# CHAPTER - IV

# EASTERN ROCKY HIGHLAND

# GENERAL

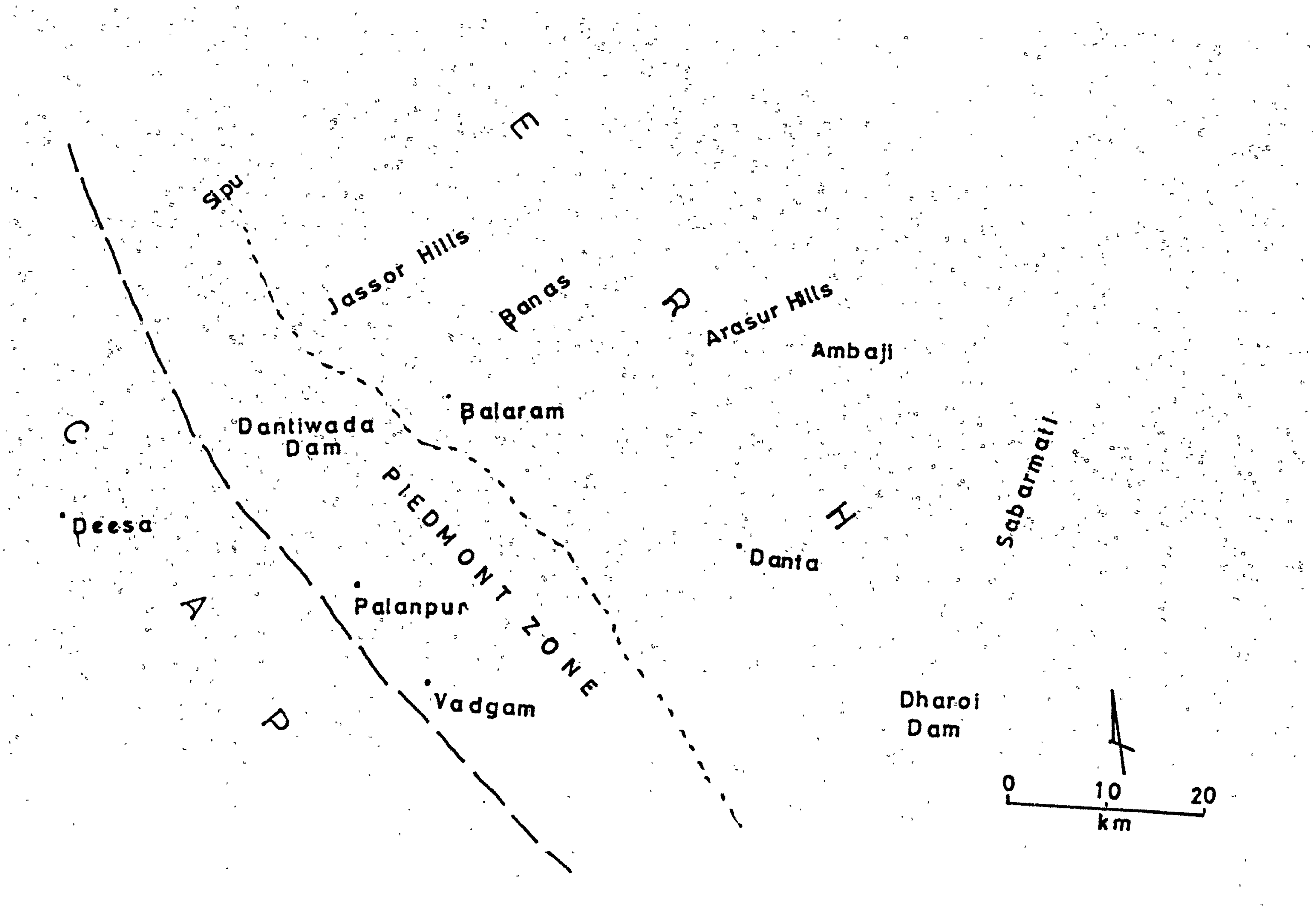
The rocky highland is made up of diverse topographic features which are the reflection of geology and subaerial processes. It occupies about 3800 sq. km (30%) of the total geographic area of the district and marks the north-eastern flank of Gujarat plains; and forming the southwestern termination of the Aravalli ranges (Plate 4.1). The highland consists of two groups of hills locally known as Jesor (Plate 4.2) and Arasur mountains (Plate 4.3 a and b). The hills exhibit typical residual landforms of Precambrian rocks characterised by NE-SW stretching bold ridges of folded metamorphic rocks (quartzites, calc-gneisses, marble, limestones etc.) extending to several kilometers with northern and southern flanks made up of prominent peaks and massifs of granite. The area in the foothills forms a typical piedmont zone where rocks are covered by a thin veneer of fluvial outwash and aeolian sand(Plate 4.4). It has a diagnostic low undulating topography in which, discrete hillocks of granite peep above the sandy cover at a number of places.

# TERRAIN ATTRIBUTES

The highland is characterised by a landscape comprising a variety of erosional and depositional landforms. The major terrain attributes viz. topography, groundslope, landforms, drainage, soils and geology of this unit has its own distinct characteristics in comparison to other two units.

## LANDSCAPE

The ERH unit has got a picturesque landscape of Aravalli mounts in the vicinity of Mt. Abu and characterised by high rising hills and deep cutting valleys. The various features of its vivid landscape are briefly described.



Sipu
Jassor Hills
Banas
Arasur Hills
Ambaji
Balaram
Dantiwada Dam
PIEDMONT ZONE
Deesa
Palanpur
Vadgam
Danta
Sabarmati
Dharoi Dam
0
10
20
km

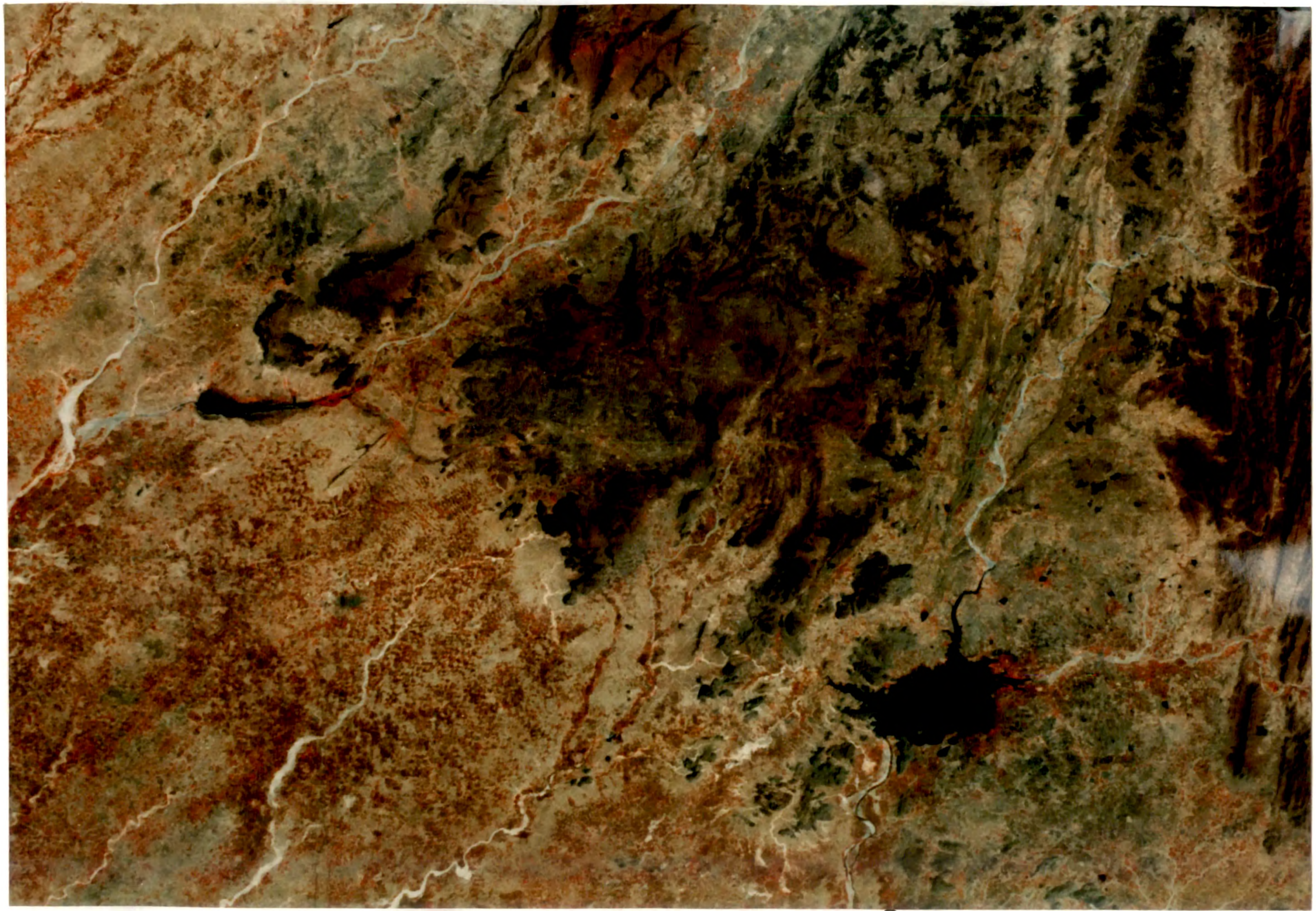


PLATE 4.1 SATELLITE VIEW OF EASTERN ROCKY HIGHLAND (ERH)

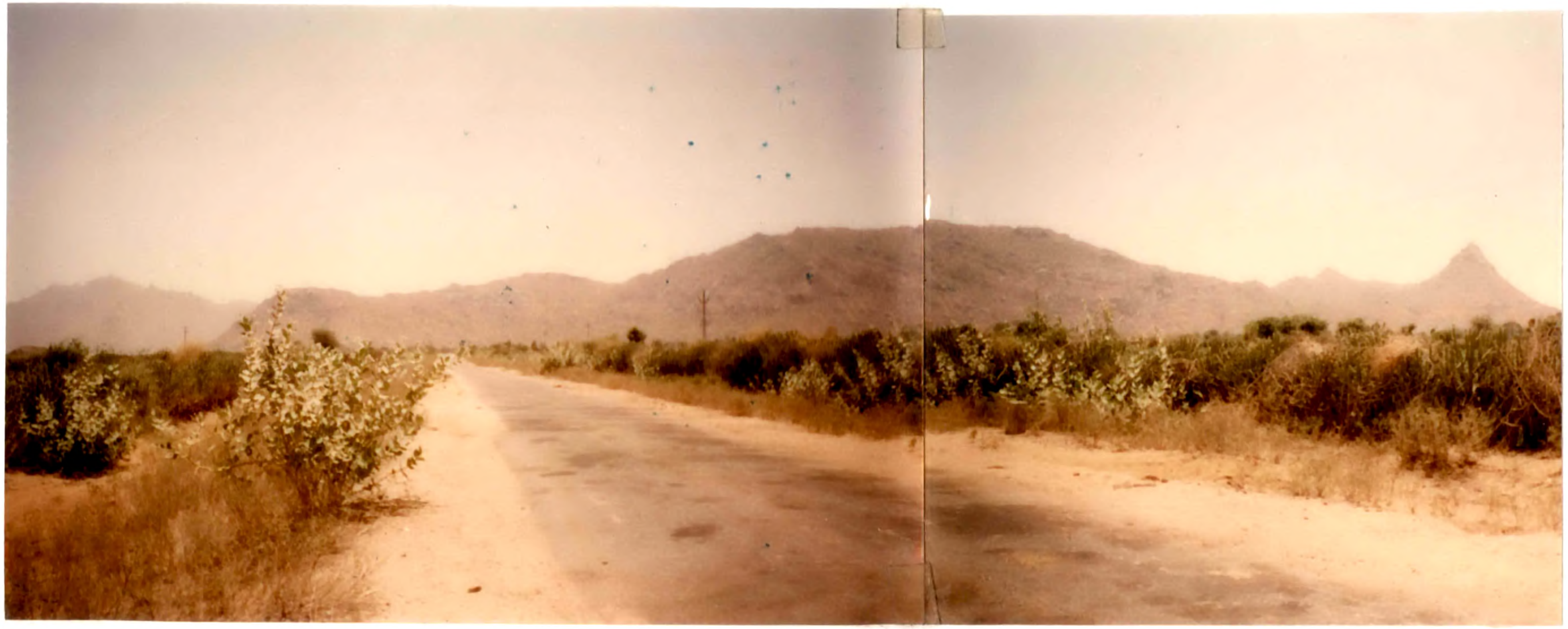


Plate 4.2 Panormic view of Jesor mountains facing north as seen from Hadmatia village

Plate 4.3 a  A view of Gabbar hill Ambaji-Balaram road in the foreground

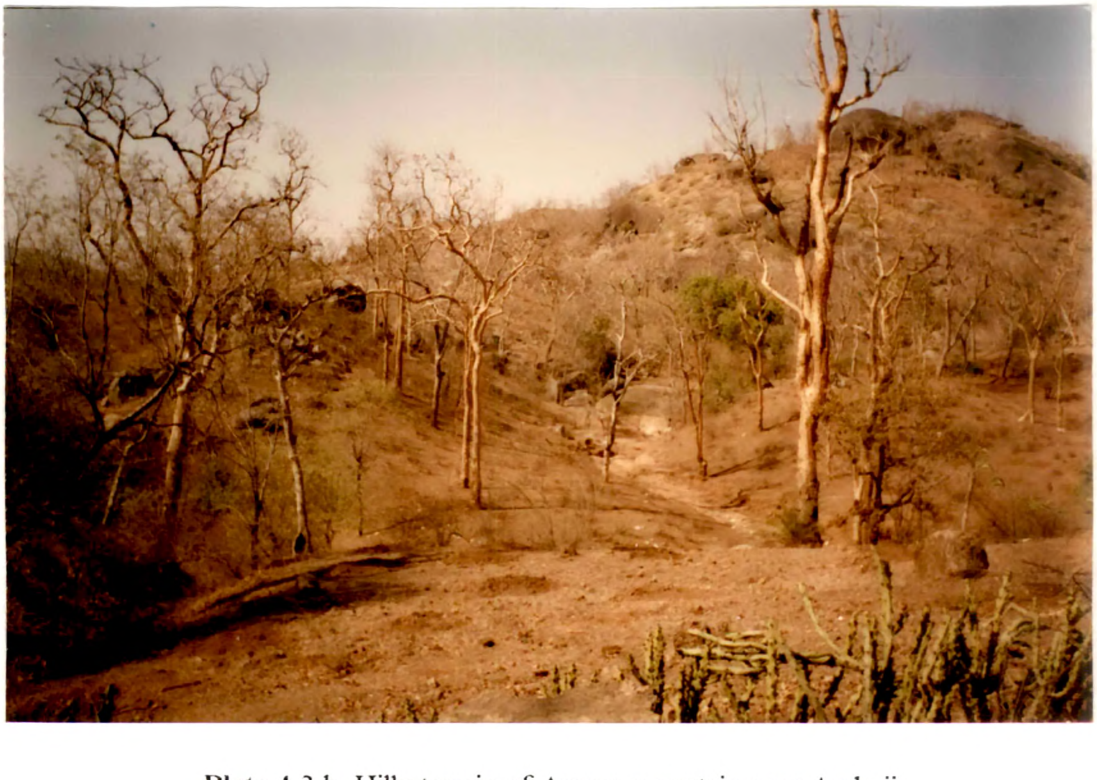


Plate 4.3 b  Hilly terrain of Arasur mountain near Ambaji

## TOPOGRAPHY

Physiographically, this unit is characterized by a highly rugged topography consisting of rocky hills, long stretching ridges with intervening broad shallow valleys and scattered mounds of blown sands (Plate 4.5). The ground rises from a general elevation of 200 m to a maximum of 1090 m. On the basis of ground elevation, the ERH unit is divisible into three broad hypsometric zones; and the extent and distribution of these zones are given in Fig. 4.1.

(i) The area in the elevation range of 200 to 300 m (70%)

(ii) The area in the elevation range of 300 to 500 m (25%) and (iii) the rest is above 500 m (5%).

## GROUND SLOPE

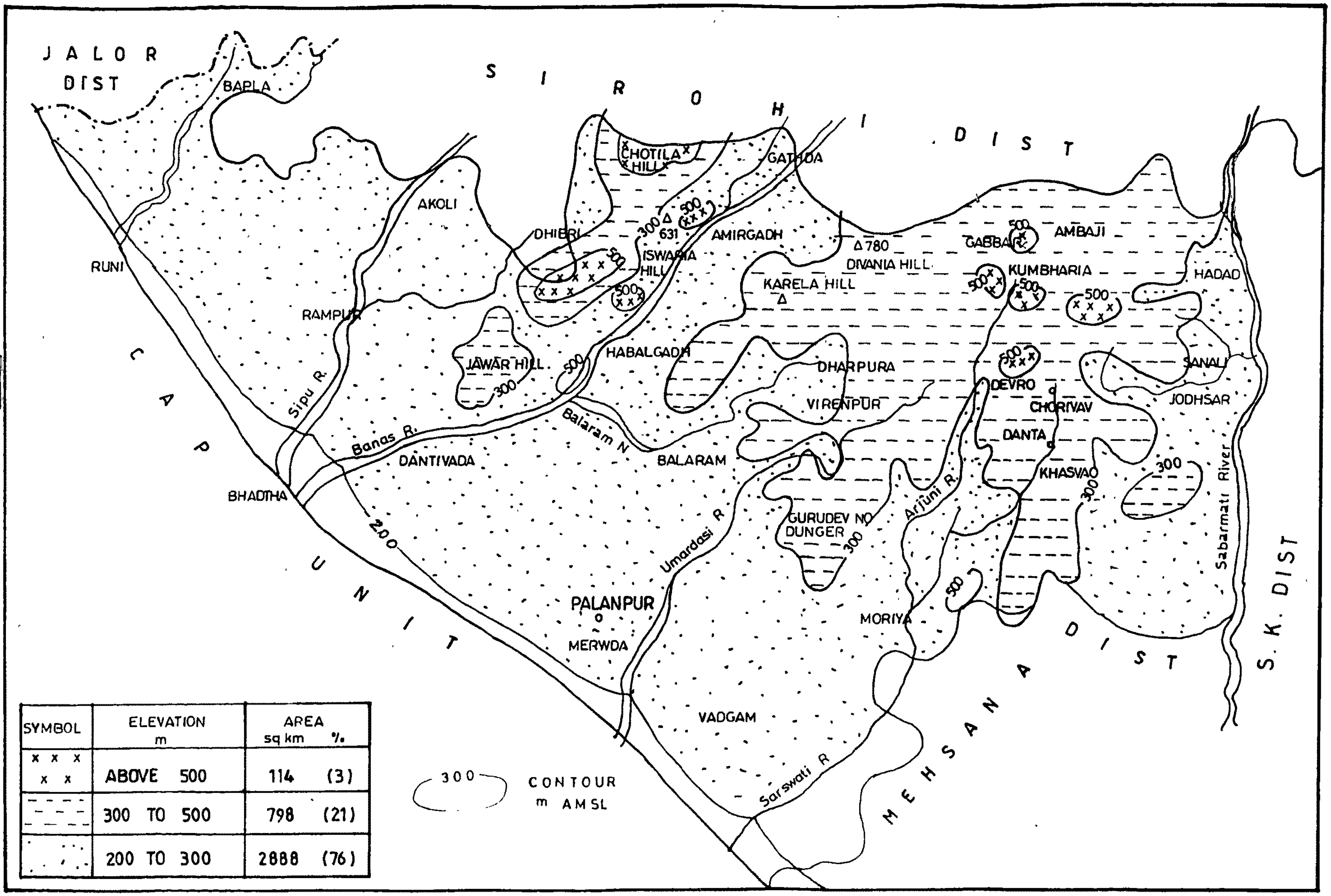
The ground slope is an important terrain parameter that governs the surficial environmental processes like rates of runoff and percolation, extent of erosion and deposition, formation of soil profile etc.

The highland unit shows a general overall slope towards SW which tends to increase from east to west. The slope factor is well illustrated in the various rivers which, irrespective of their place of origin flow due southwest and west (Plate 4.1).

The landforms show varying degrees of slopes. On the basis of the scrutiny of the 20 m interval contours on the SOI toposheets (1:50,000), the terrain has been divided into three broad categories of ground slopes as under.

**Category I : Very steep slopes with a gradient range of 1:2 to 1: 5.**

50% to 20 % of this category of slopes are restricted to the exposed rocky hills with their base generally at 300 m to 500 m levels, and peaks attaining the heights of 600 m to 1000 m (Plate 4.6). Slopes of the major hills, ridges, tors etc. fall under this




| SYMBOL | ELEVATION m | AREA sq km | % |
|---|---|---|---|
| x x x x x | ABOVE 500 | 114 | (3) |
| - - - - | 300 TO 500 | 798 | (21) |
| . . . . | 200 TO 300 | 2888 | (76) |

FIG-4.1 PHYSIOGRAPHIC MAP OF ERH UNIT

Plate 4.4 A view of piedmont zone; aeo-fluvial deposits in the foreground. (Loc. Mumnvas on Palanpur-Danta Road)

Plate 4.5 Panaramic view of piedmont zone dotted with granitic hills (Loc. near Andharia, on Palanpur-Danta road)

category. The slopes of these hills are generally devoid of soil cover and they hardly provide support base for vegetation growth. As a result, almost entire precipitation flows down to produce high quantity of surface runoff, and as zones of weathering are more or less absent, groundwater percolation is almost nil.

**Category II : Moderately steep slope with a gradient range of 1:5 to 1:50.**

20% to 2% of the terrain falls in this category. A majority of the landforms falling in the hypsometric zone of 300 m to 500 m elevation range shows ground slopes of this category. Such landforms are typical of granitic, metasedimentary and metabasic rocks. The slopes support a shallow soil cover and have a thick vegetation growth. The land in this slope category however is not suitable for agricultural purpose and almost entire area falls under the reserve forest. First and second order streams are developed on such slopes, to a considerable extent are governed by joints, fractures, foliations, beddings, etc. The slopes of this category significantly contribute to generate a high proportion of runoff and also a significant amount of percolation for groundwater recharge. Almost all the landforms of this slope category are of erosional type.

**Category III : Moderate to gentle slope with a gradient range of 1:50 to 1:200.**

2% to 0.5% of the terrain area fall into this category and the landforms included in this slope category mostly fall within hypsometric zone of 200 to 300 m elevation. By and large, they represent erosional features but, there are some exceptional patches in this zone which are of depositional origin (river terraces, stream beds, dunes etc.). The undulating terrain of the piedmont zone, valley bottoms, river terraces, sand mounds etc. show slopes of this category and the landforms generally have moderate to thick soil cover suitable for agricultural use (Plate 4.7). The major streams mostly follow structural lineaments and these streams, cut steep escarpments along its flow and gully erosion is also generally quite common. The rocks show deep weathering extending for several tens of meters. The areas in this slope category generally have lower index of surface runoff and a much higher index of infiltration. The piedmont zone which falls in this slope category, forms the typical recharge area for the confined aquifer system in the adjoining Central Alluvial Plain.

## LANDFORMS

The southwesterly flowing wide valley of Banas, broadly divides the highland into two groups of hills; northwestern Jesor group and the southwestern Arasur group. The former group of hills is bounded by the valleys of Sipu and Banas showing a progressive rise in elevation northeastward merging into the Mount Abu massif 20 km outside the limits of the area. This group of hills is composed of granite intrusives marked by some important peaks like Chotila (839 m), Iswania (631m) and Jawar (591m).Towards southwestward the hills abruptly truncate to give a low altitude dunal topography (Fig 4.1). Towards northwest, the landscape is formed of lower level hills and ridges of metamorphic rocks of Delhi Supergroup.

The Arasur group of hills are bounded between the Banas in northwest and Sabarmati in the east. To the northeast the hills extend into Sirohi district of Rajasthan, attaining higher elevations and merging into the main Aravalli mountain range, while towards southwest they are seen merging into the low dunal topography. The long stretching ridges and low level hills are generally composed of folded metamorphic rocks (Plate 4.7), whereas high projecting hills are of granite, generally forming tors, conical peaks or small domes either barren or covered with boulders (Plate 4.8 a & b). The conspicuous peaks include Diwania (780 m), Guruno Dungar (776 m), Kalera hills (740 m) and Gabbar (597 m).

Plate 4.6 Barren granitic hills of Eastern Rocky Highland
(Loc. Mumanvas on Danta-Palanpur road)

Plate 4.7 Quartzite ridge along Kui-Chitrasani Fault (NE-SW) as from Malana on Palanpur-Chitrasani road. Aeolian sand in the foreground

**Plate** 4.8 a  A granite hill showing typical tor weathering  Loc. near Bhakhar)

**Plate** 4.8 b  Granite showing dome hill (Loc. near Vagrol)

The southwestern part of the highland, forms a zone of relatively low altitude in the elevation range of 200 to 300 m and the landscape is characterized by a depositional topography (Plate 4.9). It forms an undulating foothill topography showing typical characters of a piedmont zone, made up of a stabilized dunal topography interspersed with scattered outcrops of granite hills and the deposition of sand sheet extends inside the high level hilly terrain. The landscape of this part of highland is characterised by a mix of erosional and depositional landforms. The development of erosional landforms on a very limited scale is generally confirmed to the elevations more than 300 m and occupy most of the northeast part of the highland while between 200 to 300 m elevation and occupying most of the southwestern part are the depositional landforms.

The Sabarmati river, flowing along the eastern border of the district has formed flood terraces along its bank in a stretch of 36 km of its flow. Each terrace is of approximately 4 to 5 sq. km size. Banas also forms extensive flood terraces along its bank for a stretch of about 25 km between Awal and Karja. Terraces of aerial extent of 3 to 4 sq. km has been recorded on its right bank, but the straight east-west course of Banas between Karja and Bhadath, there is no development of flood terraces.

## DRAINAGE

The highland unit is closely drained by a number of southwest and west flowing rivers viz. Banas, Sipu, Saraswati, Sukal and Baragaon flowing in northern part while Balaram, Arjuni, Umardasi, and Kuwarka drain the southern part. Sabarmati marking eastern limit of the district flows southwards, receives discharges from east flowing streams of Siri, Kidi and Dhamni.

The lower order streams show different patterns, of dendritic, trellis and radial drainage. The dendritic pattern is governed by the lithology and slope; the trellis reflects minor structural features like joints, bedding etc.; while radial pattern indicates rounded hills of intrusive granitic masses. Higher order stream courses generally follow major structural features like fault zones or regional strike directions of bedding, foliation etc.

On the basis of selective morphometric analysis for the higher order stream courses, it was observed that most of the streams flow due southwest and west with low winding ratio in the range of 1:1.12 to 1:1.57, and bed slope ranging from 1:100 to 1.1800. The average bed width ranges from 50 m to 500 m (Table 4.1).

Banas is the main river of the district, originates from Pindwara hills in Sirohi district of Rajasthan. A dam across the river has been constructed near Swarupganj in Rajasthan. Flowing almost for 40 kilometers due southwest downstream of the dam, in a relatively narrow valley, enters the study area (Banaskantha) at Awal. The valley, then becomes broad and open for about 5 km, forming flood plain terrace. The river is seen cutting its own deposits and form 10 to 20 m high cliffs on its bank near Amirgadh. From Awal to Iqbalgadh along its course of 25 km, it flows due southwest and then, it takes a sharp westerly turn. In this stretch of about 25 km, the course is almost straight, numerous streams meet the river on its right bank, but not a single stream as is seen draining its left bank. The terrain morphology on the two banks are quite contrasting. The right bank is rocky while the left is marked by sand dunes, with cliff sections of about 10 m cuts and extensive gully erosion all along the length.

**Table : 4.1 River Morphology of Highland**

| Sr. No. | River (flow direction) | River stations | Straight length\ Meandering length (Winding Ratio) | Elev. diff. (m) . (Bed-slope gradient) | Average width ( m) |
|---|---|---|---|---|---|
| 1 | Sabarmati ( NE-SW) | Kheroj to Vijalsar | 24\36 (1:1.5) | 20 (1: 1800) | 500 |
| 2 | Siri Nadi (NE-SW) | Hadad to Sanali | 7\8 (1:1.14) | 20 (1:400) | 100 |
| 3 | Siri tributary (NW-SE) | Talati to Kuvarsi | 3\3.5 (1:1.16) | 25 (1:140) | 250 |
| 4 | Siri tributary (W-E) | Kuvarsi to Jodhasar | 7\10 (1:1.57) | 30 (1:210) | 100 |
| 5 | Kuwarka Nadi (NW-SE) | Chorivav to Khasvad | 5.5\6.5 (1:1.18) | 30 (1:210) | 50 |
| 6 | Kuwarka Nadi (NW-SE) | Khasvad to Moriya | 15\20 (1:1.33) | 60 (1:333) | 50-100 |
| 7 | Arjuni Nadi (NE-SW) | Kumbharia to Devro | 7\8 (1:1.14) | 30 (1:270) | <50 |
| 8 | Arjuni Nadi (NE-SW) | Devro to Karanpur | 14\17 (1:1.14) | 70 (1:243) | 100-200 |
| 9 | Saraswati (NE-SW) | Karanpur to Devpura | 22\30 (1:1.36) | 60 (1:500) | 150-300 |
| 10 | Umardasi Nadi (NE-SW) | Guruno dungar to Merwada | 15\20 (1:1.33) | 90 (1:220) | 100-200 |
| 11 | Kalari Nadi (NE-SW) | Gathada to Sonwadi | 15\16 (1:1.06) | 35 (1:450) | 100- 150 |
| 12 | Banas (NE-SW) | Awal to Bhadath | 55\48 (1:1.14) | 90 (1:600) | 300- 400 |
| 13 | Balaram (E-W) | Dhanpura to Karja | 20\15 (1:1.33) | 100 (1:1.200) | 100- 150 |
| 14 | Dholva (E-W) | Dhibri to Rampura | 15\20 (1:1.33) | 100 (1:200) | 100- 150 |
| 15 | Sipu (NE-SW) | Akoli to Bhadath | 25\28 (1:1.12) | 75 (1:370) | 200- 300 |
| 16 | Sukal (Rel) (NW-SE) | Bapla to Runi | 15\18 (1:1.2) | 50 (1:360) | 200- 300 |

After flowing for 30 km in this direction, it meets Sipu river near Bhadath. Between Iqbalgadh and Bhadath, at Dantiwada, a dam has been constructed on this river for the purpose of irrigation and flood control. Balaram is the major tributary, meeting Banas on the left bank. It originates from Biramberi hills (about 700 m high) southwest of Ambaji, drains the central part of the highland and after winding its way for 30 km, meets Banas at Karja. Sarod, Arado and Gomati are other smaller tributaries which drain into Banas on its right bank. It is interesting to observe that there is not a single tributary meeting Banas downstream of the Balaram till its confluence with Sipu.

River Sipu is another important river which originates from Mount Abu (Guru Shikhar 1722 m) Sirohi district in Rajasthan. After flowing for about 55 km it enters the district near village Akoli, flows due southwest for about 25 km across this unit between Akoli and Bhadath till its confluence with Banas. Sipu follows regional strike of Delhi Supergroup. Dholva nadi, Harnav nala and Mahadevyo nala are the major tributaries of Sipu and are obviously governed by an the E-W joint system on the left bank but right bank is devoid of any significant stream. Younger terrace levels are seen at four localities, i.e., villages Rampura, Ganodara, Bhadar and Dhanpur. A dam (Sipu) has been constructed near village Atal for the purpose of irrigation (Plate 4.10).

Sukal and Baragoan are the other two parallel streams passing through the northeastern part of the highland. Both of them originate in Rajasthan and flow across the unit for about 10 and 5 km respectively. They have shallow channels and flow due west and southwest.

The streams that drains southern part of the highland are Umardasi, Arjuni, Kuwarka , Kidi, Siri and Telyia. All these originate from the hills around Ambaji. Telyia is the only streams that flow northwards, and crosses over the district boundary into

**Plate** 4.9 Panoramic view of piedmont topography between Merwada and Mumanvas

**Plate** 4.10 A downstream view of Sipu dam.(Loc. near Atal village)

Rajasthan, ultimately meeting Banas south of Abu Road. River Umardasi originates from the Guruno dungar (776 m) and flows due west across the dunal topography, while Arjuni originates from the Kumbhariya hills (737 m), gathering discharge from numerous nalas, between Kumbhariya and Vasi it develops into a well defined stream, flows due southwest. The Kuwarka starts from Chori-Vav hill (595 m), carves a very narrow and straight valley flowing due southwest upto Kundal and Moryia, beyond which its course becomes broad and with the and banks show extensive gully erosion.

The two streams of Arjuni and Kuwarka meet at Moryia and the river is then known as Saraswati. Flowing southwest it follows due southwest follows the regional trend of the Delhi Supergroup. It flows upto the western limit of the highland near Palanpur; where it enters the dunal topography with granite hillocks peeping out on either bank. Along meandering course it has developed several flood plain terraces. A medium size dam near Mukteshwar across the river has been constructed for irrigation.

River Sabarmati, originating from Udaipur hills in Rajasthan flows due south-southwest along the eastern boundary of the area. Its flow is governed by NNE-SSW tectonic lineament zone. It flows for about 25 km within the Banaskantha and during its course the streams of Siri, Kidi and Dhamnai originating within the highland, and flowing east and southeast join Sabarmati at different locations. It has extensively meandered and has developed well defined flood terraces at the concave bends. The terrace have provided sites for village settlement and agricultural activity. At the border of the area with the adjoining district of Mehasana, a dam has been constructed across the river near Dharoi village for the purpose of irrigation and water supply.

A study of the trends of the major drainage courses vis-a-vis the lineaments was made using the satellite imagery along with geological and structural maps, this was substantiated by field observations. The study has revealed the control of lineaments on the river courses. It is observed that the NE-SW and E-W trending faults and the general NE-SW strike of the Delhi Supergroup of rocks have controlled the trends of the major stream courses (Table 4.2).

**Table 4.2 Drainage control features of the area**

| River | Segment | Length (km) | Direction | Controlling factors |
|---|---|---|---|---|
| Sipu | Revdar to Bhadath | 45 | NE-SW | Delhi Strike |
| Banas | Abu Road to Iqbalgadh | 30 | " | Kui-Chitrasani fault (Delhi) |
| Banas | Iqbalgadh to Bhadath | 25 | E-W | Post Delhi Fault |
| Balaram | Virampur to Balaram | 15 | " | " |
| Arjuni | Ambaji to Danta | 15 | " | Delhi Strike |
| Saraswati | Dantato Thalwada | 40 | NE-SW | Delhi Strike fault |
| Sabarmati | Hadadto Vijalsar | 25 km | " | Delhi Strike |

The study of satellite imagery, toposheets and field checks give ample evidences to show that, the river Banas has been captured by the river Sipu. Earlier Banas was flowing independently due southwest following the NE-SW trending Kui-Chitrasani fault and there was a west flowing tributary controlled by an E-W fault, meeting Sipu at Bhadath. The headward erosion of this tributary progressively extended backward upto Banas near Karja, and as a result, the Banas flow was diverted to Sipu along the fault bound capturing stream. Gradually, the entire Banas flow got diverted to Sipu and the two rivers merged at Bhadath. The abandoned paleochannel of Banas still can be traced on the imagery (Plate 4.1).

## SOILS

The highland is characterised by a rather poor development of soil profiles. Soils occurring in different landscapes show variations in their taxonomic characters. As per the soil taxonomic classification scheme of Sharma et. al., (1994) the soils of ERH fall into two major categories belonging to those of hilly terrain and piedmont zone; falls in the Order of Entisols and Inceptisols (Fig. 4.2).

The major constraints for soil resource of the region are rock outcrops, steep slopes, severe erosion, shallow soil-depth and low 'availability water capacity'(AWC). The moderate to steeply sloping hills, ridges and isolated hillocks are devoid of soil cover and are occupied with barren rock outcrops.

The foothills and sloping interhilly basins, are associated with extremely shallow to shallow (10-50 cm) soil cover. The soils show a coarse loamy-skeletal texture and available water capacity (AWC) is low (150-100 mm/m). They are severely eroded and commonly stony (surface and subsurface) and neutral in reaction, classified as Lithic Ustorthents.

The soils occurring on very gently sloping interhill basins are very deep (>150 cm), somewhat excessively drained, coarse to fine loamy in texture and neutral in reaction. They are moderately eroded and have slight surface stoniness. They have low to medium AWC (50-150 mm/m), classified as Typic Ustochrepts.

The soils occurring on the undulating as well as gently sloping pediment zone are mostly shallow ( 25-50 cm), well drained, loamy-skeletal to clayey-skeletal and are neutral in reaction. They are moderately to severally eroded and generally stony, with low to medium AWC (50-150 mm/m) and have been classified as Lithic Ustorthents (Table 4.3).

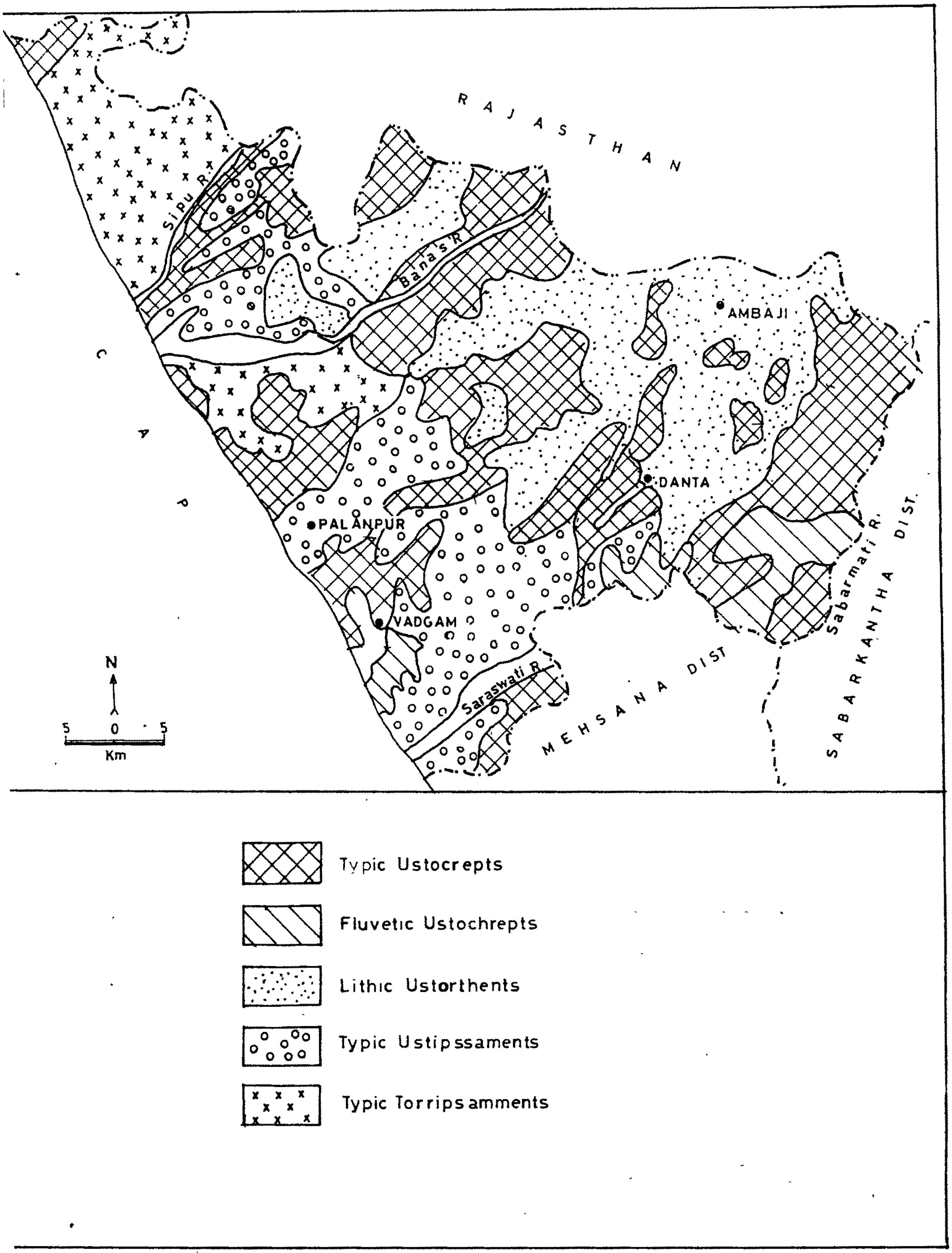



FIG. 4.2 SOIL MAP OF EASTERN ROCKY HIGHLAND

**Table : 4.3 Taxonomic soil classification of the Eastern Rocky Highland**

| Order | Suborder | Greatgroup | Subgroup | Description |
|---|---|---|---|---|
| Entisols | Psamments | Usti samments | Typic Ustipssamments | Very deep calcareous sandy coarse to fine loamy soils. |
| | | TorrI psamments | Typic Torripsamments | Very deep calcareous coarse loamy to fine loamy soils. |
| Inceptisols | Orthents | Ustorthents | Lithic Ustorthents | Rock outcrops, associated with shallow loamy skelated soils on hills and ridges. |
| | Ocrepts | Ustocrepts | Typic Ustocrepts | Moderately Deep to very deep fine to coarse loamy soils with moderate sodicity and strong salinity. |
| | | | Fluventic Ustochrepts | Shallow, loamy soils usually associated with narrow valleys. |

## GEOLOGY

The Proterozoic rocks are extensively exposed in the highland and are represented by the Delhi Supergroup (Fig 2.4). The geological evolution of the rocks of Delhi Supergroup of this unit is controlled by the Precambrian orogenies of Aravalli and Delhi cycles. The rocks show superposed folds, faults of different generations, and complex metamorphism and magmatism related to the two orogenies.

The exposures of rocks when traced towards southwest in their strike extention, gradually go beneath the thick alluvium beyond Palanpur. In fact, they get truncated by the eastern limit of the Cambay Graben. The rocks of Delhi Supergroup rocks exposed in the eastern parts of the district belong to Kumbalgarh Group, Sirohi Group, and Sendra-Ambaji Granite. These rocks extend for more than 50 km in their strike length within this unit. The rocks of Kumbhalgarh Group, the most important stratigraphic unit of the Delhi

Supergroup, show conspicuous lithological and metamorphic variations, structural complexities and magmatism. The Group includes a major portion of the Ajabgarh Series of Heron and Ghosh (1938) and forms NNW-SSW trending linear belt in the western part of the main Aravalli range. It represents metamorphosed calcareous sediments with subordinate argillaceous and arenaceous components. The schistose members of the group at Ambaji are known to host sulphide mineralisation of copper, lead and zinc. The mineralized zone is about 700 m wide in a ENE-WSW direction and shows occurrence of chalcopyrite, sphalerite and galena within talc-tremolite schist. These have been considered as stratiform syngenetic deposits by Deb (1973). These deposits are explored and developed by Gujarat Mineral Development Corporation (GMDC). White saccharoidal marble also occurs in association with calc-gneiss near Ambaji, which is extensively quarried, processed and marketed as an ornamental building material.

The rocks of Sirohi Group occur to the northwest of Palanpur at the border with Sirohi district of Rajasthan. It consists a metamorphosed sequence of muscovite schist and biotite schist with intercalated bands of marble and quartzite.

The Sendra-Ambaji Granite is partly synchronous with Delhi orogeny and it has caused widespread granitisation of Delhi pelitic schist giving rise to large areas of biotite gneiss all over North Gujarat. This granite occurs in intimate association with the younger Erinpura Granite. The gneissic terrain around Ambaji and Danta provides a good example of the varieties of mode of occurrence of these granitic rocks.

A Post-Delhi Pre-Erinpura Granite mafic igneous phase is represented by a large number of dykes, sills and plugs of metadolerite all over the area. The constituent rocks are always olivine-bearing gabbro and dolerite occurring profusely around Ambaji. These rocks are also found to occur in abundance near Virpur and Kanpura. Near Balaram these rocks occur abutting against Kui-Chitrasani-Abu Road fault. The mafic rocks of the area are also found to occur within Sirohi Group in Kapasia area in the northwest. The rocks are represented by numerous narrow E-W dykes of trachy-andesite occurring around Kapasia within Sirohi group. There area about 300 such dykes recorded by Patel (1972) and represent the youngest Precambrian mafic rocks of Gujarat.

The Erinpura Granite occurs extensively as impressive outcrops north of Palanpur and around Danta. It is prominently exposed along the Delhi strike NE-SW and separates the metasedimentaries of Kumbalgarh Group in the southeast from Sirohi Group to the northwest.

## CLIMATE

The highland unit is characterised with somewhat lesser aridity as compared to the rest of the district. It is due to the higher elevation and the vegetation cover. The General Aridity Index of the area is 15% to 25% indicating a arid-low to slight Sub-humid conditions (D.A.S, 1991). The highland supports tropical forest characterized by a mix of dry deciduous and scrub types, which helps in keeping the aridity level on lower side. Within the highland also, there is significant variation in aridity. The northwestern half of the highland having greater elevation of terrain, thicker forest cover and higher average rainfall has lower aridity as compared to the southeastern half.

Mount Abu with an average elevation of 1300 m above MSL forms a unique pocket of a cool climate. It is a famous hill station located just 20 kilometers to the northeast. The Abu massif has a significant climatic influence on the highland area of the Banaskantha by way of a localized high rainfall, greater moisture availability and lower aridity.

The climatic parameters are based on 30 years' data (1931-60) obtained from the two nearest India Meteorological Department, (IMD) observatories, one located 20 kilometers in the northeast at Mt. Abu, and the other at Deesa 10 km west of the highland limit. The comparision of various parameters of the two stations gives some idea of the climatic conditions of prevailing in the highland unit (Table 4.4).

**Table 4.4 Climatic characteristics based on the data from IMD stations at Deesa and Mt. Abu.**

| **Parameters** | **Unit** | **Deesa station** | **Mt. Abu station** |
|---|---|---|---|
| Distance from highland limit | km | 10 km W | 20 km NE |
| Height AMSL | m | 136 | 1195 |
| Mean Station Level Pressure | mb | 992.45 | 879.35 |
| Temperature | $^0$C | | |
| Annual Mean | " | 23.9 | 18.0 |
| Monthly mean max. \ min. | " | 44.8 \ 5.4 | 35.4 \ 4.0 |
| Daily mean max. \ min. | " | 34.3 \ 19.4 | 24.9 \ 16.5 |
| Extreme Highest (date) | " | 46.3(26.4.1958) | 38.5 (9.6.1889) |
| Extreme Lowest (date) | " | 2.8 (10.1.1954) | -1.1 (31.1.1929) |
| Relative Humidity | % | 49.5 | 29 |
| Cloud Amount | Octas of | | |
| All clouds \ Low clouds | sky<br>" | 2.8 \. 1.4 | 29 \ 25 |
| Mean wind speed | km\h | 5.1 | 7.6 |
| Rainfall | mm | | |
| Av. Annual | " | 575.2 | 1691.3 |
| Av. No. of Rainy days | days | 27 | 51 |
| Wettest in y ear | mm | 1037.5 (1959) | 3990.5 (1944) |
| Driest in year | " | 291.3 (1951) | 290.1 (1899) |
| Heaviest in 24 hrs | " | 53.3 (1960) | 484.9 (1941) |
| Weather Phenomena | days | | |
| Hail | " | - | - |
| Thunder | " | 8.0 | 7.0 |
| Fog | " | - | 32.0 |
| Dust storm | " | 1.7 | 0.2 |

The special hydromorphic situations resulted due to the combination of the climatic characters and physiographic features in the highlands have produced conditions most favorable for high potential of surface water resource and biogenic products.

## RAINFALL

The highland receives average annual rainfall of 704 mm in 31 days, as against that for the whole district which is 555 mm in 24 days. This marked contrast is due to the close proximity of the Abu hills in northeast and Idar hills in southeast. The rainfall shows quite high dependability of 50-55%. An analysis of 70 years' rainfall data (1901-70) from the State Department of Agriculture, (1991) for the 4 taluka stations within to the highland show the rainfall characteristics as under (Table 4.5).

**Table 4.5 Rainfall characteristics of Eastern Rocky Highland**

| Taluka | Average Annual Rainfall (mm) | Average Rainy days (Number) |
|---|---|---|
| Danta | 906.2 | 39.7 |
| Palanpur | 758.4 | 31.5 |
| Vadgam | 689.5 | 30.3 |
| Dhanera | 461.2 | 21.0 |
| **Highland** | **703.8** | **30.6** |
| **District** | **555.0** | **24.0** |

It can be inferred from the above table that even within the highland region there is significant variation in the rainfall pattern. The difference between the average values of rainfall for the two stations of Danta and Dhanera is as high as 445 mm and that for the rainy days is also 18.7. As per the records in the District Gazetteer (1981), at Palanpur highest rainfall of 1585 mm (211% of normal) occurred in 1907 and lowest of 157 mm (21% of normal) in 1911; while highest intensity of 409.7 mm in 24 hrs occurred in 1911; while highest intensity of 409.7 mm in 24 hrs occurred on September 16th of 1893.

## TEMPERATURE, HUMIDITY AND WIND.

After mid March there is a general increase in **temperature** but not with much variation as compared to that in the other units. The mean annual temperature of the highland is $26^0$ to $27\ ^0C$. Mean maximum and mean minimum are $34\ ^0C$ and $20\ ^0C$. The range of extremes being around $44\ ^0C$. **Humidity** is low for most part of the year, but in monsoon tends to slightly increase to around 60-80%. On an average, Relative Humidity varies from about 50-60%. Data for all the seasons are however not available. **Winds** are light to stormy and variable in intensity and direction. They blow from southwest to west during summer and monsoon while in winter they are northerly. On an average wind velocity ranges from 5-10 km/hr.

# WATER REGIME

The water resources of ERH are governed by factors of (i) average high precipitation, (ii) consolidated nature of rock formations and (iii) highly rugged physiographic conditions. The availability of water is thus characterised by high surface runoff generation and poor groundwater recharge. The unit, has an added advantage of receiving sizable additional runoff from the upper catchment of the adjoining district of Sirohi in Rajasthan.

## SURFACE WATER

Relatively higher rainfall, (average 704 mm) steeper ground slopes ( 1:2 - 1: 200 ) and crystalline nature of rocks, produce a surface runoff of about 121 mm, comprising almost 18% of the average rainfall (TEC,1995). The total effective watershed of the area includes that of the upstream catchment (3100 sq. km) of the Banas river basin draining from the adjoining area of Rajasthan, producing the total runoff of almost double the available surface water falling within the limits of the terrain unit. The major watersheds are those of Banas, Sipu, Balaram, and Saraswati rivers (Fig. 4.3). The total effective area of all these basins is 6900 sq. km Sabarmati, tangentially passing across the eastern flank of the unit has 4118.06 sq. km of upper catchment (Rao, 1979). The runoff produced within the district limit flows out to the Sabarkantha. Thus its water is not available to the district but physiography provides good sites for harnessing this water resource. Taking advantage of this situation several sites can be selected for harnessing the available runoff (of Sabarmati basin) which at present escapes to the neighbouring district.

The State Government has already constructed two major storage dams across Sipu and Banas and one medium size dam across Saraswati. The gross storage capacity from the three dams is 681.8 MCM and total irrigation potential is 82.59 Th ha (NWRD 1992). Eleven more sites have been identified for medium size. Over and above, there are around 135 minor schemes with irrigation potential of 8.5 Th ha (TEC,1995).

The ERH terrain also provides numerous ideal sites for rainwater harvesting by constructing village ponds. Unfortunately, at present there exists only few village ponds. The highland has only 8% of the total number of village ponds of the district. In fact, most of the Irrigation command for the major and medium size schemes, lies outside the highland. In spite of the extensive development of the available resource, a major portion of the available potential flows down to the adjoining plains.

## GROUNDWATER

The highland has a limited groundwater potential. The occurrence of groundwater in the metamorphic and granitic rocks is restricted to the zone of weathering and fracturing; the water occurs under phreatic aquifer conditions. The rocks are devoid of primary porosity and hence no continuous aquifers are formed. The sporadic local

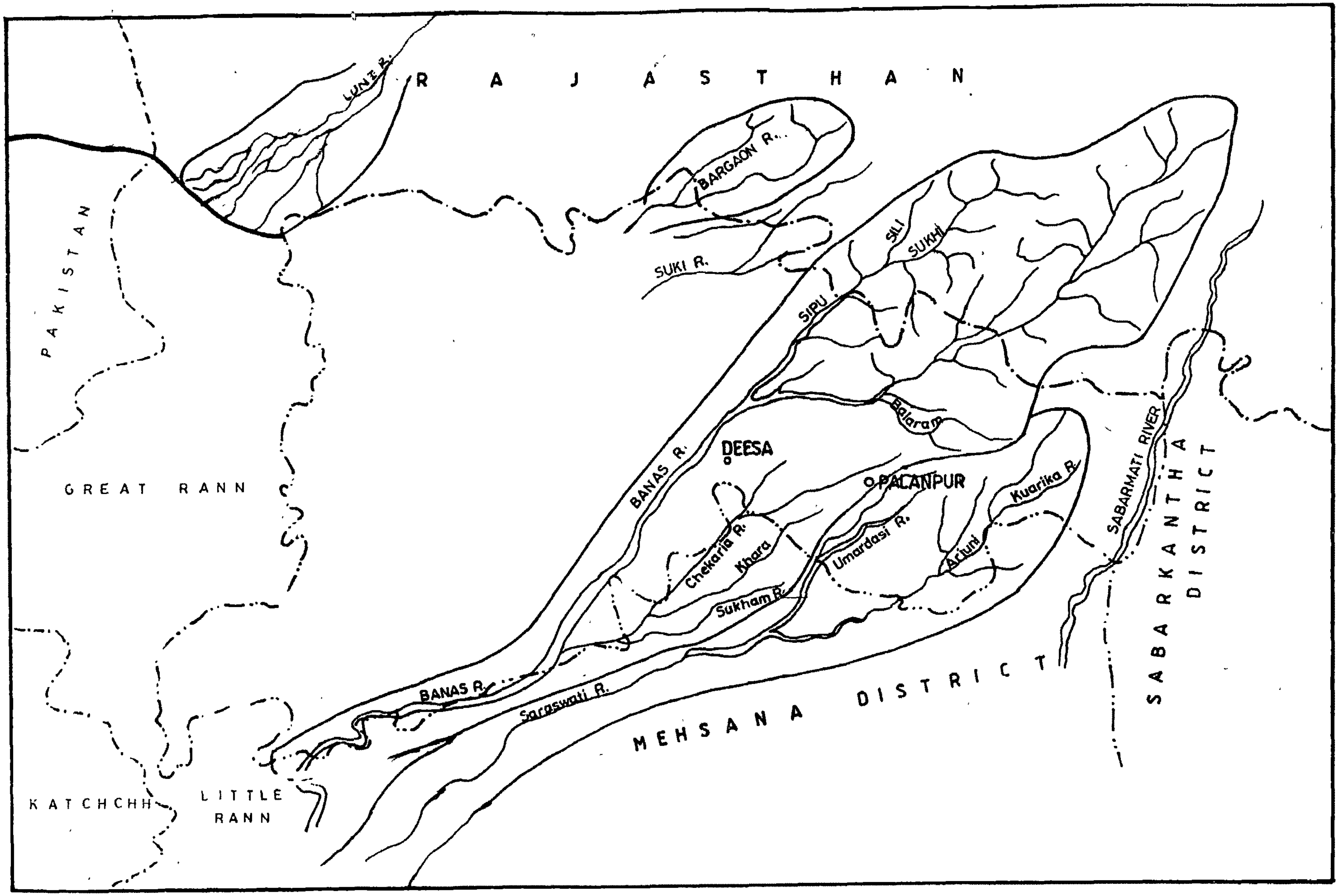



FIG- 4·3 RIVER BASIN MAP OF BANASKANTHA DISTRICT waterbearing zones are encountered where secondary porosity has developed, are usually hydraulically disconnected. Depth of such phreatic aquifers extends to about of 100 m. The open dugwells tapping the aquifers have generally a low yield of 10-50 lpm. However, the wells located in piedmont zone at times have exceptionally higher yield of about 1000-2000 lpm. Most ground water levels generally show marked seasonal fluctuations and go dry in summer. The quality of groundwater is generally good but at places higher concentration of fluorides and nitrates are observed. There are around 40% dugwells located in the highland.

The average recharge has been estimated as about 12 % of the rainfall (GWRDC 1991) The recharge for the highland as per by GWRDC (1991 ) is given in the (Table 4.6).

**Table 4.6 Groundwater Recharge and Development for ERH Unit.**

| Sr. No. | Taluka | Total Recharge (MCM/Yr) | Utilisable recharge (MCM/Yr) | Level of development (%) |
|---|---|---|---|---|
| 1 | Danta | 45.56 | 38.73 | 53.70 |
| 2 | Vadgam | 54.62 | 46.43 | 236.52 |
| 3 | Palanpur | 218.55 | 185.76 | 79.43 |
| 4 | Dhanera | 157.53 | 133.90 | 78.16 |
| | | 119.06 | 101.20 | 111.95 |

## ANTHROPOGENIC IMPACT AND INTERFERENCE

Increased anthropogenic activity has been directly related to the exploitation of the natural resource like land, minerals, forest, water resources, etc. The anthropogenic activities in the old days were dominantly forest based, which is now fast changing to agriculture, irrigation, mining and industry. Agricultural development of the land is on a limited scale due to terrain conditions. But growing pressure on agriculture has resulted in progressive encroachment on forest land. About 70% of the total forest of the district lies in the highland, and the forests is under great stress due to haphazard exploitation (ORG, 1994). The conflicting interests between exploitation forest resources, and agricultural development have resulted into overall ecological degradation. The highland is endowed with rich mineral deposits; but the unscientific exploitation is a source of increasing threat to the local environment. The mineral exploitation includes extensive marble and limestone quarrying. Jariba, around Ambaji has marble mining activity of almost more than 100 years old. The total estimated reserves of marble in Ambaji exceeds 50 million tonnes. GIDC has established a functional estate at Ambaji known as 'Marble Estate of Ambaji'. But limestone deposits have not yet been exploited to their full extent. Two cement factories, located in the Danta taluka are producing Portland Cement on small scale. In recent years, granite quarrying has also been taken up with increasing use in a variety of building constructional activities. The highland also provides large scale construction materials as crushed and natural aggregates. There are several mini cement plants based on local limestone deposits. Promising reserves of granite are found to the north of Palanpur and Deesa, and also to the east of Dhanera and Danta.

Regular mining and processing of basemetal deposits of Ambaji is slowly expanding. Gujarat Mineral Development Corporation (GMDC) is involved in developing the multimetal zone of mineralisation consisting of copper, lead and zinc minerals. The mineralised zone is located west-northwest of the temple town. The total estimated reserves are around 8.50 million tonnes (Merh, 1995). Actual exploitation has not yet been started. GMDC is in process of setting up a plant for beneficiation and extraction of metal concentrates.

Development of local surface water resources during last few decades in the form of major and medium size dams has provided a special impetus to the professional activities in the area and as a result the culture, life style, economic activities reflect the changing pattern of the natural resources ultilisation. The religious centers like Ambamata and tourist the spot like Balaram attracting large number of people from long distances also have a special influence on the human activities of the area.

Environmental degradation of the highland is a subject matter of considerable concern. It is caused not only by the unplanned and over exploitation of natural resources, but the sudden increased urbanisation of the area, problems of pollution is also inducted as well.