Photonirvachak
Journal of the Indian Society of Remote Sensing, Vol. 25, No. 3, 1997

Geomorphology and Landscape Evolution of Bharatpur District, Rajasthan

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ABSTRACT

The morphometric analysis of the surface drainage has been carried out for the four micro-watersheds of Bharatpur district, Rajasthan to quantify the drainage morphometry of the district. The morphochronology of landscape evolution has been described. Banaganga represents anomalous drainage, which causes large scale inundation during rainy season. The strain of post-collision Himalayan tectonics resulted in slope mutation in Bharatpur district which changed slope from westerly to easterly. The landform characteristics of Bharatpur district have been archieved at the National Informatics Center, District Data Base, Bharatpur in alpha numeric mode.

Introduction

The Bharatpur district presents a complex record of landscape evolution. The rocks of Delhi and Vindhyan Supergroups underwent polycyclic planation. Banaganga represents anomalous drainage, which causes large scale inundation during rainy season. The strain of post-collision Himalayan tectonics resulted in slope mutation in Bharatpur district which changed slope from westerly to easterly.

A study on geomorphology of Bharatpur District, Rajasthan was carried out to create a District Data Base for natural resources of Bharatpur district with village level resolution under Natural Resource Informatics System project of National Informatics Centre, Planning Commission, New Delhi.

Methodology

The present study on geomorphology has been carried out using time and cost effective remote sensing technique. Satellite data pertaining to LANDSAT TM False Color Composite (FCC) on 1:250,000 scale of bands 2, 3 & 4 have been used. Visual interpretation

(Recd. 16 Aug. '97; in final form 15 Dec. '97)

technique was applied for delineating different landforms and geomorphic features in the study area. Limited field checks were carried out in the district. Ground inputs were incorporated in the geomorphological map prepared from LANDSAT TM FCC.

Results and Discussion

The paper presents the landforms and drainage morphometry of Bharatpur district. The village level information on geomorphology has been archived at NIC District Data Base at Collectorate, Bharatpur.

Geomorphic Zones

The Bharatpur district has been divided into following six geomorphic zones based on photographic and geotechnical elements:

1. Structural Hills and Valleys of Delhi Supergroup
2. Vindhyan Plateau
3. Aligarh Older Alluvial Plain (AOAP)
4. Burried Pediment
5. Banganga Recent Food Plain
6. Aeolian Deposits

1. *Structural Hills and Valleys of Delhi Supergroup*

The hills and ridges of the Bayana, Ajabgarh and Alwar groups form hogback, cuesta and domal outcrops aligned in NE-SW to ENE-WSW directions in the northern and southern parts of the district (Fig. 1). The following three geomorphic subunits have been identified in this zone:

a) Cuesta: Cuesta ridges correspond to Bayana Group and are aligned in a linear pattern in ENE-WSW direction developed near Deeg in the north and around Bayana in the southern part of the district. This geomorphic unit was identified on Landsat TM FCC by its dark tone, linear pattern, isolated hillocks, parallel pattern of first order channels and scanty or no vegetation. The Cuesta exhibit asymmetrical ridge profile. The Cuesta topography is controlled by gently dipping strata with moderate resistance to erosion.

b) Hogback ridges: The hogbacks occur as NE-SW trending steep ridges of Delhi Supergroup with symmetrical profile defining the main architecture of the Aravalli ranges, forming natural fortification on the western boundary of the district. The dip slopes and obsequent slopes are nearly symmetrical and smooth. In the TM FCC the ridges are defined by tonal banding, linear forms, parallel drainage and symmetrical profile. Vegetation cover is scanty and resistance to erosion is high. The continuity of the ridges at places is punctuated by faults or joint controlled drainage. These are seen prominently in the Pahari and Kaman Tahsils. The Kaman ridges terminate at Barsana in Mathura district, while the Pahari hog backs continue northwards in Haryana and Delhi States, in south these merge with the Lalsot Hills of Rajasthan.

c) Erosional Valleys: The erosional valleys have developed within the Bayana Hill ranges and in Pahari and Kaman Tahsils of Bharatpur District. These are characterised by depressed topography, carved out of soft lithologies in the rocks of Delhi Supergroup. The erosional valleys are sandwiched within the hogback zone and exhibit restricted agricultural practice, centripetal drainage and form rib and furrow topography due to their low to moderate resistance to erosion.

2. *Vindhyan Plateau*

The Vindhyan Plateau in the southern part of the district forms the monolith overlooking the AOAP of Bharatpur and Banganga valleys. This zone is defined by Cuesta ridges of the Upper Bhander Sandstone and hogback ridges of Rewa Sandstone of the Vindhyan Supergroup.

The hogback ridges strike in ENE-WSW direction in a linearly stretched belt aligned parallel to the Great Boundary Fault which separates the Vindhyan Plateau from the rocks of Bayana Group and Delhi Supergroup.

The cuesta occupy a higher topographic elevation than the Vindhyan Plateau and range in elevation from 220 m to 318 m. These are characterized by structurally controlled drainage, the drainage density is medium to low and resistance to erosion is moderate to high. The Cuesta in the Vindhyans are inliers of remnants of palaeo-planar surfaces in the area. Besides, these hogback and cuesta ridges, the Vindhyan Plateau is also characterized by association with loess and ravines.

3. *Aligarh Older Alluvial Plain*

The Aligarh Older Alluvial Plain (AOAP) covers major part of the district under Kaman, Pahari, Deeg, Kumher, Nadbai and Bharatpur Tahsils (Fig. 1). It is characterised by well developed paleo-drainage system which originated from the Vindhyan uplands and Bayana Hills in the south and flowed towards north. The alluvial plain has a sharp contact with the burried pediment zone. It has irregular boundary outline and extensive agricultural activity is characteristic of this unit. The zone represents almost uniform plain with elevation ranging from 178 to 190 m. The scars and paleo-channels of the paleo-drainage are characteristic elements, picked up on LANDSAT TM FCC.

a) Paleo-channels: The paleo-channels correspond to the north flowing paleo-drainage (Fig. 1), which originated from the south and predates the Newer Alluvium (Iqbaluddin, 1994). This paleo-drainage was sinuous with medium to high drainage density. The paleo-channels are recognized on the TM FCC by their medium to dark tone, curvilinear pattern, uniform texture and continuity beyond the district boundary along the Mathura border. The groundwater conditions along these paleo-channels are good to very good and hydro-chemically the water is potable.

A younger set of abandoned paleo-channels south of Bharatpur and Nadbai define the earlier channel courses of the river Banganga and are helpful in reconstructing the channel migration of the Banganga river. These features show that Banganga is gradually shifting from north to south and the individual channels of this river are well picked up on TM FCC. These are recognized by light tone, uniform texture, linearity of tone, sharp contact, development of channel sinuosity etc. The water table along the paleo-channels is shallow but quality is not good. The landuse pattern is defined by agricultural activity. The Banganga paleo-channels are separated from the north flowing paleo-drainage by the roughly east-west trend of these channels. The Nabdai-Bharatpur water divide separates the Banganga paleo-channels in the south from the north-easterly flowing paleo-drainage of Aligarh Older Alluvial Plain.

b) Scars: These are the remnants of the highly sinuous north flowing paleo-drainage system, which were cut-off from the main channel. These are recognized north-east of Nadbai and north of Bharatpur (Fig. 1) by accurate shape, uniformity in tone, isolated occurrence and depressed relief, characterized by loss of hydraulic continuity with parent channel.

4. *Buried Pediment*

This geomorphic zone occupies a significant area in the north, south-west and north-eastern parts of the district fringing the structural hills of Delhi's and Vindhyan plateau. The zone is characterized by undulated topography, accidented slope, thin alluvial cover, higher elevation as compared to the Aligarh Older Alluvial Plain and favourable soil conditions for agriculture.

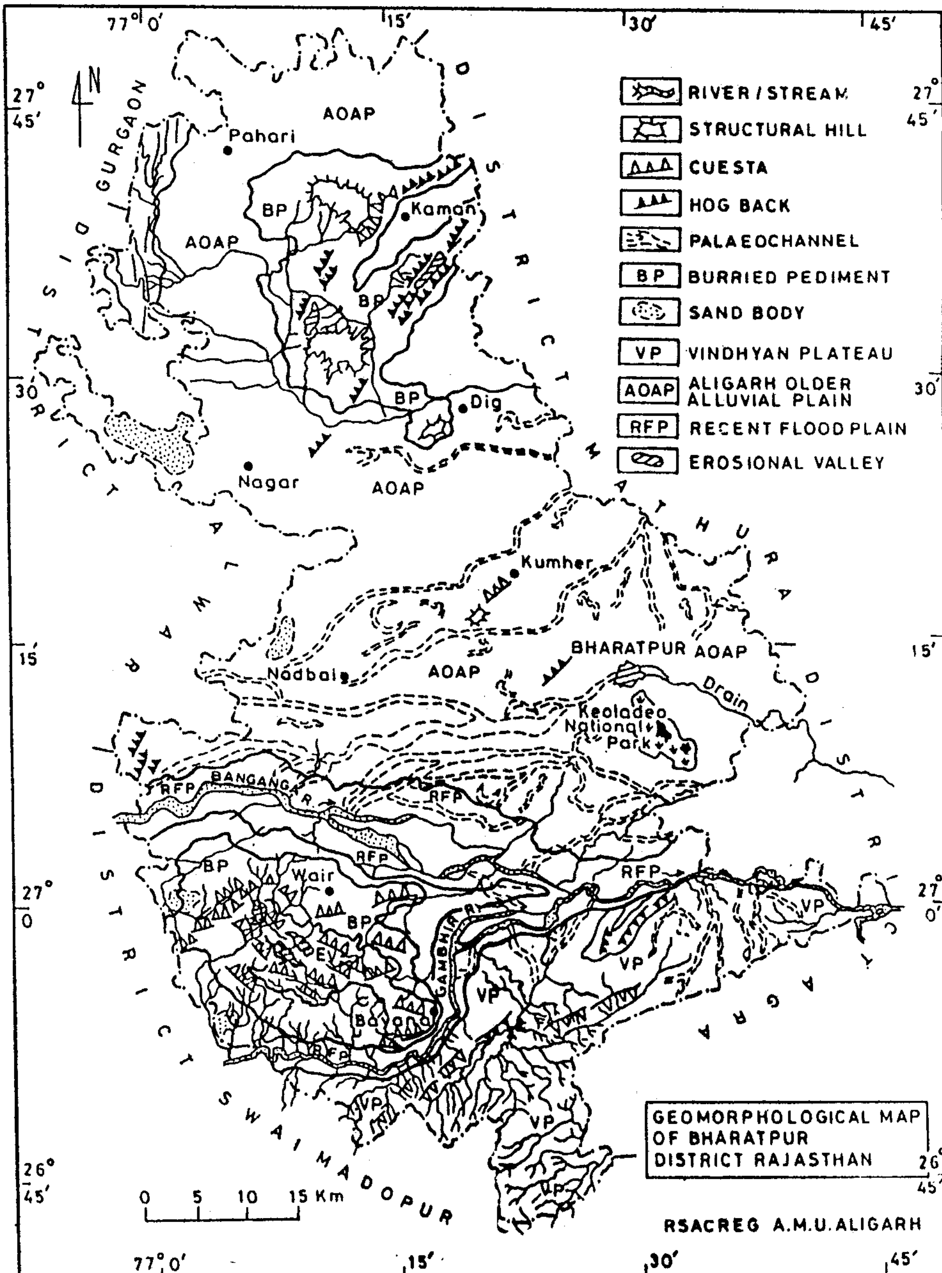
RIVER / STREAM
STRUCTURAL HILL
CUESTA
HOG BACK
PALAEOCHANNEL
BP BURRIED PEDIMENT
SAND BODY
VP VINDHYAN PLATEAU
AOAP ALIGARH OLDER ALLUVIAL PLAIN
RFP RECENT FLOOD PLAIN
EROSIONAL VALLEY
GEOMORPHOLOGICAL MAP OF BHARATPUR DISTRICT RAJASTHAN
RSACREG A.M.U. ALIGARH
0 5 10 15 Km
N
GURGAON
DISTRICT MATHURA
DISTRICT AGRA
DISTRICT ALWAR
DISTRICT SWAI MADOPUR
Pahari
Kaman
Dig
Nagar
Kumher
BHARATPUR
Nadbai
Keoladeo National Park
Drain
BANGANGA R.
GAMBHIR R.
Wair
Bayana
77° 0'
15'
30'
45'
27° 45'
30'
15'
27° 0'
26° 45'

Fig. 1

This zone is identified on the remotely sensed data by light to medium tone, sharp contact with the adjacent geomorphic zones, irregular boundary outline and partly internal drainage with low drainage density.

5. *Banganga Recent Flood Plain*

This includes the flood plain deposits of the Banganga and Gambhir rivers, which correspond to Quaternary period. These two rivers are characterized by their overall sinuous courses which locally become braided and the two finally confluence in the north-west of Rupbas town forming a low lying plain adjacent to Vindhyan Plateau in the south. It is recognized on the remotely sensed data by its dark to medium hue, sharp contact with adjacent geomorphic zone, irregular boundary outline, low settlement density, restricted landuse pattern, association of point bars/channel bars, gully erosion, scars, badland topography, sand bars, etc.

The Banganga river possibly indicate a drainage anomaly defined by the higher channel width in the western part, as it enters from the adjacent Sawai Madhopur district. The channel width decreases as it flows towards east. This anomaly clearly indicates that there has been reversal in the drainage which was from east of west in contrast to the present day west to east flow. The drainage mutation in the area has possibly taken place in the Quaternary. The frequent floods in the Bharatpur district may be attributed to the drainage mutation in the area.

6. *Aeolian Deposits*

Sand dunes and the loess deposits are reported from the Nadbai, Nagar, Bayana and Rupbas Tahsils. These sand dunes comprise > 85 per cent sand, the grains are fine subangular to angular and forming 6-8m high heap of sand. Texturally the sand is very well sorted to well sorted, fine to medium grain, possess high porosity, devoid of any biocover and has internal drainage. These are the aeolian features which have been brought to the area by wind action, but do not show the direction of the wind. Texturally these reflect uneven texture, irregular shape and outline and are spatially associated with the Aligarh Older Alluvial Plain, Vindhyan Plateau and Bayana Hills.

Drainage Morphometry

Fig. 1 presents the drainage of Bharatpur district, based on SOI toposheet and Landsat TM FCC output. The Banganga and Gambhir rivers flow from west to east in the southern half of the district. The Banganga river is sinuous in nature but locally behave as braided type. The Vindhyan plateau is drained by Kakund sub-basin which joins the Ghambhir river south of Rupbas. The central part of the district is devoid of natural drainage where runoff takes place, by sheet wash. The northern part of the district in Pahari and Kaman tahsils is drained by Kaman sub-basin, which join the Yamuna drainage near Mathura.

The drainage morphometry has been worked out in an attempt to develop relationships between drainage basin parameters and runoff characteristics, basin shape, sub-soil material, infiltration and relief characteristics (Zernitt, 1932; Boulton, 1965). The present day drainage in Bharatpur district is developed as a superimposed drainage over paleo-flood plain deposit. There has been a drainage mutation in Banganga sub-basin due to (post Himalayan collision tectonics) strain generated in the Indian shield by continued plate accretion in the Indian ocean region (Iqbaluddin & Mohammad, 1986) in the area, which is manifested by drainage and topographic anomalies.

For the purpose of morphometric analysis, the present drainage system has been divided in four sub-basins namely, Banganga, Gambhir, Kakund and Kaman. The morphometric analysis of the drainage system has been attempted for quantification of micro-watersheds in terms of Stream Order, Stream Number (Nu), Stream Length (Lu), Bifurcation Ratio (Rb), Stream Length Ratio (Sr), Stream Frequency (F), Drainage Density (D), Basin Perimeter (P), Basin Length (Lb), Basin Elongation (Re), Basin Circularity (Rc), Form Factor (Rf) and Infiltration Number (If) (Schumn, 1956; Chow, 1964; Strahler, 1964; Nautiyal, 1994). Table 1 presents the details of the morphometric analysis of the four sub-basins and briefly discussed below:

Banganga Sub-Basin: The Banganga sub-basin covers an area of about 259.37 km^2 in the south-central part of the district (Fig. 1). The perimeter of the sub-basin is about 86 km and maximum basin length (Lb) is 33.75 km. The total number of streams (Nu) of the various orders is 40, out of which the number of 1st order stream is 31, the number of 2nd order is 8 and that of 3rd order is 1. The total length of all the stream (Lu) is 173.0 km, the length of 1st order channels is 106.25 km, the 2nd order is 49.0 km and of 3rd order is 18.75 km. The bifurcation ratios (Rb) between 1st/2nd orders is 3.87 and between 2nd/3rd orders is 8.0. The stream length ratio (Sr) for 2nd/1st orders is 0.45 and for 3rd/2nd orders is 0.39. The values of drainage density (D) is 0.667 and that of stream frequency (F) is 0.154. The elongation ratio (Re) is 0.538, circularity ratio (Rc) is 0.44. The values of Infiltration number (If) is 0.102, Form factor (Rf) is 0.227 and Overland flow (Lg) is 0.749. (Fig. 2a & 2b).

Gambhir Sub-Basin: The Gambhir sub-basin covers an area of about 534.37 km^2 in the southern and south-western parts of the district (Fig. 1). The basin perimeter (P) is about 141.25 km and maximum basin length (Lb) is 42 km. The total number of streams (Nu) of various orders is 83, out of which the number of 1st order stream is 63, the number of 2nd order is 6, the number of 3rd order is 3 and 4th order is 1. The total stream length (Lu) of all orders is 289.50 km, the length of 1st order stream is 181.0 km, of 2nd order is 70.75 km, length of 3rd order is 19.50 km and that of 4th order is 18.25 km. The bifurcation ratio (Rb) of 1st/2nd orders in 3.93, that of 2nd/3rd order is 5.33 and between 3rd/4th orders is 3.0. The values of stream length ratio for 2nd/1st orders is 0.39, for 3rd/2nd orders is 0.27 and for 4th/3rd orders is 0.93. The value for drainage density (D) is 0.541 whereas for stream frequency (F) is 0.155. The elongation ratio (Re) of the basin is 0.621 and circularity ratio (Rc) is 0.336. The value of form factor (Rf) is 0.302, infiltration number (If) is 0.084 and overland flow (Lg) is 0.923. (Fig. 2a & 2b).

Kakund Sub-Basin: The area covered by Kakund sub-basin is 84.37 km^2 in the southern part of the district on Vindhyan plateau (Fig. 1). The perimeter (P) of the basin is 48.5 km and maximum basin length (Lb) is 18 km. The total number of streams (Nu) of various orders is 27, out of which the number of 1st order stream is 20, the number of 2nd order streams is 6 and 3rd order stream is 1. The total stream length (Lu) of all orders is 85.75 km. The length of 1st order stream is 52.0 km, 2nd order is 26.5 km, length of 3rd order is 7.25 km. The bifurcation ratios (Rb) of 1st/2nd orders is 3.33, that of 2nd/3rd orders is 6.0. The value of stream length ratio for 2nd/1st orders is 0.5, for 3rd/2nd orders is 0.27. The value for drainage density (D) is 1.016, whereas stream frequency (F) is 0.32. The elongation ratio (Re) of the basin is 0.576 and circularity ratio (Rc) is 0.45. The values of form factor (Rf) is 0.26, infiltration number (If) is 0.325 and overland flow (Lg) is 0.491 (Fig. 2a & 2b).

Kaman Sub-Basin: The Kaman sub-basin covers an area of about 796.87 km^2 in the northern part of the district (Fig. 1). The basin perimeter (P) is about 110.25 km and maximum basin length

(Lb) is 46.25 km. The total number of streams (Nu) of various orders is 33 out of which the number of 1st order streams is 25, the number of 2nd order is 5, the number of 3rd order is 2 and 4th order is 1. The total stream length (Lu) of all orders is 214.25 km, the length of 1st order stream is 102.5 km, that of 2nd order is 30.5 km, length of 3rd order is 41.25 km and that of 4th order is 40.0 km. The bifurcation ratio (Rb) of 1st/2nd orders is 5, that of 2nd/3rd orders is 2.5 and between 3rd/4th orders is 2.0. The values of stream length ratio for 2nd/1st orders is 0.2, for 3rd/2nd orders is 0.4 and for 4th/3rd others is 0.5. The value for drainage density (D) is 0.269 and stream frequency (F) is 0.041. The elongation ratio (Re) of the basin is 0.689 and circularity ratio (Rc) is 0.823. The value of form factor (Rf) is 0.372, infiltration number (If) is 0.011 and overland flow (Lg) is 1.859 (Fig. 2a & 2b).

Table 1

Drainage Parameter	*Kakund Sub-Basin*	*Banganga Sub-Basin*	*Gambhir Sub-Basin*	*Kaman Sub-Basin*
Stream Order				
1st Order	20	31	63	25
2nd Order	6	8	6	5
3rd Order	1	1	3	2
4th Order	–	–	1	1
Total	27	40	83	33
Stream Length (Lu) km				
1st Order	52.00	106.25	181.00	102.50
2nd Order	26.50	49.00	70.75	30.50
3rd Order	7.25	18.75	19.50	41.25
4th Order	–	–	18.25	40.00
Total	85.75	173.00	289.50	214.25
Bifurcation Ratio (Rb)				
1st/2nd Order	3.33	3.87	3.93	5.00
2nd/3rd Order	6.00	8.00	5.33	2.50
3rd/4th Order	–	–	3.00	2.00
Stream Length Ratio				
2nd/1st Order	0.50	0.45	0.39	0.20
3rd/2nd Order	0.27	0.39	0.27	0.40
4th/3rd Order	–	–	0.93	0.50
Perimeter (P) in Kms	48.50	86.00	141.25	110.25
Basin Length (Lb) in Kms	18.00	33.75	42.00	46.25
Area in Sq Km	84.375	259.375	534.375	796.875
Drainage Density (D)	1.016	0.667	0.541	0.269
Stream Frequency (F)	0.320	0.154	0.155	0.041
Basin Elongation (Re)	0.576	0.538	0.621	0.689
Basin Circularity (Rc)	0.450	0.440	0.336	0.823
Infiltration Number (If)	0.325	0.102	0.084	0.011
Form Factor (Rf)	0.260	0.227	0.302	0.372
Length of Over-land Flow (Lg)	0.491	0.749	0.923	1.859

Landscape Evolution of Bharatpur District

The geomorphic process has operated in Bharatpur form Proterozoic to recent periods of earth's history. The saga of the landscape evolution of the Proterozoic and Palaeozoic has possibly been lost in the erosional cycles, which the area must have witnessed. The accordance of summits and occurrence of diverse lithologies at the same geomorphic level suggest that oldest planation surface developed around 360 m level in the rocks of Delhi and Vindhyan supergroups, which were peneplain with an easterly slope. The age of this peneplain surface is uncertain but it is decidedly older than the Cretaceous.

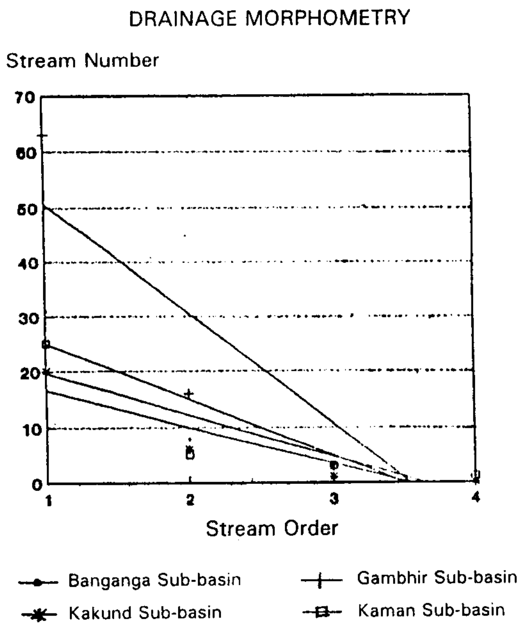

Fig. 2a

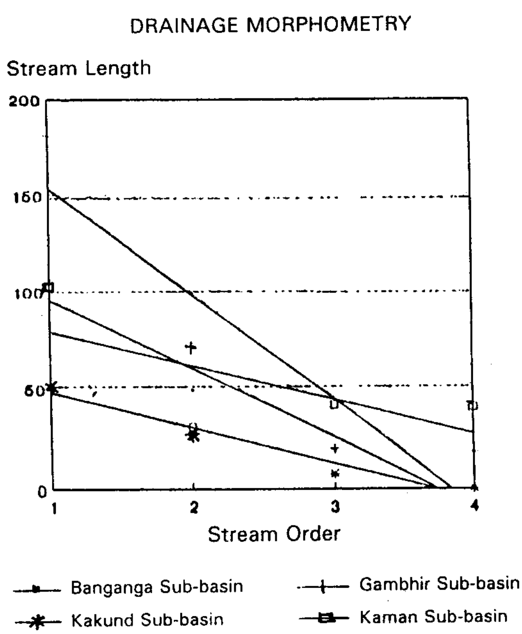

Fig. 2b

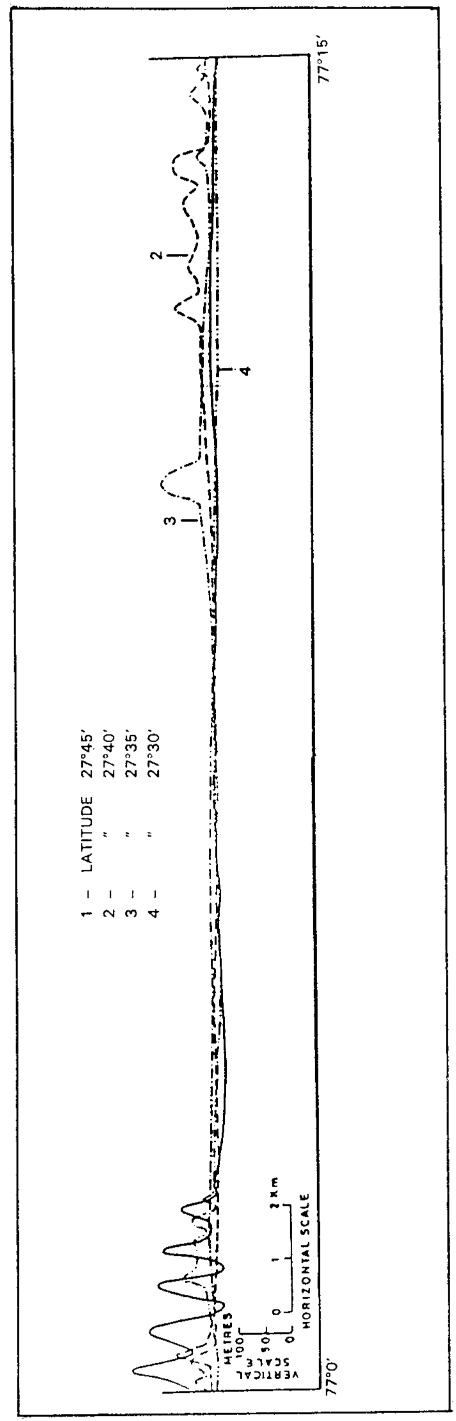

Fig. 3

A second cycle of planation is recorded by the accordance of flat top hills corresponding to 300 - 280 m level, with easterly slope (Fig. 3). This surface is manifested by the cuesta and hog-backs of Bayana Group and Lower Rewa Sandstone hills in the district. This surface is possibly pre-Cretaceous, as in southern Rajasthan the 280 m contour represents the unconformity between the Deccan Traps and the Proterozoic basement, which has been interpreted as planation surface (Iqbaluddin, 1989).

The third erosional cycle started in the post-Cretaceous period. This cycle of erosion is represented by retreating escarpment and shrinking mountain fronts in Bharatpur, which resulted in the development of rock cut pediments. In the geomorphic profiles the pediments are defined by 200 m contour and the nick points along the escarpment and ridges in Bayana and Pahari Tahsils (Fig. 3). The pediments in the area are buried under the later Quaternary cover.

The fourth and perhaps the most important phase in the landscape evolution started in the Quaternary when the rivers flowing from the southern upland of Aravalli ranges and the Vindhyan Plateau poured their clastics in the northern depression covering the Proterozoic basement of the Indo-Gangetic depression. These clastics formed a uniform alluvial plain, which in the regional context has been referred as Aligarh Older Alluvial Plain (Iqbaluddin, 1994). This surface is characterized by the presence of the scars of the north flowing palaeo-drainage, which is anomalous with the existing southerly slope of the Indo-Gangetic plain.

The Aligarh Older Alluvial Plain characterized by north flowing drainage underwent a change in the regional slope. Possibly the post-Himalayan collision tectonics was responsible for the drainage changes in the plains of Bharatpur. The regional slope changed towards south-east. The flow regime of the rivers emerging from the Vindhyan uplands changed and drained the area along the east-west Banganga drainage system. The drainage morphometry and channel geometry of the Banganga suggest that the river initially originated from the east and continued towards the west where the channel grow in width with the increase in the watershed area. This westerly drainage is manifested by the presence of migratory paleo-channels from north to south.

The Banganga underwent a drainage mutation concomitantly with the changes in the morphotectonics of the Yamuna drainage system. Possibly at a time when Yamuna changed its course from Luni drainage in the west, to the Ganga drainage system in the east. The Banganga also experienced the drainage mutation from westerly slope to easterly slope. This change in the drainage is clearly seen in the Banganga river system where the channel morphology is wide in the proximal part and constricted in the distal part of the micro-watershed. The obtuse angular relationship of the tributaries, which during the flood behaves as distributaries are anomalies, which are responsible for uncontrolled flooding of the district during the monsoon period. The channel is not tuned to the easterly flow regime that has been imposed on the Banganga micro-watershed by the post Himalayan collision strain of the Indian plate, due to continued plate accretion in the Indian ocean region (Sen & Sen, 1983; Iqbaluddin & Mohammad, 1986).

The last event in the geomorphic evolution is related to the arid phase of Rajasthan. The Bharatpur district lies at semi-arid fence and has received the sand and loess deposits in recent times, which have covered the pediment at the mountain face and filled the valleys in the Alluvial plain of the district. The landscape evolution of the district started perhaps in the Mesozoic and continued in the recent. The process is on, the changes at the micro-level are manifested as recurring floods in the district.

Acknowledgement

The work was carried out as part of NRIS R&D programme sponsored by National Informatics Centre, Planning Commission for generation of Natural Resource Data Base for Bharatpur district, Rajasthan. The research grant extended by National Informatics Centre is thankfully acknowledged. The authors are thankful to Dr. N. Seshagiri, Special Secretary, Planning Commission and Director General, National Informatics Centre, for the keen interest and guidance extended to investigating team. Thanks are due to the staff of Remote Sensing Applications Centre for Resource Evaluation and Geoengineering for their assistance in field work and to the referees for their critical review.

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