CHAPTER I

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

PURPOSE AND SCOPE

The vast stretch of the coastline, overlooking the Arabian Sea and extending from Koteshwar in Kutch to Umbargaon in South Gujarat, covering a length of 1663 km is unique in many ways. It marks a terrain wherein during the Quaternary period, the processes of neotectonism and eustasy have operated in different combinations on the rocks of various geological ages, and provides an interesting diversity in the coastal environments prevailing in its different segments. The geomorphological characteristics of the coastline ideally reveal the complex interplay of the various environmental and geological

processes that have been operating since the beginning of the Cenozoic Era.

The different coastal segments of Saurashtra and Mainland Gujarat have preserved within them a fascinating record of the various Neogene and Quaternary episodes, and the diversity which marks the various segments is typically reflected in the coastal geomorphology, sediment types and the microfauna. By and large, the Gujarat coastline has evolved during Pleistocene and Holocene epochs and the present day coastal features and deposits, have preserved within them a fairly faithful account of successive Quaternary events of tectonism and sea-level changes. It has been observed that the coastline not only shows diversity in its geology, geomorphology, seciment nature, but its different segments are marked by quite distinct microfaunal assemblages. It is also seen that a close relationship exists between the prevailing coastal ecology and the geological controls like the coastal configuration, processes of erosion and deposition and their intensity. Not much work has been done on this coastline in the past. Though it did receive some attention in respect of its geologic and geomorphic aspects, no serious attempt has been made by any one to investigate in detail the microfauna of the Gujarat coast. The present study, which pertains to the Holocene (including Recent) coastal sediments of Saurashtra and Mainland Gujarat not only aims at describing the microfaunal assemblages encountered in the different parts of the coast, but it also deals with a critical evaluation of the various natural

processes operating in offshore and onshore areas that have indirectly controlled the ecological conditions of the coastal waters. The present investigation thus comprises an analytical account of the diversity in the microfaunal assemblages encountered in the various coastal segments bringing out the close relationship that exists between the geological processes and the coastal environments. As already stated, the Gujarat coast is marked by striking diversities. The Saurashtra coast mostly comprises a rocky shoreline with sluggish streams carrying low detrital load; a large part of the coast is open to Arabian sea thereby being expcsed to strong surf action. In contrast, the Mainland Gujarat coast is marked by numerous detritus laden rivers, a large part of which is a low energy coast overlooking the Gulf of Carbay. The different segments of the two coastal blocks themselves differ considerably as a result of which, the coastal ecology also varies from one part to the other. Interestingly, these are adequately reflected in the microfauna.

Any microfaunal study, especially of a coastal area, without appropriate understanding and evaluation of the direct and indirect factors influencing the faunal characteristics can never be complete, and it is with this conviction, that the present author has investigated the microfaunal content of the coastal deposits of Saurashtra and Mainland Gujarat. Her studies were appropriately supported by an appraisal of the three most relevant factors controlling the coastal ecology,

viz., the morphology of the offshore and onshore areas, nature of coastal sediments and energy conditions. Certain other factors like climate, currents and sea-level fluctuations that have influenced the distribution of faunal assemblages, were also taken into account. The whole approach being geomorphology-oriented, the author had to work out an appropriate methodology for her studies. Her approach to the problem comprised studies on the following lines:

1. A critical evaluation of the geology and geomorphology of the coastline, including backshore and foreshore features, and features of the inner offshore continental shelf zone.

2. Investigation of the beach sediments occurring along the different coastal segments with special reference to their bulk lithology and heavy mineral content.

3. Appraisal of the meteorological conditions (rainfall, temperature, wind direction and velocities etc.) and nature of onshore and longshore currents.

4. Detailed microfaunal studies of the beach and tidal mud deposits including those of the estuarine river mouths.

In order to achieve the above objectives the author's strategy of investigation consisted of the following steps :

1. Study of all available previous information on geology, geomorphology anc micropalaeontology of Saurashtra coast and the Mainland Gujarat.

2. Study of the Survey of Incia Toposheets (1 : 50,000 and 1 : 250,000 scales).

3. Field trips to all accessible parts of the coastline for collecting field data and sediment samples.

4. Laboratory studies of the sediments from the lithological and microfaunal points of view.

5. Interpretation of results.

LOCATION, GEOGRAPHICAL LIMITS AND IMPORTANT PORT TOWNS

The present study is restricted to the coastline of Saurashtra and Mainland Gujarat, which comprises northern portions of the West Coast of Incia (Fig. I.1). The coastal terrain investigated is restricted between Rozimata (22^{o} $33^{'}$: 70^{o} $3^{'}$) (Jamnagar) in Saurashtra and Umbargaon (20^{o} $35^{'}$: 72^{o} $45^{'}$) (Valsad) in South Gujarat, the geographic limits of which are marked by N. latitude 20^{o} to 22^{o} $30^{'}$ and E. longitude 68^{o} $45^{'}$ to 73^{o}.

The coastline is dotted all along with a number of small port-towns, which are known for various seafaring activities. The Jamnagar (Bedibandar) port overlooking the Gulf of

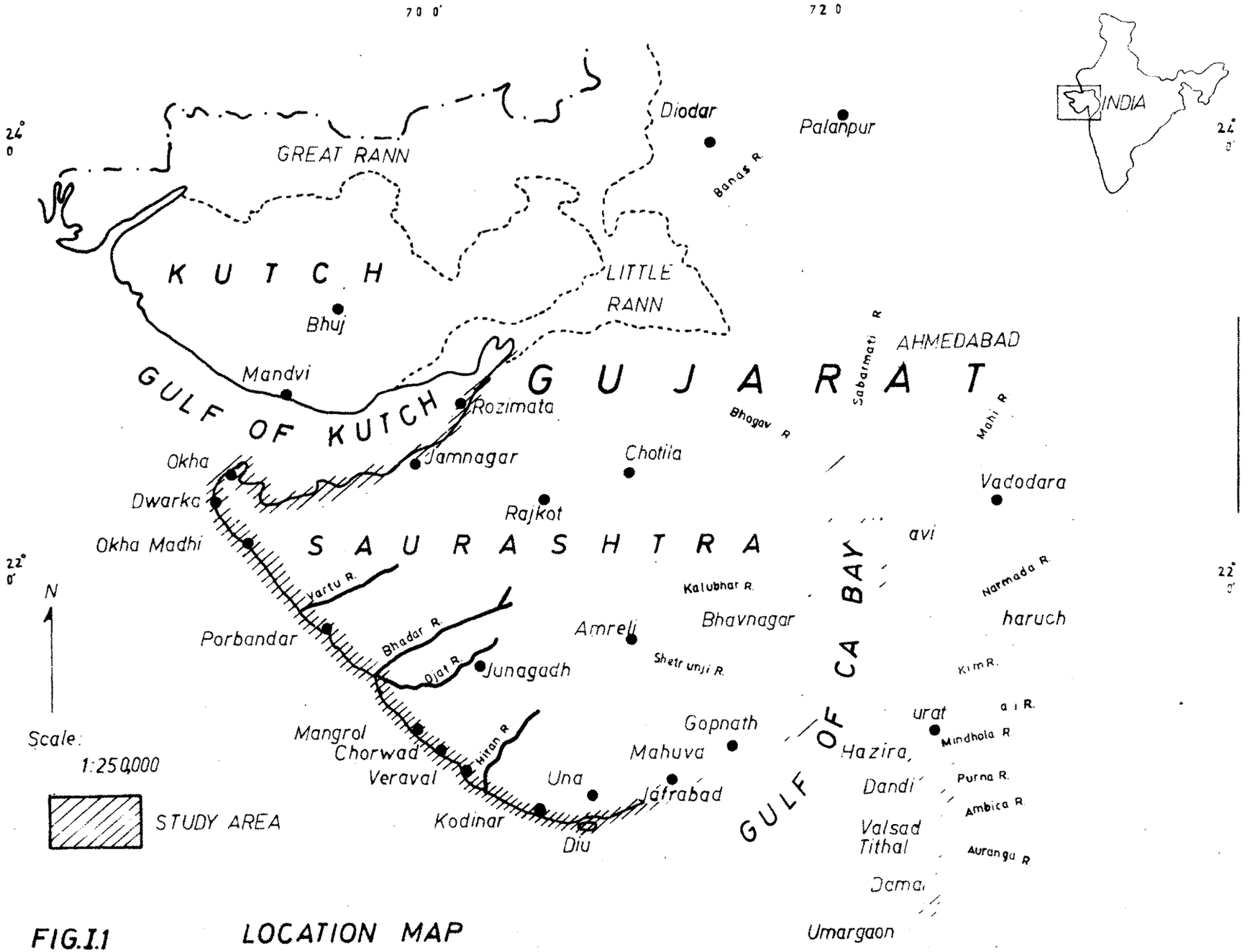


FIG.I.1 LOCATION MAP

Kutch, is not only one of the major towns of Saurashtra, but it is important from the point of view of location of numerous industries as well as of Naval and Airforce Stations. The Okha port at the tip of the Saurashtra peninsula is noted for fishing and other numerous industries. The port town of Dwarka on the western coast of Saurashtra is a famous Hindu pilgrimage centre. Further south, the coastal town of Porbandar is again known for various industries, cement as well as chemical. Along the Saurashtra coast in the southwest and west, smaller ports like Mangrol, Kodinar, Veraval, Una, Mahuva etc. essentially support considerable fishing activities. Bhavnagar facing the Gulf of Cambay, is again a small port which is used for coastal trade and navigation with the Mainland Gujarat.

On the Mainland Gujarat, the ports are relatively few and the noteworthy ones are those of Dahej, Bharuch, Surat, Bilimora, Valsad, etc.

All these ports in the historical past have provided considerable international trade on a limited scale. Also, these have served as fishing centres. In recent years, the port towns of Hajira and Magdalla are coming into prominence on account of the setting up of fertilizer and cement industries.

TOPOGRAPHY AND DRAINAGE

From the point of view of topography and drainage characteristics, the coastline provides considerable diversity. The Saurashtra coast is quite distinct from that of the Mainland Gujarat. Also, the various coastal segments within the Saurashtra and Mainland Gujarat are quite different from one another in their physiography and drainage.

The coastal terrain of Saurashtra, on the basis of physiography can be divided into two categories as under :

1. The northern coast of Saurashtra overlooking the Gulf of Kutch characterizes a typical rocky submergent coast, devoid of any steep gradient. The coastal plains rise gently inward culminating into the central trappean highlands, showing an altitude rise of 700 m. The actual shoreline is highly crenulated, characterized by mudflats and coral reefs. The rivers along this coastal block flowing from north to south show a distinct control of a combination of slope and N-S lineaments.

2. The western and southern coastline overlooking the Arabian Sea is somewhat different. The coastal plains are almost gradientless and covered by residual soil, laterite, Tertiary sediments and Quaternary deposits. Unlike the northern coast, it is straight and fringed

by continuous beach sands. Most of the rivers that drain this coastline flow along trappean lineaments. On account of the lack of gradient, these streams hardly carry any sediments. This coast has been a site of biogenic carbonate sand accumulation since the beginning of the Quaternary and provides an example of an emergent carbonate coast.

The Mainland Gujarat coast is quite different. Its northern half is almost exclusively an alluvial coast while the southern half gradually becomes rocky. The coastal terrain to the north of river Narmada is seen to comprise very thick Quaternary alluvium; the actual shoreline is marked by steep alluvial cliffs against which abut wide tidal flats. This north Mainland coast is dissected by three major rivers viz. Mahi, Dhadhar and Narmada. The rivers Mahi and Dhadhar flow across the alluvium, carving out entrenched meandering valleys. To the south of Narmada river, the alluvium in the coastal areas is thinner, cliffs are absent and the shoreline is characterized by discontinuous coastal sand ridges. Beyond the river Auranga the coast is rocky, and at Umbargaon and beyond Umbargaon the actual shore area is made up of exposed basalt. The rivers to the south of Narmada, barring Tapi, are of smaller dimensions, show typical meandering cliffy banks.

CLIMATIC CONDITIONS

From the climatic point of view the coastal areas of Saurashtra and Gujarat show an interesting diversity. The region of Gujarat as a whole points to climatic conditions that mark a transition from the arid Rajasthan to highly wet Deccan coast.

The state lies within the monsoon area and the rainfall period is confined to four months from the middle of June to the middle of October. The coastal areas of Gujarat receive most of their rainfall from the southwest monsoon; monsoon breaks in June, reaches its maximum intensity in July and tapers off towards the end of September, October month marked only by occasional showers. The amount of total annual rainfall varies considerably from one part of the coast to the other. The southernmost part receives as high as 2000 mm of rainfall. The decrease in the amount of rainfall northward is rather abrupt and in less than 100 km north of Bulsar, it dwindles to almost 1000 mm at Surat. Thereafter, the rainfall shows a gradual decrease northward so much so that in the northern part of the Mainland coast, the rainfall is between 700 to 800 mm.

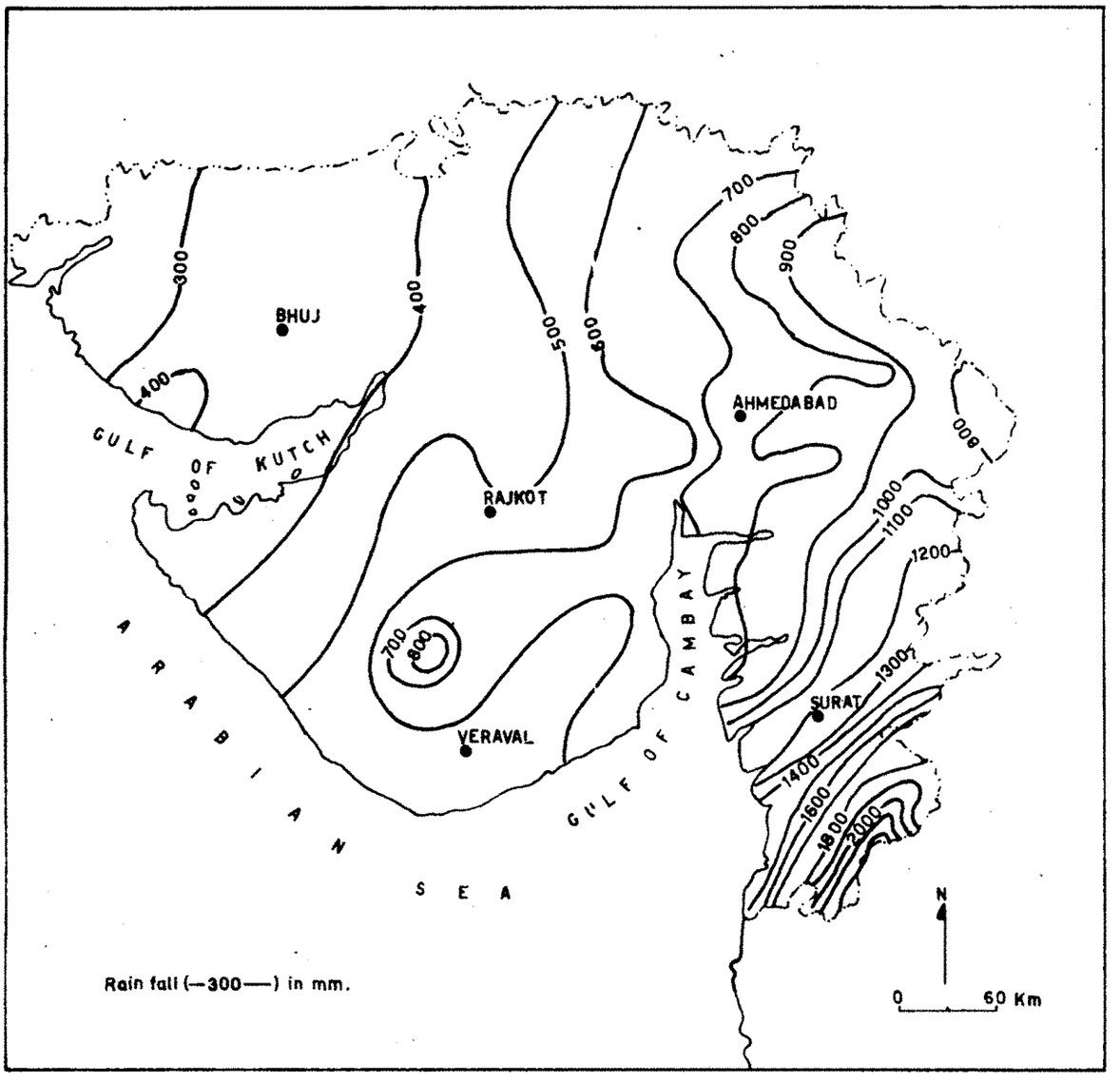
Almost the whole of Saurashtra coast receives relatively a low rainfall, varying from 400 to 700 mm. A progressive decrease in the rainfall is observed from south

to north. The north Saurashtra coast as well as parts of west and southwest coast of Saurashtra receive a rainfall less than 400 mm. The accompanying map (Fig. I.2) gives an idea of the rainfall pattern of Gujarat coast.

The temperature conditions in Gujarat, also show marked variations. The north Gujarat temperatures are high as compared to the coastal areas of central and southern Mainland as well as those of Saurashtra. Between Saurashtra and Mainland there is not much significant temperature difference and it appears that the temperatures are relatively low along the entire coastline. Obviously the meridian influences modify the temperature conditions, the sea breezes penetrating to several kilometers inland lowering the temperature and their ranges. The seasonal variations of temperature are given in the accompanying map (Fig. I.3). Though the Relative Humidity in other parts of Gujarat State is low, along the coastal areas, it is moderately high all the year round, being maximum in summer and monsoon months. Some idea of the annual Relative Humidity percentages for the coastal areas can be obtained from following average data based on the climatological observations of the Indian Meteorological Department from 1930-1960.

Jamnagar	70 %
Veraval	69 %
Bhavnagar	56 %
Bharuch	71 %
Surat	71 %

Fig. I. 2



RAINFALL MAP OF GUJARAT

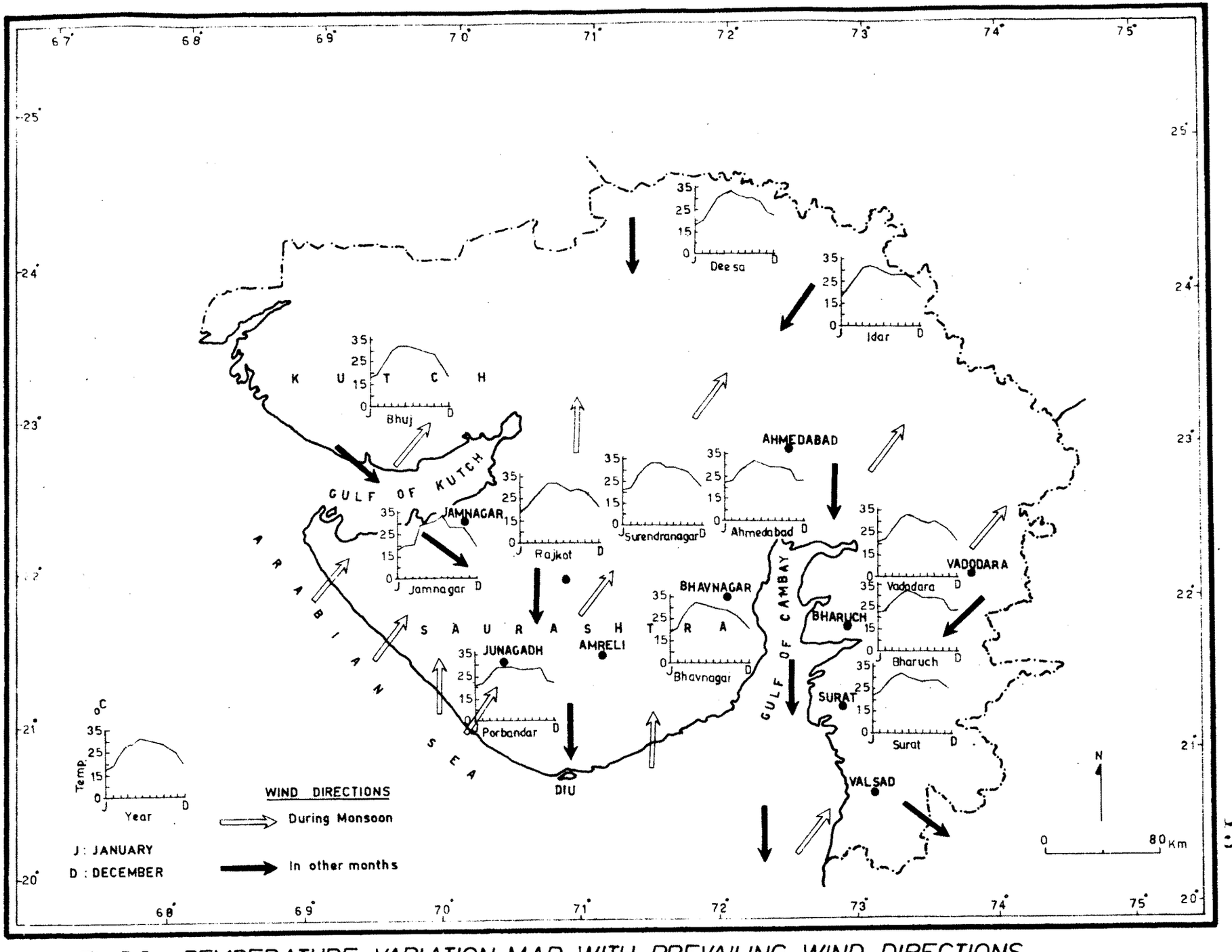


Fig.I.3 TEMPERATURE VARIATION MAP WITH PREVAILING WIND DIRECTIONS

The above values, however, considerably exceed during the summer and monsoon, and they could even go as high as 90 % .

In comparison to the inlard areas, the Gujarat coastline experiences stronger winds especially during the monsoon season. During the monsoon months, winds blow mostly from ~~west~~ south and south-west, while during the months of October to April, the winds blow from north, north-east to north west and are relatively weaker. Anidea of the seasonal wind directions (1930-60) are shown in Table nos. I 1.2.3.4 & 5 & Fig. I.3.

VEGETATION

The coastal vegetation shows much diversity which is controlled by the landforms, the nature of sediments, the chemical constituents and pH of the soil. The coastal flora on the whole shows a mixture of saline and inland type. The soil being less nutritive, the flora is rather scanty. Along the north-west, south west and south Saurashtra coast, as the sediments are rich in $CaCo_3$ the vegetation is dominated by thorny shrubs of Acacia nilotica, Euphorbia nerifolia, Commiphora wighetti, Grewia tenax, Lycium barbarum, Maytenus emarginata and Salvadora persica. The east coast of Saurashtra has a lateritic soil and supports a flora dominated by Aerva persica, Butea monosperma, Solanum trilobatum, Calotropis procera and Hyphaene indica.

Table I-1 : Wind directions (Jamnagar)
(based on the Meteorolcgical Observatory Data)

Wind Direction		N	NE	E	SE	S	SW	W	NW	Calm
January	I	10	21	17	11	10	4	2	3	22
	II	42	27	2	0	0	1	16	12	0
February	I	7	11	9	8	11	11	8	5	30
	II	33	20	0	0	0	0	29	18	0
March	I	8	7	3	2	6	21	20	9	24
	II	16	9	0	0	0	6	52	17	0
April	I	7	2	1	1	2	26	38	13	10
	II	8	2	0	0	0	1	73	16	0
May	I	3	0	0	0	3	36	47	7	4
	II	2	1	0	0	0	1	86	10	0
June	I	2	0	1	1	4	40	40	5	7
	II	1	0	1	2	5	14	65	12	0
July	I	1	1	1	1	3	47	37	3	6
	II	2	1	1	1	3	22	63	7	0
August	I	1	0	0	0	4	47	36	4	8
	II	0	0	0	0	1	18	72	9	0
September	I	1	0	0	0	4	36	32	8	19
	II	3	1	0	0	2	8	68	18	0
October	I	5	6	6	4	5	14	16	7	37
	II	28	8	2	0	1	2	30	28	1
November	I	7	26	1	0	0	0	6	13	32
	II	54	20	19	13	8	2	1	0	0
December	I	10	29	3	0	0	0	9	10	27
	II	49	7	6	4	6	24	23	6	0
Average	I	5	7	6	4	6	24	23	6	19
	II	20	10	1	1	1	6	47	14	0

I - First half of the month, II - Second half of the month.

Table I-2 : Wind directions (Dwarka)
(based on the Meteorological Observatory Data)

Wind Direction		N	NE	E	SE	S	SW	W	NW	calm
January	I	26	51	11	2	0	1	2	4	3
	II	22	21	4	0	0	2	9	42	0
February	I	33	21	4	0	0	3	9	14	4
	II	13	28	8	0	0	3	25	48	0
March	I	28	9	2	1	0	6	22	29	3
	II	5	3	1	0	0	5	42	44	0
April	I	14	2	1	1	1	17	36	27	1
	II	2	0	0	0	0	44	56	28	0
May	I	2	0	0	1	2	41	43	10	1
	II	0	0	0	0	2	35	55	8	0
June	I	1	1	1	1	4	46	42	4	0
	II	0	0	0	0	3	51	44	2	0
July	I	1	1	0	1	1	45	49	2	0
	II	0	0	0	0	2	59	47	2	0
August	I	0	0	0	0	1	43	50	5	1
	II	0	0	0	0	0	45	51	4	0
September	I	63	1	0	1	2	32	44	14	0
	II	11	0	0	0	1	30	54	21	10
October	I	26	14	3	3	3	6	14	21	10
	II	9	5	2	0	1	6	31	26	0
November	I	28	43	15	3	1	0	2	5	3
	II	20	21	5	0	0	1	9	44	0
December	I	20	53	18	2	0	0	1	3	3
	II	26	25	5	0	0	1	7	36	0
Average	I	15	17	5	1	1	20	26	12	3
	II	8	7	2	0	1	20	36	26	0

I - First half of the month, II - Second half of the month.

Table I-3 : Wind directions (Veraval)

(based on the Meteorological Observatory Data)

Wind Direction		N	NE	E	SE	S	SW	W	NW	Calm
January	I	35	47	4	1	0	0	1	5	7
	II	6	5	1	3	9	15	35	25	1
February	I	42	30	2	1	0	0	1	12	12
	II	2	1	0	1	8	14	47	27	0
March	I	46	13	1	0	0	0	3	29	8
	II	1	0	0	1	3	7	52	36	0
April	I	30	4	0	0	1	4	11	46	4
	II	1	0	0	0	2	9	54	34	0
May	I	7	0	0	1	4	16	33	34	5
	II	0	0	0	1	3	16	60	20	0
June	I	2	0	0	2	6	28	48	11	3
	II	0	0	0	1	7	34	52	6	0
July	I	1	0	0	0	1	25	63	9	1
	II	0	0	0	0	0	27	64	8	0
August	I	2	0	0	0	1	23	60	11	3
	II	0	0	0	0	1	21	68	10	0
September	I	10	13	1	1	4	11	37	23	10
	II	1	0	0	1	2	13	58	24	1
October	I	35	24	5	2	1	1	3	19	10
	II	1	2	1	5	12	13	36	29	1
November	I	25	54	8	1	0	0	0	3	2
	II	1	2	1	11	25	22	24	12	9
December	I	26	57	5	1	0	0	0	3	8
	II	5	5	1	8	15	13	31	21	1
Average	I	22	19	2	1	1	9	22	17	7
	II	2	1	0	3	7	17	48	21	1

I - First half of the month, II - Second half of the month.

Table I-4 : Wind directions (Bhavnagar)
(based on the Meteorological Observatory Data)

Wind Direction		N	NE	E	SE	S	SW	W	NW	Calm
January	I	0	2	1	0	1	11	33	20	22
	II	11	35	29	9	3	2	2	5	4
February	I	8	1	1	1	2	16	39	17	15
	II	8	29	28	14	5	4	4	6	2
March	I	10	2	0	1	2	15	36	23	11
	II	5	22	26	20	11	4	4	6	20
April	I	10	2	2	2	5	17	29	30	3
	II	3	11	15	27	24	11	3	4	2
May	I	3	0	0	1	7	30	42	16	1
	II	2	3	4	14	54	25	12	6	0
June	I	1	1	0	1	8	39	41	7	2
	II	1	1	1	9	29	39	16	4	0
July	I	1	0	0	1	5	45	43	4	1
	II	0	1	1	4	14	42	33	4	1
August	I	1	0	0	1	8	42	40	6	2
	II	1	1	1	6	15	40	31	4	1
September	I	2	0	0	1	3	31	44	16	3
	II	2	3	4	18	19	26	19	6	3
October	I	11	3	2	2	3	9	26	22	22
	II	7	27	24	21	9	4	2	2	4
November	I	12	4	2	2	1	6	24	19	30
	II	10	42	24	11	2	0	0	1	10
December	I	10	0	1	0	1	9	33	22	24
	II	11	43	28	7	2	0	1	3	5
Average	I	6	1	1	1	4	23	36	17	11
	II	5	18	15	13	14	17	11	4	3

I - First half of the month, II - Second half of the month.

Table I-5 : Wind directions (Surat)
(based on the Meteorological Observatory Data)

Wind Direction		N	NE	E	SE	S	SW	W	NW	Calm
January	I	21	28	13	6	1	1	1	7	22
	II	10	10	1	1	1	15	17	40	5
February	I	16	24	10	11	3	1	2	8	25
	II	5	8	1	0	3	22	17	40	4
March	I	13	18	6	16	7	5	3	9	23
	II	6	3	0	1	4	30	18	37	1
April	I	9	9	3	10	17	18	6	10	18
	II	3	1	0	1	8	47	15	25	0
May	I	3	1	0	3	19	45	11	7	11
	II	1	1	0	0	21	65	8	5	0
June	I	0	1	1	7	20	49	13	3	6
	II	0	0	0	1	23	68	6	1	1
July	I	0	0	1	5	13	53	18	3	7
	II	0	0	0	0	17	73	8	1	1
August	I	0	0	1	2	9	57	19	5	8
	II	0	0	0	0	13	76	9	1	1
September	I	3	1	2	7	7	26	21	13	21
	II	2	1	1	1	12	65	11	5	2
October	I	6	20	19	18	4	5	2	15	21
	II	6	18	7	4	6	24	11	18	6
November	I	6	31	35	12	1	0	0	1	14
	II	9	29	9	3	1	11	11	18	9
December	I	14	34	23	5	1	0	0	5	18
	II	11	19	4	1	1	6	14	35	9
Average	I	8	14	9	9	8	22	8	6	16
	II	4	8	2	1	9	42	12	19	3

I - First half of the month, II - Second half of the month.

The raised mudflats of Saurashtra coast with a loamy and sandy soil support a thorny shrub and Xerophytic vegetation dominated by Euphorbia nerifolia, Opuntia elatior and Prosopis spicigera.

The muddy seashore along Bhavnagar has a fairly good mangrove growth, the main constituents being Avicennia alba, Avicennia marina var. acutissima, Suaeda nudiflora, Acanthus ilicifolios, Bruguiera conjugata and a few varieties of grasses along the channels.

Some of the relict alluvial patches within the mudflats overlooking the Gulf of Cambay support thorny shrubs such as Acacia nilotica, Prosopis spicigera, Argemone mexicana, grasses and few herbs in monsoon.

Along the Gujarat Mainland coast again, the different coastal landforms are characterized by distinct flora. In between river Mahi and river Dhadhar, the coastal alluvial cliffs are marked by species of Acacia, Zizyphus, Xanthium, Cassia, Tephrosia.

Southward the alluvial soil reduces, rainfall increases affecting the vegetation. The vegetation is of two types semi-arid and moist types, and consists of Hyphaene indica, Phoenix sylvestris, Borassus flabellifer, Cassia auriculata, Butea monosperma, Salvadora persica, Acacia nilofica, Acacia chundra,

Tectona grandis, Cassia fistula, Emblica officinalis, Zizyphus xylopyra, Achyranthus aspera, Barleria Prionitis.

The flora of sandy ridges and dunes south of Narmada comprises Ipomea pes-caprae, Portulaca oleracea. The stabilized dunes support Zizyphus nummularia, Cyperus arenarius, Spinifex spicigera.

Vegetation of the river channel mouth deposits which are under tidal influences is dominated by succulent herbs or shrubs like Suaeda fruticosa, Portulaca oleracea, Tamarix gallica, Heliotropium supinum, Eclipta erecta.

COMMUNICATION AND TRANSPORT

The entire coastline is well connected with the major cities of the State by a network of highways and all weather roads. The National Highway No.8 and 8 B, a number of State Highways and District Roads, together with Broad gauge and Meter gauge Railways, provide ideal communication facilities. The National Highway No.8 (Bombay-Delhi) runs via Valsad, Navsari, Surat, Bharuch and Baroda, while No. 8 B extends to Porbandar. The various State Highways criss-cross through and connect ~~port~~ port all major cities of the study area. From the State Highways, emerge a number of local roads which connect practically all the villages. The nationalised passenger road

transport is managed by Gujarat State Road Transport Corporation, popularly known as 'ST' service. The Broad gauge line of the Western Railway connects the major cities of the Mainland Gujarat, viz. Ahmedabad, Baroda, Surat, Navsari and Valsad with Bombay. The coastal cities of Saurashtra are well linked by numerous Meter gauge railway lines.

Indian Airlines flights connect Jamnagar, Porbandar, Keshod, Bhavnagar and Baroda with Bombay and Delhi. Jodia, Bedi, Sikka, Salaya, Okha, Porbandar, Veraval and Bhavnagar are the smaller ports which are at present in use. These ports are mainly used for the transport of goods for internal as well as foreign markets. In Gujarat the various minor ports, used for carrying goods by sailing vessels and motorships are those of Dumas, Valsad, Umarsadi, Kolak, Maroli, Daman and Umbargaon. Ferry boats are used to cross Tapi, Narmada, Kalai, Damanganga Kolak, Auranga and Par rivers. In very near future Dahej-Ghogha Ferry Service is to be started and with that, the distance between Saurashtra and Mainland Gujarat will be considerably reduced.