A QUANTIFIED APPROACH TO THE MULTIVARIATE INFLUENCE OF GEOMORPHIC PARAMETERS ON THE DRAINAGE NETWORK OF THE KONKAN COASTAL BELT, MAHARASHTRA

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ABSTRACT : The relief and drainage parameters of three rivers basins in the Konkan Coastal Belt have been statistically correlated in order to establish their combined effect on drainage network formation. With the help of Principal Component Scores the basins are classified according to the influential nature of these variables. The structural control over drainage network formation has been brought out by the collection of lineament and drainage patterns of the three basins.

INTRODUCTION

The necessity of a quantitative approach to problems of geomorphic evolution was brought out in the years immediately following the Second World War through the publications of Horton (1945), Stralher (1952, 1956, 1957), Savigear (1956, 1967), Scheidegger (1961, 1965) and others. In these publications the river basin was generally accepted to be the ideal geomorphic unit for morphometric analysis but the parameters or parameter-groups studied, such as relief, slope or drainage were largely univariate or bivariate. However, as Chorley (1967) pointed out, geomorphic phenomenon is the result of a number of simultaneously operating variables which should be evaluated separately, relatively and in combination. Hence, a multivariate approach becomes essential. In India, such an approach has not been generally adopted except for a few isolated case-studies, like that of Pravara river basin of Maharashtra by Kale and Rajaguru (1986). In this paper we present the results of a multivariate parametric approach to the problem of drainage basin evolution, that was adopted for three basins–the Patalganga, the Amba and the Kal–in the Konkan Coastal Belt of western Maharashtra.

THE GEOMORPHIC SETTING

The three river basins studied fall within the Konkan Coastal Belt of Maharashtra– the narrow coastal plain lying between the coastline of Arabian Sea and Western Ghats Scrap that is developed in Deccan basalts of Cretaceous–Eocene volcanocity. This belt displays a variety of landforms developed due to fluvial and marine activity–both, erosional and depositional. The altitude varies from sea level to about 1180 mts. with the elevated areas occurring in the form of north–south, northwest–southeast and east–west trending ranges rising over a low plain. Kale (1983) is of the view that the Konkan drainage was established during the post-Western Ghats formation period and is of Mio-Pliocene age.

METHODOLOGY

In order to evaluate the variation in the drainage and relief aspects, it is necessary to undertake a microlevel study. The main approaches are normally adopted

(1) by dividing the study area on the basis of stream orders, and

(2) by dividing the basin into grids i.e. the quadrat method.

The second approach has the advantage of highlighting the microvariations, irrespective of the basin order. Further the study area exhibits significant variations in its morphological characteristics which can be evaluated only by the quadrat method. Hence, in this study it has been adopted. The three river basins were subdivided into grids of 1.6 × 1.6 km. (1 mile × 1 mile) and this gave 149 quadrates within the Patalganga basin, 284 quadrates within the Amba basin and 95 quadrates within the Kal river basins. Absolute relief, relative relief, stream frequency, drainage density (Kale and Rajguru, 1986) and major stream directions were computed for each quadrat. Slope was calculated following the procedure given by Stralher (1965). The ordering of streams was done according to Horton's (1945) method.

The different geomorphic parameters listed above (except stream directions) were compared by using correlation which indicates whether the relationship between any two variables is positive or negative. Intercorrelating groups were identified (Lawley and Maxwell, 1963) by Principal Component Analysis (PCA) which enables the abstraction of influential or 'causal' data, responsible for observed variability, from a set of measured data.

DRAINAGE CHARACTERISTICS

The drainage channels in the three basins are characterised by more or less straight segments with sharp, almost right angled turns, suggestive of structural controls, (Dikshit 1976, Powar , et al, 1978, 1979). The drainage patterns within the three basins (Fig. 1) vary from dentritic to sub-dendritic. In the Patangalga, the streams exhibit dendritic, sub-dendritic to trellis type of drainage, network of Amba is characterised by dendritic, sub-dendritic, parallel and trellis types. The basin is subjected to tidal influence upto Nagothana.

The Kal basin has sub-dendritic, parallel to trellis type of drainage.

These three basins drain into the Arabian Sea. The Patalganga and the Amba merge into the sea at Dharamtar Creek. The Kal river forms a major tributory of Savitri. The drainage parameters of the three basins have been summarised in Table I.

It is observed from Table I that the Patalganga and Amba are 7th order streams, while the Kal is 6th order stream. The average bifurcation ratio for the Patalganga basin is slightly lower than that of the average values between 3.00 to 5.00 normally obtained. In Amba and Kal they range between 4.06 and 3.33. Further, in the case of Amba basin an anomalously high bifurcation ratio of 8.60 was obtained for the 3rd order streams suggesting a strong structural control. The plots of logarithms of mean stream lengths against the logarithms of order of streams (Fig. 2) are concave downwards, which are suggestive of headward erosion of streams along shear or fracture zones as opined by Kanegaonkar (1977).

BIVARIATE CORRELATION

Although the relationships between the drainage and relief parameters have been accepted, the degree of association may vary from one basin to the other. These variations reflect the control of lithology, structure, climate and environment. The most widely used technique for such an evaluation of the association is the correlation.

The bivariate correlation coefficients obtained for the three basins are presented in the Table II.

In case of Amba, all the correlations are positive. These are also true for the Patalganga and Kal basins, except for the negative correlations obtained between slope on one hand and, drainage density and stream frequency on the other. As is to be expected,
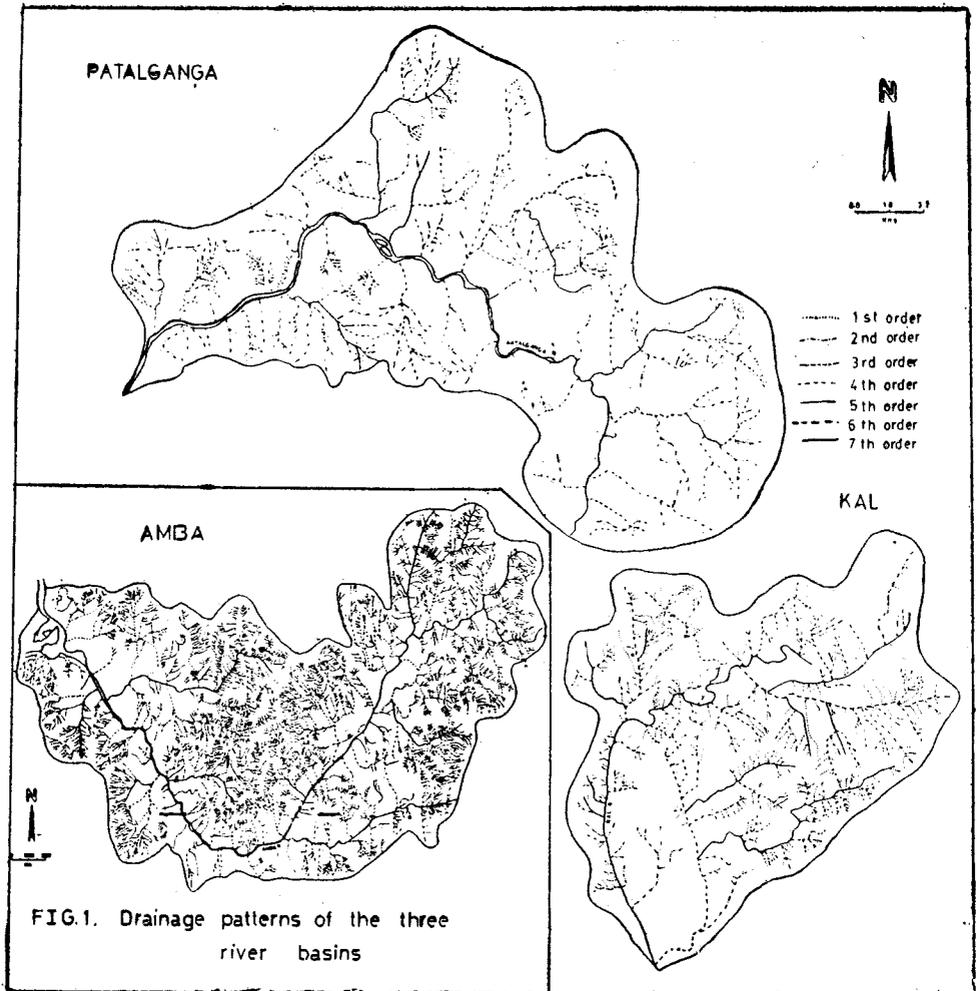
PATALGANGA

N

1 st order
2 nd order
3 rd order
4 th order
5 th order
6 th order
7 th order

KAL

AMBA

N

FIG.1. Drainage patterns of the three
river basins

TABLE I

Drainage parameters of the Patalganga, Amba
and Kal river basins

Streams	Number	B. R.	Total Length (in kms.)	Mean Length (in kms.)
Patalganga Basin				
1st order	527	—	196.80	0.37
2nd order	136	3.87	150.42	1.10
3rd order	46	2.95	107.20	2 30
4th order	15	3.06	44.06	2.90
5th order	7	2.14	48.04	6.80
6th order	2	3.50	15.50	7.70
7th order	1	2.00	32.16	32.16
Total / (Av.)	734	(2.92)	594.18	7.61
Amba Basin				
1st order	1870	—	417.62	0.22
2nd order	456	4.10	282.80	0.64
3rd order	53	8.60	166.50	3.13
4th order	40	1.32	149.62	3.74
5th order	11	3.63	71.28	6.46
6th order	4	2.75	36.20	8.80
7th order	1	4.00	58.40	48.40
Total / (Av.)	2435	(4.06)	1183.22	(11.6)
Kal Basin				
1st order	360	—	184.00	0.51
2nd order	107	3.36	141.60	1.32
3rd order	27	3.96	60.00	2.22
4th order	8	3.37	43.20	5.40
5th order	2	4 00	18.40	9.20
6th order	1	2 00	25.60	25.60
Total / (Av.)	505	(3.33)	473.00	(7.37)

FIG. 2   Regression of log of mean stream length on log of order for three river basins.
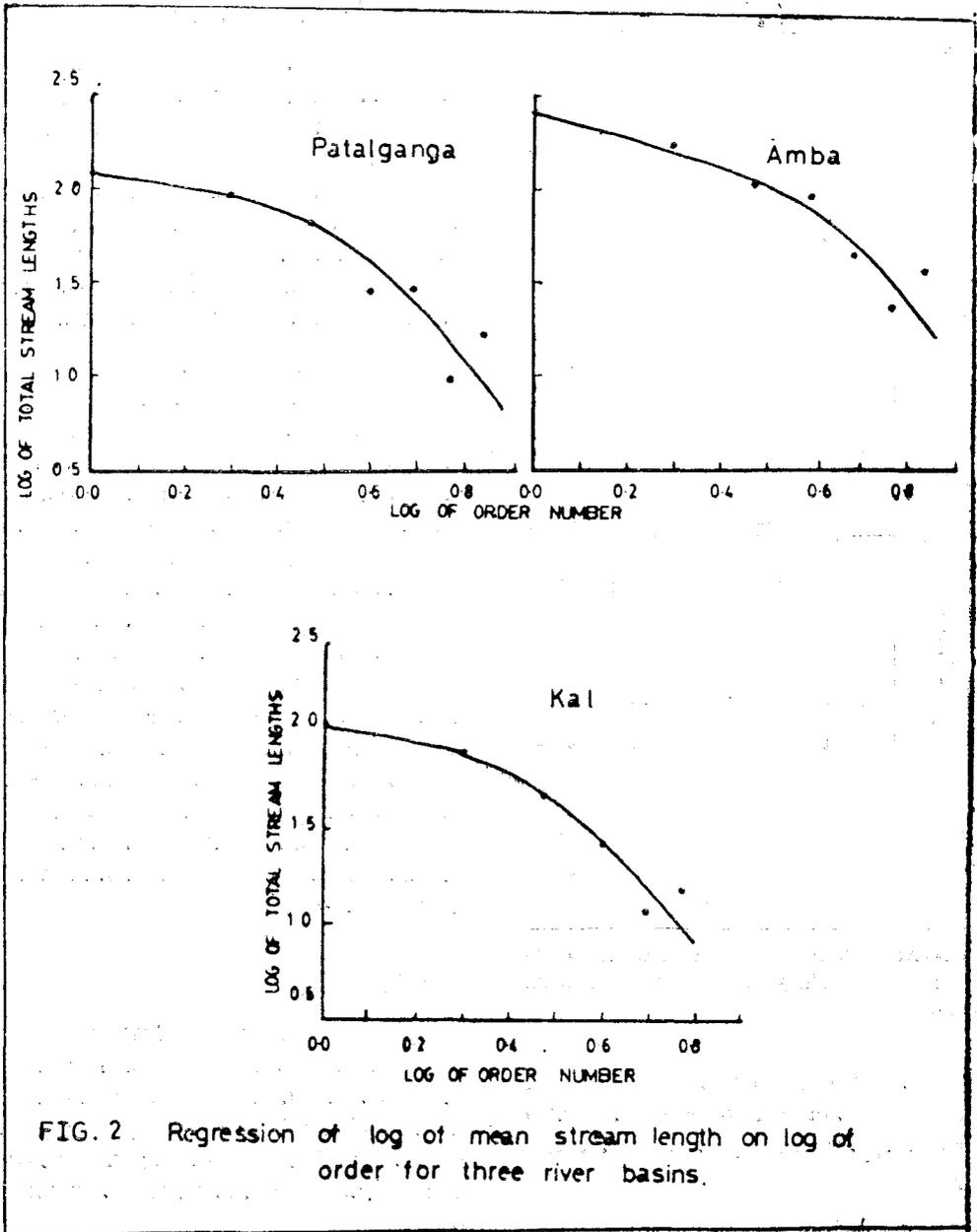
TABLE II

Bivariate correlation matrices for the Patalganga, Amba and Kal basins

Variables	Bivariate Correlations				
	Ar	Rr	φ	Dd	Sf
Patalgauga Basin					
Ar	1	0.96	0.51	0.05	0.15
Rr		1	0.44	0.09	0.19
Q			1	−0.06	−0.13
Dd				1	0.82
Sf					1
Amba Basin					
Ar	1	0.84	0.46	0.20	0.28
Rr		1	0.57	0.17	0.27
Q			1	0.15	0.13
Dd				1	0.45
Sf					1
Kal Basin					
Ar	1	0.63	0.16	0.25	0.26
Rr		1	0.40	0.11	0.14
Q			1	0.20	0.26
Dd				1	0.70
Sf					1

Ar—Absolute relief; Rr—Relative relief:
φ— Slope: Dd—Drainage density & Sf—Stream frequency.

there is a strong correlations between absolute relief and relative relief, and also between drainage density and stream frequency.

PRINCIPAL COMPONENT ANALYSIS

The results of Principal Component Analysis for the three basins are presented in Table III. The first two components explain 83.6%, 74.4% and 75.7% of the total variance for the Patalganga, Amba and Kal basins respectively. As these explained variances are statistically significant, they can be used for further analysis.

The Principal Component Analysis indicates that each Principal Component need not reflect a single process but can be a combination of distinct processes that influence relative behaviour among the variables in a similar fashion. The pivotal nature of drainage is suggestive of structural control over drainage parameters causing the rapid erosion along structural lineaments.

The two dimensional plotting of the component loadings, which represents the two orthogonal components shows that there are two similar groups of variables in the case of Patalganga and Amba rivers which cluster around relief and drainage respectively (Fig. 3). The groupings suggest that the first three variables are inter-correlated (Ar, Rr and Q), as are the other two–Dd and Sf. The grouping of the variables in the Amba basin is slightly higher and therefore, suggestive of greater geomorphic maturity. The Kal river exhibits a different grouping and perhaps, suggests an integration of drainage with relief. This can be interpreted in terms of the advanced stage of basin and drainage network development.

GEOMORPHIC SIGNIFICANCE

The Principal component scores were represented separately for each grid in the three basins and depending upon their nature of dominance, these were grouped separately. These groupings are shown in Fig. 4 (a, b, c) and their classification is as follows :

Dominantly Dissected Region :

It is characterised by the regions of high relief with greater degree of drainage network formation. It includes the scarp

TABLE III

Component loadings for the Patalganga, Amba and Kal basins

Variables	Patalganga		Amba		Kal	
	C I	C II	C I	C II	C I	C II
Ar	0.61	—0.14	0.52	—0.26	0.53	0.28
Rr	0.61	—0.10	0.54	0.29	0.47	0.46
O	0.39	—0.30	0.40	—0.34	0.04	0.59
Dd	0.18	0.66	0.33	0.63	0.48	—0.40
Sf	0.23	0.65	0.39	0.57	0.49	—0.41
Eigen value	2.36	1.82	2.51	1.21	2.09	1.70
%Trace	47.20	36.40	50.20	24.20	41.70	34.00
Total explained variance	83.60		74.40		75.70	
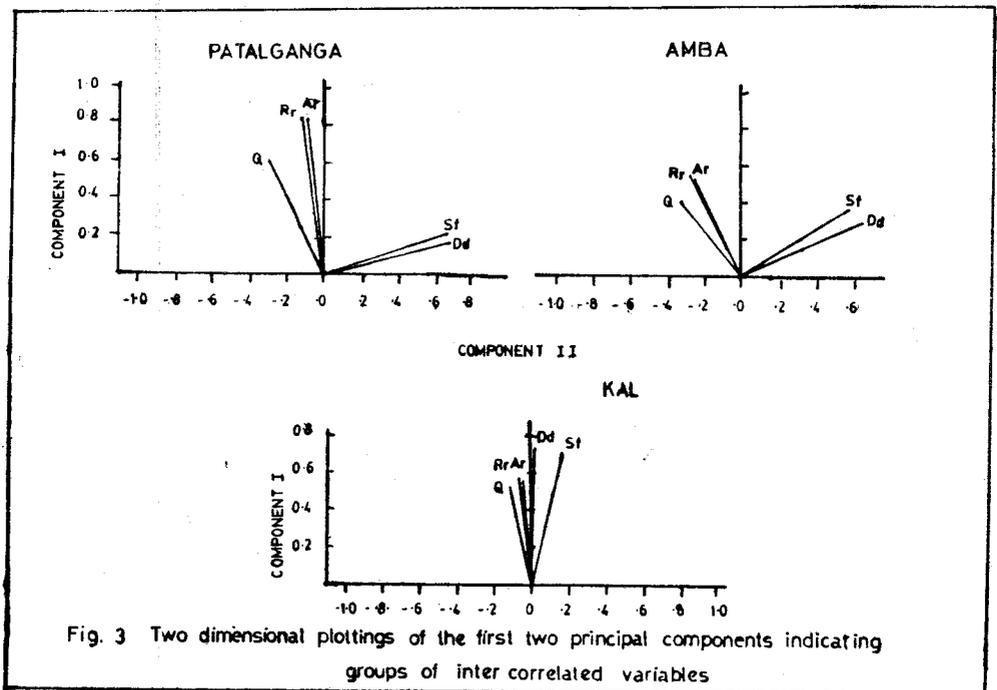
Fig. 3 Two dimensional plottings of the first two principal components indicating groups of inter correlated variables

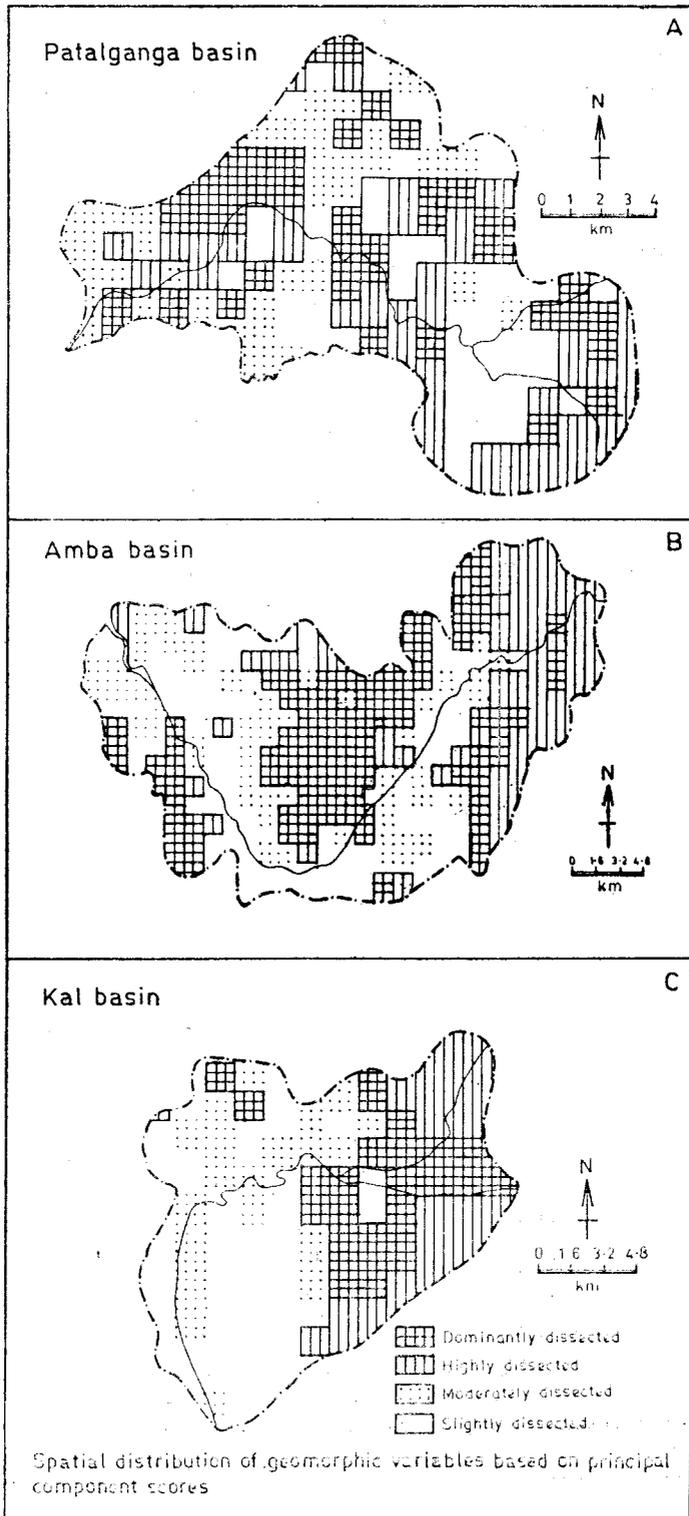Fig. 4   Spatial distribution of geomorphic variables based on principal component scores

region along with steeply sloping water divides. The elevated localities near Khopoli are covered in this category in the Pantalganga basin. In case of Amba, the regions to the west of Khandala-Lonawala fall under this catagory. In the Kal river, dominantly dissected region is observed in the vicinity of eastern region of Nizampur.

This region covers about 26.84% area of the Patalganga basin, 29.92% area of the Amba basin and 21.21% area of the Kal basin. The localities of highly dissected scarp region, structurally controlled and closely spaced lineaments are observed in this region. The hot springs of Pali are seen along the straight segment of Amba river bed indicating deep structural controls.

Highly Dissected Region :

It covers about 28.18% of the Patalganga basin, 21.12% of the Amba basin and 20.20% of the Kal basin. Some parts of the source regions of the three rivers are included in this type. The region characteristises high relief but with low relative relief, with low secondary divides of the drainage basins.

Moderately Dissected Regions :

It covers about 20.13% area of Patalganga basin, 22.53% of the Amba and approximately 23.23% area of the Kal basins. The ridges lying along the foot-hills of the Western Ghats Scraps have such characteristics. The erosional surfaces at 150 mts. are included in this type. These also include almost flat topped flows which have been dissected along weaker zones.

Slightly Dissected Region :

These are the morphologically nature low lying plains of the three basins. The relief, drainage density, stream frequency and slopes are low. The marine planar surfaces of 3 to 15 mts. (Powar et al, 1978; Kulkarni, 1986) are included in this type with braided stream channels to the West. This part of the basin covers about 24.83% of the

Patalganga, 26.40% of the Amba and 34.34% of the Kal basins.

The microlevel analysis of the drainage and relief parameters has clearly indicated the spatial variation in the parameters. The variation can be accounted by the influence of lithology and structure as well as the geomorphic history. With respect to lithology there is little variation in the three basins and therefore, it is unlikely that the rock type would have exerted a very strong influence on drainage basin–characteristics. The association of high relief in the scarp zone with high frequency of streams suggests that the evolution of drainage network with time has an important role to play in determining the drainage characteristics. Therefore, some of the anomalous geomorphic conditions can be attributed to the stage of the drainage network development. However, the stage of drainage development does not account for abnormally high bifurcation ratios and the sub-dendritic and trellis patterns in the sub-ghat zone. Therefore, it was felt necessary to undertake detail lineament analysis of the three basins.

The lineaments provide a good measure for such a study of a regional stream characteristics (Closs, 1955, Blanchet, 1957, Badgley, 1962, 1965; Powar et al. 1978, 1979, Powar and Patil, 1983; Kulkarni 1986). Hence lineaments were identified in the aerial photos on scale 1:80,000 and their concentration along different directions is shown in Fig. 5 (a and b).

In order to collate the lineament pattern with the drainage network pattern it was necessary to prepare a rosette diagram drainage orientations (Fig. 6). The exercie manifests a strong association between the two variables and establishes that the structure has controlled the orientation, pattern, as well as the frequency of drainage. The authors are aware that the lineaments identified on the aerial photos may reflect
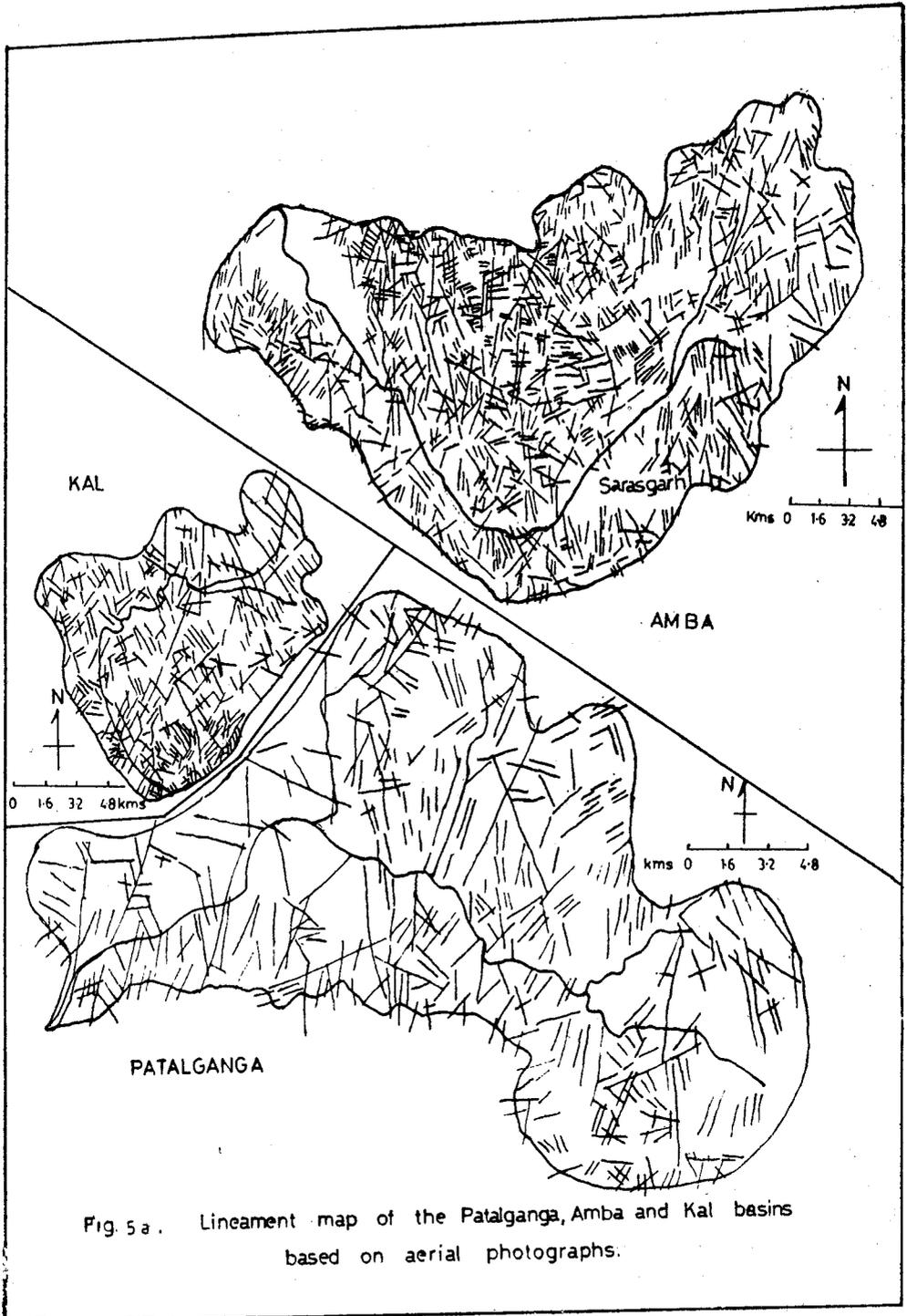
Fig. 5a.   Lineament map of the Patalganga, Amba and Kal basins based on aerial photographs.
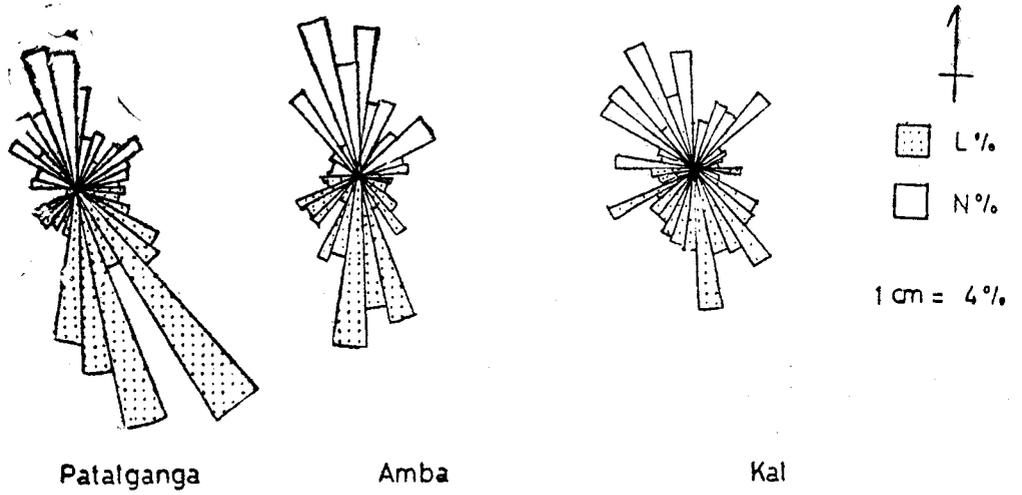
Patalganga   Amba   Kal

Fig.5b   Frequency distribution of the major lineament directions
                of the three   basins

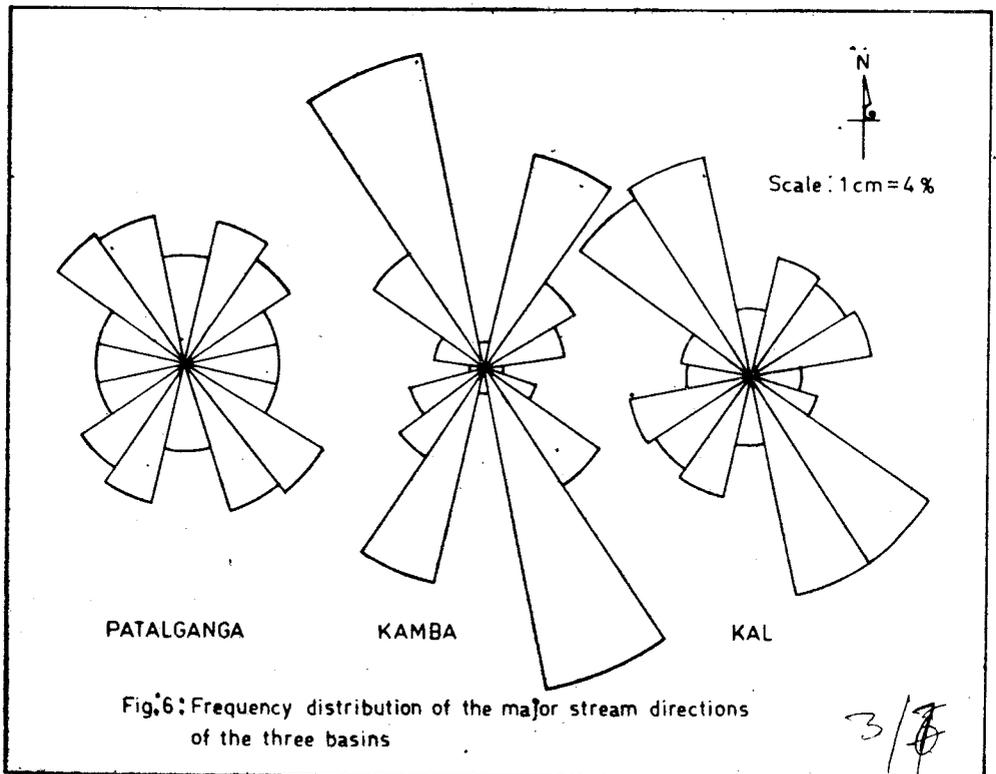PATALGANGA   KAMBA   KAL

Fig.6: Frequency distribution of the major stream directions
        of the three basins

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drainage orientations to a considerable extent. However, they also coincide with the dykes and shear and fracture zones. Hence, such a comparision will not lead to spurious and wrong results.

OVERVIEWS

The present exercise on the drainage and basin morphology has clearly brought out the differences in the basin–characteristics. The Patalganga, Amba and Kal rivers exhibit statically significant variation in their relief and drainage parameters. This is inspite of uniform lithology, uniform climatic conditions as well as, similar evolutionary history. The present study suggests that the interbasin differences are related partly to the stage of drainage network development and, to a considerable extent, to the structural framework of the river basins. The collation of the lineament pattern and the drainage has emphasised the strong influence of structure on the drainage network. However, because the drainage as well as relief is inherrited one cannot rule out the possibility of other environmental factors on the drainage organisation and composition. Therefore, there is a need to ascertain the structural influence by undertaking detail geological and geophysical studies to arrive at valid conclusions.

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