CHAPTER III

DRAINAGE AND SLOPE ANALYSIS

GENERAL

The author has selected four sub-basins of the Kosi catchment for detailed study of drainage and slopes. The sub-basins have been so selected that one sub-basin falls within each of the separate lithotectonic units, and has characteristic morphological features. The selected sub-basins are as under:

Sub-basin A : Kosi catchment north of Someshwar (Figs 8 to 13) Metasediments (Quartzites, compact limestones, chlorite schists and slates); North Almora fault zone and sheared gneisses in the immediate vicinity south of the fault.

Sub-basin B : <u>Sual river</u> : (Figs. 14 to 19)
Crystallines (mainly schists and micaceous quartzites belonging to the Almora nappe synform).

Sub-basin C : <u>Kuch gad</u> : (Figs. 20 to 25)
Metasediments (quartzites and slates) in between the South Almora thrust and the Ramgarh thrust.

Sub-basin D : <u>Kali gad and Dhangari Sot</u>: (Figs.26 to 31)
Sedimentary rocks (mainly sandstones) belonging to the Siwalik group.

For each sub-basin the author has investigated the drainage characteristics, both from the latest 1:50,000 maps and from the drainage tracings from aerial photographs, the latter showing a faithful representation of the total drainage network. This was subsequently verified on the ground, and the photo-tracings were found to be fairly accurate.

The drainage characteristics derived from the study, were utilised to correlate various lithologic variations and tectonic zones. Smaller basins within each sub-basin were taken for comparisons pertaining to Horton's Laws of morphometry (1945). Longitudinal profiles for trunk streams within all sub-basins were prepared, to bring out the breaks in the graded profile vis-a-vis rejuvenation. These were correlated with the number of terraces deposited downstream, as well as with the effect of cymatogeny and with the effect of compact, hard lithologies in the profile. Superimposed cross profiles at various sections within each sub-basin starting from the mouth to the headward portions were investigated for the generalised slopes and profile irregularities. This was corroborated by the study of slope maps which depict the generalised downslope directions, amounts and positions in the sub-basins. These slope maps were prepared with the help of 'Gliding Tangent Scale' without taking into account the micro-relief for each generalised slope category.

The aspect of micro-relief, however, has been considered during the aerial photo-interpretation.

MORPHOMETRIC PARAMETERS

The morphometric parameters investigated for each sub-basin and smaller basins (within sub-basins) include the linear, areal and relief aspects. Amongst the linear aspects, the relationship of various stream orders (Horton, 1945 modified by Strahler, 1956) with the number of channels and stream lengths have been investigated. The smallest finger-tip tributaries are designated as first order. Where the two first order channels join, the channel segment of second order is formed and so forth. The channels of higher order also receive the drainage of the smallest orders.

The ratio between the number of segments of a given order to the number of segments of the next higher order gives the bifurcation ratio. The mean stream length of a channel segment is the cumulative length of all the channel segments of that order divided by the number of such segments.

Amongst the areal aspects of the drainage basin, the catchment areas for the channels of different orders were measured to investigate their relationship with the various orders of channels. The quantitative expression of the basin shape is expressed as an elongation ratio (Schumm, 1956) which is defined as the ratio of the diameter of a circle of the same area as the basin, to the maximum basin length. The drainage density is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area as projected on the horizontal plane. The stream frequency (Horton, 1945), indicated by the number of stream segments per unit area, has also been calculated for the various sub-basins.

Amongst the relief aspects, the channel gradient, cross profiles, maximum basin relief, relief ratios and the ruggedness numbers, have also been calculated. All the variations in these morphometric parameters have been correlated with the lithostratigraphy and with the structural elements within each sub-basin.

SUB-BASIN A

Drainage

The Kosi channel north of Someshwar, becomes a sixth order channel (Fig. 8), draining a total area of 174.86 sq km. This sub-basin is roughly rectangular in shape, its northern limit being the Kausani (WNW-ESE) ridge. The southern divide, nearly 400 metres less in height, also trends in the same direction. Along its western limit, the Lod saddle (1900 m) forms the lowest point, whereas along the eastern limit the lowest point is nearly 150 m higher than Lod. This sub-basin could be divided into two equal segments, the right bank and the left bank, the Kosi flowing between the two. The trunk stream flows southeasterly, with several major E-W offsets along the strike of beds. A careful observation of the drainage network reveals a broad arc formed by the tributaries from both the segments (Sai nala and Mansa Rauli; Deogad and Lamgada gad). The smaller order channels show a definite variation in drainage pattern, which is seen to be mainly controlled by the bedding joints. This drainage pattern indicates the lithologic differences of metasediments, viz. quartzites, dolomitic limestones, soft slates and thinly foliated schists. Munshi (personal communication) has corroborated this view based on his detailed field findings. The geologic photointerpretation (Fig. 9) brings out the differences more clearly.

The smaller N-S offsets within the drainage of Sai nala and a very distinct abrupt break in the slope north of Nirai gad point to a tectonic discontinuity between the two groups of rocks on either side of the North Almora fault. The Kosi river itself reveals the effects of this N-S joints in the form of offsets in the vicinity of Someshwar. The drainage pattern in the crystallines to the south is sub-dendritic to sub-parallel for the major consequent streams, whereas it becomes sub-trellis for the smaller order channels due to foliation joints.

Longitudinal Profile

The longitudinal profile of the main channel of this sub-basin shows three major breaks (Fig. 10), two within the higher slopes upstream of Deo gad and one south of Sai nala confluence, the latter indicating some activity along the North Almora fault. It is interesting to note that the channel width in the upstream portion of the third break is of the order of 50-70 metres, and the slopes of the wide valley flats are of the order of 3° to 5°, but south of this, the channel suddenly narrows down to 20-40 metres with high terraces and entrenched meanders, indicating tectonic rejuvenation.

Cross Profiles

Several cross profiles for this sub-basin along and across the strike were prepared (Fig. 11). Along the strike, the cross profile indicates a broad saucer shape with minor depressions in the stream thalwegs and the Kausani saddle. The slopes are of the order of 25° to 30° in the upper reaches, while in the immediate vicinity of the drainage channels, they sharpen to as much as 40°. In the central portion, the slopes are gentler and point towards active linear degradation and peneplanation. Heim and Gansser (1939) have suggested an active peneplanation here on a regional basis.

The cross profiles across the strike reveal typical hog-backs indicative of metasedimentary horizons. The long dip slopes of 45° point towards north and the short reverseslopes of 40° to 50° pointing towards south. The general base level of these hogbacks, however, is gentler. The valleys of Lamgada gad and Kosi river are very flat and nearly 200 to 800 m in width.

Analysis of Drainage Channels

The author has selected three smaller basins A_1, A_2 and A_3 within sub-basin A for the drainage analysis. All the three smaller basins fall within the Nagthat-Deoban metasediments and are away from the tectonic zone of North Almora fault. The channel orders when plotted against the number of channels (as taken from the photo tracings), on semilog paper, show a remarkably straight linear relationship indicating an equilibrium in the drainage net. The plots of channel order against average length, however, do not show the linear relationship so well, at least for the lower orders (Fig. 12). This implies that before these smaller order channels unite with the next higher order within their own catchment, they attain a higher stream frequency and form a small basin controlled by joints and higher relief, pointing towards an indirect tectonic rejuvenation. It is these third order channels that cut across the strike. This probably is also due to the length of a second order stream being taken from the confluence of two first order channels, and its headward continuity being not considered. The plots of channel order vs drainage area, however, do not show this ambiguity, since every successive higher order channel takes into account the drainage area of all the lower orders. Thus the morphometric analysis of the drainage channels conforms to the Horton's Laws.

Slopes

A study of the generalised slopes within this sub-basin reveals three main groupings according to the position in the landscape, i.e. the crests of the strike ridges, hill slopes and valley bottoms. The correspondence of these with the geological set-up and with the drainage clearly points towards a meta-sedimentary sequence (Fig. 13). The crests are peaked, with an area of 5° to 10° sloping towards north and 15° to 20° sloping towards south. The generalised dip of the strata in this sub-basin is moderate to high (45° to 50°), due N, but the topographic slopes are less, being upto 25° to 35°. Thus, there is a difference of nearly 20° between the dips of rocks and the slopes in the dip direction, and in a way, these so called dip slopes are only indicative of the dip direction.

The southern slopes, opposite to the dip direction, are not uniform and comprise alternating narrow stretches of 30° and 40°. The scarp slopes exceeding 40° form short arcuate areas. Stretches of steeper slopes also occur in the lower portions forming the banks of major streams that have cut steeper channels. As mentioned earlier, the slopes of the stream bed and the adjoining flood plains, range between 1° - 5° (Fig. 13). Formation of terraces has been observed in the Sai nala section, and two well formed levels and one incipient terrace have been observed. In general, the terrace formation in this zone is not of that magnitude as that in the other sub-basins. The coalesced alluvial fans ESE of Someshwar with slopes of 3° to 5°, abut against rather steeper slopes of 25°. This corresponds with the R_vR type of break of Anhert (1970) - a concave break between two rectilinear segments. At other places adjoining, the valley flats, the slope break is of the type ~~R_vV~~ R_vV (concave break between the rectilinear and concave segments).

SUB-BASIN B

Drainage

Sual river joins Kosi on its left bank and drains an area of 246.18 sq km that lies entirely within the Almora Nappe rocks, mainly schists and micaceous quartzites (Figs. 14 and 15). The trunk channel here is of the sixth order. The basin shape is that of a irregular triangle, the apex pointing towards the mouth of the basin and the base forming the eastern Kosi divide. The general height variations are between 1850 m and 2400 m on the eastern divide. The height at the basin mouth is nearly 1100 m. The total length of the main channel is 29.25 km, and the downstream direction is towards SW.

Halfway in its course, it is joined by That gad (a 5th order channel), on the right bank. That gad flows mainly across the strike of the rocks. The drainage pattern is dendritic for 3rd and higher order channels, whereas it shows trellis pattern for 1st and 2nd order channels. The trunk channel exhibits pseudo- meanders all along its course, which, in fact, are the various joint controlled segments with sharp angular bends. Three prominent joint sets are observed, the bedding joint controlling the consequent 1st and 2nd order channels, the NS vertical joints controlling the flow of 3rd, 4th and 5th order channels, as also the various offsets in the trunk channel, and thirdly the joints oblique to the strike.

In contrast to the sub-basin A, in this sub-basin, clear distinction of stratigraphic horizons is not discernible in the orientation of drainage segments. The 1st order channels show diverse orientation while the higher order channels show ill-defined NS orientation.

Longitudinal Profile

The longitudinal profile for Sual river and its tributary That gad are plotted separately (Fig. 16). In the Sual profile, there are in all, six breaks indicating rejuvenation. The initial two breaks are in the headward portion. The third break is near the confluence of Malari gad, and the remaining three are in the lower reaches. The last three breaks are due to the hard gneissic bands extending across the profile. Within this sub-basin, there is no well defined deposition of terraced levels.

In the That gad profile there are in all five breaks all before its confluence with Sual, and these appear to be mainly due to a cross strike orientation in the high relief zone.

Cross Profiles

The superimposed cross profiles of this sub-basin (Fig. 17) show numerous hog-backs, the gentler dip slopes of which point towards the median part indicating a synformal arrangement of the strata. If the crests of these hog-backs are joined, they lie on a relatively flat datum, indicating a fast and strong peneplanation. This peneplanation is much more marked in this sub-basin than in the case of sub-basin A. The dip direction slopes are of the order of 25°, whereas the slopes opposite to the dips, are short and of the order of 30° to 35°. The valleys in this sub-basin are of asymmetrical shapes, though they maintain uniform angles on both valley sides.

Analysis of Drainage Channels

The drainage analysis has been carried out for the smaller basin B_1 (That gad) which drains more than one third of the Sual catchment. The plots of the orders of the drainage channels against the numbers and average length as well against the drainage areas, all show a marked straight linear relationship. In this case due to a generally subdued topography and gradually merging slopes, the relation of the average length does not deviate much from the linearity. Here the Horton's Laws fit ideally (Fig. 18) because this sub-basin is away from the tectonic zones, and consists of a fairly uniform lithology.

Slopes

The generalised slopes range from 3° to 25°, the most predominant being 15°, occupying extensively the middle slopes (Fig. 19). The entire topography being subdued, only a few isolated hills like that of Almora stand out in the landscape.

The strike of rocks in this sub-basin are WNW-ESE with northerly dips of 10° - 25°. In its northern portion, passes the axis of the Almora Nappe synform and along this axial zone the dips are almost sub-horizontal. The dip direction slopes, however, maintain a uniform 20°-25° amount. Thus the variation in the topography and the dip slope in this basin is not much. The observations of Heim and Gansser (1939) about the peneplanation of these crystallines is fully supported by the above data.

SUB-BASIN C

Drainage

This basin is drained by Kuch gad, a 5th order channel covering a 96.75 sq km area. It is sandwiched between the South Almora thrust and the Ramgarh thrust, the former passing along the left bank divide. The maximum basin relief is of the order of 1,160 m and the elongation ratio indicates a strong linearity. The trunk stream follows the regional strike, and its lower reaches, follow the trace of a fault which is roughly along the axial plane of a local N-S anticline. The extension of this NS alignment southward touches Khairna and Garampani, and has played a significant role in the evolution of this sub-basin's drainage. The smaller order consequent channels are roughly at right angles to the trunk stream, and form a sub-parallel drainage pattern. The drainage map studied in juxtaposition with the map of the inferred geology (Figs. 20, 21) shows a strong correlation between the lithologic variations and the drainage characteristics. A strong closely spaced parallel drainage is imprinted upon a thin zone of phyllonites which fringe the South Almora thrust. A sub-parallel to sub-trellis drainage pattern marks the quartzite horizon of the underlying Nagthat metasediments. Below this is a zone of weathered and eroded slates, which is easily marked by the decreased stream frequency and an increase in the 1st order channels along the strike joints. Of course, all these inferences are fully supplemented by other photocharacteristics also.

The zone underlying these slates constitutes mainly the hard and highly jointed quartzites. Shah C.P. (1973) has reported the occurrence of displaced limestone outcrops near the mouth of this sub-basin, dipping away from the main drainage. This observation gives an additional support to the author's NS fault mentioned earlier. Near the confluence with Kosi, passes another dislocation - the Ramgarh thrust, but its extention further in the NW falls outside the basin. It is evident, that the linearity of the basin is controlled by strikes of rocks as well as by the tectonic lineaments. The softness of the slate horizon that is followed for some length by the trunk stream and the downstream portion being an anticlinal axial trace are the other factors for this linearity. It is a common observation that in Kumaon Himalaya, at quite a few places, the anticlines are sharply crested, faulted and occupied by streams (Chansarkar, 1968).

Longitudinal Profile

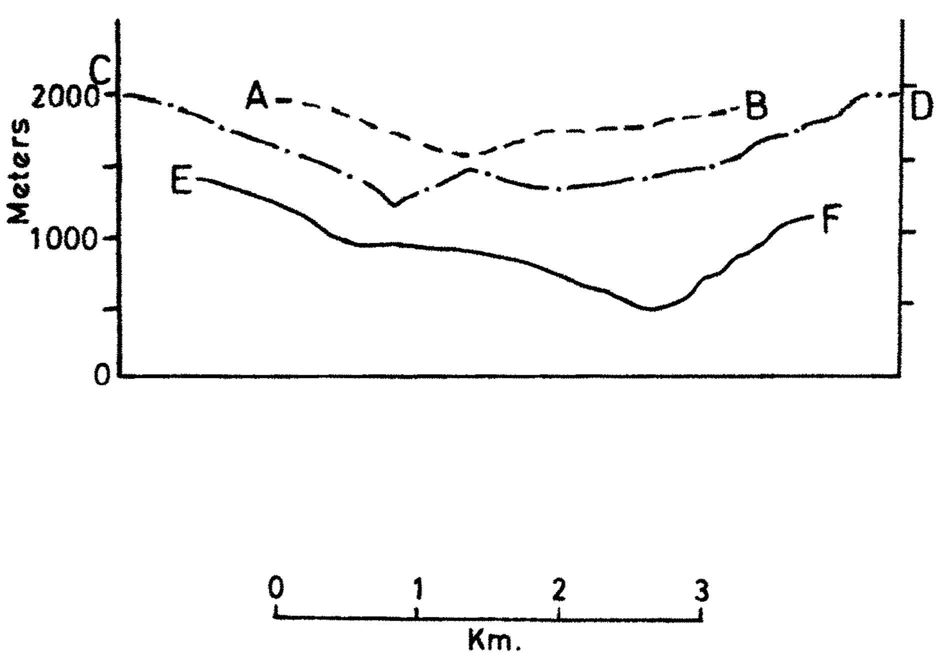
The longitudinal profile (Fig. 22) of the sub-basin indicates ten breaks before it joins the Kosi river. This sub-basin has also the maximum number of terrace levels in the entire Kosi basin, and along the Kuch gad course, at least six terraces have been distinctly observed ~~(Plate 14)~~. Heim and Gansser (1939) have made a special mention of these beautiful river terraces. The author believes that a correlation exists between these terraces and the successive tectonic rejuvenations in this part of the study area.

Cross Profiles

The superimposed cross-profiles (Fig. 23) show a marked asymmetry in the valley slopes in the lower reaches. The left bank fault scarp is short and steep (being more than 50° near the river bank and about 45° in the upper parts). The right bank is gently sloping (20° to 25°

SUB BASIN - C

Superimposed cross profiles



slope), and at most places the slope break segment of the nature of RvR (rectilinear convex break; Anhert, 1970) occurs in the mild slopes. Identical slope breaks are observed on the left bank side in the upstream portions also. These breaks are obviously due to lithologic variation between the rocks like quartzites and slates such that the hard quartzites form abrupt slope breaks with the softer, easily eroded slates.

Analysis of Drainage Channels

Drainage analysis has been carried out for a smaller basin C_1. This smaller basin falls within the Nagthat quartzites and is not affected by the N-S (Kuch gad-Khairna nala) fault.

The plots of channel orders vs numbers, average lengths and drainage area, show the same relationship as those in case of the sub-basin A, the local basin relief being of the higher order (Fig. 24). The average lengths of the smaller order channels do not increase in a geometric progression as in the case of higher orders. The strike controlled trunk stream receives smaller order channels draining the both valley slopes. Due to this, the scope of lengthening of the lower orders is much limited. This phenomenon thus, shows a marked deviation from the Horton's Law of stream length. The laws of stream numbers and drainage areas, of course, hold good.

<u>Slopes</u>

The slope distribution within the basin also shows basin asymmetry (Fig. 25). The fringe area of the drainage divide has slope of about 20° to 25°, followed by wide areas of about 15° slopes. These wide areas are dotted with numerous linear and arcuate steep slopes of the order of 25° to 30°. Occasionally, scarps (more than 45°) also exist on the mid slopes. The central valley portion has a combination of both steep slopes and very gentle slopes, formed due to a combination of steep river banks and terrace scarps and different terrace levels. In the headward portion, the basin asymmetry is much reduced, and the trunk stream follows a mid path. Some of the flat levels of the terraces in the downstream stretches are as high as 250 m from the present river bed. The bed of the river which is quite wide has a gradient of 50 metres in 200 metres, and in this part, the channel meanders through its own flood plain. ([illegible]).

SUB-BASIN D

Drainage

The sub-basin D which falls within a narrow zone of Siwaliks, has been studied by dividing it into two smaller basins D_1 and D_2, taking into account the flow direction of the trunk stream. In the case of D_1, it flows across the strike while in D_2, channel runs along the strike (Fig. 26). Basins D_1 and D_2 cover areas 9.18 and 20.40 sq km respectively, and the total lengths of the trunk streams are 5.5 and 7.6 km. Both these are triangular in shape with the basin mouths towards the confluence. The drainage of D_1 is of 3rd order and D_2 of 4th order. The smaller order channels in both D_1 and D_2 follows the strike joints and form a trellis drainage pattern which is more clear from the drainage traced from aerial photographs (Fig. 27). Geologically, the rocks belong to the Lower and Upper Siwaliks, the contact between the two being a thrusted one. It is quite obvious that the main channel of D_2 has taken advantage of this tectonic contact.

Longitudinal Profiles

The longitudinal profiles of D_1 and D_2 show two distinct breaks in each, and these correspond to the terrace levels within the drainage areas (Fig. 28).

It is interesting to note that the terraces in this zone are of lesser heights, as compared to those in the sub-basin C.

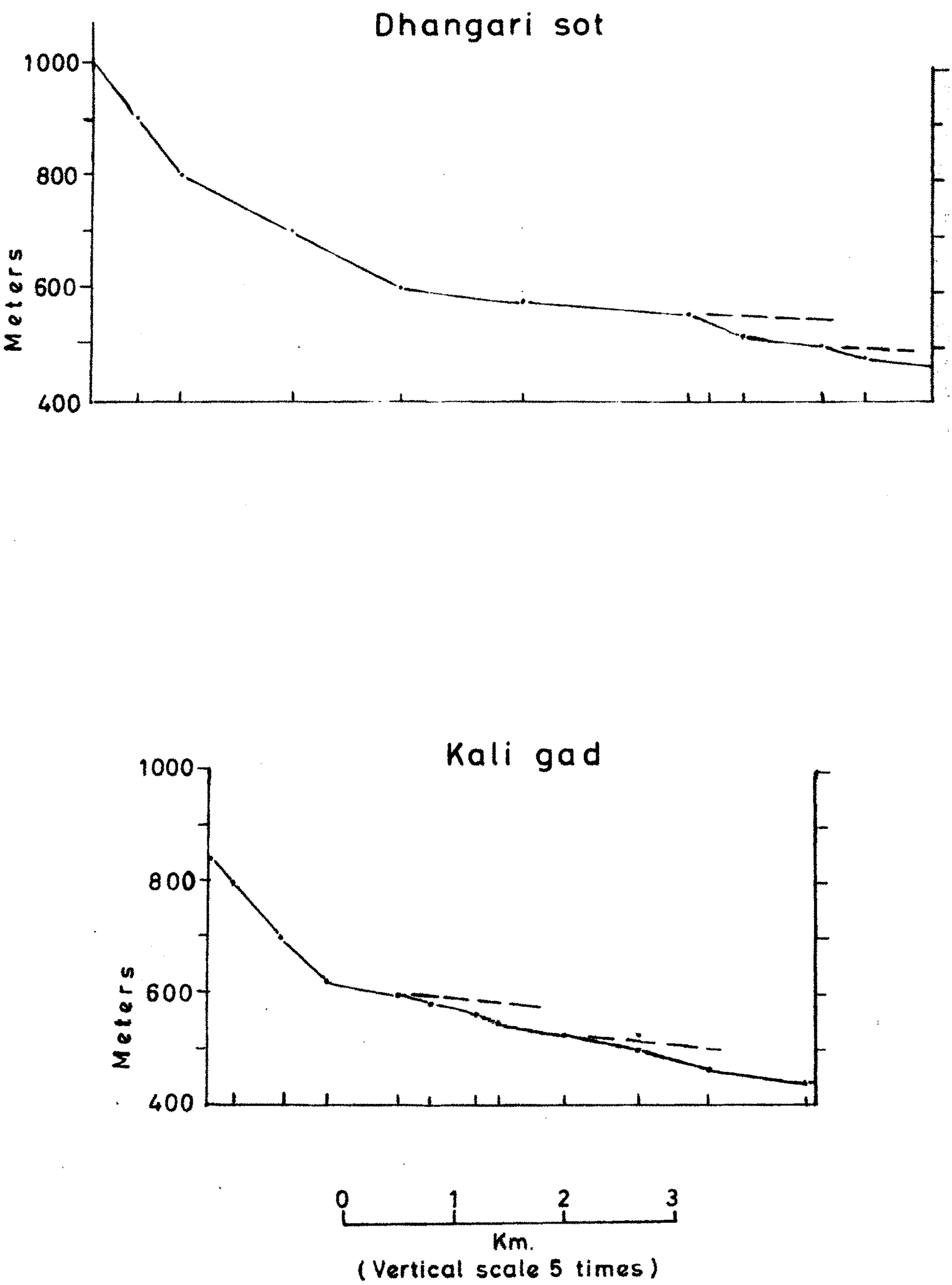
Cross Profiles

Cross profiles across the strike show a regular arrangement of dip slopes wherein the difference between the topographic slopes and the dip of the strata is very little (15° to 40° dip due N and 15° to 25° slope). There is a regular arrangement of individual inclined beds one over the other with the formation of long gentle dip slopes and short steep (25° -35°) scarp slopes (Fig.29). These slopes are rather vaguely recognised on the maps, but on the aerial photographs ~~but~~ the dip slopes and scarp slopes are diagnostically recognised.

Analysis of Drainage Channels

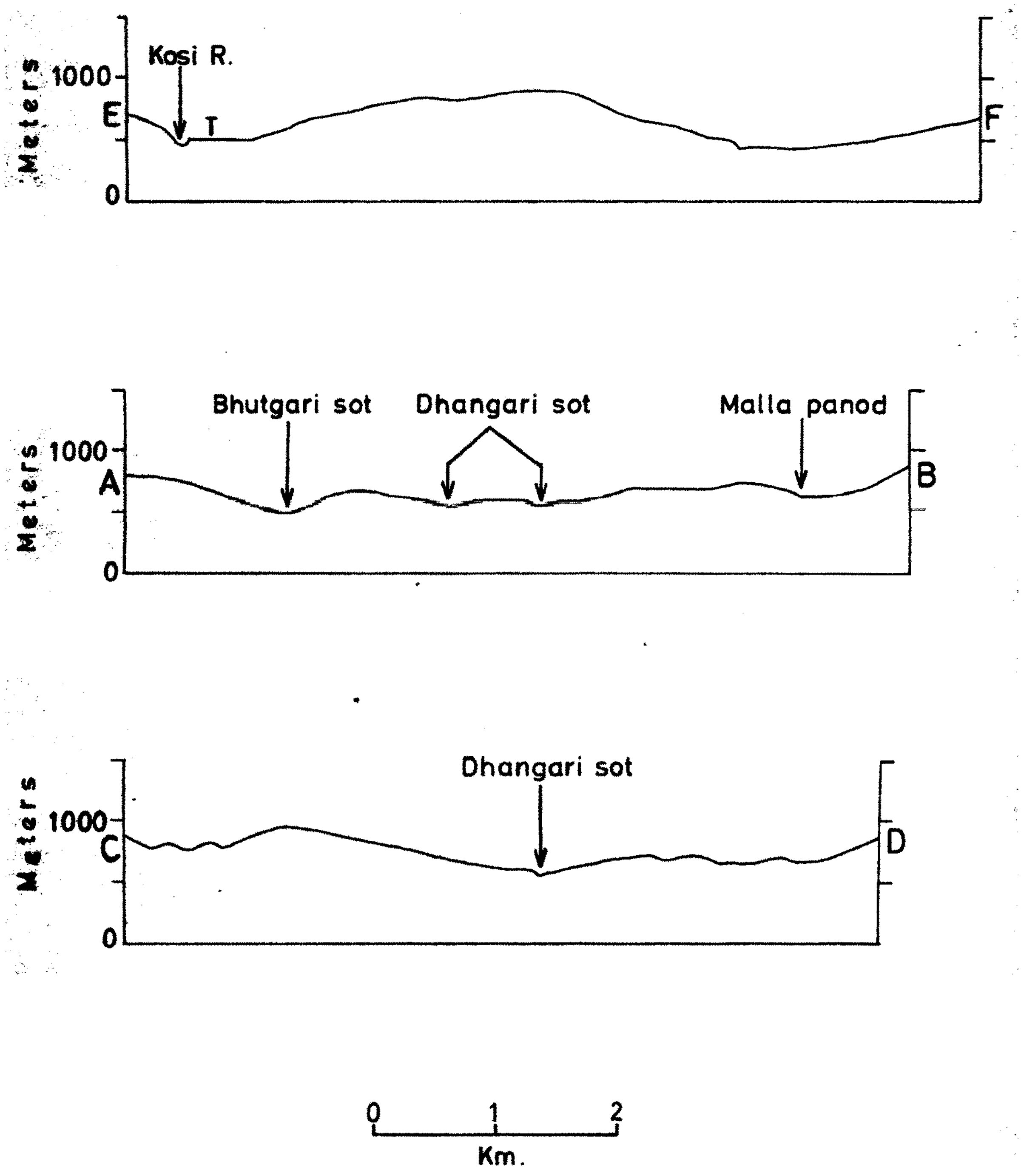
The plots of channel order versus number and drainage areas lie on the usual straight line as in the case of sub-basins A and C (Fig. 30). But in respect of the average length, it is not so and the relationship between the order and the average length is not linear.

LONGITUDINAL PROFILES-SUB BASIN D



SUB BASIN - D

Cross profiles



This deviation has been attributed to the small length 1st and 2nd order channels along the strike joints, which when joined with the 3rd and 4th order channels across the strike suddenly increase in length. This is a typical case of structural control due to joints wherein the erosional development is preferred along the planes of weakness and the rock ~~is~~ does not act~~ing~~ in a strictly homogeneous manner.

Slopes

The slopes in the entire sub-basin are grouped into three categories based mainly on the slope aspect, (i) slopes in dip direction, (ii) slopes against the dip, and (iii) slopes along the valley (Fig. 31).

In basin D_1, in which the flow is across the strike, the dip slopes are of the order of 10°-15°, and the reverse slopes 25°-30°. The valley slopes are 5°-10°. In case of sub-basin D_2, the trunk stream which roughly follows the strike of rocks, the north sloping dip slopes are 15°, but the south sloping reverse slopes are 10° to 20°. This is a phenomenon of stream erosion accentuated by the softness of the sedimentary strata. The higher terrace deposits have a slope of 5° towards the Kosi river which cuts this zone with a sharp bend.

COMPARISON OF MORPHOMETRIC PARAMETERS

A comparison of the various morphometric parameters for the smaller order basins within each sub-basin reveals (i) changes in ruggedness, (ii) drainage spacings, (iii) intensity of erosion and, (iv) altitudinal differences, all of which are again, the effects of lithologic variations and structural discontinuities (Tables 6 to 9). The values for bifurcation ratio range between 2 to 4.5, but the most common values are between 3.7 to 4.5. The drainage density values are lowest in sub-basin B_1 (2.7) and sub-basin D_2 (2.3), the former being a softer lithology having least relief ratio, and the latter following the tectonic contact between the Lower and the Upper Siwaliks and having low relief. The maximum drainage density values are in sub-basin C_1 and A_1, A_2, A_3 (3.1 to 3.6), all these draining the hard metasediments having high basin relief.

The maximum ruggedness number values are in the sub-basins C_1 (3.9) and A_1 (3.38). These sub-basins having long steep slopes, are confined to fault zones. The minimum ruggedness values are in the case of Siwaliks (D_1, D_2 with values 1.73 and 1.26) the entire Siwalik ranges being lowest in altitude having undergone maximum stream erosion. Sub-basin B_1 has a ruggedness number

Table 7 : Morphometric Parameters - Sub-Basin B

Sub-Basin	Channel order	Number of channels	Bifurcation ratio	Total length (km)	Average length (km)	Average drainage area (sq km)	Maximum basin relief (m)	Total drainage area (sq km)
B_1	1	498	4.25	107.75	0.216		1308	81.80
	2	117	4.5	54.20	0.46	0.39		
	3	26	3.7	27.20	1.05	1.7		
	4	7	7	20.80	2.97	11.87		
	5	1		13.3	13.3	81.80		

Table 6 : Morphometric Parameters - Sub-Basin A

Sub-basin	Channel order	Number of channels	Bifurcation ratio	Total length (km)	Average length (km)	Average drainage area (sq km)	Maximum basin relief (m)	Total drainage area (sq km)
A_1	1	177		85.35	0.482		1092	43.0
			4.9					
	2	36		23.90	0.682	0.22		
			4.0					
	3	9		6.85	0.761	1.70		
			4.5					
	4	2		11.30	5.65	10.98		
			2.0					
	5	1		7.10	7.10	43.0		
A_2	1	97		47.4	0.479		768	21.70
			4.6					
	2	20		13.05	0.652	0.57		
			4.0					
	3	5		7.75	1.55	2.60		
			5.0					
	4	1		6.6	6.6	21.70		
A_3	1	138		70.0	0.507		796	30.50
			4.7					
	2	29		23.5	0.810	0.52		
			4.5					
	3	6		8.4	1.40	2.2		
			3					
	4	2		3.2	1.60	8.22		
			2					
	5	1		6.2	6.2	30.50		

of 3.53 but it does not represent the total landscape of the Almora crystallines and this high value is attributed to the remnants of hill ranges in an otherwise subdued topography, forming divides.

Sub-basins A_2 and A_3 have ruggedness values lower as compared to that of A_1 (3.38). These low values are due to the factors of active erosion along the faults and to the formation of gentler slopes, thereby lowering the ruggedness.

The stream frequencies, i.e. number of channel segments per sq km , are also indicative of lithologic differentiation (Table 10). Within sub-basin A itself, in the zone of North Almora fault, the lowest value of 16 is obtained. In the high hills of Deogad catchment (A_1) the values are as high as 59, as here the rocks are hard, jointed quartzites occupying higher altitudes. The compact limestones and the quartzites within A_2 and A_3, however, show a value of 37. These values do not reveal lithologic variations. The horizon of chlorite schists in A_2 has lesser value, i.e. 23, mainly due to its soft and schistose character of the rocks.

The Almora crystallines, south of the North Almora fault also have values similar to those of chlorite schists.

Table 10 : Stream frequencies in different Sub Basins (Number of channel sigments per sq km as on photo tracing)

Sub Basin	Lithologic units	Stream frequency
A	Quartzites in A_1	59
	Chlorite schists in A_2	23
	Compact limestone of A_2 & A_3	37
	Quartzites and slates in A_3	37.5
	Zone of N Almora fault	16
B	Almora crystallines (sheared gneisses)	23.25
	Schists and gneisses	38
C	Slates	23
	Quartzites (right bank)	28
	Quartzites (left bank)	34
D	Lower Siwaliks	22
	Upper Siwaliks	20

In this zone of crystallines wherever gneisses and quartzite bands occur the stream frequency values reach upto 38. In sub-basin C, the slates show the least values (23), whereas the underlying quartzites and slates show a value of 28. The quartzites on the left bank in contact with the Ramgarh thrust reach higher values as much as 34. These rocks form steeper slopes and are highly jointed. In sub-basin D, the stream frequency values are similar to those in the soft metasediments like slates and crumpled schists (20-22).

It may be thus concluded that the stream frequency is a function of rock competency, inherent structural weakness, and local relief.

The study of the drainage network on the maps of 1:50,000, and that from the aerial photographs (traced under stereoscope) show that the 1st order channels on the map are actually the second order channels on the ground (Table ii). It is not possible to show all the first order channels on the map since at 1:50,000 scale if it is done so, the entire map area will get covered by the drainage network alone and other features like roads, habitations etc would be masked. The author has therefore

Table 11 : Numbers of various channel orders as on 1:50000 map and on 1:70000 aerial photos

Sub Basin	On map		On aerial photos	
	Channel order	Numbers	Channel order	Numbers
A_2			1	552
	1	97	2	110
	2	20	3	22
	3	5	4	6
	4	1	5	1
A_3			1	827
	1	138	2	151
	2	29	3	33
	3	6	4	9
	4	2	5	2
	5	1	6	1
B_1			1	1928
	1	498	2	490
	2	117	3	90
	3	26	4	20
	4	7	5	5
	5	1	6	1

contd...

Table 11 (contd.)

Sub Basin	On map		On aerial photos	
	Channel order	Numbers	Channel order	Numbers
C_1			1	724
	1	145	2	145
	2	32	3	31
	3	7	4	6
	4	1	5	1
D_1			1	183
	1	40	2	48
	2	8	3	10
	3	1	4	3
			5	1
D_2			1	242
	1	58	2	49
	2	12	3	11
	3	4	4	3
	4	1	5	1

taken into consideration the drainage from the airphotos to study the relationship between the drainage orders vs number of channels for all the sub-basins. The lengths of these smallest channels have not however been indicated since on airphotos these are shortened or lengthened due to relief displacement and minor tilt.

It is obvious from above that the slope and drainage for the four representative sub-basins, representing one litho-tectonic zone each, clearly indicate the variations in the morphometric parameters. These variations provide a very dependable basis to evaluate the impacts of geomorphic processes operating on the litho-tectonic framework in the entire basin.