastal region and discussed their stratigraphic position on the basis of the forminifera content.

Shrivastava (1968) described the geology, stratigraphy and geological history of the peninsula of Saurashtra in his unpublished O.N.G.C. Report. According to him the stratigraphy of the geological formations in Saurashtra is as under :

Name of Rock Unit	Lithology	Thickness in metres	Facies	Geological age
Alluvium	Alluvium, black cotton soil; coastal sand dune; Rann salt waste; coral reef, laterite etc.	7-7.6	..	Recent and sub-recent
	UNCONFORMITY			
Porbandar formation	Dirty white, oolitic, sandy limestone and calcareous sandstone; occational grits, conglomerates and thin clay bands	30	Littoral	Pleistocene to sub-recent
	UNCONFORMITY			
Dwarka formation	Silty clay occasionally gypseous; yellow calcareous clays and marls. Top portion-arenaceous limestones with broken shell fragments.	32	Littoral to epineritic	Uppermost Miocene to Pliocene
	UNCONFORMITY			

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Name of Rock Unit	Lithology	Thickness in metres	Facies	Geological age
Gaj formation	Hard fossiliferous grits; conglomerates with clay marl layers	40	Epineritic	Lower Miocene
	UNCONFORMITY			
Lateritic rocks	Red and brown hard laterite with white patches, sometimes bauxite with volcanic ash and tuffaceous material	10-15	Residual deposit	Lower Eocene
Deccan trap formation	Basaltic flows associated with some acidic lavas. Plutonic masses and dykes intrusive in the trap flows and Mesozoic formation	600(+)	..	Upper Cretaceous to Lower Eocene

E. Ahmad (1972) pointed out for Saurashtra a remarkable straight shore of emergent aspect (southwest) and a highly irregular inner shore of submergent aspect (Northern) associated with indentations of all sorts; lagoon, lakes and numerous islands within them. The shore line of the Gulf of Kutch particularly its southern shore, is very indented despite the low level plain surface of the

coastal interior and has submergent aspect indicated by marked indentations, deep inlets, number of offshore islands and several estuarine river mouths.

Gupta (1976) suggested that the coral reefs and raised beaches on the Saurashtra coast were remnants of high sea level strands. Further he says that sea level in the Saurashtra coast during interglacial around 120,000 years before present and interstadial around 30,000 years before present and 6000 years before present had reached about 2-6 metre higher than today.

The miliolite rocks of southwestern and southern coast, though not encountered in the study area have considerable importance from the point of view of eustasy and neotectonism. Ever since they were described several decades back by Carter (1849), Fedden (1884), and Chapman (1900), these pelletoidal and oolitic carbonate rocks rich in a variety of foraminiferal shells, have remained controversial. The origin of their vast accumulations along the coastal areas as well as inland, have been taken to be either marine or aeolian. The aeolian-marine controversy is more for the high level occurrences.

While Carter (1849), Fedden (1884), Foote (1898), Shrivastava (1968a, 1968b), Lele (1973), Mathur & Mehra (1975), Mathur (1978), and Varma & Mathur (1978) have considered many of the high level miliolites to be of marine origin; Chapman (1900), Biswas (1971), Glennie (1970) and others invoked aeolian origin for many of the inland miliolites. By and large, however, it has been generally agreed that the originally marine deposits, have been reworked by strong winds and deposited as coastal dunes and obstacle dunes, during the emergence of the coastline. The miliolites, thus, provide a good example of the emergence of the SW and S coast of Saurashtra during the Quaternary.