CHAPTER - 5

GEOMORPHOLOGY

GEOMORPHIC DIVISIONS

The Khari basin is divisible into several distinct geomorphic units. Each geomorphic unit is characterized by a major structural feature. Following are the easily recognizable geomorphic units in the area (Fig.5.1):

(1) Katrol Hill Ranges in the southern part,

(2) Central and Eastern plains with scattered hills,

(3) Northern hilly region, abruptly ending in the plain of Banni.

(4) Western Upland.

KATROL HILL RANGE

The Khari river of Central Mainland Kachchh arises from the E-W

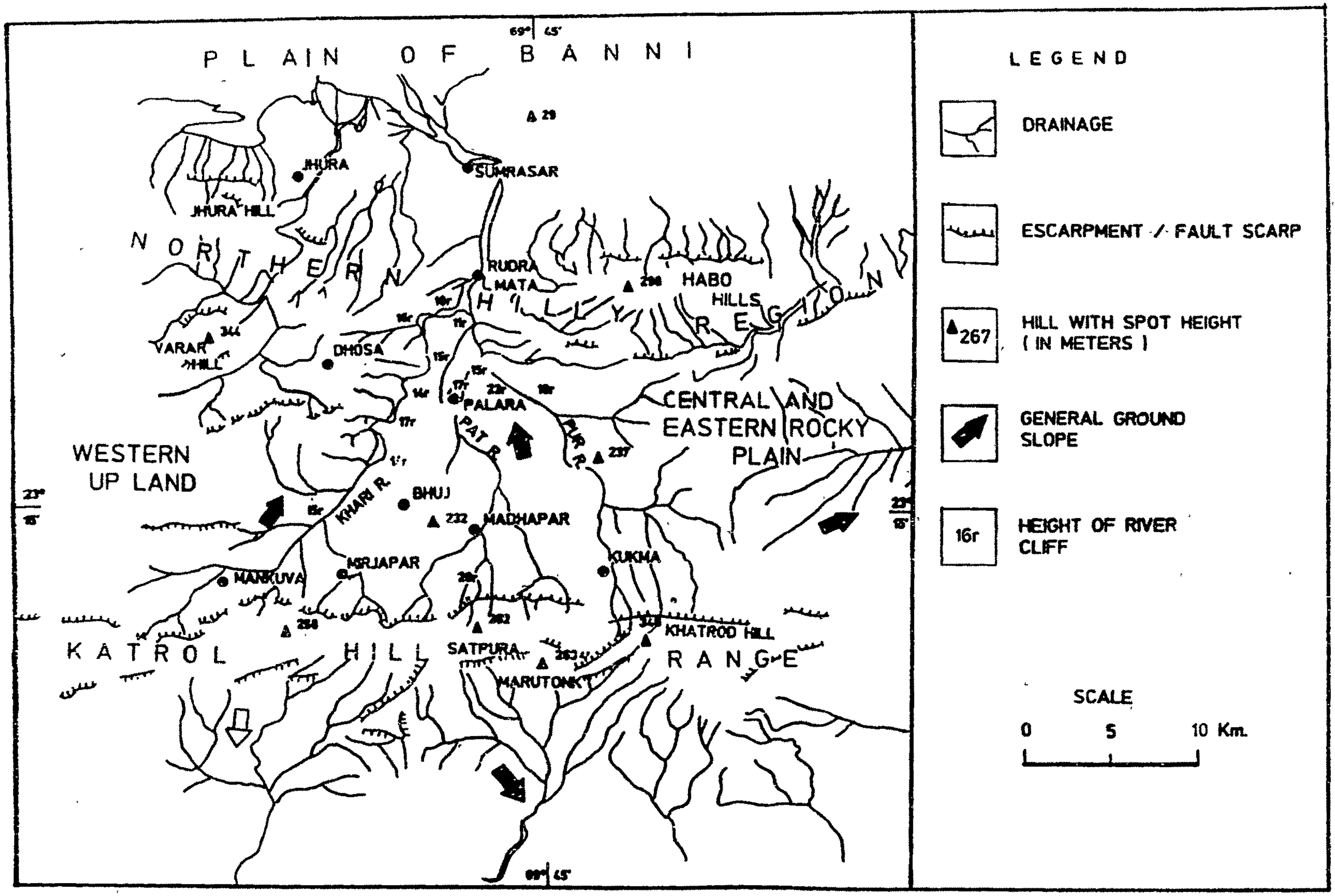

Fig. 5.1 Geomorphic map of the study area.

trending high Katrol hill range. The Katrol hill range represent varied topographical features, typical of the areas which have suffered active tectonics. Northern faces of these ranges are steep, while it has very gentle slope southward (Plate 4.3). The highest elevated line of the range acts as a water divide area, from where the nothernly flowing streams of high gradient depart from the southerly flowing streams.

The prominent cliffs associated with the Katrol hill range are as follows:

1.Cliffs NE of Sanitarium,

2.Cliffs SE of Tapkadevi Mandir,

3.Cliffs at Khatrod village.

The prominent peaks of the Katrol range (Fig.5.1) falling in the Khari basin are (1) Khatrod hill (349 m), (north of village Kukma, near Khatrod village), (2) Jogi Timba (225 m) (east of Gangeshwar Mahadev), (3) Marutonk (263 m) (South of Gangeshwar Mahadev), (4) Satpura Dungar (262 m) (East of Hamadra Talav), (5) a 258 m pinacle (southeast of Shiv Paras Mandir), (6) a 240 m pinnacle (at bifurcation of Bharasar-Mankuva road), (7) a 251 m peak (southeast of Bharasar).

The Katrol hill range consists of high hill slopes, straight mountain fronts, triangular and less sinuous facets (Plate 5.1), colluvial fans and Quaternary miliolite deposits, which take their position in the hollowed parts of the active mountain fronts (Plate 5.2). The older fans seen at a medium height, while the tow of the mountains at some places are represented by deep steep sided valleys or just faces. The fans and miliolite deposits are dissected and make the gully like structures (Plate 3.12).

CENTRAL AND EASTERN PLAIN WITH SCATTERED HILLS

This rocky plain occupies the central and eastern part of the Khari basin (Plate 1.1,5.3). The plain is characterized by a gentle slope towards north merging into the plain of Banni. The southern boundary of the plain is marked by Katrol hill range.

Low ridges of sandstones are common in the southern part of the plain. The table topped hills and ridges of Cretaceous sandstone of Bhuj Formation are situated in the western part of the central plain of the basin. Scattered hills and hillocks of the area are the results of basic intrusions. The Bhujiya hill located in the centre of the basin has elevation of 232m and is mainly composed of basic intrusive rocks in the core. The central plain identified as an Early Quaternary stony landsurface by Biswas (1974) is drained by the gullies, ravines, gorges and deep cut river valleys. The Khari and its tributaries the Pat and the Pur Nadi represent such gorges (Plate 5.4), ravines (Plate 5.5) and vertically cut prominent cliffs (Plate 5.6a). The narrow gorge has developed in a continuous stretch of tectono-erosional terraces due to the recent upliftment. Most of the part of this zone is represented by the uppermost Mesozoic-Bhuj Formation. Four erosional rocky terraces have developed in hard rocks of Bhuj Series. Numerous pot-holes have developed in the rocky terraces in the Khari river (Plate 6b).

NORTHERN HILLY REGION

The spire of the upright triangular Khari river basin is surrounded by Habo and Jhura group of hills in the northeast and northwest of the basin respectively (Fig.5.1; Plate 1.2,3.1). These are peculiar kind of

Plate 5.1 Photograph of Katrol Hill Fault Scarp. Note the degradation of fault scarp in the form of gullies and colluvial material at the base.

Plate 5.2 Photograph of the colluvial fans and the overlying miliolite (see Plate 3.13) along Katrol Hill Fault . Photograph taken from the Khatrod Hill.

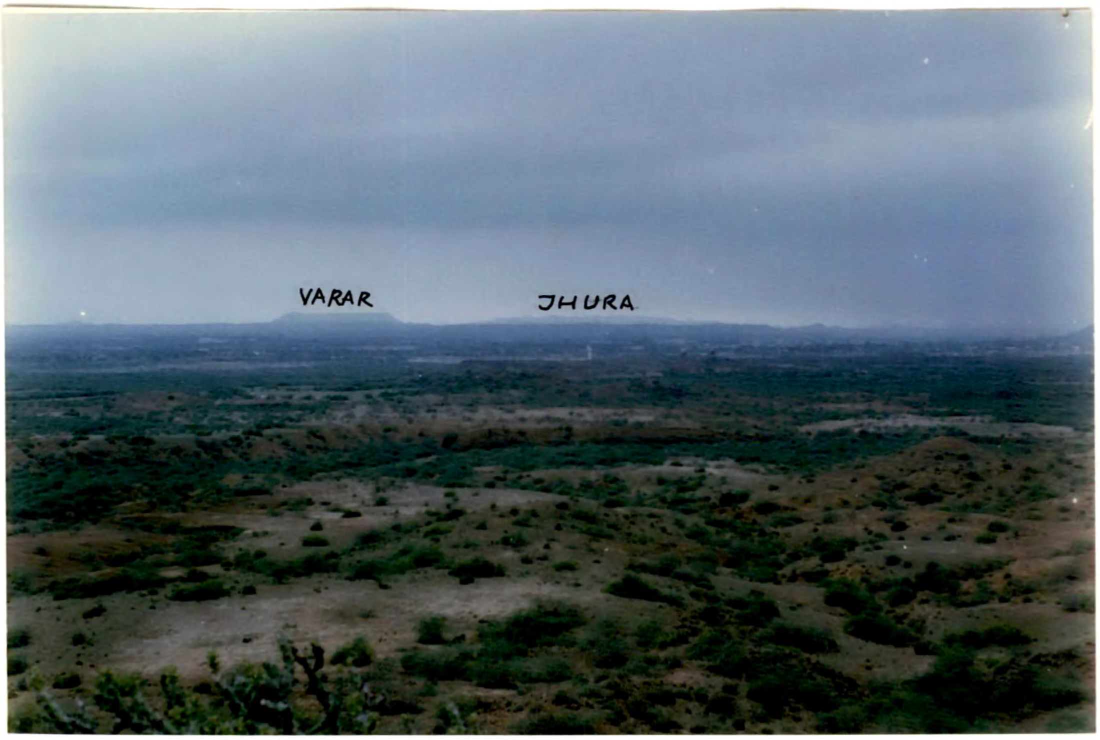

Plate 5.3 Photograph showing the general topography of the central rocky plain. In the foreground is the colluvial material associated with the Katrol Hill Fault (Photograph taken from Satpura Dungar).

Plate 5.4 Downstream view of gorge cut by Khari river in Bhuj sandstone. A weathered dyke cuts across the gorge along which the subsurface water has seeped on to the surface (Loc. 4 km from west of Bhuj on Bhuj- Kodki road).

Plate 5.5 Photograph showing deep gullies developed in Jhuran shales (Loc. Palara Mahadev).

Plate 5 6a Incised cliffs of Jumara Formation along Pat river. (Loc. near Palara Mahadev).

dome shaped uplifted regions. Both have steep slopes towards north, while southern slopes are very gentle and almost concurrent with the dip of the beds. Closely spaced Habo hills have intervening deeply cut `v` shaped valleys. The gradient of the rivers and streams are very high compared to that of Jhura hills. The hills are stretched almost in E-W directions from Lodai in the east to Kunaria in the west. They crop out the Jurassic rocks in the semi circular shape. Kaswali river flows almost on the periphery of the semi circle southern margin of Habo dome; but scattered hills and ridges seem to be continuous beyond the Kaswali river in south merging into the central plain. A smaller but higher order stream represents deep gullies, ravines and river cliffs in the eastern part of the semi circular outcrop of Habo Hills. It finally meets to the main Khari Channel at Rudramata Dam.

Jhura hills are trending nearly ENE - WSW and they resemble the Habo Hills structurally, while in age the rocks of Jhura hills are older than that of Habo. A very small part of eastern flank of Jhura domal uplift falls in the Khari basin. A number of lesser order small streams arising from southern and south-eastern slopes of Jhura hills meet the Khari main channel.

WESTERN UPLAND

The upland forms a small part of Khari river basin and comprise rocks of Cretaceous sandstone and Deccan traps. The general elevation of the upland area is about 150 m, barring a few scattered hills made up of basic intrusions.

DRAINAGE

The lower order streams of the Khari river basin arise from the hilly region of Katrol hill range (Fig. 1.3). These flow along either a fracture or fault or synclinal troughs and flexures. These lower order streams successively build higher order streams as they approach the piedmont zone and the flat rocky land surface around Bhuj. The higher order streams flowing on the gentle surface, follow the general slope direction and successively reveal Jhuran and Bhuj Formations in the vertically cut river cliffs. The cliffs are generally 20-25 m high, but occasionally they exceed more than 40 m.

The river on the rocky land surface around Bhuj resembles a typical alluvial meandering river, but unlike the alluvial rivers the Khari river displays hard rocks in its high cliffs (Plate 5.7). The Khari river shows negligible fluvial deposits of recent time as if the river has passed very less time after its evolution. Moreover the river flows on the Early Quaternary land surface (Biswas, 1974), therefore it must have evolved late in the geological history. Distance between right and left divides of the river channel is nearly 500 m and at places it is less than 100 m. Besides the deeply cut ravines and gorges the main river channel shows evidences of uplift. Ground rupturing and cliff destruction witness recent seismic activities (Plates 5.8). Huge blocks of horizontally bedded sandstones occur almost in vertical position in the Khari river channel. These are some of the vital evidences of recent seismic events (Plate 5.9).

The Khari river to the north of Rudramata Dam becomes wide and sandy. In the viscinity of the Dam it shows a few scattered rocky cliffs.

Plate 5.6b Photograph showing pot holes near the gorge in Khari river (Loc 4 km west of Bhuj on Bhuj- Kodki road).

Plate 5.7 Photograph showing incised cliffs of Jhuran Formation along Khari river (Loc. 4 km NW of Bhuj Air Port) .

Plate 5.8 Unstable rocky cliff attributed to periodic seismic activity in the area (Loc. 4 km NW of Bhuj Air Port)

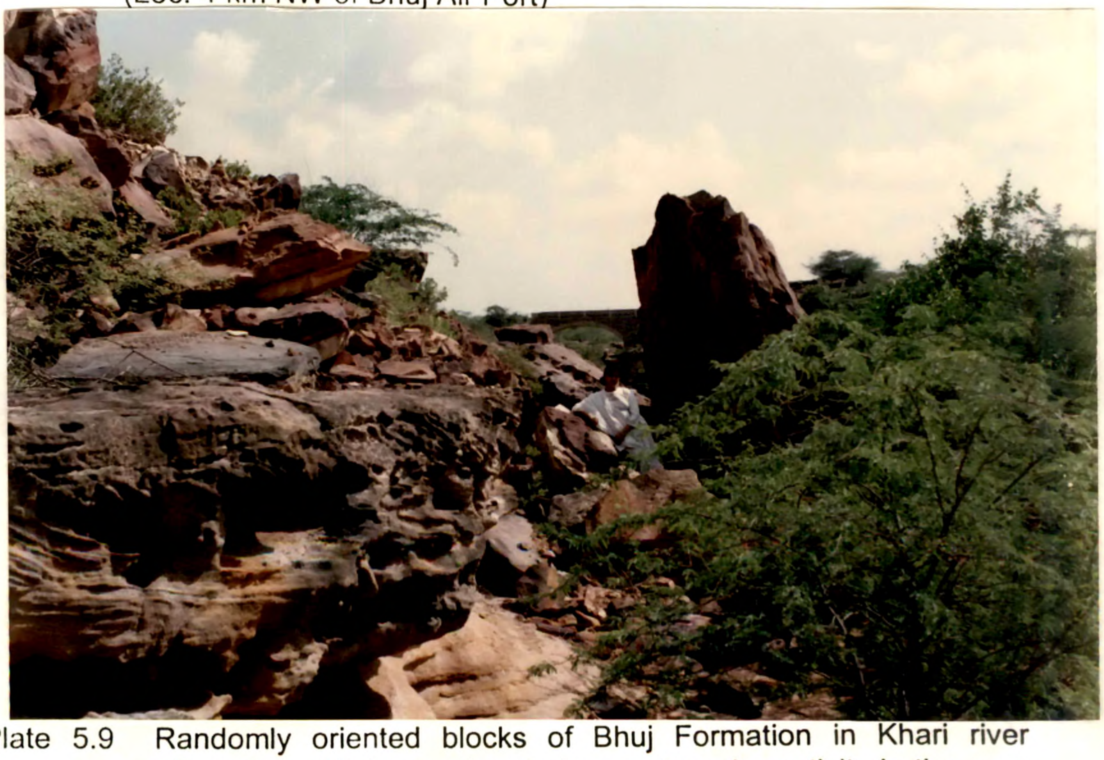

Plate 5.9 Randomly oriented blocks of Bhuj Formation in Khari river attributed to cliff destruction during earthquake activity in the area (Loc. 4 km west of Bhuj on Bhuj- Kodki road).

The river merges into the plain of Banni in the north and becomes indistinguishable.

EROSIONAL SURFACES

The present day landscape of the Khari basin is an end-product of various processes like sub-arial erosion, pediplanation and tectonic activities. The in-depth study of the various erosional surfaces of the Khari river basin shed adequate light on the base levels and processes of erosion and the role of recent tectonic movements. The series of erosional surfaces have constituted a stepped topography following the normal age sequence where the oldest surface occurs at the top and the youngest at the bottom.

The processes responsible for generating the polycyclic denudational landscape of the Khari river basin are climate, tectonism and sea-level changes. These have given rise to various erosional surfaces. The erosional surfaces were identified on the basis of the occurrence of flat topped surfaces and accordant summits of a group of hills, ridges or plateaus over an extensive area.

A total number of six erosional surfaces E_1 to E_6 (Fig.5.2) have been identified in the Khari river basin of Central Kachchh Highland. These stand at an altitude of 260-300m, 240-260m, 160-200m, 120-140m, 80-120m, and 0-20m, respectively. These surfaces have formed because of intermittent uplift due to repeated reactivation of basement faults followed by lateral planation. In order to obtain information about these surfaces a number of N-S topographical profiles were drawn (Fig.5.3). The general slope of these surfaces is towards south, indicating that there have been

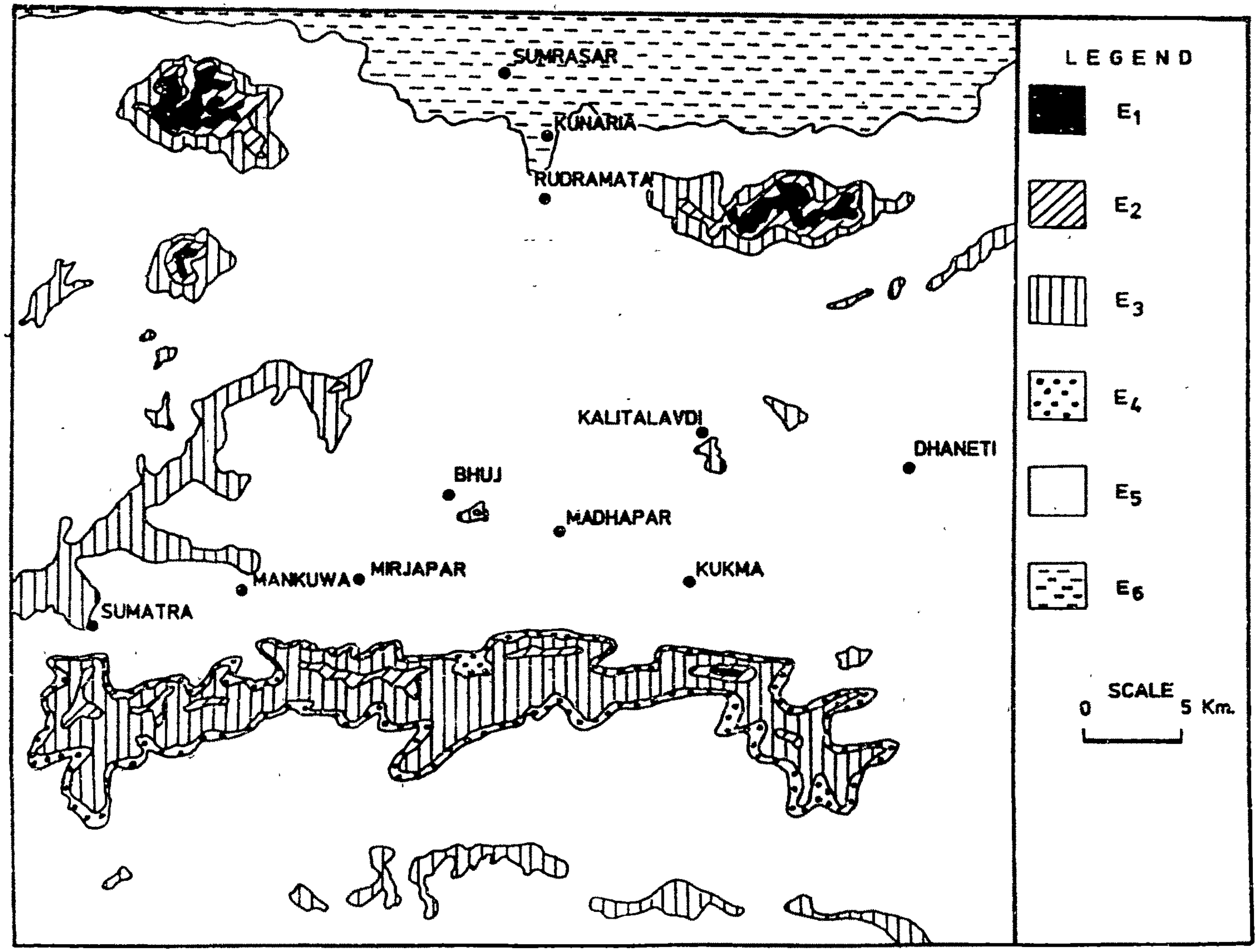

Fig. 5.2 Map showing erosional surfaces in the study area.

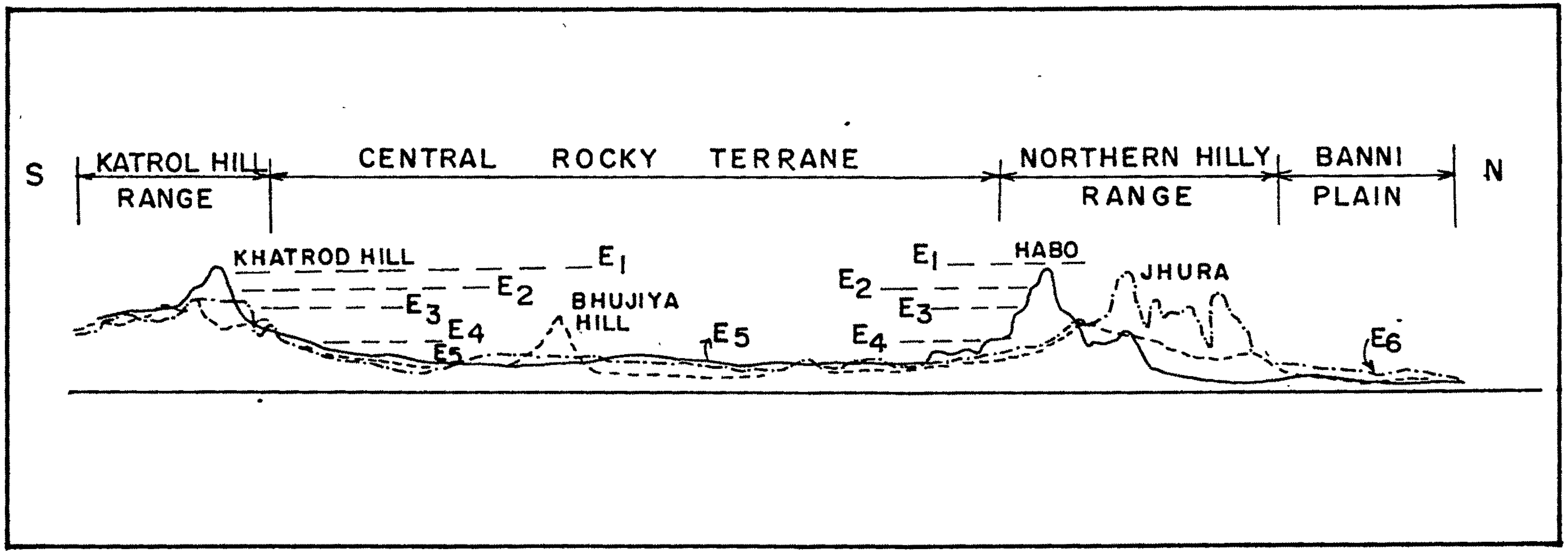

Fig.5.3 N-S topographic profiles across the study area showing various erosional surfaces.

an unidirectional tectonic movement from time to time causing periods of tectonic instabilities and stabilities leading to the formation of polycyclic landscape. Biswas (1974) recognized five denudational surfaces in the Kachchh Mainland and correlated them with the unconformities or hiatuses in the sedimentary sequence exposed in the bordering coast land. The chronological arrangement of these erosional surfaces are mainly based on field evidences and their correlatability with unconformities as described by Biswas (1974). The details of these surfaces are given in Table(5.1).

PRE-QUATERNARY EROSIONAL SURFACES

The pre-Quaternary erosional surfaces E_1 and E_2 occurring at an altitude of 300 and 240 m are mostly seen within the Katrol hill range of the study area (Plate 5.10). There is only one hill that crosses 300m altitude which Biswas(1974) has identified as remnants of Upper Cretaceous landscape. A number of scattered hills ranging in altitude between 240-300m occur and forming E_1 and E_2 surfaces in the area. These are at places represented by discontinuous ridges and plateaus such as Khatrod ridge (280-342m) at Khatrod village, and Satpura plateau (262 m m), south of Madhapar village. These landsurfaces in the Katrol hill range show steep mountain fronts and longitudinal profiles. Most of the first order streams of the Khari river basin originate from these land surfaces. These are believed to have evolved during Early Tertiary (Biswas,1974).

The E_3 surface (Fig.5.2; Plate 5.10) is distinguished from E_2 surface by flat hill tops, discontinuous ridges, plateaus and cuestas which generally fall between an altitude range of 160-200m (Plate 3.7) . The

Table: 5.1 Table showing characteristics of the various erosional surfaces in the Khari river basin.

EROSIONAL SURFACES	APPROXIMATE RANGE OF ALTITUDE (in m above msl)	ASSOCIATED PHYSIOGRAPHIC FEATURES	AGE
E_6	0-20	Low lying Banni plain, terraces in deeply incised valleys in the hilly regions, alluvial and colluvial fans, miliolites and alluvial deposits.	Mid-Late Quaternary
E_5	80-120	Extensive rocky plains, cultivated land, small erosional mounds.	Early Quaternary
E_4	120-140	Flat topped low ridges, cuestas, mesas and terraces.	Late Tertiary
E_3	160-200	Flat topped hills discontinuous ridges, plateaus and cuestas.	Mid Tertiary
E_2	240-260	Scattered hills and plateaus and discontinuous ridges	Early Tertiary
E_1	260-300 and above	Isolated and scattered, towering hills and pleatues.	Late Cretaceous

first order streams of the Khari basin drain through this land surface. The streams flowing through this landsurface contain huge boulders and ruptured blocks indicating recent tectonic activities.

The youngest pre-Quaternary erosional land surface (E4) is marked by gently sloping pediments, residual hills, flat stony surfaces, plateaus, cuestas, mesas and terraces (Fig. 5.2; Plate 5.11). The surface is drained by the second order and third streams. All the pre-Quaternary surfaces show a southerly tilt which points to an unidirectional movement along E-W Katrol Hill Fault. Biswas(1974) also recognized similar kind of tectonic movements along basement faults in Kachchh. The erosional surfaces show a wavy configuration which could be attributed to the differential movements along various fault systems and varying degree of erosional processes.

QUATERNARY EROSIONAL SURFACES

The two prominent Quaternary surfaces (E_5 and E_6) at an altitude of 80-120m and 0-20m been recognized in the Khari river basin. The E_5 surface ranging in altitude between 80-120m (Fig. 5.2; Plate 5.11) is dominant in the central part of the basin. It is marked by low residual ridges, mesas, flat rocky and sandy pediments and rocky river terraces (Plate 5.12). This land surface slopes towards north opposite to dip, this phenomenon could be due to the vertical upliftment of the Central Kachchh Highland due to differential movement along Katrol Hill Fault. Biswas (1974) has postulated that Kachchh Mainland suffered a vertical upliftment during Early Quaternary. This landsurface is traversed by higher order streams which have incised the surface and given rise to

Plate 5.10 West facing view of Katrol hill range showing the various erosional surfaces. Note the consistant southern tilt of all the surfaces.

Plate 5.11 Photograph showing erosional surfaces E4 and E5 (Loc. Near Ler).

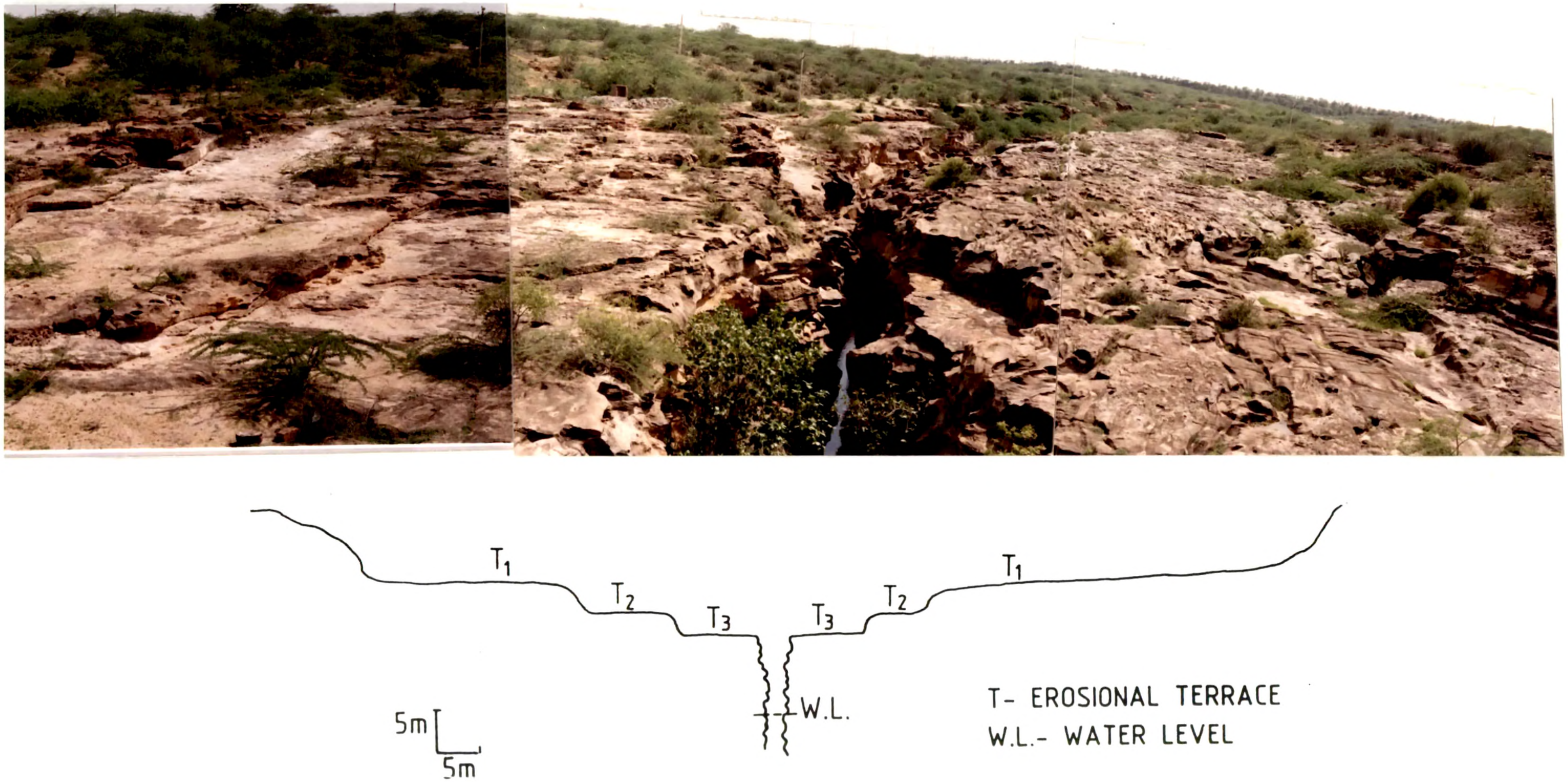

Plate 5.12 Upstream view of the narrow gorge cut by Khari river in Bhuj Formation. Note the four levels of rocky terraces (Loc. 4km from west of Bhuj on Bhuj- Kodki road).

tectono-erosional terraces. The deeply incised valleys, gorges and ravines indicating neotectonic activity during Quaternary. Biswas(1974) has reported a displacement of about 30-35m in the elevation of this surface on either side of the Katrol Hill Fault during Early Quaternary.

The latest erosional surfaces (E_6) occurring at an altitude of 20m is marked by boulder and gravel beds in river valley terraces at levels higher than the valley floor, the depositional terraces within the Katrol hill range (Plate 5.13), the rubble deposit 1-15m high above the valley floor, the clay and rubble terrace 8-9m above the river bed and the Banni plain.

The Banni deposits at the mouth of Khari river near Sumrasar village are cut by streams and gullies up to a depth of 0.3-1.5m (Biswas,1974). All these are indicative of Recent uplifts.

FAULT SCARP MORPHOLOGY

The scarps produced directly by faulting are called 'fault scarps'. The near surface geomorphic processes of erosion and deposition modify the fault scarp and make the degraded fault scarp (Keller and Rockwell, 1981). Study of the fault scarps not only help in deducing their shapes, slope elements and other morphological characteristics but are found useful in inferring the processes involved in their formation and in determining a general chronology of the scarps (Wallace, 1977) (Table 5.2).

According to Wallace (1977) the recurrent displacement produces a composite fault scarp. The displacement can be recognized by break in the slope of the fault scarp profile, unusually high (from crest to toe) of the scarp, knick points along channels that cut across the scarp and

Table: 5.2 Fault scarp morphology of Katrol hill range, slope elements, processes involved and approximate chronology.

SLOPE ELEMENT	MORPHOLOGY	PROCESS (formation and modification)	COMMENTS AND GENERAL CHRONOLOGY
Crest	Top of fault scarp (initially sharp but rounded with time)	Faulting weathering; mass wasting	Becomes rounded after free face disappears after around 10^3 yrs
Free face	Straight segment (initially 60^0 or more)	Faulting weathering, gullying, mass wasting, buried by accumulation of debris with time	Remains for about 10^2 disappears after about 1000 to 2000 yrs
Debris slope	Straight segment but becomes 45^0 or less due to debris	Accumulation of debris material in the form of colluvial fans	Dominant element after about 100 yrs, remains for about 10^5 yrs , disappears at about 10^6
Wash slope	Straight to gently concave segment Overlaps the debris slope Generally 6^0 to 15^0	Fluvial erosion and deposition, alluvium at the toe of the fan and miliolite overlies the colluvial fans	remains for about 10^3 and dominant for about 10^5
Toe	Base of the fault scarps, initially sharp but becomes indeterminant with time	Fluvial erosion and deposition Gullying, deposition of miliolite at the base	More prominent in Khatrod hill and Tapkadevi hills (young nature)

progressive displacement (old materials are displaced more than younger). The scarp slope angle for a scarp with constant height of 3 m decreases about 28-10^0 as the age of the scarp increases from about 10^3 to 10^5 yrs B.P. (Bucknam and Anderson, 1979). The fault scarps found in the Khari river basin are mostly associated with E-W regional faults and transverse faults.

Numerous fault scarps in the Khari river basin have been recognized particularly along Katrol Hill Fault and Mainland Fault. The prominent scarps are as follows:

(1) A scarp south of Kukma village on Katrol hill range near Khatrod village (Plate 5.1),

(2) Marutonk Dungar scarp (Plates 4.17,5.14),

(3) Tapkeshwari scarp (Plate 4.3),

(4) Bharapar scarp near sanitarium (Plate 5.15),

(5) Habo hill scarp (Plate 5.16),

(6) Kas hill scarp (Plate 3.7).

The Khatrod scarp, Tapkeshwari scarp (Plates 3.3, 4.3) and other associated with Katrol Hill Fault are exhibit nearly rounded to sharp crest (Plate 4.3) with unusually steep free face suggesting its youthfulness (about 10^3 to 10^4 yrs B.P). Moreover the debris flow (Plate 4.6) at Khatrod scarp and the Tapkeshwari scarp have an angle of more than 30^0 which suggests that it might have been formed between 10^2 to 10^5 yr B.P. According to Wallace (1977) very high (55^0 to 45^0) to nearly 25^0 to 30^0 angle of debris flow remains dominant until about 10^5 yrs B.P. Even at the base of such scarps, the slope is very high, while the toe of the scarp profile is dissected and exposes the Quaternary material like colluvial fan

Plate 5.13 Photograph showing erosional surface (E_6) in the Katrol hill range (Loc.Gunawari river near Gangeshwar temple).

Plate 5.14 South facing view of the NW-SE trending Marutonk Dungar Fault . Note the fresh nature of the fault scarp.

Plate 5.15 Photograph of the E-W trending Bharapar Fault Scarp.

Plate 5.16 Photograph showing E-W trending Habo Hill Scarp which marks the Kachchh Mainland Fault .

deposits and miliolites along the fresh gullies (Plate 3.12, 3.13). This is indicative of active tectonics along the scarps around 12,000 yrs B.P.

The scarp at Marutonk Dungar (Plate 5.14) is a vital evidence of the seismic events in Recent times which are responsible for the straight free face segment, very sharp crest and 30 to 38^0 debris slope (Plate 5.14). This indicates that the scarp age might not be older than 10^2 to 10^4 yrs B.P. The Marutonk dungar scarp line is trending NW-SE suggesting the transverse faults are more active during the Late Quaternary to Recent. Other transverse faults near Khatrod hill and at Shiv Paras dome near Mandvi road (Plate 4.7) have also similar characters suggesting their youthfulness. The scarps associated with the Kachchh Mainland Fault have comparatively low debris slope value, 45 to 75^0 free face slope (Plate 5.16) and gently dipping slope at the base and toe indicates the scarps are older than those associated with Katrol Hill Fault but not older than Middle Quaternary, as they also displace colluvial fans at the toe region. The Kas (Plate 3.7) and Bharapar scarp (Plate 5.15) are other prominent scarps associated with E-W faults parallel to Kachchh Mainland Fault and Katrol Hill Fault. These also show evidences of recent seismic activity along the faults. Based on detailed morphological characteristics of the E-W running fault scarps developed in the Katrol Hill range, a model is thus prepared to show the general fault scarp morphology of the Khari river basin (Fig. 5.4).

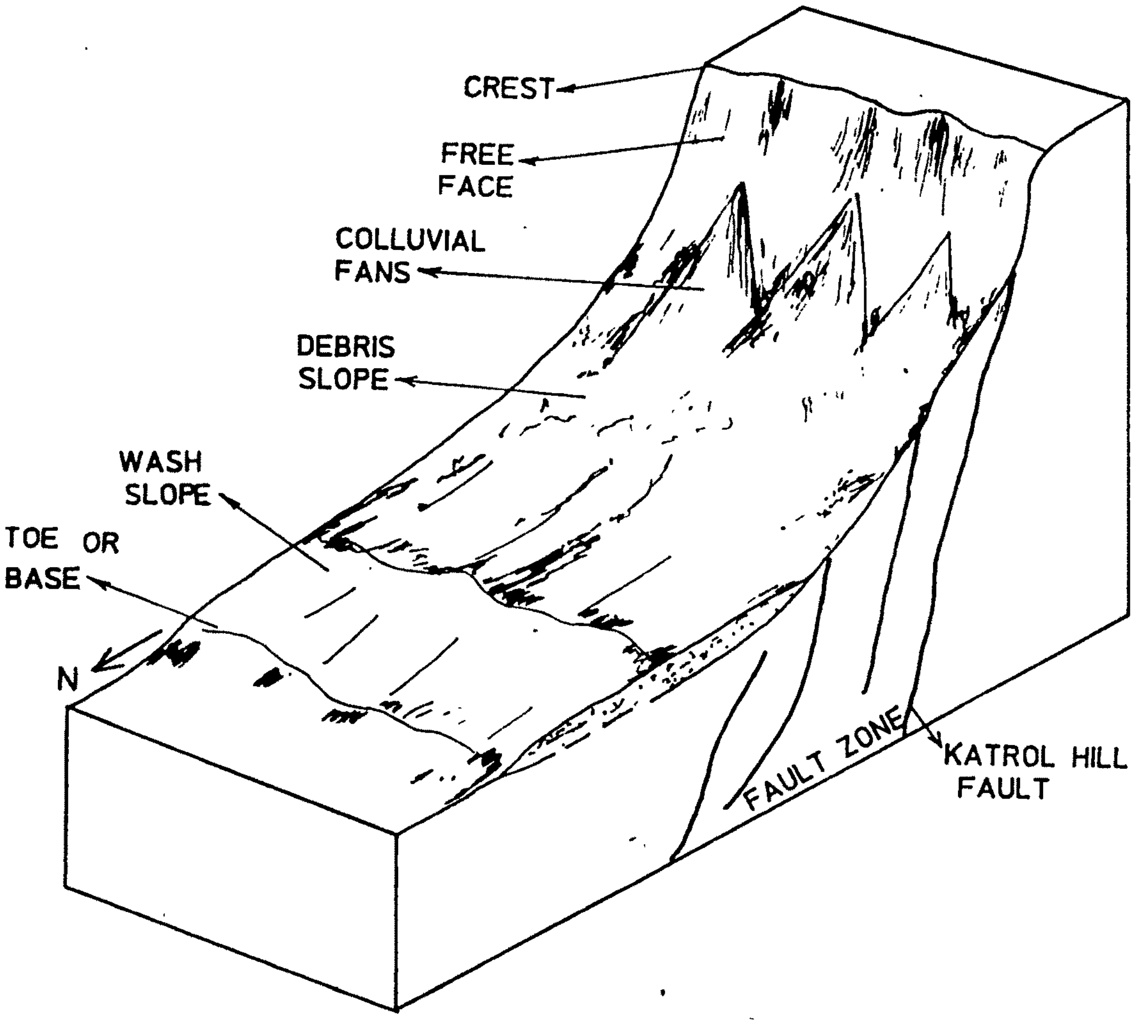

Fig.5.4 Diagrammatic representation of the general fault scarp morphology of the E-W fault system of the study area.