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CHAPTER I

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

PURPOSE AND SCOPE

The West Coast of India provides fascinating diversity in the coastal environments prevailing in its different parts. From south to north its different segments are marked by their own distinct sets of onshore and offshore environmental parameters. The West Coast, especially in its northern part which falls within the limits of the Gujarat State is much more interesting and the Gulf of Khambhat which forms an important coastal segment comprises a very interesting and unique feature. The funnel shaped Gulf dividing the Mainland Gujarat coast from that of Saurashtra provides a baffling picture of coastal marine processes involving extensive

transport, deposition and redistribution of sediments. Relatively shallow, the Gulf waters have been found to be rough, characterised by high tides and strong tidal currents. Although the Gulf of Khambhat is easily accessible from all sides, surprisingly it has practically remained uninvestigated in terms of its intriguing coastal geomorphology and offshore and onshore coastal marine processes.

The Gulf of Khambhat comprises an area characterised by strong and powerful tidal action, marking a site where the tide-rise is the highest along the West Coast. The high and low tides during different parts of the season in combination with the extensive addition of the detritus-laden waters of the rivers of Mainland Gujarat have generated a very complex pattern of erosion and deposition of sediments since the advent of the Quaternary period. The Gulf waters are always churning up the sediments, constantly rearranging them by tidal currents. Today also one does not really know how the sediment-laden waters of the Gulf behave. Not much is known about the various offshore processes and their interaction with the shoreline.

In recent years some studies on the geological and geomorphic aspects of the coastal areas overlooking the Gulf have been carried out by the Oil & Natural Gas Commission (ONGC) and the Department of Geology, M.S. University of Baroda. However not much information is

available on the offshore environment and on the precise controls exercised by the various shallow marine processes on the evolution of the coastal landscape. No doubt, the geology and gemorphology of the Gulf coast is closely related to the processes of sea level changes, neotectonism, fluvial regimes of the surrounding areas and the erosional and depositional processes operating along the coastline and within the Gulf waters.

The present thesis is an endeavour towards understanding the Gulf of Khambhat especially from the point of view of what is happening today and what happened in the immediate geological past, the approach being essentially that of a geologist. It is observed that the various onshore and offshore features have been brought about mainly during the Quaternary times, the factors responsible for the diversity being those related to geology, geography and climate, and include (1) tectonic set up, (2) eustatic and neotectonic sea-level changes, (3) lithology of the geological formations, (4) shape and size of the Gulf, (5) shallowness of the Gulf, (6) trends of the coastline segments, (7) rainfall, (8) wind directions and temperature, (9) fluvial regimes, and (10) action of tides and waves. This investigation has aimed at understanding the controls exeercised by these factors to obtain a clearer picture of the offshore and onshore processes that

have contributed towards the evolution of the Gulf. The study is first of its kind, its scope is rather wide, the main purpose being that of collecting and putting together some vital information on the Gulf. The present study thus includes a critical appraisal and evaluation of the various geo-environmental parameters of the coastal areas which include geological, geomorphological and geohydrological characteristics as well as the offshore conditions prevailing in the Gulf. The various sections of the coastline overlooking the Gulf are so diverse in their terrain features that each section presents its own distinctive geologic and geomorphic characteristics. Not only the coastline geology and geomorphology is interesting and varied, but the geohydrological conditions prevailing in the coastal areas show marked diversity. The offshore investigations comprised (i) studies on tides, currents and waves, (ii) mode and pattern of sediment transport and (iii) lithological, mineralogical and genetic aspects of the sediments. Obviously, in such a case scope of investigation has to be very broad-based and the diverse methodologies have to be followed involving a variety of approaches. His contribution has to be viewed keeping in mind two constraints, viz. (i) lack of adequate previous information and (ii) the hazardous nature of the Gulf waters from the navigational point of view.

The present author has been able to generate a

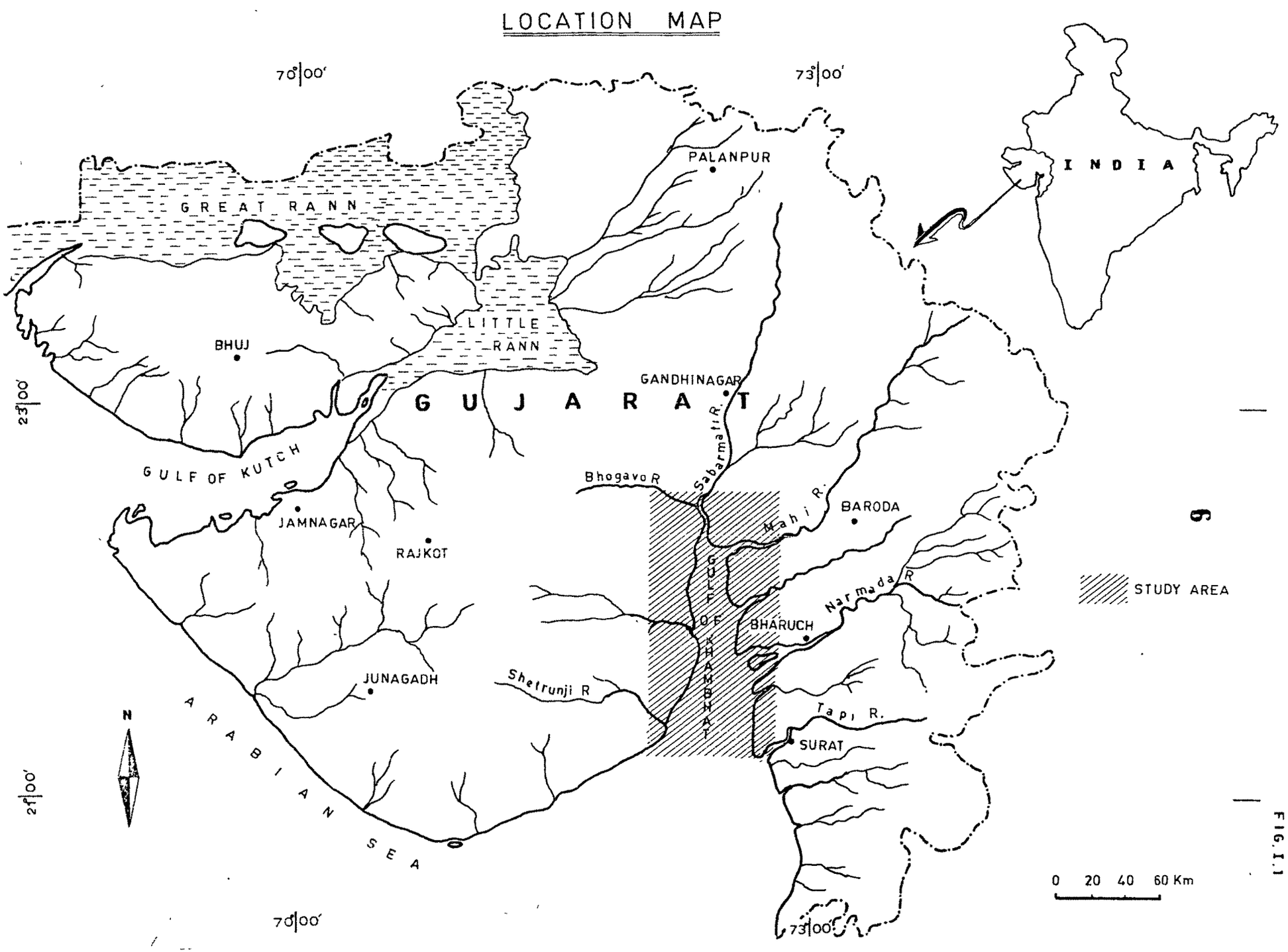
a reasonably good amount of data which for the first time provides an insight into the prevailing environments in and around the Gulf of Khambhat.

GEOGRAPHIC LOCATION AND SALIENT FEATURES OF THE GULF

The Gulf of Khambhat forms a funnel shaped entrant of the Arabian sea sandwiched between the Gujarat Mainland, and the Saurashtra Peninsula (Fig.1.1). It opens up into the Arabian Sea rather abruptly, and is located in the widest portion of the West Coast continental shelf. It is 50 km in its widest part along its southern limit and is approximately 135 km long in the north-south direction.

Geographically the limits of the study area are marked by N latitudes 21°05' and 22°30' and E longitudes 72°00' and 72°55', and covered by the Naval Hydrographic Chart No.254, and Survey of India Toposheets No.46 B and C.

The Gulf of Khambhat though comprising a very small portion of the West Coast provides a fantastic geoenvironmental diversity. This funnel shaped narrow sea inlet forms a Quaternary coast with very well defined geological and geomorphological features in its different onshore segments and is marked by equally complex offshore processes.


LOCATION MAP
70°00'
73°00'
PALANPUR
INDIA
GREAT RANN
LITTLE RANN
BHUJ
GANDHINAGAR
GUJARAT
23°00'
GULF OF KUTCH
Bhogavo R
Sabarmati R.
Mahi R.
BARODA
JAMNAGAR
RAJKOT
GULF OF KHAMBHAT
Narmada R
BHARUCH
JUNAGADH
Shetrunji R
Tapi R.
SURAT
N
ARABIAN SEA
21°00'
70°00'
73°00'
STUDY AREA
0 20 40 60 Km
FIG. 1.1

The geological set up of its western flank is distinct from that of the eastern. The coastal segment that overlooks the Gulf from the Saurashtra side is made up of thin Tertiary and Quaternary sequences resting over the basalts of the Deccan Trap. In contrast, the Mainland Gujarat coast facing the Gulf is made up of fluvial sediments of considerable thickness; nowhere hard rocks are encountered on the surface along the coast.

Geomorphically too, the Saurashtra coast is quite distinct from that of the Mainland. On the Saurashtra side the coast rises rather gradually ~~in~~ landward, and is characterised by vast intertidal deposits. The rivers that flow into the Gulf from Saurashtra are sluggish and carry small quantities of water and sediments. On the other hand, the Mainland Gujarat coast is alluvial dissected by big rivers (Narmada, Mahi, Dhadhar, Tapi etc.) ~~and~~ with cliffy river mouth banks. The rivers carry a lot of water and also bring vast quantities of sediments every year.

The offshore environment is equally interesting. The Gulf marks a protected area with less wave action but is influenced by very high tides. In fact, tides in the Gulf of Khambhat are highest along the West Coast. The waters of Gulf heavily loaded with the fluvial sediments brought from the Mainland side as well as with the Gulf sediments, constantly churned up by the tidal currents of the Gulf. The extreme muddiness of the Gulf waters and the complex interplay between

the tides and river water flow has resulted into an interesting assemblage of depositional landforms in and around the Gulf.

ECOLOGICAL ASPECTS

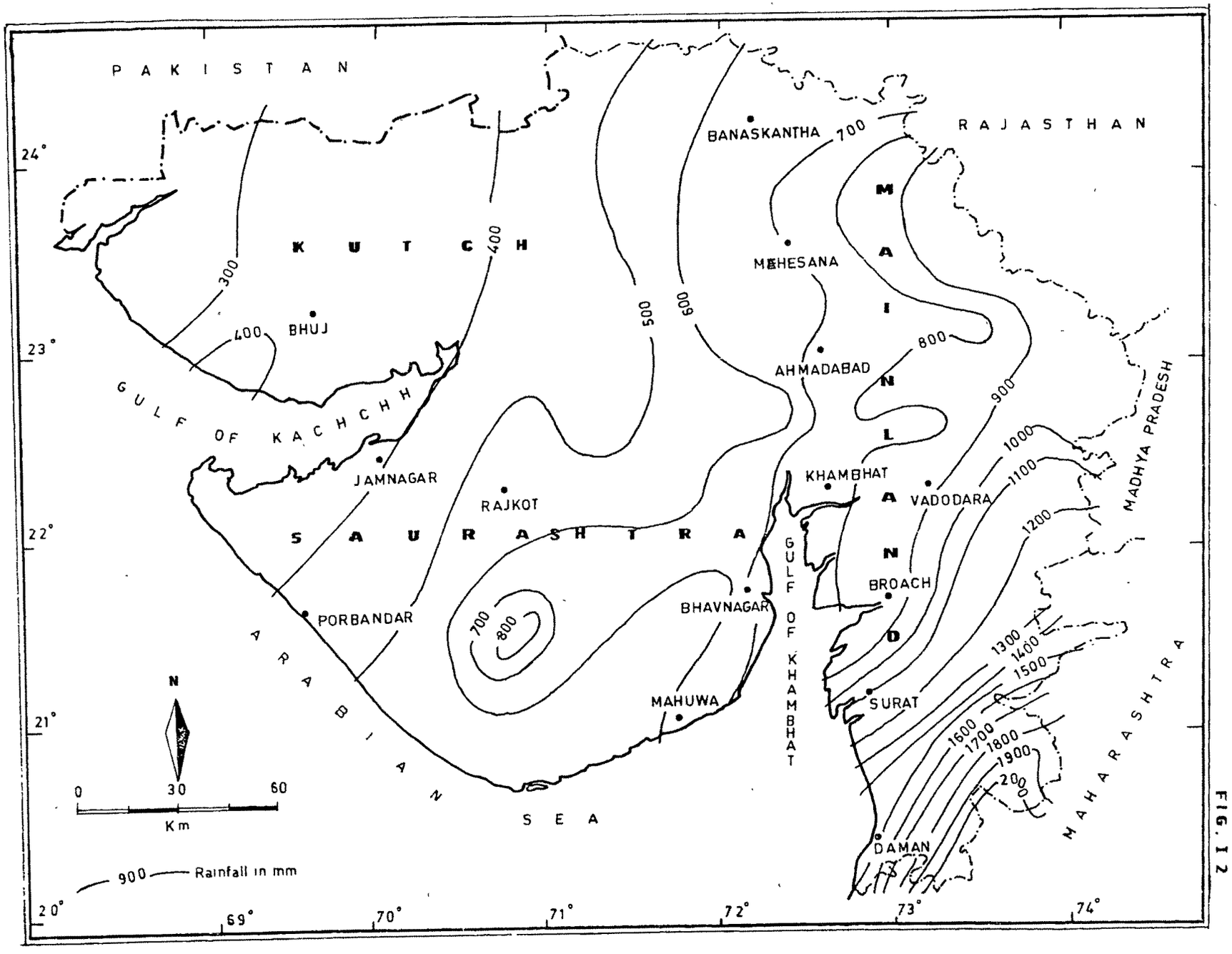
CLIMATE

The various environmental parameters namely, rainfall, temperature and wind directions, show marked variation within the limits of the Gulf from north to south and on its western and eastern coasts. Climatically, there is a distinct change from semiarid to somewhat temperate conditions. Though there may not be any significant variation in the seasonal temperatures, the Saurashtra side tends to be hotter during summer months and receives relatively less rainfall as compared to the Gujarat Mainland. The south westerly winds blow during the summer and monsoon months whereas during winter the winds blow from the north. On account of the protection afforded by the Saurashtra peninsular landmass, the effects of south westerly wind are very much inhibited within the Gulf. The meteorological conditions prevailing in the Gulf are shown in Fig. Nos. 1.2 and 1.3.

FLORA :

The vegetation of the coastline areas is of mixed type and could be categorized as follows:

1. Vegetation along the shoreline and
2. Vegetation of the coastal plains.



ISOHYETS MAP OF GUJARAT

FIG. I 2

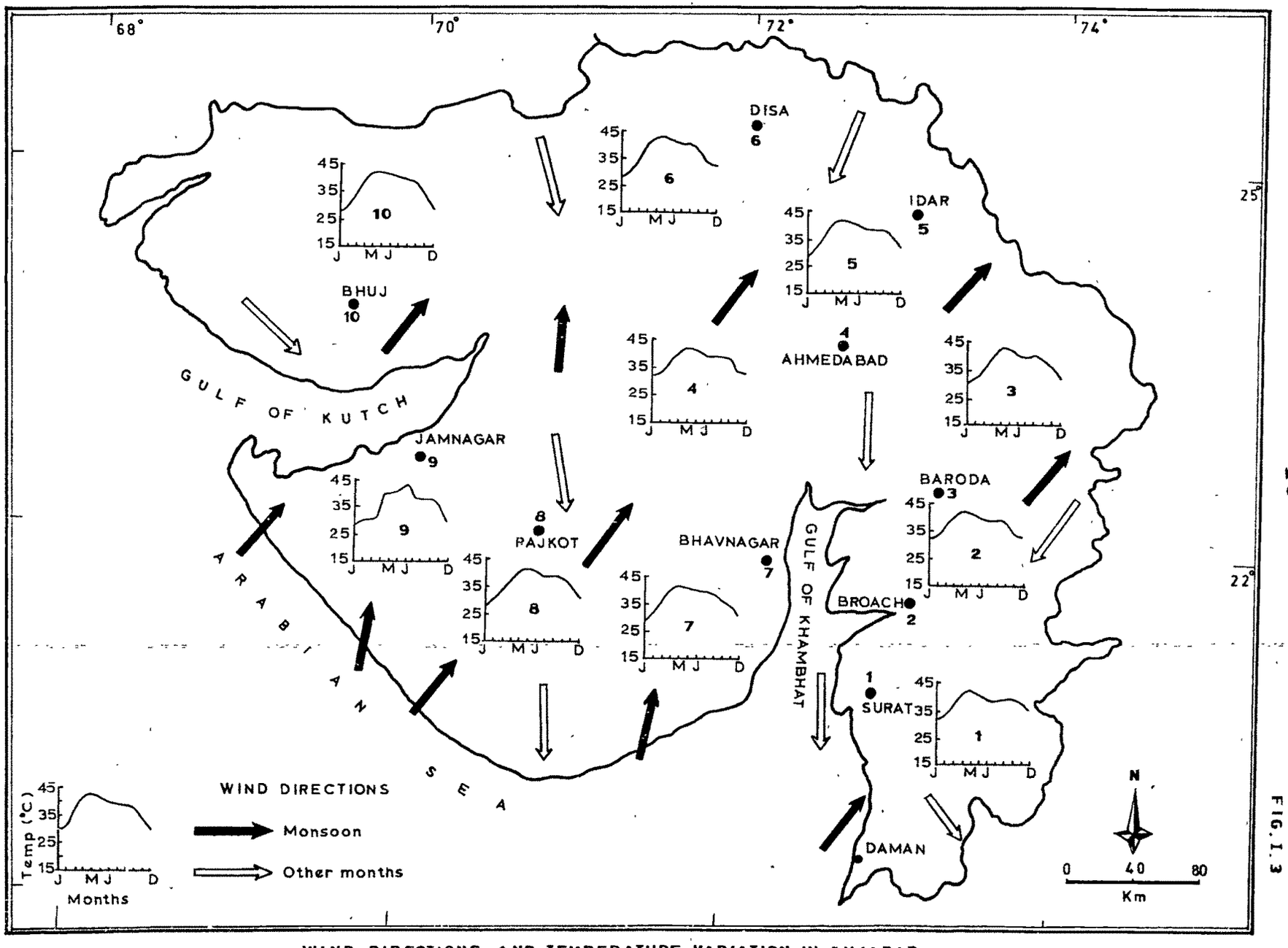


FIG. I. 3

WIND DIRECTIONS AND TEMPERATURE VARIATION IN GUJARAT

Vegetation along the shoreline

The present day mudflats are characterized by Avicennia marina, Salicornia brachiata, Acanthus ilicifolius, Bruiguiera conjugata etc. and a few variety of grasses along the channels. On the raised mudflats grow Sueda nudiflora, Prosopis spicigera, Argemone maxicana, Xanthium strumarium, Echinops echinatus etc. Cressa cretica is seen to grow in the salt pans. The sandy beaches, ridges and dunes are characterized by Ipomoea pescaprae. In dunes, Psilostachys scricea, Calotropis procera, Zizyphus nummularia and Cyperus arenarius are common. Other plants that grow in the dunes are Hydrophylax maritima, Halopyrum mucronatum, Cyperus aristatus, Sporobolus tremulus etc. Eindenbergia indica, Kickxia ramosissima, Portulae quadrifida usually grow on the rocky platforms on the Saurashtra side.

Vegetation of the coastal plains

The vegetation in the coastal plains mainly comprises shrubs, undershrubs, herbs and the climbers growing on shrubs. The most common shrub in both Saurashtra and Mainland Gujarat coast is Hyphanae indica. Other shrubs like Aerva javanica, Butea monosperma etc. and Phoenix sylvestris, Borassus flabullifer etc. are also common both on Saurashtra and Mainland Gujarat coast. Common trees are Acadia senegal, Azaderacta indica, Manilkara hexandra etc. In the relict alluvium patches grow thorny shrubs such as Acacia nilotica,

Calotropis procera, Prosopia spicigera, Argemone maxicana etc. A few varieties of grasses and herbs also grow in the monsoon.

Near the mouth of the rivers, where the mixture of sea water is more, herbs or shrubs like Suaeda fruticosa, Portulaca pleracea etc. are seen growing, Tamarix ericoides, Cyperus rotundus, Tribulus terrestris, Heliotropium supinum etc. are common on the banks where the contamination by sea water is less.

The alluvial areas support a variety of crops. Black cotton soil is very fertile and comprises richly cultivated fields of cash crops like cotton (Gossypium herbacium), groundnut (Arachis hypogea), til seeds (Sesamum indicum) etc. The loamy soil is characteristically suitable for growing fruits like mango (Mangifera indica), guava (Psidicum gujara) chickoo (Archrus sapota) and Banana.

FAUNA :

The wild life consists mainly of fox (Vulpes benegalensis), wild cat (Felis chaus), wolf (Canis lupus) etc. The other common fauna comprises tree shrew (Anathana ellioti), bat (Petropus giganteus), langoor (Prebytis entellus), pangolin (Manis crassicaudata), rat (Vandeleura bendicata), Saras (Grus antligone), titehri (Vanellus indicus), Pigeon (Columba livea), Cobra (Naja naja), Viper (Vipera russelli), cow, buffalow, donkey, ox, horses, goat etc.

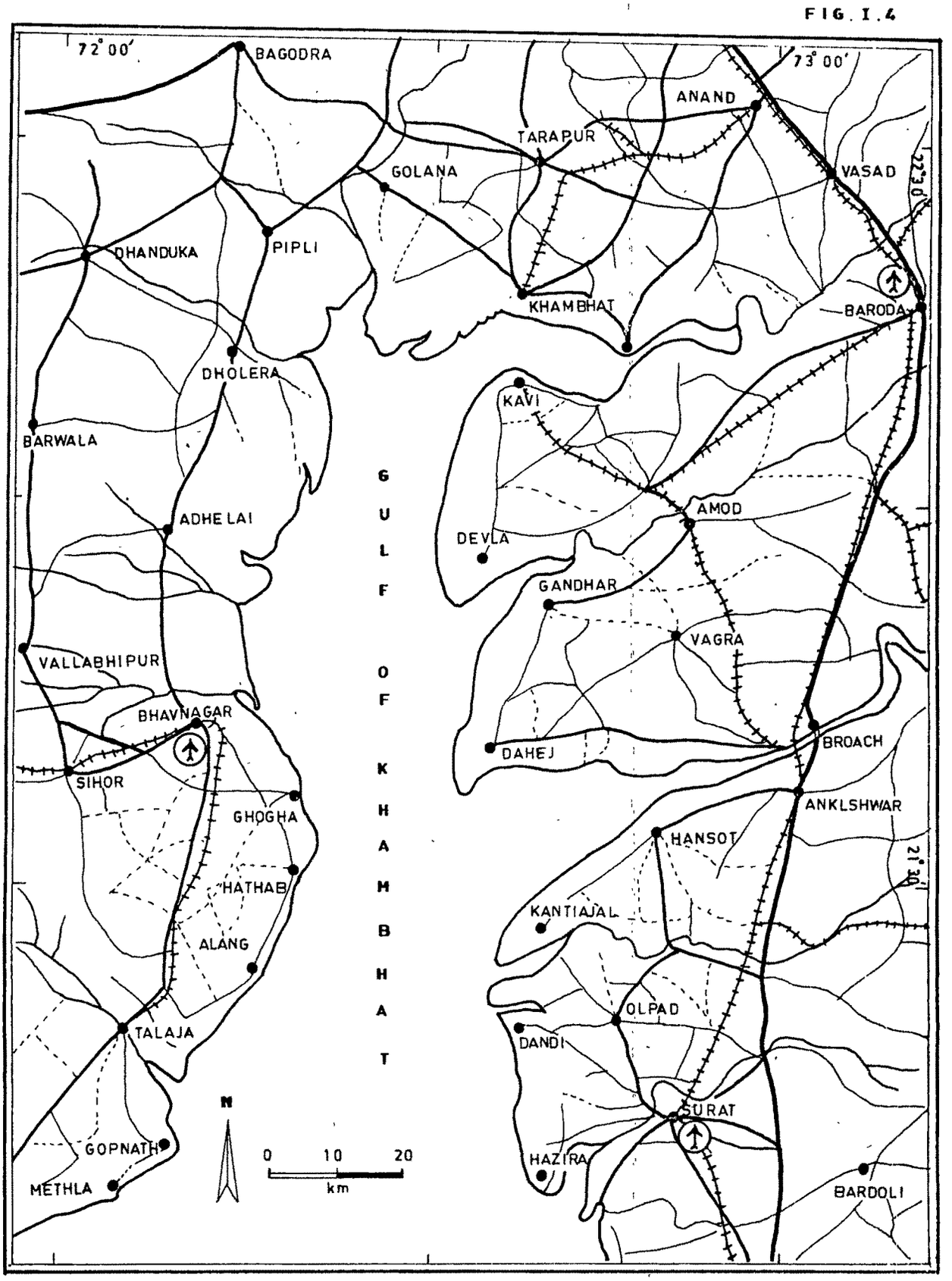
COMMUNICATION

The coastal areas of the Gulf are endowed with comparatively good communication facilities (Fig 1.4). All parts are connected with respective district headquarters through National or State highways. District roads and metalled and unmetalled roads connect all the coastal villages with the State highways. Daily bus services are made available by Gujarat State Transport Corporation to all district headquarters as well as to important coastal areas. In such coastal areas where metalled road are not present S.T.buses ply only during dry season. 'Three-wheelers', privately owned taxis and bullock carts, also find extensive use as different modes of transport. A Broad-Gauge Railway line connects the cities of Surat, Baroda and Ahmedabad. Also Meter-Gauge and Narrow-Gauge Railway lines connect coastal areas like Broach-Dahej, Baroda-Kavi, Baroda-Khambhat, Bhavnagar-Talaja etc. Daily air services are also available between Bombay-Baroda-Ahmedabad, Bombay-Bhavnagar, Bhavnagar, Ghogha and Dahej are small trading harbours.

SOCIO-ECONOMIC ASPECTS

The coastal areas of the Gulf are inhabited by a population with a variety of socio-economic conditions. In fact, the geoenvironmental extremes ranging from the most hostile to most amiable, are seen appropriately reflected in the economic prosperity or otherwise of the people. The social customs too have been influenced accordingly.

FIG. I.4



COMMUNICATION MAP OF THE STUDY AREA

On the Mainland side, between rivers Narmada and Tapi, lands are fertile, with wide scope of employment opportunities in the agricultural lands and industries. Whereas between Narmada and Mahi rivers the population is relatively less as the land is less fertile with limited sweet water availability. The main sources of livelihood are dependent upon agriculture and fishing. Quite a few skilled and enterprising people have migrated to outside areas for the purposes of better livelihood. Due to canal water supply and good agricultural lands, the inhabitants living between Mahi and Sabarmati rivers have somewhat higher socio-economic status. The rather hostile terrain conditions between the rivers Sabarmati and Bhavnagar have kept this part quite backward. Here the land is saline and rainfall is very less. This situation is reflected in the sparseness population in this region. The area south of Bhavnagar again gives favourable conditions in terms of quality and availability of water and better overall climate. This in turn, has provided better living conditions for the people.

METHODOLOGY

The present study, essentially comprising an integrated appraisal of the geological and geomorphological features of the Gulf coast and of the Gulf waters in terms of tides, waves and sediment dynamics, required formulation of an appropriate methodology.

The study undertaken by the author thus required an altogether new approach. The author had no available model before him and also he had to keep in mind the logistic and resource constraints. Hence he worked out his own approach to the study which comprised following:

I. General

(a) Study and perusal of Survey of India Topographical Sheets on scales 1:50,000 and 1:250,000, Naval Hydrographic Charts and Satellite Imageries.

(b) Perusal of all available research papers, theses, unpublished reports dealing with geological and geomorphological conditions of the coastal and offshore areas.

II. Onshore

(c) Study of the coastal landforms, coastal sediments and drainage characteristics.

(d) Appraisal of hydrological conditions including modes of occurrences of surface and subsurface water in the coastal areas.

(e) Study of intertidal sediments, both beaches as well as muds, from different parts of the coastline.

f) Study of coarser fractions to know their mineralogy.

g) X-Ray studies of the finer fractions to identify various minerals as well as to know the percentages of clay minerals.

h) Determination of the bulk geochemistry of the finer fractions.

i) Preliminary studies of selected samples under Scanning Electron Microscope (SEM).

III. Offshore :

j) Monitoring of the sediment transport in different parts of the Gulf during different seasons of the year. For this eleven observation points were fixed and samples were collected at intervals of three months.

k) The quantitative estimation of different size fractions of the tidal water sediments.

l) XRD studies for the finer fraction to identify various minerals as well as to know the percentages of clay minerals.