CHAPTER II

GEOLOGY AND MORPHOLOGY

GEOLOGY

In the present study, the morphologic characteristics of the Kosi drainage basin have been evaluated with special reference to the lithologic and structural framework, and therefore, the details like variation in lithology, strike and dip of beds, fold axes and axial plane traces, thrust contacts, fault traces and prominent joint sets are of special importance. As the author has utilised the geology of the area to analyse the morphocharacteristics of the drainage basin, he has not gone into the intricate details of structure and stratigraphy. The problems like subdivisions of stratigraphic horizons and dating of tectonic events has

also not been attempted. The geologic framework followed in the present study has been worked out by the author by means of aerial photo studies and field checks. He has also taken help from the works of Merh and his associates.

The fundamental work carried out by Auden (1937), Middlemiss (1890), Heim and Gansser (1939) and Gansser (1964) forms the main foundation for the geology of this region. Keeping in mind his requirements, the author has, on the basis of all the previous work, worked out the following stratigraphic sequence for the study area (Figs. 4 & 5).

Autochthonous	Middle Miocene to Pleistocene	Siwalik System	Upper - Sandstones and shales
			Middle- Conglomerates, clays and shales
			------Thrust---------
			Lower - Compact sandstones
----------Main Boundary Fault----------			
Krol nappe	Late Palaeozoic	Krol-Nagthat Group	Shales, limestones and quartzites
			Quartzites and slates
			Chlorite schists and quartzites
			---Ramgarh Thrust----
			Quartzites, slates, limestones and porphyries

	Early to Late Palaeozoic	Nagthat-Deoban group	Quartzites with slates Dolomitic limestones and slates Chlorite schists
		----------Almora Thrust----------	
Almora nappe	Cambrian to Pre-Cambrian	Metamorphics and crystalline rocks	Gneisses Mica schists with quartzites Mica schists Sericite Quartzites (Phyllonite)

Merh (1968) has given quite a convincing structural history of the area. According to him, the rocks of this region have undergone three main events of deformation, and the various major and minor structural elements preserved in the rocks point towards these three major deformation, the geosynclinal sediments were folded into several big reclined isoclinal structures and the resulting schistosity (which is the most dominant metamorphic foliation) characterised the axial planes of these folds. The culmination of this folding activity resulted into the Almora Thrust.

The second phase of deformation gave rise to the major folded structures like the Almora synform and the anticlines at Bhowali (Rataura) and Someshwar. The axes of these folds are subhorizontal and extend WNW-ESE. The thrusting at Ramgarh, and the synformal folding of Almora

thrust were believed by Merh to be genetically connected events, resulting from a single deformational phase. Recently Devendra Pal (1973) working in Naini Tal area has suggested that the Naini Tal syncline is a later structure superimposed over the anticlines of the second generation. Merh (personal communication) also now believes that this could be true and that the Ramgarh thrust developed even later than the Naini Tal syncline. Of course, there is not much difference in the axial trends of these folds of different generations.

The third major deformation developed N-S to NE-SW folds, and along the axial planes of these folds displacements occurred at numerous places giving rise to several faults, resulting in the shifts of the thrust contacts.

As will be seen in Fig. 4, the geologic set up of the study area from NE to SW, is divisible into 4 major tectonic zones as under:-

(i) Area of Nagthat-Deoban group of rocks separated by the North Almora fault,

(ii) Almora crystallines and metamorphics covering a wide stretch of the basin,

(iii) Area of Krol-Nagthat group of rocks, bound in the NE by the South Almora thrust and towards SW by the Main Boundary fault and

(iv) Siwalik group of rocks, south of the Main Boundary fault.

The geologic details of each zone are discussed below:

Nagthat-Deoban Group

This zone has its southern limit along Lod, Someshwar, Niral gad and Gananath, which is the trace of the North Almora fault also. The rock types are the metasediments, chiefly quartzites, slates and dolomitic limestones. These rocks trend NE-SW and dip towards NW, by amounts varying between 25° to 55°. Lying between the Kausani thrust (in the north) and the North Almora fault, this group constitutes an upthrown faulted block, which it appears forms the northern limb of a truncated anticline. The south-dipping limb of this anticline, together with the Almora crystallines, has been pushed below. Along the northern fringe of the Kosi divide near Kausani, passes another tectonic contact but covers a very small portion of the basin. The prominent joint sets in this zone are bedding joints (NE-SW) and

oblique joints (N-S Sub-vertical and NNE-SSW Sub-vertical to 50°).

Almora Nappe

The crystalline rocks of the Almora nappe are bound to the north by the North Almora fault and in the south by the South Almora thrust. According to Merh (personal communication) the North Almora fault is a steep reverse fault with its upthrow side to the north and dips towards NE. Due to this displacement, the low angle southerly dipping North Almora thrust lies concealed. This fault trace itself is displaced along N-S dislocations at four places, west of Bayala, near Ranman, south of Someshwar, near the bend of Niral gad, and along the upper reaches of Kartigad.

The South Almora thrust passes south of Ranikhet, Kakrighat and west of Mukteswar. This is a low angle thrust dipping 10°-15° towards NE. Its trace is wavy and this waviness is due to topographic undulations and subsequent deformation (third folds) on NE-SW axis.

The Almora nappe forms a synform, such that its axis trends ESE-WNW and passes north of Bhainsket, Ren gad, Kalimat ridge, south of Bare Chinna and Panuwanaula.

The lithologic variations within the crystallines includes phyllonites (in the thrust vicinity), puckered and crumpled schists, compact mica schists, gneisses with micaceous quartzites and compact gneissic granites, all of which represent the metamorphosed and granitised sediments of a geosyncline. North of the synformal axis these crystalline rocks occupy lesser width due to the steepness of the limb, and all the 4 main divisions can be easily recognised on the aerial photographs. In the wider and gently dipping southern limb of the synform only one gneissic band can be traced. This occupies a narrow but distinct zone extending from Ranikhet, Chaubatia, through Kaligad and reaching upto Kali Rau. Beyond Kali Rau, the photo expression is not clear, but it can be tentatively connected with the gneissic band across the Sual river, south of Almora.

The general strike of rocks in this zone of crystallines, is WNW-ESE, changing to NW-SE in the Kapaleshwar-Mukteswar area. The prominent sets of joints include N-S subvertical bedding joints and subvertical joints trending NE-SW perpendicular to the strike. The waviness in the trace of the synformal axis and the fluctuations in the orientation of the

related minor fold axes, seen in quartzites, puckers etc. point to a superimposition of the later NE-SW to NS flexures.

Krol-Nagthat Group

This group comprises the lithologic sequence between the South Almora thrust and the Main Boundary fault. The whole sequence with the asseciated dislocation planes, have a general dip towards NE. The dips vary between 25° to 50° at different places depending upon the location of fold structures.

Apart from the numerous faults that cut the sequence, a prominent thrust separates the rocks of Krol group in the south-west from those of mainly Nagthats in the north. This dislocation passes along the ridge between Kosi and Kuch gad, Kosi confluence with Kuch gad, Khairna, cuts Ram gad and follows the ridge east of Ninglat nala. The quartzite expesures east of this Ramgarh thrust within the Kuch gad basin indicate a probable displacement along a NS trace joining Khairna nala and part of Kuch gad. However, this dislocation is conjectural.

The rocks north of the Ramgarh thrust and south of the South Almora thrust are mainly quartzites,

limestones and slates. All these are strike ridges and have a characteristic photoexpression. The prominent joint sets are the bedding or foliation joints, subvertical NE-SW joints and the subvertical N-S joints. The rocks between the Ramgarh thrust and the Main Boundary fault belong mostly to the Krol sequence. The fringe of Nagthat quartzites associated with metabasics in the anticlinal core at Bhowali have been taken as Nagthat by most previous workers. C.P. Shah (1973) and O.K. Shah (personal communications) however believe that these rocks are Blainis and comprise the lowermost portion of the Krol sequence along the Ramgarh thrust. The rocks of the Krol sequence are limestones, slates and quartzites. The general trend of these is NW-SE with moderate northeasterly dips. Structurally, the rocks to the SW of Ramgarh thrust form a NW-SE anticline at Bhowali (Rataura) and an open E-W syncline at Naini Tal, the two structures being of different ages. All the fold axes trend in the direction of general strike of strata. The prominent joint sets in this part are bedding joints, NE-SW subvertical joints and less prominent subvertical N-S joints.

Siwalik Group:

The rocks of this group are bound in the north by the Main Boundary fault, along which the Pre-Siwalik

Krol-Nagthat group of rocks have been thrust over. The southern limit is the erosional contact with the piedmont plain. The Siwaliks are divided into Lower, Middle and Upper. Compact sandstones of Lower Siwaliks rest over the normal sequence of Middle and Upper Siwalik sandstones, shales, clays and conglomerates with a thrusted contact.

The strike of these beds is fairly uniform i.e. ENE-WSW. The dips are 15° - 35° northerly. The prominent joint sets in this zone are the bedding joints and subvertical joints perpendicular to the strike.

MORPHOLOGY

The shape of the Kosi drainage basin more or less resembles a reverse 'S' trending E-W. The total drainage area is about 1756 sq km and comprises a major arc pointing towards SE, covering nearly 80% of the total area; the complementary smaller arc which is rather acute, points towards NW and covers the remaining basin area. The river originates from the southern flank of the EW trending Kausani ridge, from an altitude of 2480 metres. The highest point on this ridge is at 2620 metres, but the effective drainage starts from a height of 2480 metres only. The river travels a map distance of 144 km before emerging on the plains at about 360 metre level near Ramnagar.

All along its course, for the most part, it cuts across the regional strike of the rocks and the only the stretches where it follows the strike of beds are the 7 km portion near Rataura and two small portions of 2.5 and 5 km in the Siwalik zone.

As stated already, the Kosi river drains through 4 main lithostratigraphic units of the Kumaon Himalaya, and several tributaries join it along the right and left banks in all the four lithotectonic zones (Fig. 6). The important tributaries are given below zonewise:-

	Left Bank	Right Bank
1. Nagthat-Deoban zone (Someshwar-Kausani)	Menol gad	Deo gad
	Mansa rauli	Sai River
	Niral gad	
2. Almora crystallines (Someshwar-Kakrighat)	Sim gad	Ban gad
	Jamthara gad	Jainal gad
	Sual River (Kali Rau)	Ren gad
	Halkula gad	Nana Kosi
		Khul gad
		Khuralibgad
		Sarod gad
4. Krol-Nagthat group (Kakrighat-Basela)	Khairna nala (Jakh N, Ninglat N. Ramgad)	Kuch gad
		Panth gad
		Khodan gad
	Kaluwa gad	Dhamni gad
	Ghiroli nala	Taklari gad

	Khaula nadi	Kyari gad
	Gharam sot	Gaunchhil gad
	Kamchiya sot	Dhauli gad
		Bauras gad
4. Siwalik zone	Panyali gad	Kali gad
(Basela-Rammagar)	Bhutgari sot	Rumyani sot
	Dhangori sot	Sukha sot
	Malle panod	Pipalia sot

Channel Gradient

The author has plotted the longitudinal profile of Kosi river with vertical scale exaggerated five times (Fig. 7) and has tabulated the channel characteristics (Table 4). There are, in all, 14 breaks in the profile indicating rejuvenation and effect of hard lithologies. Two breaks are in the high relief hills of Kausani before Deo gad confluence. One break coincides with the trace of the North Almora fault.

In the Almora crystallines, there are four important breaks in the profile, (1) near the confluence of Bam gad, (2) near the confluence of Sim gad, (3) before the Sual confluence and (4) near the confluence of Halkula gad, about 6 km upstream of South Almora thrust contact.

In the Krol-Nagthat zone, the longitudinal profile indicates 5 breaks, (1) before the Kuch gad confluence,

(2) 4 km upstream from Rataura, (3) near Betalghat at the confluence of Panth gadhera, (4) near Seti and (5) 4 km upstream of Basela.

In the Siwalik zone, on the other hand, the channel gradient is rather smooth and without major breaks, except one near the confluence of Dhangari sot.

River bed

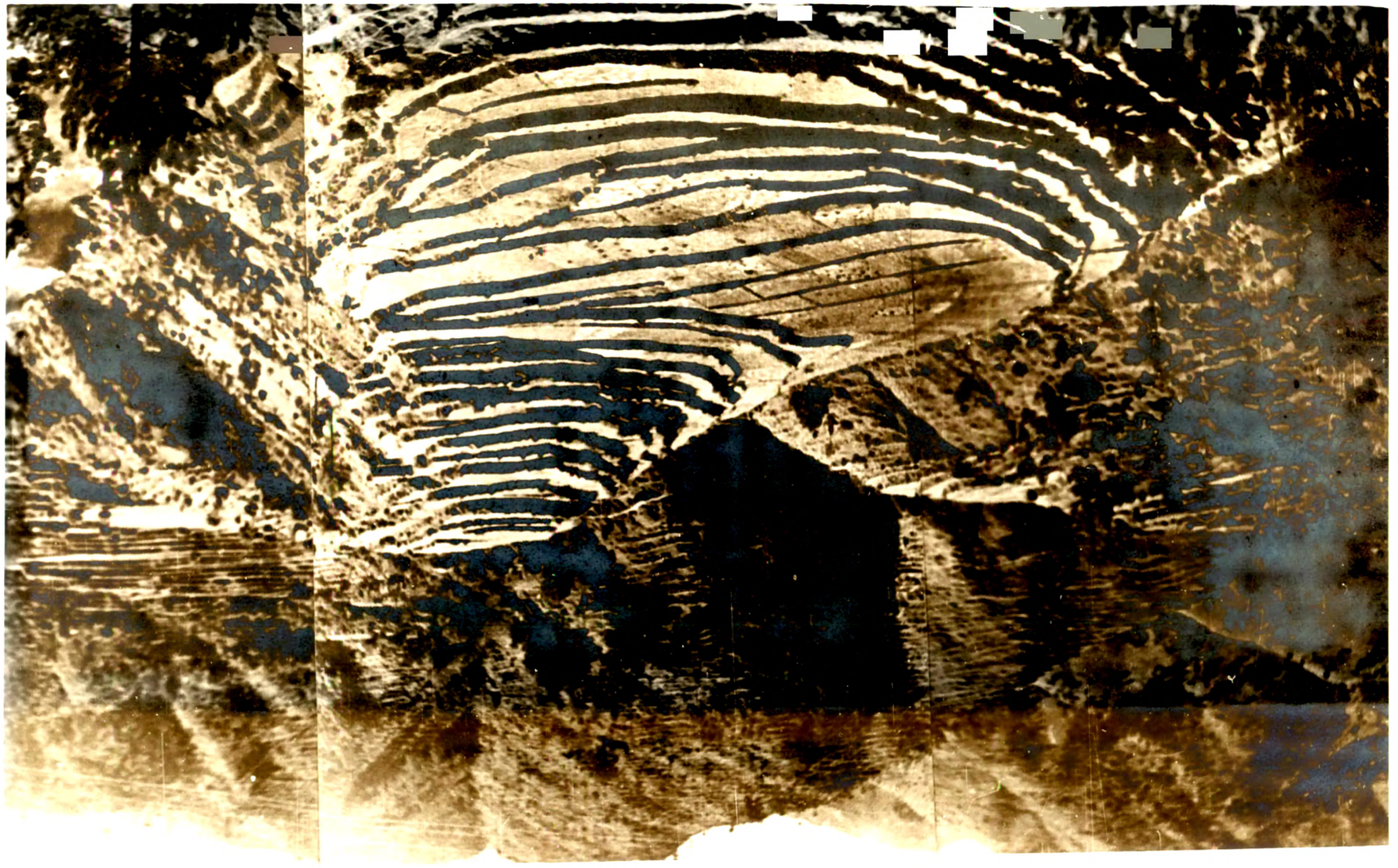
Being a seasonal river, Kosi has a rather restricted wet channel. But the wet channel and the dry bed taken together constituting the total river bed is not that narrow, and varies in width from a few metres in headward positions to as much as 500 metres in the wider sections in the lower reaches. At one place it is 1200 metres wide.

In the Nagthat-Deoban group around Someshwar the river bed widens considerably, and is seen meandering in its own flood plain. But it suddenly narrows down as soon as it crosses the North Almora fault. In its entire stretch in the Almora crystallines, the river flows over a rocky bed and at places is also deeply incised. South of Parolia, an entrenched meander has cut the rocky banks to a depth of 50-60 metres leaving the alluvial terraces at higher levels (Plate 3). Elsewhere the incision is rather less-2 to 6 metres

PLATE 3

Downstream view of entrenched meander near the confluence of Jainal gad.

Deep entrenchment of Kosi channel (C) and formation of terrace (T) at 45 metres above the bed level.



(Plates 4 & 5). In the Nagthat group of rocks between the South Almora thrust and the Ramgarh fault, the river has a relatively wider bed (150metres). Here it cuts through rocks, and has steep rocky valley side slopes. From Khairna to Seti also, the river flowing in the Krol section has wide bed, which again narrows down from Seti to Basela. After that it starts widening. In the Siwalik zone, the river bed is of the width of about 500 metres (Plate 6). On crossing the Main Boundary fault near Mohan, its bed is as wide as 1200 metres. Near Garjia, however the river bed again narrows down (Plate 7) suddenly to about 100 metres only, and this is due to the lithologic contact between the hard Upper Siwaliks and the relatively softer Middle Siwaliks.

Downflow Directions

In the Someshwar section (Kausani valley) the general flow direction is towards SE with frequent offsets along NE-SW direction, such that the stream sometimes flows due NE and sometimes due SW. This trend of offsets corresponds with the regional strike. Niral gad and Sai nala in general follow the trace of the North Almora fault. In the Almora crystallines, Kosi cuts across the regional strike and flows southerly with numerous short offsets, upto the

PLATE 4

Upstream view of Kosi cutting the Almora crystallines.

Subdued topography; relatively narrow channel (C); rocky bank (Rb) and terrace material (T) above the mica schists in the road cut (Rc), along the right bank.

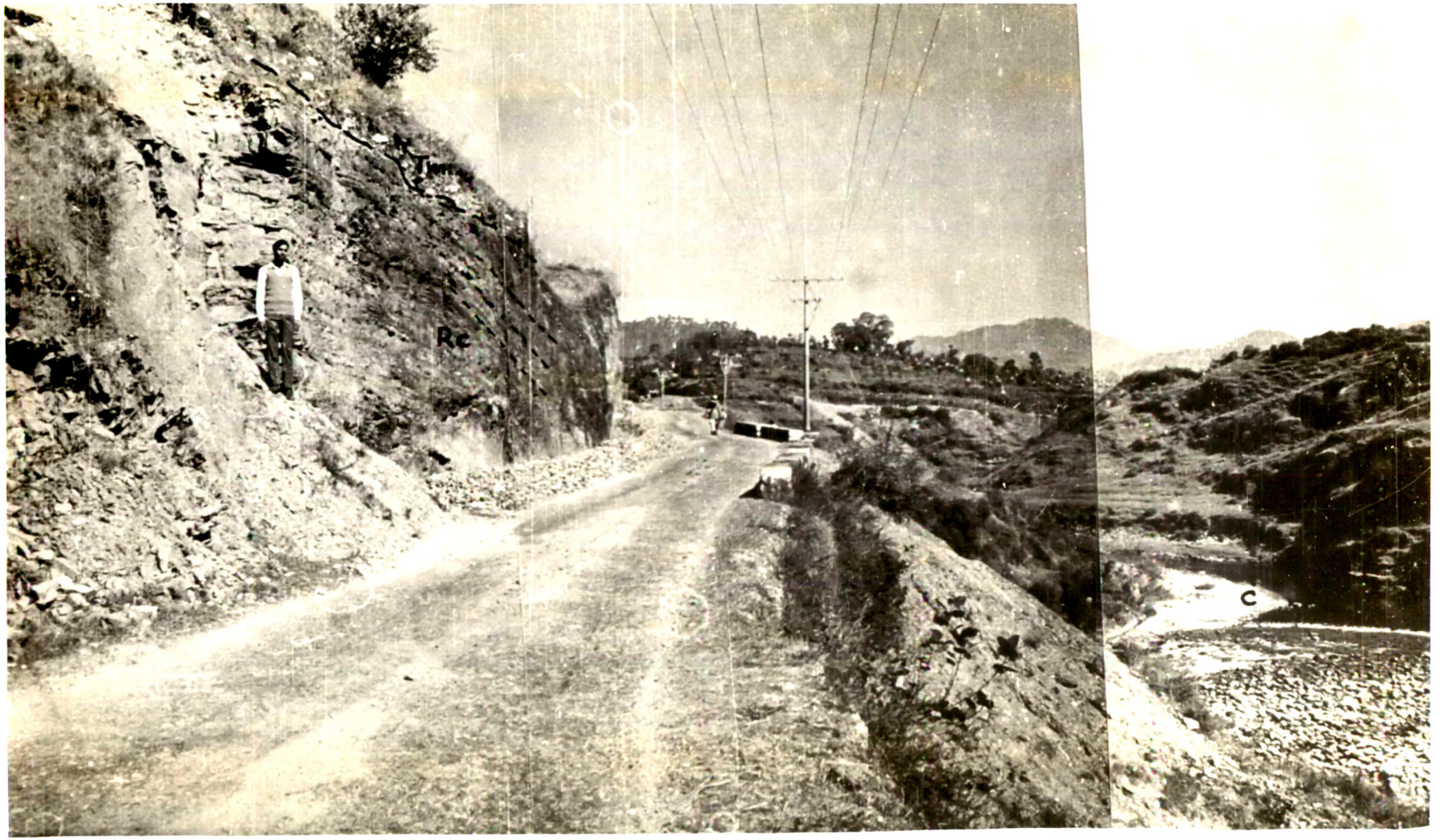

Re
C

PLATE 5

A view of Kosi entrenchment near Hawalbagh, looking downstream.

Entrenchment of the order of 5 metres; narrow channel (C); rocky bed (Rb) and the N-S alignment of the channel across the strike, in the subdued topography of the Almora crystallines.


C

PLATE 6

Upstream view of the wide river channel in the Siwalik zone, north of Garjia.

Sharp crested Siwalik foot hill ranges cut by wide Kosi channel; the river bank material stratified showing thick boulder-gravel horizon overlain by thin sand-gravel layer.

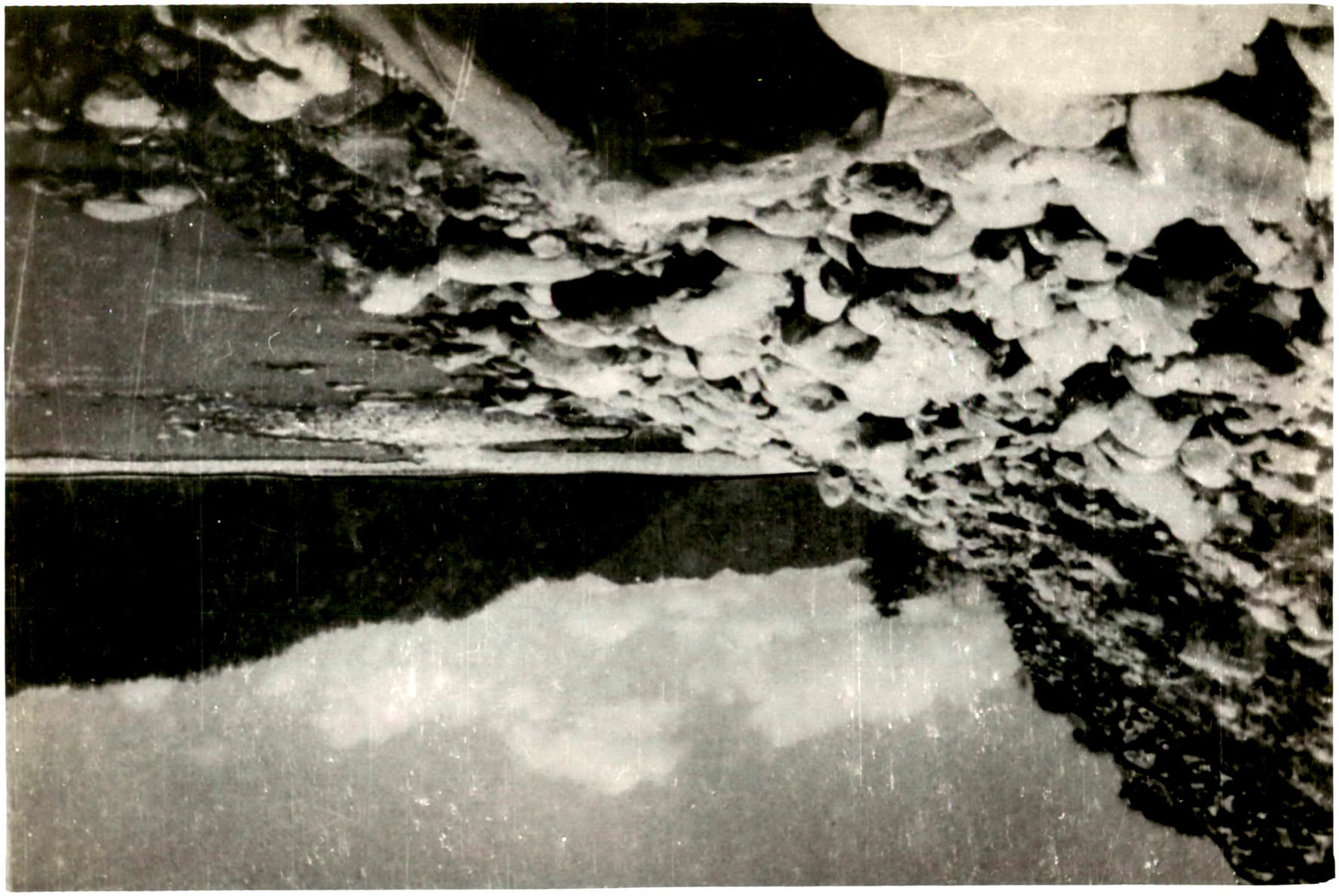


PLATE 7

Upstream view of the narrow Kosi channel near Garjia.

The Garjia neck formed at the contact of Upper Siwalik sandstones underlain by the softer middle Siwalik shales and sandstones; the compact sandstones (sst) forming sharp crested asymmetric strike ridges having gentle dip slopes and short scarps on reverse slopes; the river bed comprising channel (C) and dry bed (B); the terrace covered by riverine Sissu forest (Rf) which is differentiated from the moist Sal forest on the hill slopes.


Rf
B
C

confluence of Sual river (Plate 8). At this confluence, the river takes a southwesterly turn and follows the general alignment of Kali rau, a tributary of Sual river, which flows along the regional strike. Near Kakrighat, the Kosi river takes a sharp right-angled turn towards south and enters the rocks of the Krol-Nagthat group, crossing the South Almora thrust. Then further downstream, upto Ramgarh thrust, this trend continues. West of the Khairna nala - Kuch gad N-S alignment, the river flows along the regional strike which near Rataura, coincides with the trace of the anticlinal axial plane. This strike orientation continues upto the confluence of Khodan nala, beyond which the river again cuts across the strike of the rocks, flowing southwesterly upto Basela. From Basela, it follows the trace of the Main Boundary fault, then cuts across the Siwalik strike by taking an arcuate bend and flowing southerly through Ramnagar into the alluvial plains.

Drainage Pattern

The drainage pattern varies considerably from one lithostratigraphic unit to the other. While the drainage network in the Almora crystalline rocks is dendritic to subdendritic (Plates 9 and 10), those in the Deoban-Nagthat, Krol-Nagthat

PLATE 8

Upstream view of Kosi valley near the confluence of Sual river.

Kosi channel cutting across the regional strike of the Almora crystallines; the valley sides steep and landslide areas (white) on the lower steep slopes.

PLATE 9

View of the subdued topography and dendritic drainage in the Dhaula gad valley.

The area of Almora crystallines is Dhaula gad valley showing typical subdued topography and the effects of peneplanation; the extensive gentler valley slopes superimposed by the dendritic drainage pattern; dark patches of vegetation on the ridge crests.

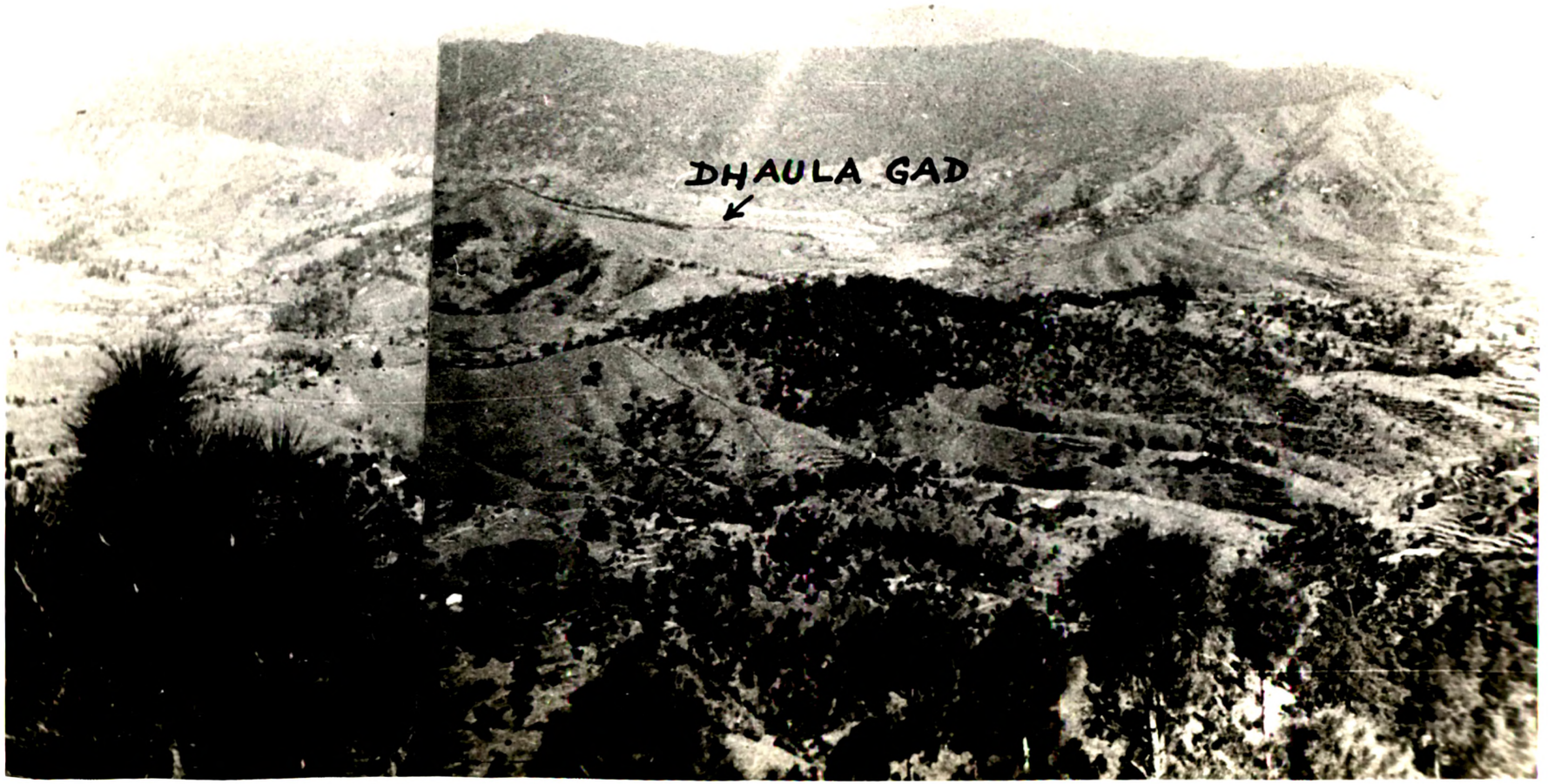

DHAULA GAD

PLATE 10

Kosi valley west of Almora.

Asymmetric ridges and dendritic drainage pattern; cultivation on slopes in the dip direction; winding Kosi channel flowing southerly; flat spur tops near Balam-talla

and Siwalik zones are of parallel and trellis type. In the Almora crystalline group, the higher order channels show dendritic to sub-dendritic patterns, while the smaller order channels reveal trellis type, indicating a strong control of strike and oblique joints. On the other hand, the consequent streams draining the steep slopes of the remaining groups of metasedimentary and sedimentary rocks show parallel to subparallel drainage and the smaller channels joining these form trellis pattern again indicating a strong joint control.

Drainage Divides

Kausani ridge trending EW forms the northernmost divide of the basin, separating it from the Gomti drainage in the north. This divide comprises the western ridge summit (2520 metres), Kausani saddle (1888 metres) and the eastern high point (2150 metres). From here the Kosi basin divide trends NS at both ends. On the western margin is the Lod saddle (1600 metres) with convex bulge towards the basin, joining Bhainskhet saddle (1643 metres) and Majkhali. The eastern Kosi divide has a concave bulge with its convexity towards the Sarju drainage. This bulge joins the hill point of Binasar (2120 metres), Binsar (2412 metres), Panuwanaula (2326 metres) and Dhapsa (1896 metres). The lower half of the Kosi basin has very tortuous

northern and southern divides. The northern divide (Ranikhet-Bhatronjkhal ridge) separates the Kosi basin from the Ramganga, drainage in the north. From here the divide is seen to descend from 1800 metres to nearly 500 metres in the vicinity of the plains. This southern divide connects Naini Tal, Bhowali and Mukteswar ridges and its height variations are 2991 metres (West of Naini Tal), 1823 metres (Bhowali), 2294 and 2393 metres (Mukteswar and east). It separates the drainage of Gola and Lodhiya rivers in the south and southeast respectively. It is interesting to note that this southern divide of the basin surprisingly occupies the highest elevation on the basin perimeter. Obviously, this has a tectonic control. Thus, the southern ridge and part of eastern bulge form the highest portion of the basin. The northern limit is next in height and the vast expanse of metamorphics and crystallines are rather low in height with saddles along the synformal axis and scattered low ridges within the basin. Lod saddle is the continuation of North Almora fault. Siwaliks are the lowest hills and reach general heights upto 1050 metres within the basin.

So far as the drainage divides separating the various sub-basins within the main basin are concerned, they show

the following trends:-

(1) Within the Siwaliks and the Krol-Nagthat zone, they are strike ridges.

(2) In case of Nagthat-Deoban zone, the trends are slightly oblique to the regional strike.

(3) In the areas of the crystallines, north of the synformal axis, they are strike controlled, but to the south of this axis, the ridges are low in height and do not show any definite orientation. Except for the hills of Siahi Devi and Kalimat, that stand out prominently, the rest of the spurs are scattered diversely.

Drainage Characteristics of Tributaries

The author has selected nineteen main tributaries of Kosi from all the four lithotectonic zones for detailed studies of their drainage characteristics (Table 5). Tributary basin Nos. 1 to 3 fall within the Nagthat-Deoban group, 4 to 9 lie in Almora crystallines, 10 to 17 in Krol-Nagthat group and 18 to 19 in the Siwalik zone. For each tributary, following parameters were investigated:-

1. Channel order,
2. Length,
3. Area,
4. Maximum altitude of its basin,
5. Local base level,
6. Maximum basin relief,
7. Stream frequency,
8. Relief ratio,
9. Elongation ratio.

Orders of the various channels designated after Horton (1945) modified by Strahler (1956) were helpful in the comparison of other characteristics. Maximum basin relief is the difference between the maximum basin altitude and the local base level. Relief ratio, a dimensionless number is a ratio between maximum basin relief and the horizontal distance parallel to the main drainage line (Schumm, 1956). It is a measure of overall steepness of the drainage basin. Stream frequency is the number of stream segments per unit area (Horton, 1945) and measures the texture of the drainage net. The elongation ratio is the ratio of the diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956).

It will be seen from Table 5 that the tributary drainage basins in the Siwalik zone are of the lowest order, have minimum lengths and drain the smallest areas, the basin reliefs and elongation are also less but have good relief ratio and stream frequency. On the other hand the basins of the tributaries from the immediate northern Krol-Nagthat group have channels of the same order as in the zones further north. They have maximum stream frequency, lengths and areas but the elongation is too high and also show much variation in the relief ratio. They however have maximum basin reliefs in the entire Kosi drainage. The tributary basins in the crystallines are poorly elongated, the channels are of maximum lengths and drain maximum areas. The maximum basin relief is less than that in Krol-Nagthat or even Nagthat-Deoban group.

Within the Deoban-Nagthat group, the Channel frequency varies considerably even within the same tributary basins. The variation is due to the sudden flattening of the steep slopes towards the wide flat valleys.