## CHAPTER - III

# GEOMORPHOLOGY

## GENERAL

The study area shows an array of geomorphic features (Fig. 3.1), which are the reflections of the various tectonic, erosional and depositional processes of the late Quaternary. To a casual observer, the vast alluvial plains of north Gujarat may look uninteresting and monotonous but a careful and indepth appraisal of the terrain with the help of topographical sheets, satellite imageries and field studies reveal very interesting details. Essentially comprising unconsolidated continental sediments deposited by fluvial and aeolian agencies under varying climatic

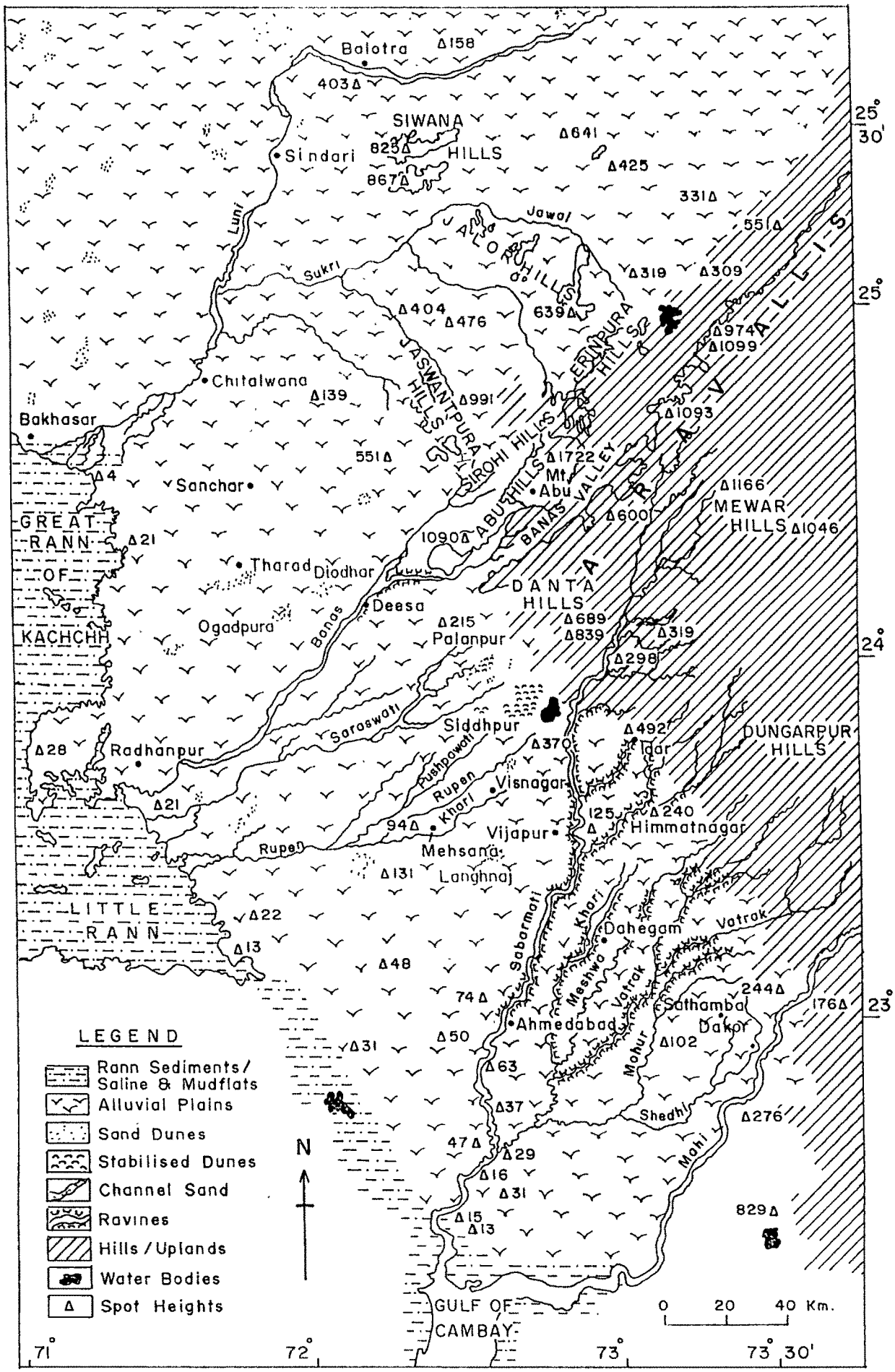



Fig. 3·1 'GEOMORPHIC MAP OF STUDY AREA

conditions, the terrain is replete with a wide variety of physiographic features. Although the present study is restricted to the deposits formed by the various north Gujarat rivers viz. Sabarmati, Rupen, Khari, Banas and Luni, to fully understand their evolutionary history, it is essential that the geologic and geomorphic settings within which these deposits occur have to be understood and highlighted.

Geomorphology is a reflection of the geology of the Gujarat region. The study area is situated in a geological setting marked by Precambrian rocks along the eastern flanks and by the Mesozoic rocks, comprising both sedimentaries as well as volcanics, marking the Western limit (Peninsulas of Kachchh and Saurashtra). The geological setting is given in Fig. 3.2.

From the geomorphic point of view the study area can be broadly categorized into 3 main NNW-SSE running divisions (Fig. 3.3); the eastern most division mainly comprising the rocky provenance whereas in the western most division the rivers tend to end their journeys. The central part is cut across by the various rivers that constitute the important portion on which this study dwells upon.

## EASTERN ROCKY HIGHLANDS

These highlands mark the eastern flank of the Gujarat plains and comprise the southwestern terminations of the Aravalli hill ranges. The Gujarat hilly terrain marks the southwestern and western flanks of the Dungarpur hills and western flanks of the Mewar hills. Falling within the limits of Gujarat state (Panchmahals, Sabarkantha and Banaskantha districts) and extending eastward into Madhya Pradesh and Rajasthan, the highlands constitute provenance for not only the main

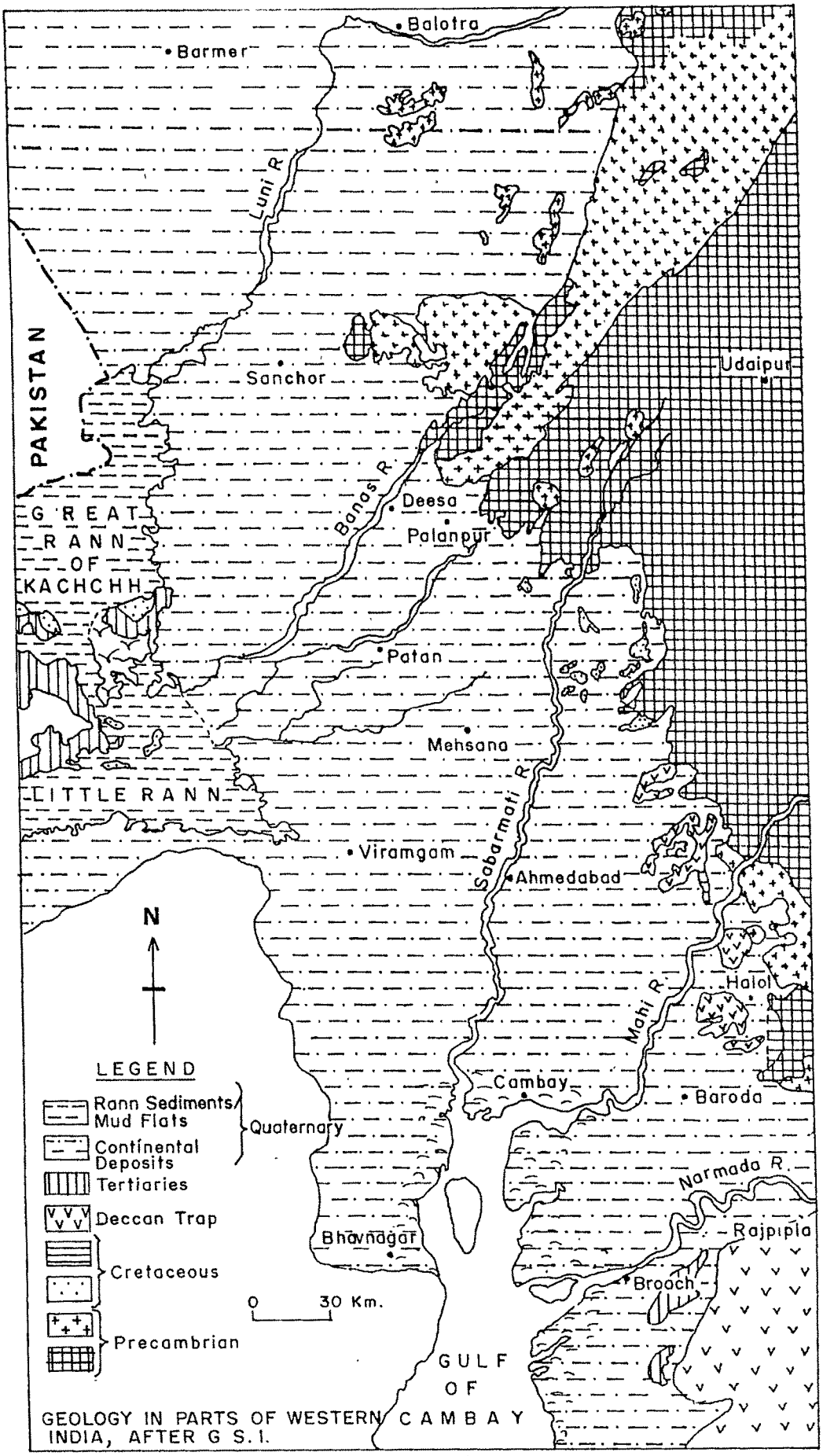

Balotra
Barmer
Luni R.
PAKISTAN
Sanchor
Udaipur
Banas R.
Deesa
Palanpur
GREAT RANN OF KACHCHH
Patan
Mehsana
LITTLE RANN
Sabarmati R.
Viramgam
Ahmedabad
N
Mahi R.
Halol
LEGEND
Rann Sediments/ Mud Flats
Quaternary
Continental Deposits
Tertiaries
Deccan Trap
Cretaceous
Precambrian
Cambay
Baroda
Narmada R.
Bhavnagar
Rajpipla
Broach
0 30 Km.
GULF OF CAMBAY
GEOLOGY IN PARTS OF WESTERN INDIA, AFTER G S.I.

Fig.3·2

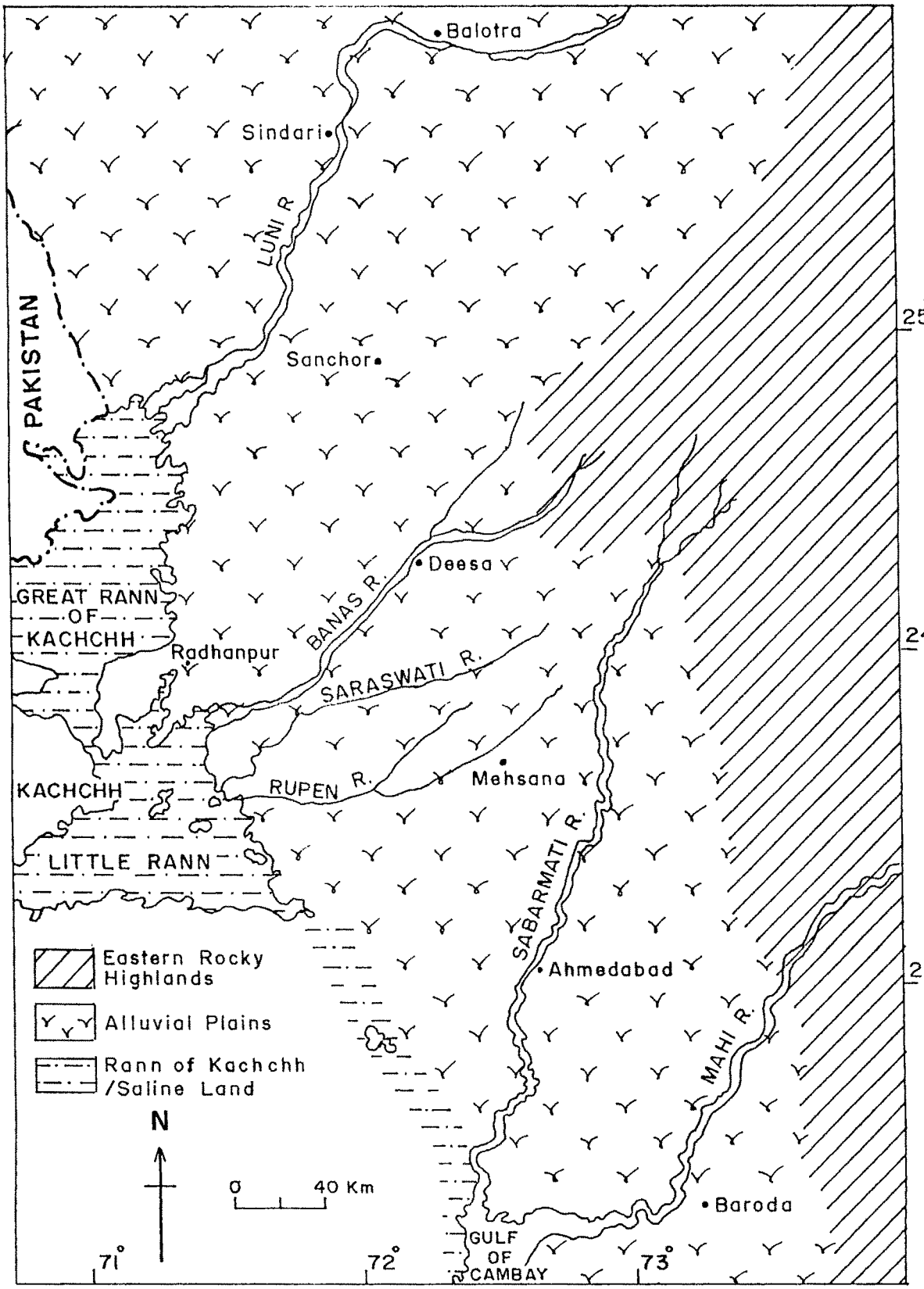



Fig.3·3 PHYSIOGRAPHIC DIVISIONS OF STUDY AREA

rivers but also for most of the major tributaries. These highlands comprise the western flanks of the higher hill ranges and show an altitude range from around 1100 m to 200 m amsl (Fig. 1.2). In a general way the terrain in the Banaskantha district shows high altitude and is dotted with numerous peaks (Δ 1722 m, Δ 1099 m, Δ 1090 m etc).

Geologically, the rocky highlands comprise various rock formations of Aravalli and Delhi Supergroups with associated granitic intrusions of various ages (Fig. 3.2). Generally the terrain is moderately rugged with low hill ranges extending for several kilometers, and are made up of metamorphics, viz. quartzites, calc-gneisses, marbles, limestone etc. These ranges are separated by extensive shallow valleys through which flow various streams. The northern part is dotted with a number of granite hills which form prominent peaks and massifs.

No specific topographic or physiographic trend in the rocky highlands is seen; only further northeast towards Rajasthan, the well defined Aravalli trend (NNE-SSW) is observed. The overall physiography is a product of a combination of a few major northeast-southwest (NE-SW) lineaments and related smaller fractures which mark the courses of most of the tributaries. The limits of the rocky highlands are tectonically controlled. In the northern part of the state the delimiting lineaments trending NE-SW are obviously the extensions of the longitudinal faults so characteristic of the structure of south Rajasthan. The southern part marks a NNW-SSE trending fault system, which broadly parallels the Eastern Cambay Basin bounding fault.

## THE RANNS OF KACHCHH

The Little and the Great Ranns of Kachchh and the low saline tract of Bhal mark the western margin of the Gujarat plains. These areas of Gujarat rising only a few metres above the mean sea-level and into which a number of rivers debouch, provide an unique landscape of saline wasteland. The two Ranns represent marine to fluvio-marine unconsolidated Holocene sediments which perhaps overlie the Mainland Quaternaries. The limits of the Great Rann and the Little Rann and the trend of the low lying Bhal-Nal Sarovar tract, all point to very distinct influence of North-South and Northwest-Southeast (N-S & NW-SE) trending major faults. The average elevation of the Rann surface is around 4-6 m amsl and the continental deposits to the east rise abruptly by about 10-12 m, a characteristic feature indicative of vertical movement along faults. This part of the Great and the Little Rann is annually inundated by the waters of the various rivers during the monsoon.

## ALLUVIAL PLAINS

The median part of the Mainland extends from Narmada river in the south to the Luni river in the north. These alluvial plains consist of a vast thickness of unconsolidated continental deposits of Quaternary age. These plains show a gradual slope from ENE to WSW and range in altitude from 150 m to almost sea level. They are broadest between Mahi and Banas rivers. From the gradient point of view these plains within the limits of the study area could be divided into three segments as under:

1. Segment between Mahi and Sabarmati
2. Segment between Sabarmati and Banas
3. Segment between Banas and Luni

The slope of the plains between Mahi and Sabarmati is south-southwestwards and shows a sharp gradient, indicating a drop of almost 50 m in a distance of 40 km. The various smaller rivers that drain this segment follow a south-southwesterly course. In the southern part in lower reaches of the two rivers, it is characteristically observed that all the rivers take a westerly trend before finally meeting the Sabarmati (Fig. 1.2). This phenomena perhaps is due to the westerly slope.

The segment between Sabarmati and Banas, though showing an overall slope to the SW tends to show increasing gradient from E to W. This factor of slope is well illustrated in the various rivers which, irrespective of their place of origin flow SW and west and either meet Banas river or the Little Rann. The gradient in the upper part of the segment is relatively high but in the lower reaches the slope tends to decrease considerably almost showing negligible values; a drop of 100 m in a distance of 100 km.

The plains lying between Banas and Luni are also characterised by a very gentle slope due west. In the eastern part of the segment the slopes are higher but its major portion as usual shows a very low gradient. A characteristic feature is the near total absence of any southwest flowing rivers.

The overall landscape tends to be increasingly dunal from southeast to northwest. The surface topography between Mahi and Sabarmati is typically flat

and featureless but on crossing Sabarmati, proceeding northwards, the plains become increasingly undulating (Plate 3.1) and are endowed with numerous dunal mounds (Fig. 3.1). The aeolian topography begins from Sabarmati with an increase in dunal hills northward. The landscape is characterised by a very well defined uneven topography and numerous dunal hills rise several metres above the ground level (Diodhar Δ 73 m, Ogadpura Δ 109 m (Plate 3.2), Tharad Δ 59 m, Langhnaj Δ 79 m). A characteristic feature of the area south and west of Luni within Gujarat is replete with stabilised dunes dissected by ill defined stream courses. These dunes are stabilised and typically indicate a period of aridity followed by a humid phase.

North of Banas right upto Luni and beyond, dunes and sand ridges of unconsolidated fine sand, are very common. Infact these dunes are the indicators of the northern limit of the Gujarat plains, beyond which they go below the sands of the Thar desert. The nature of topography in the extreme north marking the boundary of Gujarat is also of some interest. Whereas north of the boundary, the terrain has a better development of consolidated and unconsolidated dunes, southward in Gujarat except for a few sporadic stabilised dunes the unconsolidated sand accumulations are much less. Altitude wise the Gujarat portion is somewhat higher by about 10 m. The rise being abrupt, coinciding with the border.

## DRAINAGE CHARACTERISTICS

The Gujarat plains are traversed by a number of major rivers originating in the rocky highlands to the east, beyond the limits of the Gujarat state (Fig. 1.2). The rivers Tapi, Narmada, Mahi, Sabarmati and Luni flow across the plains and have given rise to quite conspicuous cliffy banks (Plate 3.3) revealing good

**Plate 3.1** A view of undulatory North Gujarat plains (Loc. Tharad).

**Plate 3.2** Low stabilised dunes around Ogadpura.

**Plate 3.3** Incised river cliff on the right bank of Sabarmati (Loc. Mahudi).

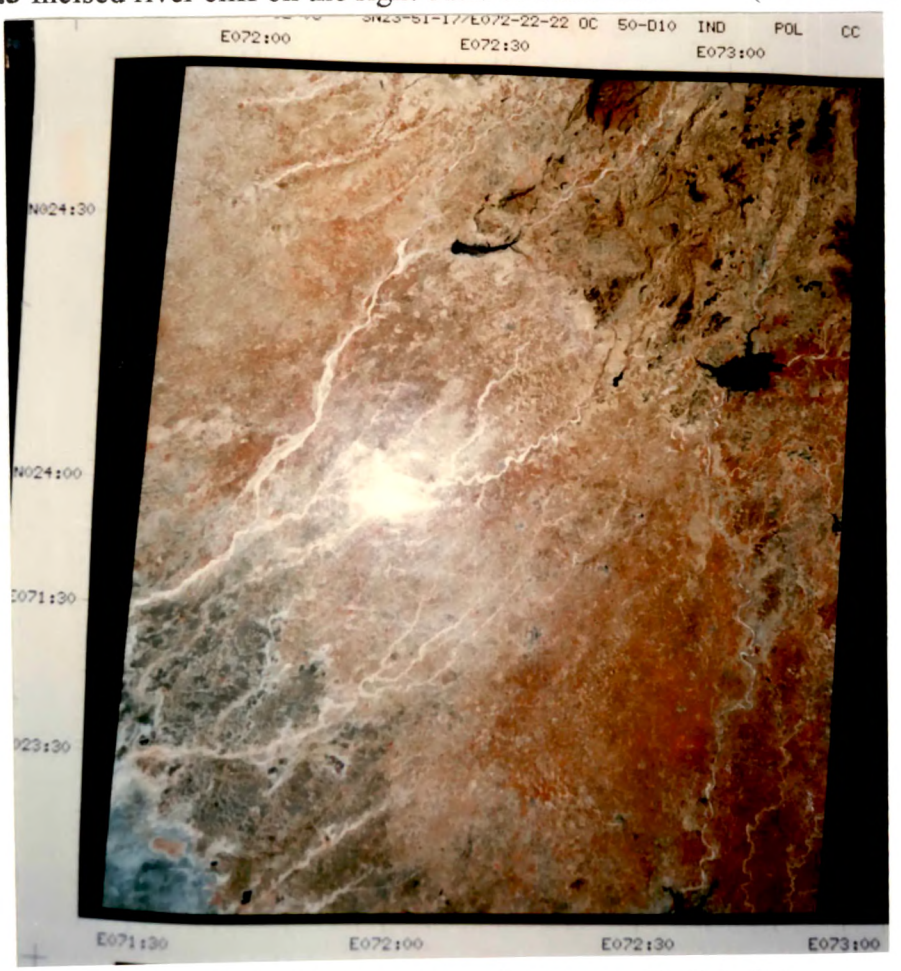



**Plate 3.4** IRS-FCC image of North Gujarat alluvial plains.

sequences of Quaternary sediments. At present these rivers bring negligible quantity of sediments as compared to the geological past, mostly during the Pleistocene. The present study of the drainage characteristics vis-a-vis significant thickness of continental deposits exposed in various river sections characteristically points to a protracted fluvial history comprising two major drainage systems. The present day drainage mainly cuts across the material deposited by the older river system. The author has been able to recognise the existence of an ancient super fluvial system (Sridhar *et al.*, 1994). It was this ancient fluvial system which was mainly responsible for the deposition of the continental sediments in the various post Tertiary depressions. The present day rivers which are observed to have been superimposed at a later date dominantly follow numerous tectonic lineaments and faults, but they do reveal relicts of the earlier fluvial system. The drainage characteristics of the Gujarat plains as recorded today have to be viewed with this background.

Drainage of the Mainland Gujarat consists of two distinct sets of rivers. Those occurring in the northwestern part are Luni, Rupen, Sabarmati, Banas and Saraswati. These rivers arise from the Aravalli hills and flow into the Ranns of Kachchh (Plate 3.4) (Rupen, Saraswati, Banas and Luni) and the Gulf of Cambay (Sabarmati). The other major rivers viz, Mahi, Narmada and Tapi drain the southern part of the plains. They fall into the Gulf of Cambay and the Arabian Sea.

The three major rivers viz, Sabarmati, Banas and Luni falling within the limits of the study area. Salient features of these rivers as they exist today have been described in the following pages. Ofcourse except the Sabarmati, the other two rivers and a few smaller ones provide ample evidences of their being

reasonably big rivers and as seen today their channel characteristics and water regimes show clear imprints of their previous magnitude.

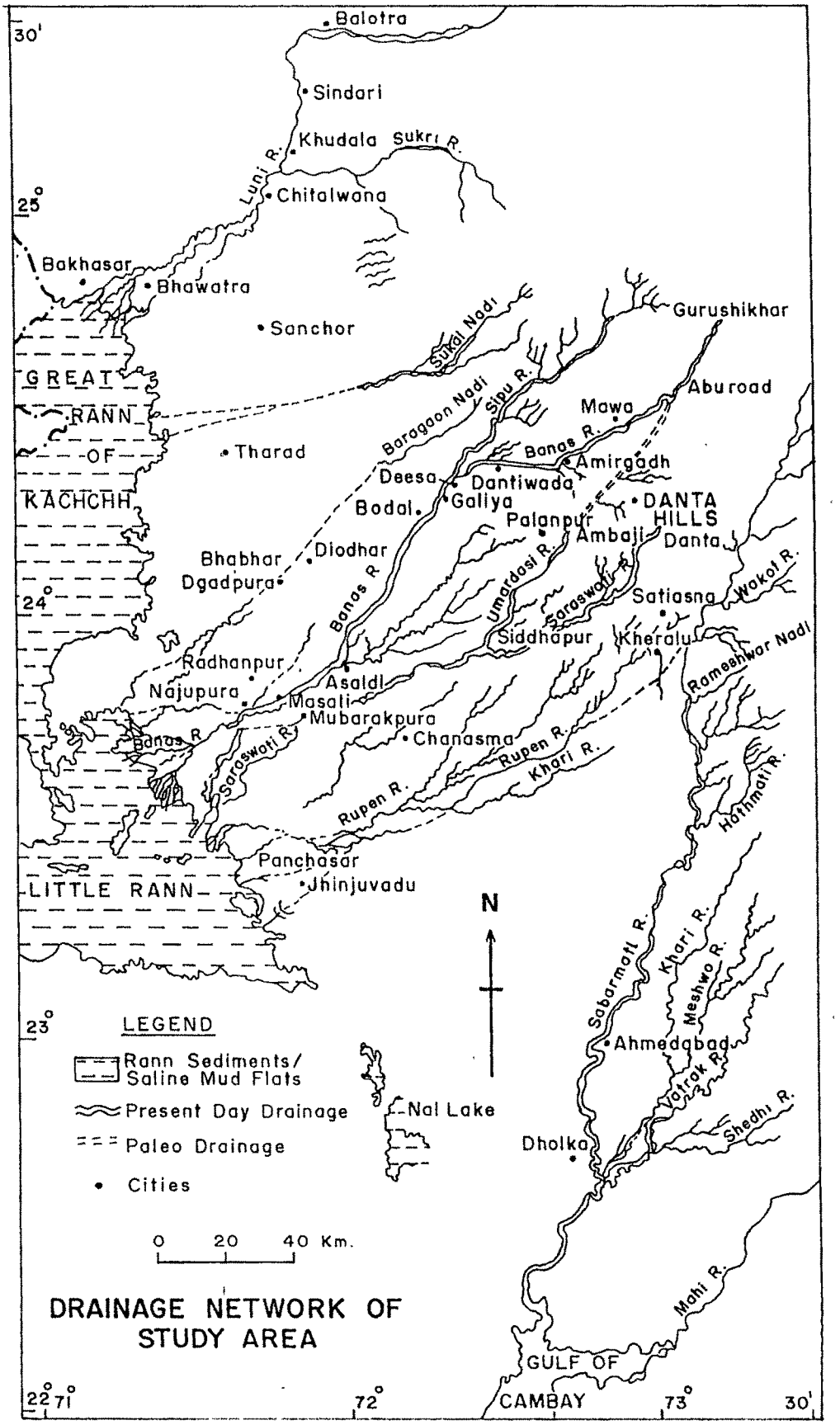
The river Sabarmati originating from the Mewar hills of Rajasthan flows across the alluvial plains before meeting the central part of the Cambay graben. The river has a total length of 416 km of which almost two third lies (Fig. 3.1) within the state of Gujarat. It has a ENE-WSW course and interestingly it shows an entrenched channel from Ahmedabad northwards upto the edge of the plains. South of Ahmedabad its channel tends to gradually flatten out before meeting the Gulf of Cambay. The last few kilometers of the river traverses the saline marshland of the 'Bhal' area. A peculiar feature of this river is that it has practically no tributaries to its west and in contrast along its left bank numerous tributaries meet the Sabarmati. The major tributaries are Hathmati, Vatrak, Meshwo, Khari, Shedhi, Rameshwar Nadi and Debhol Nadi; all these rivers provide a network of channels that are more or less parallel to the trunk stream (Fig. 3.1). They follow more or less identical courses.

The river Hathmati originates in the Dungarpur hills and flowing across Himmatnagar meets Sabarmati SW of Himmatnagar. The rivers Meshwo and Vatrak also flow down the hilly slopes of Dungarpur. The Meshwo meets Vatrak at Samadha which inturn joins the Sabarmati at Wautha. The river Khari originates at the fringe of the alluvial plains south of Himmatnagar and joins Meshwo before it meets Vatrak. The river Shedhi forms the chief drainage of the alluvial plains between Sabarmati and Mahi. It is interesting to observe that it originates in the Panchmahals at Sathamba and flows quite close by to the Mahi but instead of meeting it, it takes a westerly trend near Dakor and flows for almost 50 km to meet the Vatrak (Fig. 3.1). Except Shedhi most of the tributaries in their

upper courses show very well defined entrenchment and cliffy banks. The entire drainage network of Sabarmati and its tributaries typically reveal very prominent tectonic lineaments that control their channel trends and entrenchment. The Khari and Meshwo flowing almost parallel to each other for 67 km meet near Vanch before finally meeting Vatrak.

The Banas river originates in the Abu hills of Rajasthan and after flowing almost southwesterly for 83 km in a relatively narrow and rocky channel, its channel suddenly broadens up after entering the alluvial plains of Gujarat (Fig. 3.4). It drains a distance of 223 km before emptying into the Little Rann of Kachchh. The Banas appears to follow a course such that its various segments show alternating WSW - ESE and SW-NE to E-W trends. The channel is almost 2 km wide in its upper course from the village Mawa upto its confluence with Sipu. The left bank for the most part beyond SW of Amirgadh tends to be cliffy. The steep banks rising by about 10 - 15 m (Plate 3.5). Beyond Dantiwada. the cliff heights are around 25 m and are observed on both the banks. After meeting the Sipu river the river channel further broadens and fluctuates between Goliya and Najupura Mota and has cliffs of 15 m at Deesa and downstream at Bodal. Further downstream the cliff heights decrease and are around 4 - 5 m. The river bed all throughout is sandy and supports very little water except in the monsoon.

In the lower reaches of this river, where it flows almost in a gradientless terrain numerous evidences of the earlier course of Banas are observed (Fig. 3.4). It is not unlikely that the Banas met the Little Rann at the spot quite close to the mouth of the Saraswati river. At present it flows and meets the Rann forming a small delta like feature comprising a diverging network of small distributaries. The right bank all along does not have any major tributary though some relict




DRAINAGE NETWORK OF STUDY AREA

Fig.3·4

**Plate 3.5** Cliffy bank of Banas river at Deesa.

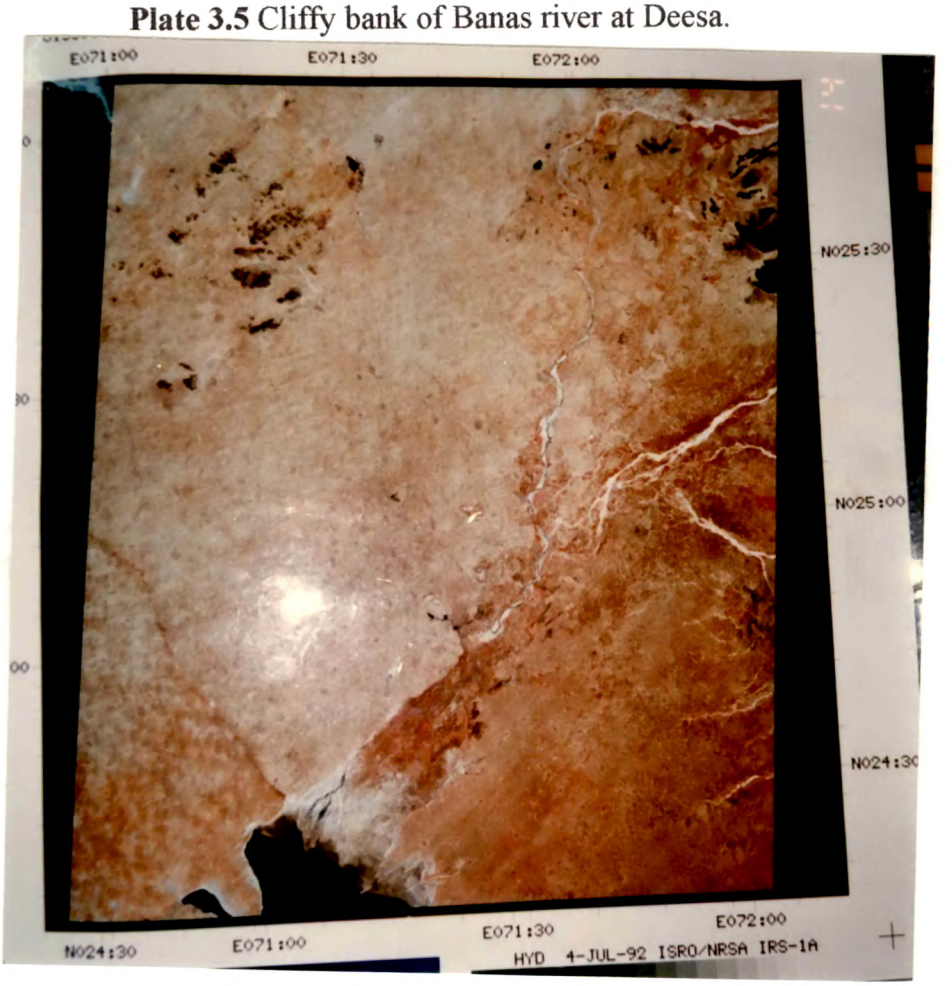



**Plate 3.6** IRS-FCC image of lower Luni river.

channels could perhaps be fragments of small streams which met Banas or Khari Nadi, a small stream that flows almost parallel from south of Radhanpur and meets Banas at Asaldi. These tributaries hardly carry any water.

The Luni river forms the northern most major river system, more or less providing a boundary to the Gujarat plains. Further north of this river, the landscape is more or less desertic sand covered with varieties of dunal accumulations; beneath these recent sands fluvial deposits have been reported by numerous workers (Ghose, 1965; Dhir, 1977).

The Luni river enters Gujarat near Gadhada flowing in a ENE-WSW direction (Balotra - Chitalwana). Further downstream it takes a south-westerly course and the river bed tends to split into smaller meandering channels flowing over almost a flat terrain (Plate 3.6). From Chitalwana, till the river meets the Great Rann, over a distance of 60 km it forms a complex of distributaries and near its mouth comprises of numerous small streams flowing within its own deposits (Fig.3.4). An interesting feature of this river is that its channel all along including those of distributaries upto Bhawatra, are cliffy rising 10 - 15 m above their beds (Plate 3.7). On the two flanks of the river occur a number of stabilised dunes and what is a most striking feature is that the river dissects the dunes also. This phenomenon is very well seen upstream of Chitalwana upto Khundala.

The other two rivers of some lesser dimensions as of today are Rupen and Saraswati. Both these rivers carry very little water, but reveal a very interesting pattern of low order streams. The Rupen river originates from the slopes of Taranga hill and flows west-southwestward and meets the Little Rann of Kachchh. All along its course, its channel is characterised by numerous curves and bends

**Plate 3.7** Lower Luni cliffs around Khundala.

and one can generalise that the two directions which dominate are East-West (E-W), and ENE-WSW. The river hardly carries any water except in the monsoon, has a comparatively narrow channel with occasional segments where its channel broadens. The upper half of this river is replete with tributaries, the two important ones being Pushpavati and Khari, very small local streams of a few kilometers length and most of the year being dry. These more or less run parallel to the main course of the river before joining it. The Rupen today provides a good example of being a remnant of an earlier big river, the channel of which has been subsequently destroyed.

Another river further north is the Saraswati. It originates near Ambaji from the granite hills and flows down again in a East-South easterly direction. Interestingly the river is more prominent in its median segment where it is characterised by a kilometre wide sandy channel. Its upper part flows within the rocky terrain whereas the lower course tends to thin out and its channel tends to become almost fragmentary. It meets the Little Rann in a very insignificant manner hardly showing any distributary system. This river comes quite close to Banas river at the point where its channel suddenly narrows down and a perusal of the network of ephemeral shallow channels in this part characteristically points to the strong possibility of this river joining Banas river at Ranawav.

The Umardasi river, a tributary of the Saraswati originates from the Danta hills, flows more or less parallel to the Saraswati with equally wide shallow sandy channels (Fig. 3.4). It meets the Saraswati at Hisor near Siddhapur on its right bank. Beyond Palanpur to the northwest the ground shows a well marked depression which is occupied by a dendritic network of lower order streams, joining to give rise to a tributary that meets the Banas. This geomorphic feature

points out to the disruption of the earlier course of Umardasi. It is not unlikely that originally the Banas on emerging over the alluvial plains continued to flow south westward joining the Umardasi at Palanpur. It was because of this fact that the Umardasi has quite a wide channel downstream of Palanpur.

A critical perusal of the satellite and toposheet data provides an alternative drainage pattern for the ancient Banas river system (Fig. 3.5). It is not unlikely that the Banas river was originally flowing through the present day Umardasi between Abu Road and the Sipu confluence, might have developed at a subsequent date on account of intersecting fractures trending E-W and NE-SW.

The existing drainage pattern comprising various major and minor rivers very clearly point to the fact that they are more or less dead streams. They carry a very limited quantity of sediments and that too only during monsoons. Obviously they are flowing across continental deposits, dissecting them to various depths. On pursuing the trend directions of the different segments of the rivers and also of their tributaries, the present day drainage quite clearly points to the existence of an earlier fluvial system which has since been more or less destroyed (Fig. 3.5). But there are quite convincing indications and evidences which can be put together to reconstruct the drainage pattern of the earlier fluvial system - a system that was primarily responsible for the deposition of the vast continental thickness. As it has already been stated earlier, the Sabarmati river and to a lesser extent Banas and Luni cut across, revealing various formations of the earlier deposited sequence. It will not be out of place to mention that the drainage disruption was primarily caused by movements along tectonic lineaments and this happened sometime during early Holocene after the loessic silts were deposited.

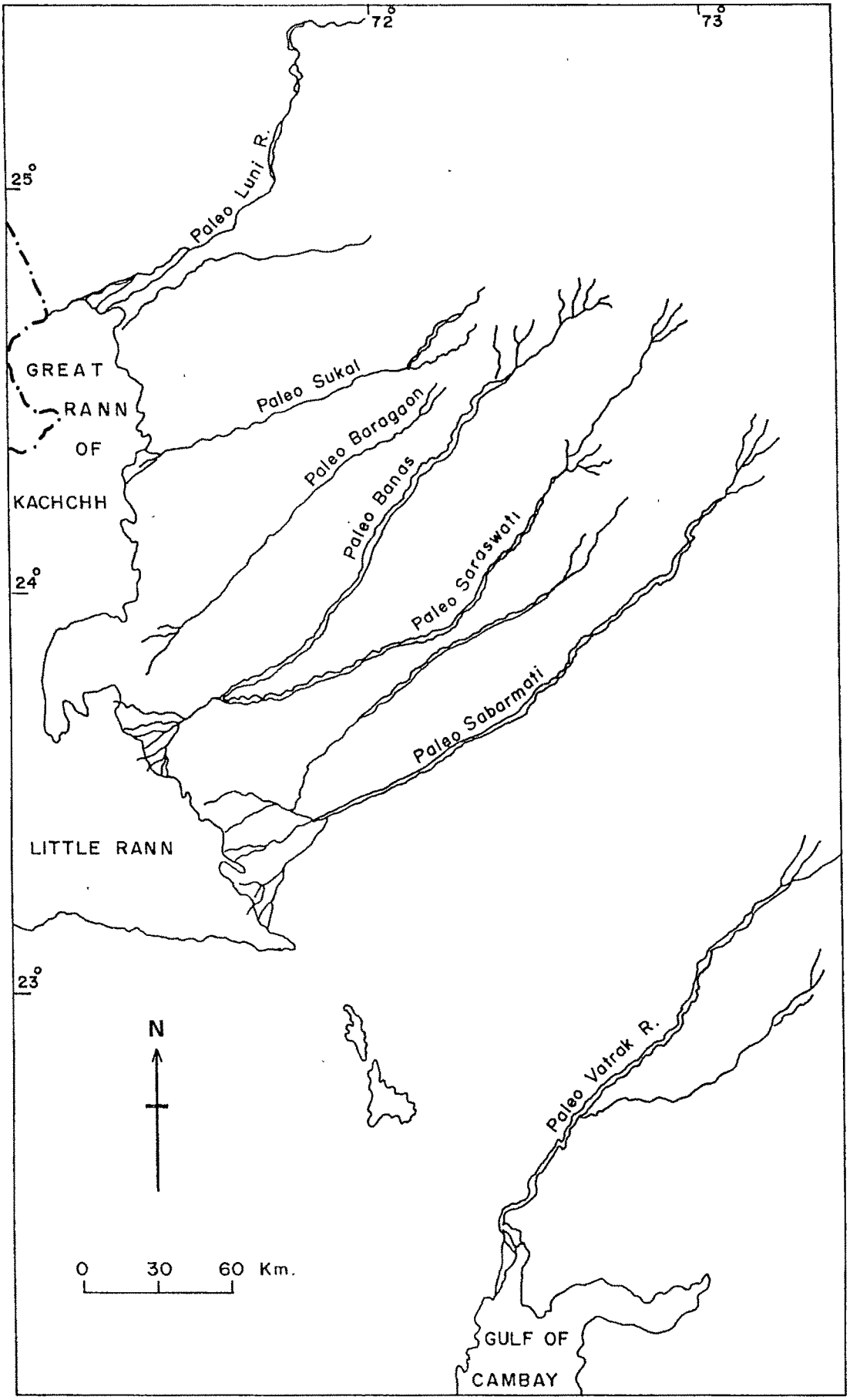



Fig. 3·5 PALEODRAINAGE MAP

The earlier drainage comprised a few major rivers originating in the Aravalli hills and flowing southwest and falling into the sea, a site which is now occupied by the Little Rann of Kachchh. The fact that the silty fluvio-marine sediments of the Little Rann which are undoubtedly of Holocene age are underlain by fluvial gravels and sand (Gupta, 1977; Ghosh, 1982), conclusively indicates that these older rivers extended southwestward for several kilometers prior to the last sea level rise (Flandrian).

The northern most river Luni, however has a different evolutionary history, though it might have contributed to the sediments of the Gujarat plains. Unlike the other rivers of north Gujarat, Luni or its ancestor was linked to the Ghaggar further north and is perhaps remnant of a Himalayan river. The drainage disruption has been well documented in west Rajasthan and numerous workers (Ahmad, 1986; Bakliwal and Grover, 1988; Pandey, 1986; Krishnan, 1952; Amal Kar, 1984) have invoked the role of climatic factors and or tectonism to explain this phenomena.

The drainage disruption in north Gujarat has to be an integral part of the similar phenomenon of Rajasthan. Satellite images and 1:50,000 toposheets of north Gujarat ideally show the relicts of the previous drainage network in the form of buried channels, ox-bow lakes, abandoned channels and discontinuous streams. Various evidences point to the existence of at least two major rivers systems, Banas and Rupen. North of Banas an interesting phenomena of abrupt truncation of two streams, Sukal and Baragaon is observed. The featureless terrain around Diodhar, Tharad, Sanchor in Rajasthan and the mouth of the Luni flanking the Great Rann and comprising a vast sandy plain with occasional dunes is strikingly devoid of any drainage, existing as well as relicts (Fig. 3.4). The two above mentioned streams viz, Sukal and Baragaon abruptly end up at the eastern

border of this sandy plain and in all probability they extended upto the Rann but are now truncated; there are strong possibilities of their channels lying buried beneath the sand cover. Looking to their southwesterly and west southwesterly trends, they are in conformity with the channel courses of the Banas and Rupen and could be belonging to the destroyed drainage system.

The Banas is the only river along with its major tributary Sipu, which appears to be comprising the only surviving river of the older fluvial system. Near its confluence with Sipu, its channel tends to broaden out and forms cliffy banks. The lower reaches of the river downstream of Shihori continues to have a broad channel but the banks show very subdued cliffs. The presence of numerous relict channels and the closeness of the point in Saraswati beyond which the latter becomes a very shallow and insignificant stream are good indicators of the fact that earlier the Saraswati river was meeting the Banas at Masali flowing west from Mubarakapura.

The Banas in its lower most part is characterised by the existence of a number of relicts so disposed that they indicate a typical ancient delta system. The existing relict, and dried up channels appear to have been connected to the main channel and the triangular delta comprising a total area of about 90 sq km existing earlier. The limits of this delta along the fringe of the Little Rann extend upto Saraswati river mouth, upto Banas river mouth and comprised a channel network with three major distributaries (Fig. 3.4). It is quite obvious that this delta extended further southwestward for atleast 3 km. The subsequent NE-SW fault delimiting the Little Rann truncated this delta.

The Rupen river which lies between Saraswati and Sabarmati though rather forming a relatively small stream at present shows numerous features pointing to its being a major river, its south westerly to westerly course is in conformity with the ancient course of the Banas river. The fact that the river originates quite close to from the place the Sabarmati flows and the behaviour of Sabarmati further downstream from that place very conclusively establishes the fact that Rupen with its numerous tributaries on both its banks represents the earlier course of Sabarmati (Sridhar *et al.*, 1994). Although this river is narrow and thin but the existence of a large number of tributaries on both its banks is an indication of this river being quite a prominent one. Interestingly most of the streams from Mehsana to the east and north which now occur as disrupted streams flow into the Rupen river.

At present, Rupen follows a westerly course and meets the Little Rann in an insignificant manner but the existence of various dried up channels obliterated partly by sand sheets indicate a major delta complex for this river. The shapes and trends of the relict channel network seen today as sandy saline waste near Panchasar can best be explained by invoking a delta system delimited by the existing channel of Rupen and the NE-SW line joining the Panchasar channel to an unnamed channel south of Jhinjhuvada (Fig. 3.4). A substantial part of this delta also lies beneath the Little Rann.

The present day Sabarmati river which flows south southwestward with an entrenched channel flows along a major fracture which has been responsible for capturing the waters of the Rupen river and it will not be inappropriate to conclude that the Rupen with its accompanying depositional features and relict tributary system represents the original course of Sabarmati river.

Between Rupen and the present day Sabarmati, a few relicts of southwest flowing streams, today which are dried up channels could be perhaps representing earlier streams which flowed into the Little Rann or the marine bay which was joining the Little Rann to the Gulf of Cambay across Nal Sarovar.

It is however most likely that the major tributaries of Sabarmati, Vatrak along with Shedhi was a part of the old fluvial system. The point where Vatrak meets Sabarmati further downstream the channel characteristics of the river all so different from those of north of Vautha, and this segment of Sabarmati could very well be taken as a lower part of the ancient Vatrak subsequently captured by Sabarmati.

The old fluvial system which now stands disrupted and described above along with the ancestors of the Mahi and Narmada river systems were responsible for the deposition of the huge thickness of fluvial horizons. The sequence stratigraphy of which has been described in this thesis.