CHAPTER IV

GEOMORPHIC PROCESSES AND GEOLOGIC CONTROLS

GENERAL

Demek (1968), discussing the principles, problems and practical utilisation of the complex physio-geographical research has stressed upon the preparation of various morphogenetic maps like those illustrating soil types, relief types and natural landscapes. The various factors applied in the preparation of such morphogenetic map include vertical dissection, topography, morphostructures(structural-geological units and lithological composition), relief, topography, soil types and biogeography. In the present study, the author has divided the basin area, based on morphostructures. The geomorphic aspects superimposed on the pre-existing topography have also been considered.

Louis (1969) has discussed the factors of valley deepening due to both tectonic and climatic causes. He has distinguished features of valley deepening which can be referred to as 'singular' and others of a more general character. He has mentioned that along the border of a rising block, a zone of increased gradient in the long profile is formed and this slowly shifts upstream. The efficiencies of such incisions are modified by the distribution of rocks. In the present area too, out of the fourteen breaks in the longitudinal profile of Kosi, at least five can be associated with rejuvenation due to different phases of uplifts of blocks, two with the changes in the lithologies (cataracts) and rest with the climatic accidents.

The polycylic landscape of Kosi drainage basin has preserved within it an admirable and rather well defined imprint of the combination of active denudational agencies and geologic controls. These two complementary factors that overlap or follow in a temporal sequence and guide the landscape evolution have been considered at length by the author, in this chapter.

GEOMORPHIC PROCESSES

Obviously, the entire landscape of the study area is youthful and is under constant attack of the processes of active erosion, transportation and deposition. These processes include the various phenomena like the weathering of rocks, mass wasting, stream load discharge, formation of flood plains and terrace levels and river entrenchment.

From the point of view of depositional features, the area has been divided into two major divisions - one to the North of the South Almora thrust (Northern Division) and the other (Southern Division) to the South and West of it. The former, particularly in the river valley portion is mainly characterised by erosional processes of great intensity resulting into entrenchment and peneplanation, while the latter Division is dominantly characterised by depositional processes of considerable magnitude. The Northern Division is further subdivided into two zones, viz (i) the area to the North of Niral gad and (ii) the area to the South of Niral gad. The Southern Division is seen to comprise seven zones based on the features like deep valley sections, narrow constrictions in the river path, and areas of wider river beds. From east to west, they could be listed as under - (Fig. 6)

1. Kakrighat to Khairna nala - Kuch gad alignment
2. Khairna nala-Kuch gad alignment to Betalghat
3. Betalghat to Seti
4. Seti to Basela
5. Basela to Kumeriya
6. Kumeriya to Garjia
7. Garjia to Ramnagar.

Out of the above seven zones, the numbers 2,3,5,6 and 7 comprise wide river bed sections separated by narrow constrictions, whereas 1 and 4 constitute very narrow parts of the channel.

The study of major terrace levels at various locations along the Kosi channel has revealed that there are two major terraces in the Northern Division and six in the southern.

Northern Division

In this Division, along the wide valley of the Almora crystallines, the highest terrace is recognised, on the flat spur tops, generally more than ten metres above the bed level. The terrace material is illstratified, and highly unsorted (Plate 11). The gravels and boulders of this terrace are of quartzites, granitic gneiss and platy schists.

PLATE 11

Alluvial terrace material near Kosi Bazar.

Illstratified unsorted alluvial terrace material, nearly 10 metres above the present bed level.

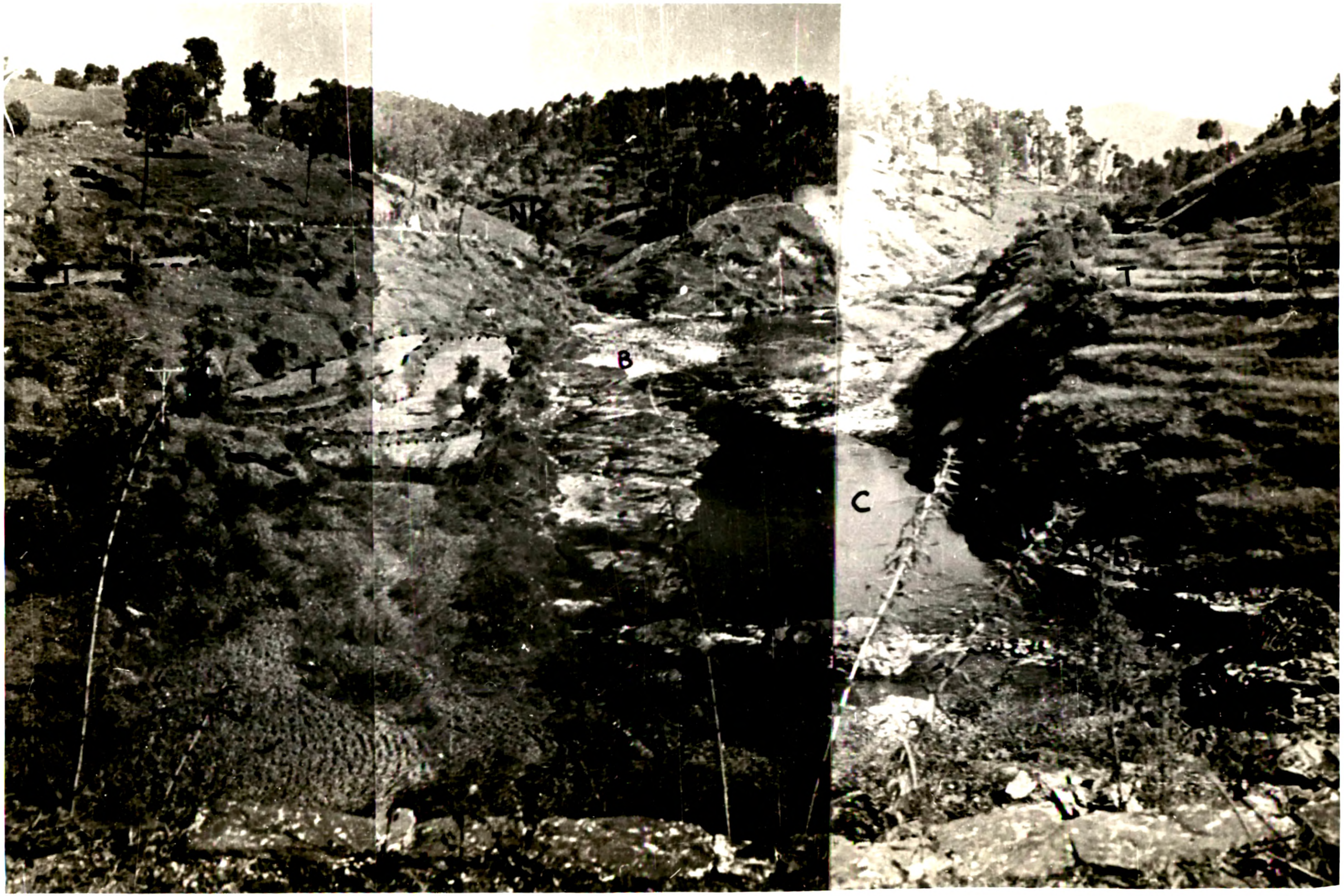
Near the confluence of Nana Kosi, the next lower terrace is also recognised. It comprises three small levels, all of which are 5 to 7 metres above the present bed level. Thus total of four terrace levels above the slightly entrenched Kosi channel are seen (Plate 12). A little upstream of the above location the upper terrace is nearly 15 metres above the present bed level and is exposed in the road cut (Plate 4).

In the upstream portions, particularly between Paroliya and confluence of Jainal gad, the river entrenchment is more and the terrace formation is not conspicuous. On the other hand, deep entrenched meanders, of the order of 45 to 50 metres are predominant (Near the confluence of Jainal gad - Plate 3). In the area south of Someshwar, shifted meanders and formation of two terrace levels are observed. North of Someshwar, the valley considerably widens and the river, without appreciable change in its width, flows straight for a considerable distance. Of particular interest in this part, are the only two terraces and a flood plain (incipient terrace) that have formed along the channel of the nala flowing eastward from Lod.

PLATE 12

Upstream view of Kosi valley near Hawalbagh*.

Subdued topography in the Almora crystallines, cut by slightly entrenched Kosi channel (C); rocky bed (B) exposed; four different terrace levels (T); Nanakosi (NK) joining on the right bank.


NR
T
B
C
T

Southern Division

In the area along the Khairna nala-Kuch gad N-S alignment, there is a sudden appearance of spectacular terrace deposits, and a deep valley - a feature nowhere noticed at any location upstream of Khairna. In the Kuch gad section the valley broadens south of Bamsyum and near Syalikhet, the channel meanders and braids through its own flood plain (Plate 13). There is one prominent terrace level, 150 metres above the bed level on which several alluvial fans have been formed. The steep valley slopes are drained by numerous second and third order channels which have cut deeply in the slopes. Significantly, the terraces and the alluvial fans are confined to the right bank only (Plate 14).

Near the Kuch gad-Kosi confluence, six terraces are recognised located on a spur, at different levels. Of these, the lowest terrace is about 5 to 6 metres in height and has a vertical face forming the river bank. Its material is well stratified, sub-rounded and semisorted. The pebbles are of quartzites and slates. Above this lowest terrace, occur five successive levels, varying in thickness from 2 to 3 metres. These overlying terraces have gentle slope of 10° to 15°

PLATE 13

Upstream view of Kuch gad valley near Syalikhet - north of its confluence with Kosi.

Wide bed on which the channel meanders, steep hill slopes, highest alluvial fans nearly 150 metres above the bed level; the lower fans gently sloping.

PLATE 14

Downstream view of Kuch gad valley near Bamsyn.

Wide valley with braided and meandering channel on the flood plain; two terrace levels on the right bank; parallel channels with deep cuts on the steep slopes.

towards the confluence (Plates 15 and 16). The present drainage course of Kosi has a flood plain 1 metre above the existing bed level, and extends upto Khairna.

Significantly, the terrace material in the immediate upstream portions of the Kuch gad-Khairna nala alignment is highly unsorted, ill stratified and lies nearly 15 metres above the Kosi bed level (Plate 17).

Downstream of Kuch gad-Kosi confluence, the terrace levels are confined to the wider sections only. Three to six terraces at different locations have been recorded. Narrower river portions, which generally cut across the strike do not have such significant terrace deposits.

The Khairna nala section forms a rather deep valley flanked by very steep and high slopes on the right bank. Remnants of three terrace levels on this bank at the heights of as much as 300 to 400 metres have been recorded. On the left bank with gentler slopes, however, the terraces conform to the level pattern of the Kuch gad confluence area. So far as the recent depositional activity of the river is concerned, there is only one prominent terrace level just two metres above the bed level on which the road is located.

PLATE 15

Terraces near the Kuch gad-Kosi confluence.

Steep fault scarp (Sl), parallel drainage on steep slopes; alluvial fans (Af) deposited at the base; the valley consisting of the channel (c), dry bed (b), flood plain (f); bound by six terrace levels (T) on the right. (In Plate 16), the six terraces are better seen.

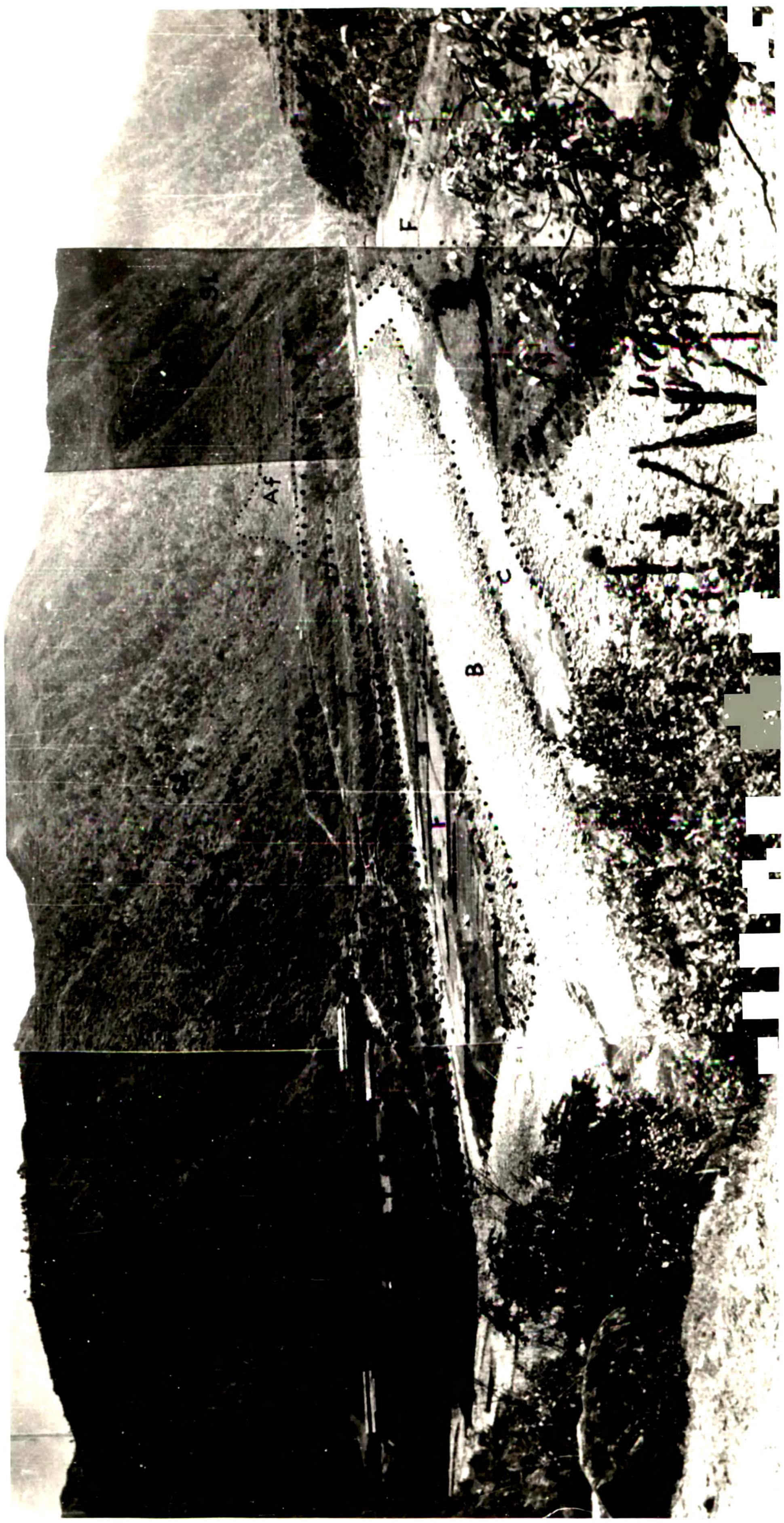

F
Af
B
C

PLATE 16

Six terrace levels on a spur, in the N-S segment between the confluences of Khairna nala and Kuch gad with Kosi.

The river bed comprising the narrow channel (C) and the dry bed (B); the flood plain (F) wide and overlain by terrace levels (T); amphitheatre like depressions (A) in the steep hill slopes on which landslide areas (L) occur.

PLATE 17

Alluvial terrace material near Khairna.

Highly unsorted, subrounded material in a fine matrix; 15 metres above the Kosi bed level.

Here also the flood plain is relatively wide and the channel orientation N-S rectilinear (Plate 18). Between this terrace level and those higher up on the steep slopes, there is a difference of about 10 to 15 metres, which according to the author is indicative of a sudden rejuvenation.

Downstream of Kuch gad-Kosi confluence upto Betalghat, the Kosi bed is wide and ranges in width from 250 metres to 500 metres. The actual channel is narrow and braides through the wide bed and flood plain. The general flow direction is northwesterly upto Rataura, beyond which it takes a short north-easterly bend and then follows a westerly course. In this narrow bend, the river bed is only 100 metres wide. Upto Betalghat, there are five terrace levels, all within 40 metres from the bed level and the remnants of the 5th - oldest terrace at about 380 metres from the bed level. The latter is confined to the left bank only, indicating migration of the channel to the north.

A 300 metre long stretch of narrow 100 metre wide channel separates the Betalghat-Seti zone. In this zone the river bed is quite wide (width 200 metres to 400 metres) and is made up of two broad meanders, the inner areas of which are occupied by five terrace

PLATE 18

Upstream view of the Khairna channel near Khairna.

Straight channel with very steep slopes (fault scarp) on the right bank; deep cutting with remnants of 3 terrace levels on the hill slopes; one continuous terrace at the base; the stream bed comprising chennel (C), bouldery dry bed (B); relatively wide flood plain (f).

levels, all within 70 metres above the bed level. The outer bends are usually associated with steep scarp-forming banks. Near Seti, is the confluence of Khodan gadhera, the trunk stream of which separates the compacted jointed quartzites in the north from the softer shale-quartzite sequence in the south. Near this confluence, all within 60 metres height from the bed level, there are six terraces on the left bank.

From Seti to Basela, the channel is again narrow, only 100 metres wide, cutting across the regional strike and flowing southwesterly. The valley slopes are steep and at places associated with very steep banks.

The stretch from Basela to Kumeriya varies in bed width from 80 metres near Kumeriya to nearly 400 metres south of Basela. Near Basela, along the Kosi left bank, there are five terrace levels, all within 60 metres height from the bed level. The right bank is steep and rocky. The general flow direction is towards WNW and this closely follows the trace of the Main Boundary fault.

The river bed widths in the zone from Kumeriya to Garjia vary between 350 metres to 1200 metres and the bed follows an acute arc pointing towards NW, the nose of the arc forming the widest portion south of Mohan. The entire river course cuts through the Siwalik foot hills having relief of the order of 560 metres only. Near the confluence of Kalgari gad, the channel forms a meander, the inner portion of which has five terrace levels, all along the left bank. The lower four terraces lie within 25 to 40 metres height from the bed level, whereas the oldest terrace rests 100 metres above, on the platform of the Siwalik strata.

Near Garjia the river bed narrows down suddenly to 100 metres, and forms a 'neck portion' connecting the two wider upstream and downstream stretches (Plate 6). Here, the sharp ridge crests cut across the channel and form high vertical banks.

Garjia to Ramnagar is the last stretch of Kosi in the Kumaon hills before it debouches into the alluvial plains. In this part the relief of the hills is the lowest, of the order of 200 metres, and the flood plain and terraces are rather wide. There are four linear terraces along the river course, and immediately to the south of the hills, a piedmont plain is formed due to the merging of closely spaced alluvial fans. Here, the terraces are on both sides of the river and this is in contrast to the other zones upstream where the terraces were confined mostly to the left bank only.

At Ramnagar, the river bank is steep in parts and has gravel-boulder layer overlying the silt-gravel layer (Plate 19). This reversal of the coarser material lying over the finer is indicative of varying stream load discharge influenced by the climatic accidents and rejuvenations.

Past Glaciation

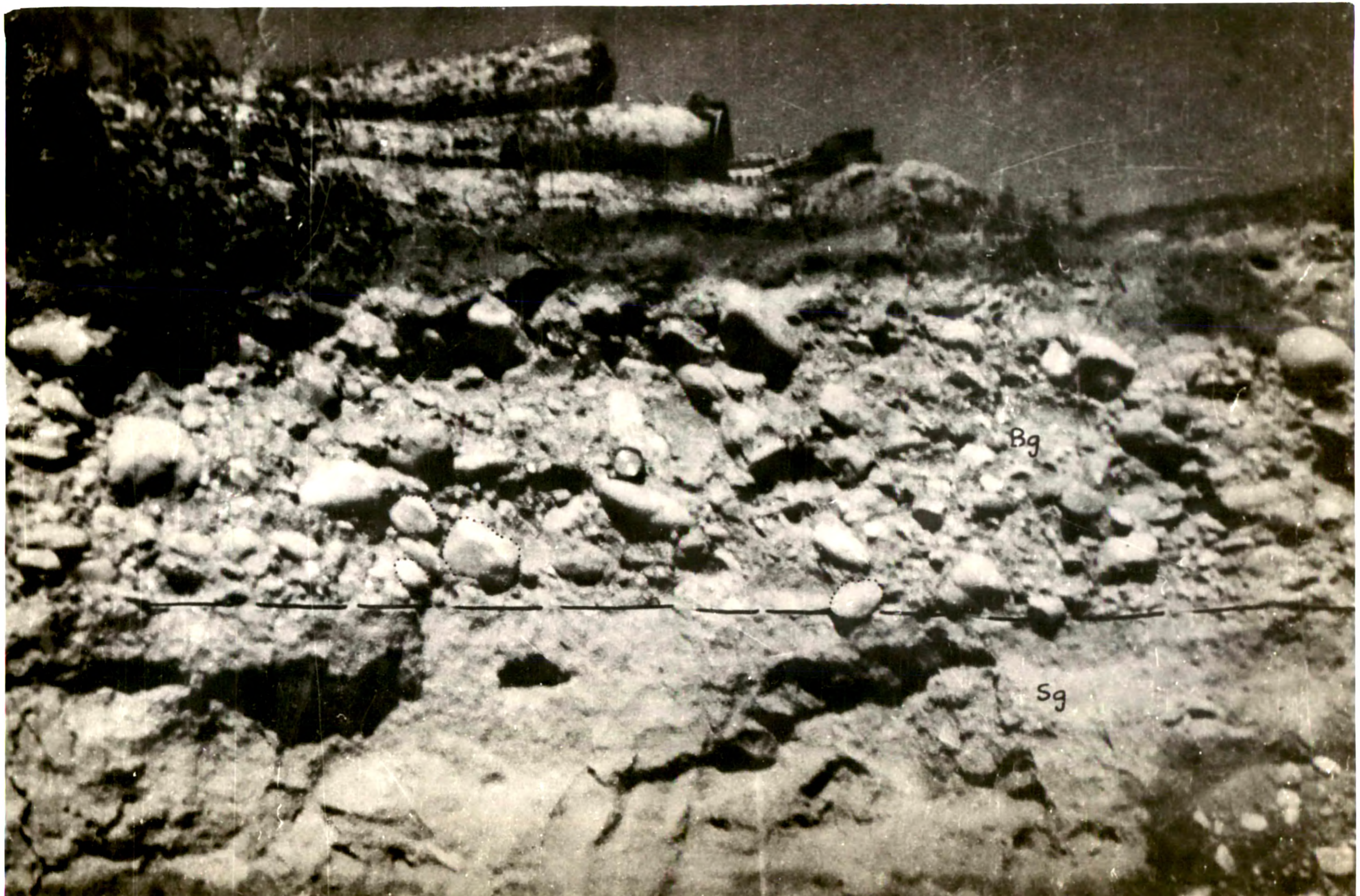
The southern limit of the past glaciation in this part of the Himalaya is not yet precisely delineated. Of course today, the entire Kosi basin is below the snow line and its morphology indicates fluvial action. However, some effects of glaciation in the past can not be ruled out. The author believes that though today there are few evidences to show the effects of snow and ice, a careful and critical scrutiny might reveal some features which could have developed by glaciation. It is also not unlikely that long spell of fluvial action could completely obliterate all evidences of past glaciation.

The author did make some efforts to investigate the likely occurrence of glacial features and landforms

PLATE 19

Kosi right bank material near Ramnagar.

Well stratified horizon of sand-gravel (Sg), overlain by boulder and gravels (Bg).


Bg
Sg

in the area, since the extension of the southern limit of glaciation to the Kosi basin area in the recent geologic past is quite likely. Today, the areas in the vicinity of Naini Tal, Ranikhet, Mukteswar and Almora do receive snowfall in mid-winter and the ground remains frozen, at least for short durations. In the past, these cold spells could have been of longer duration and higher intensity, thereby keeping the ground frozen for most part of the year under thick ice. Such as assumption is supported by a few of author's findings in respect of certain topographic details like the form, microrelief and other features suggestive of glacial and glacio-fluvial influence.

Of particular interest from this aspect, are the areas east of Katausa along the left bank valley slopes of Kosi. Very characteristic amphitheatre-like features with much debris in the funnels, scoured outlets, divides arranged in cirque-like manner, and very steep slopes point towards probable existence of small glaciers which have long melted away in the past. The glacial landscape has been subsequently modified by later fluvial agencies (Plates 20 and 21).

At the base of this peculiar topographic expression described above, is a wide zone of steeply sloping

PLATE 20

Likely effects of glaciation on the left bank of Kosi southeast of Rataura.

Amphitheatre like areas (A) in the steep, crested, irregular ridges with rock debris (D), the base covered by the moderately sloping coalesced fans (f) which are cut by the river, now its old bank (b); the base having landslide material (L); the river bed relatively wide comprising the channel, dry bed (B) and the flood plain (F).

PLATE 21

Effects of polycylic changes on the left bank topography of Kosi, near Rataura

Amphitheatre like areas (A) in the headward stream portions; the stream on the left showing deeper scour and steep banks; at its base, a large alluvial fan (f) bound by old river bank (b); on the right hand side two fans - one steeper and the other lower and gentler; the landslide area (L) crossing the upper fan; the flood plain (F) wide and the river bed comprising gravelly dry bed (B) and the channel (C).

coalesced fans which have a vertical wall towards the river. This scarp appears to be the limit of the present river (river bluff). There is no specific terrace formation in the area and the channel gradients also show a break in profile here, such that the entire feature is suggestive of a small glacier in its snout area, now considerably modified by the stream action.

The likelihood of glaciation is also supported by the peculiar amphitheatre-like areas in the upper parts of the hill slopes, especially at high altitudes. It is significant that these high altitude hollows suddenly taper out from midslope downward with steep narrow channels cutting through high level sloping terraces. The likelihood of these terraces being glacial can not be ruled out. It has already been mentioned in the drainage analysis that in this part, the average lengths of channels with increasing orders do not show geometric progression. This also could indicate an earlier glacial imprint. This aspect, however, needs further and exclusive study.

Slope Evolution

Relief is always the main controlling factor in slope evolution, apart from differences in lithologic competencies and magnitude of eroding agents. In the study area, all these factors have contributed equally and have given rise to a slope pattern that is quite distinctive. The slope variations from one part to the other, are essentially controlled by the geological factors is quite obvious because the physical agencies operative over the whole basin are fairly uniform, yet the lithologic and tectonic variations have given rise to slope diversity. According to Pecsi (1970), slope evolution and existing types of slopes are the results of joint dynamism of the tectonic, structural-morphological and lithological conditions of the relief and of the climato-morphological processes acting perennially in the region. Denudation and linear incision are alternating processes and are accompanied by the phases of deposition.

Assuming the magnitude of the fluvial agencies to be uniform all over, the slope variations in the study area could obviously be attributed to the linear and surface degradation. Of course, the response of varying lithology to this process has been different. The area of crystallines has undergone maximum linear degradation and the softer and crumpled rocks in this zone have assisted in expediting the peneplanation. This is in contrast to the response in other corresponding zones of metasediments. This process of linear degradation is cyclic. The river cuts, develop an headward incision and form steep valley sides, followed by slump and slope retreats. These slumps in turn develop additional rills which follow the same process and as a result there is an overall lowering of the generalised slopes, leaving only the high ridge summits. This is the present position of the Crystallines' topography.

In the case of the metasediments, the same fluvial processes are operating but their present steeper slopes are attributed to the resistant lithology and tectonic upthrows.

Mass-wasting is an active process particularly on the steeper slopes. Slope degradation is maximum in the Almora Nappe Crystallines, and least in the Krol sequence along the southern divide. The processes of mass-wasting being related to rock competency, structural weakness and relief, vary from source area to the mouth of the basin. The landslides and slope recession are prominent in Deoban slates, Krol shales and Middle Siwaliks, and also in areas along the tectonically weak zones. Rockfalls due to high intensity of master joints are common in the quartzite bands of Mukteswar and Kapaleshwar area. These rock falls have resulted into very high steep hills of quartzites. The erosional potential is maximum in the mica-schists of the Crystallines, chlorite schists and slates of the Deoban group and limestones of the Krols, and the softer sandstones of the Middle Siwaliks and form areas where the sediment load in the stream discharge is maximum. During high rains and discharges, it is difficult to draw a line between the material slide and its transport by water (Chansarkar, 1969).

Coming to the slopes of depositional nature, to this catagory belong the numerous river terraces. As already stated, most of the terraces are almost flat, sloping only a few degrees towards the confluence of the main river. These terraces lying one above the other are separated by intervening narrow vertical scarp-like slopes. The author has observed that all these depositional terraces were formed by processes which were mostly controlled by climatological factors, and it may not be appropriate to invoke tectonic uplifts everywhere to explain the terrace formation. There are many terraces which owe their formation to the process of "bottle-necking".

In many Himalayan rivers like Kosi, river courses comprise several alternating wider and narrower stretches.

The wider stretches are formed along the weak zones, like softer lithologies, anticlinal crests and dislocations. The narrow stretches are generally associated with across-strike orientation segments and entrenched portions. During heavy floods, sometimes the channel constrictions inhibit free flow of water and give rise to bottlenecks. The author (1968,1970) has come across several such examples of terrace formation due to bottle-necking. In the catchment of Birehiganga and Alaknanda it was so clear that due to a sudden heavy discharge in the tributary basin, the landslide areas became active and deposited huge amounts of scree and debris at the mouth of the constricted path, thereby creating a temporary blockade, a sort of a weak dam. This resulted in the formation of temporary reservoirs in the upstream portion. The latter, in the course of time got silted up. During another climatic accident (cloud-burst), this loose dam gave way, thereby allowing the river channel to cut the dam and attain its old base level and forming terraces in the so called reservoir areas in the upstream portion. No uplift or tectonic cause was thus operative in the deposition of these purely 'climatically' formed terraces. Kayerker (1970) has reported formation of 50 metre terrace near Belakuchi at the Birehiganga-Alaknanda confluence in a very short span of less than a day. Mithal and Chansarkar (1972) have also observed the formation of these big lakes due to huge landslides damming the course of Birehiganga river.

Coming to the tectonically controlled terraces, the evidences of uplifts have to be ascertained by some geologically proved features like an upthrown fault block resulting into rejuvenation and entrenchment. The upthrow of the Nagthat-Deoban block, along the North Almora fault has given rise to the entrenchment of Kosi in the Almora Crystallines. It is assumed that the uplift in the north provided a lowering of base level, accentuating the rate of erosion of the entire downstream course. So much so, that the pre-existing meanders in the peneplained crystallines got rejuvenated and entrenched.

A morphogenetic map of the downstream portions of Kosi (Plate 29 - Page 181) reveals the distribution of Siwalik stratigraphy, fault contacts, formation of terraces, flood plains, gravel bars and the piedmont plain. The morphogenetic maps for the other areas in the basin can similarly be prepared but fall outside the scope of the present work.

GEOLOGIC CONTROLS

The author has already discussed the litho-tectonic framework of the area, from which it becomes quite clear that the various rock types and their structure have contributed towards the sculpturing of the basin. The main lithological and structural controls that have governed the process of basin evolution are as under:

1. Lithologic factors

   (i) Metasediments and crystallines: Hard competent quartzites, dolomitic limestones, gneisses and granitic gneisses.

   (ii) Soft metasediments and crystallines: Chlorite-schists, mica schists, phyllonites, micaceous quartzites and slates.

   (iii) Very soft sedimentary rocks: Siwalik sandstones and shales.

2. Structural factors

   (i) Major structural elements

   (A) Folds : (a) Almora synform
   (b) Rataura anticline
   (c) Kuch gad anticline
   (d) Nainital syncline

(B) <u>Dislocations</u>: (a) North Almora fault

(b) South Almora thrust

(c) Ramgarh thrust

(d) Khairna nala-Kuch gad fault

(e) Main Boundary fault

(f) Thrust between Lower and Upper Siwaliks

(ii) <u>Minor structural elements</u>

(A) <u>Foliation</u>: (a) Bedding

(b) Schistosity

(B) <u>Joints</u>: (a) Bedding and foliation joints

(b) Joints perpendicular to foliation

(c) Oblique joints.

<u>Control on drainage</u>

Joint control on the drainage pattern is best seen in the metasediments and the sedimentary rocks. In the crystallines, the drainage pattern is dendritic with no joint control, only the trellis pattern formed by smaller order channels reveal some effects of joints. This lack of joint control in higher order channels within the crystallines is reflected in the random orientation of the channel segments.

It is observed that when the channels cut across the strike, they follow a narrow path whereas the strike valleys and the fault controlled valleys have wider beds.

The prominent joint sets in the entire basin are as under:- (i) bedding or foliation joints (ii) vertical joints perpendicular to the strike which change their orientation from zone to zone (iii) joints oblique to the strike. Of these, the joints of category (ii) which trend nearly N-S, are of fundamental importance and seem to be a dominant direction of fracture. It is due to these joints that the river course has been shifted at many places. In the Someshwar block, the drainage orientation brings out this point very clearly. Similarly, the N-S shifts in the Kosi channel in the crystallines is also due to these joints.

The alignment of Kuch gad and Khairna nala in continuous N-S trend has been very significant in the erosional framework and in the formation of the entire Kosi drainage. It appears that this tectonic alignment is very old and has received frequent pulsations resulting in several rejuvenations, river downcutting and periods of terrace formation (Plates 22 & 13). Strike joints (category-i), have mostly contributed to the direction of flow of the various tributaries of the trunk stream

PLATE 22

Upstream view of N-S Kosi bed near Khairna.

Well defined river bed comprising channel (C) and dry bed (B); bound by steep rocky banks, the right bank being a fault scarp; landslide areas (L) on the very steep slopes (Sl).

(Fig. 6). The offsetting of these tributaries also is due to the above discussed N-S joints.

Effective joint control is also witnessed in the channel configuration and trend further down stream. The short narrow band in the river near Betalghat is clearly due to the prominent joints. The bed upto Rataura follows joints along the axial plane of the anticlinal crest.

The bedding joint control in the Siwaliks is equally prominent, except, here the N-S joints do not show any effect. The Kosi alignment in the Siwalik section is controlled by the Main Boundary fault except for a stretch between Mohan and Garjia in which the Kosi cuts across the strike ridges. The river is very wide here and probably dates when the Siwalik area had just become positive or a little later so that the river could easily cut through the emerging ridges now comprising the foot-hills. This establishes the antecedence of the river, and explains deep entrenchment and sudden bending of river courses at numerous locations.

Control on slopes

The formation of slopes is governed by the tectonics and rock competency. Tectonically, the zones of displacement along thrusts and faults, make available higher reliefs for denuding agencies. The present area has following tectonically upthrown units: (i) the Someshwar block has been pushed up along the North Almora fault,(ii) the Nagthat sequence has been pushed up over the Krol sequence by the Ramgarh thrust, and (iii) the entire Nagthat-Krol sequence has ridden over the Siwaliks along the Main Boundary fault.

Besides these, a reverse fault in the Siwalik group and another reverse fault in the Krol group have pushed up locally parts of their stratigraphy. All these upthrown blocks have continued to maintain higher reliefs inspite of their continuous denudation, thereby providing steeper channel gradient, which in turn have affected the slopes in the respective segments.

The variation in lithology has also manifested in the slope formation. The sedimentary rocks like the Siwalik sandstones and shales, as also the metasediments of Krol-Nagthat and Nagthat-Deoban group have formed regular strike ridges. The hard metasediments have formed high crested ridges whereas the soft Siwaliks have given rise to the less rugged hills. Within the strike ridges of Siwaliks, due to gentler slopes in the dip direction and the steeper slopes in the opposite direction, hogback-asymmetric ridges have formed. These 'hogbacks' are typical of the Siwalik topography, and provide a very diagnostic identification feature. In case of meta-sediments, the dip slopes and the opposite slopes are more rugged and the micro-relief is of higher order and here the hogbacks produced are less diagnostic. However, the formation of asymmetric ridges can be well associated with the sedimentary and metasedimentary strata.

In contrast, the ridges in the Almora crystallines do not show much diversity in topography. The ridge summits are the erosional remnants in the process of peneplanation. As a rule generally, the strike valleys are controlled by softer lithologies, but in the case of Kosi basin, this is not true, and the valleys are usually associated with the tectonic crushed zones, irrespective of the lithology.

Relief

Relief again is controlled by tectonics and rock competency. Of course, the magnitude of eroding agents plays its due role. The areas of synformal axis like Bhainskhet-Matela-Binsar trend, and the weak zones like North Almora fault, Main Boundary fault etc. are the locii for quick wearing down of slopes and formation of flatter valleys.

The anticlinal axial plains also, being the areas of tenstional fractures (joints and vertical faults) erode rapidly and form linear and deep channels. The Kuch gad anticline and accompanying N-S fault has accelerated the process of valley deepening here. East of Khairna nala-Kuch gad, a very high and steep fault scarp has been formed. It is interesting to note that in its vicinity, the valley slopes even in the Kosi upstream are steep and are suggestive of a slow rise of the eastern block keeping pace with the downcutting. This also explains the formation of numerous terraces downstream. Of course, this is a localised phenomenon and need not be regionally applicable for the entire basin.

Reliefs in the different litho-tectonic units distinctly reveal the lithologic control. In almost all parts, the quartzites have formed high ridges, with the softer schists and slates occupying lower slopes and valleys. A typical and most revealing example of lithologic control on relief is provided by the metasedimentary sequence of Nagthat-Deoban zone. Here the hard quartzites and compact limestones have formed highest strike ridges, whereas the softer chlorite schists and slates form areas of lesser and subdued relief.

The author would like to mention a very striking and unique combination of both the factors viz lithology and tectonics, in the study area. The Nainital-Bhowali-Mukteswar area, which forms the southern and downstream part of the basin, surprisingly is of a very high relief, and even the absolute heights here are the maximum. This unusual relief phenomenon is distinctly due to the uplifts along the Main Boundary fault and the Ramgarh thrust, of a group of dominantly competent rocks like quartzites and compact dolomitic limestones.

Thus it will be seen that the present landscape of the Kosi basin is a total effect of fluvial processes operative in multiple cycles over the framework of varying lithologies, folded, faulted and tectonically rejuvenated; resulting in different drainage patterns, peneplanation, entrenchment, deposition of terraces, landslides, basin shapes and river courses. It is therefore reasonable to conclude that this evolution of the Kosi basin was controlled more by lithology and tectonics than by the physical agencies sculpturing it in the past.