Terraced Debris and Alluvium as Indicators of the Quaternary Structural Development of the Northwestern Chitwan Dun, Central Nepal

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Terraced Debris and Alluvium as Indicators of the Quaternary Structural Development of the Northwestern Chitwan Dun, Central Nepal

Kazuo KIMURA

Abstract This paper describes and discusses the geomorphology and geology with special reference to structural features in the northwestern fringe of the Chitwan Dun. It will present new information on the neotectonics of the Sub-Himalaya. Three stages of terraced debris and alluvium are recognized in the study area. The Barakot Terrace is a fill-top debris surface formed in late Mid-Pleistocene age. In the same stage, the fluvial Belani Terrace was developed on the basin floor. The Kirtipur Terrace and the Bishannagar Terrace are both fill-top surfaces formed in Late Pleistocene age. The former consists of debris flow deposits and the latter are river deposits carried by the Narayani River. The Mejhi Surface is the recent fan situated at the foot of the Churia Range. The Kawasoti Surface, located along the right bank of the Narayani River, is an alluvial terrace of Holocene age. Lithofacies of the terrace deposits and distribution of the terrace surfaces illustrate the following morphostructural evolution. The Chitwan Dun was established as a piggyback basin basin situated between the Central Churia Thrust (CCT) and the Frontal Churia Thrust (FCT) by Middle Plestocene time. Two stages of the terraced debris, the Barakot Terrace and the Kirtipur Terrace, indicate that the Barakot Fault, north dipping reverse fault developing in the Churia Range, partly acts as a boundary fault at the northern margin of the dun. The fault scarp had appeared by late Mid-Pleistocene age. Unlike other dun valleys, which have been emerged since Late Pleistocene age, the Chitwan Dun still have the characteristics of sedimentary basin in a part of the study area.

Key words: intermontane basin, fault-bounded margin, terrace, synorogenic deposit, profile morphometry

1 Introduction

Quaternary intermontane basins are expected to present important information on the interaction between neotectonics and surface processes. Synorogenic sediment is in particular a useful indicator of the palaeogeography of fault-bounded margin (Huzita 1983; Nichols 1987; Burbank & Verge 1994 *etc.*). Topographic profiles, especially

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longitudinal profiles of fluvial terraces, also provide trustworthy information to know tectonic history (*e.g.*, Sugimura 1967 ; Schumm 1986). "Duns" are wide-opened longitudinal valleys in the Himalayan foothills. Their fills are underlain by intensively deformed molassic sediments, which are termed the Siwalik Group. They were accumulated in the age between the Middle Miocene and Early Pleistocene (Tokuoka *et al*. 1986). Some morphological studies have been done for understanding the Quaternary structural development (Nakata 1972 ; Yamanaka & Yagi 1984 ; Iwata & Nakata 1985 ; Delcaillau *et al*. 1987 ; Kimura 1994). However the areas, where geomorphological or Quaternary geological researches have been completed, are quite limited because of difficulties in field survey. This report provides the distribution of colluvial and fluvial landforms, the geology of the Quaternary sediments and the tectonic features in the area of lacking previous studies. The results will be synthesised in a geomorphic development as an approach to reveal the neotectonics of the Himalayan Front.

The study area is situated in the northwestern Chitwan Dun, the south-central part of Nepal, and includes a part of the Churia Range and the Mahabharat Range (Fig. 1). The valley floor of the Chitwan Dun, consisting of flood plains and terraces, ranges from 150 to 300 metres above sea level. The Churia Range, the Himalayan foothills consisting of the Siwaliks, surrounds the Chitwan Dun with NW-SE trend. The summit levels of the Churia Range are generally less than 800 m. a. s. l.. Their slopes are dissected by trellis-patterned channels reflecting the monoclinal structure of the Siwaliks.

2 Geological background

The Siwaliks have been surveyed by various researchers and generally classified into three litho-stratigraphic units ; the Lower, Middle and Upper Siwaliks. As mapped by Department of Mines & Geology, Nepal (1982), the study area is underlain by sandstone beds of the Lower Siwaliks. These strata are monoclinally north-dipping (30-80°) and form hogbacks of E-W strike. Fig. 2 shows the general geology of the western half of the Chitwan Dun.

In the Arung Khola and Binai Khola ("khola" means river in local language) drainage basins, which are located to the west of the study area, Tokuoka *et al*. (1986, 88, 90, 94) describe the geology of the Siwalik Group in detail. According to them the Siwaliks are composed of four litho-stratigraphic units, the Arung Khola Formation chiefly consisting of siltstone, the Binai Khola Formation dominated by sandstone, the Chitwan Formation of well-sorted and clast-supported conglomerate layers, and the Deorali Formation of poorly-sorted and matrix-supported conglomerates including huge boulders, in ascending order. Palaeomagnetic data (Tokuoka *et al*. 1986) demon-

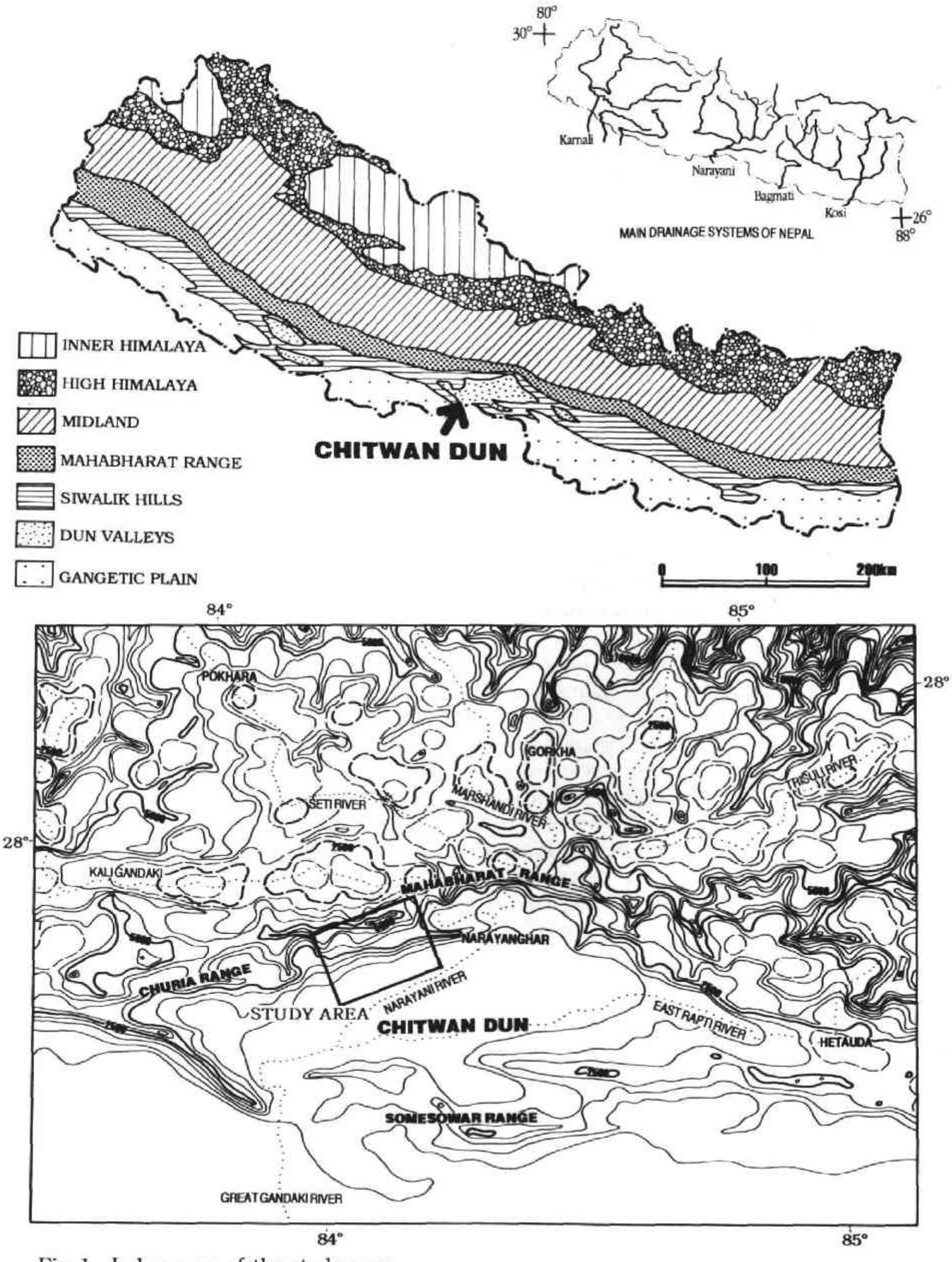


Fig. 1 Index map of the study area.
A : Topographic province of Nepal, modified after Sharma (1990) ; The Chitwan Dun is the largest dun located in southcentral Nepal, B : Summit level map of central Nepal ; contour interval : 500 feet ; The Chitwan Dun is surrounded by the Churia (Siwalik) Range and the Somesowar Range, both of which are composed of tertiary molasses. The study area (boxed; fig. 3) is north western margin of the Chitwan Dun.

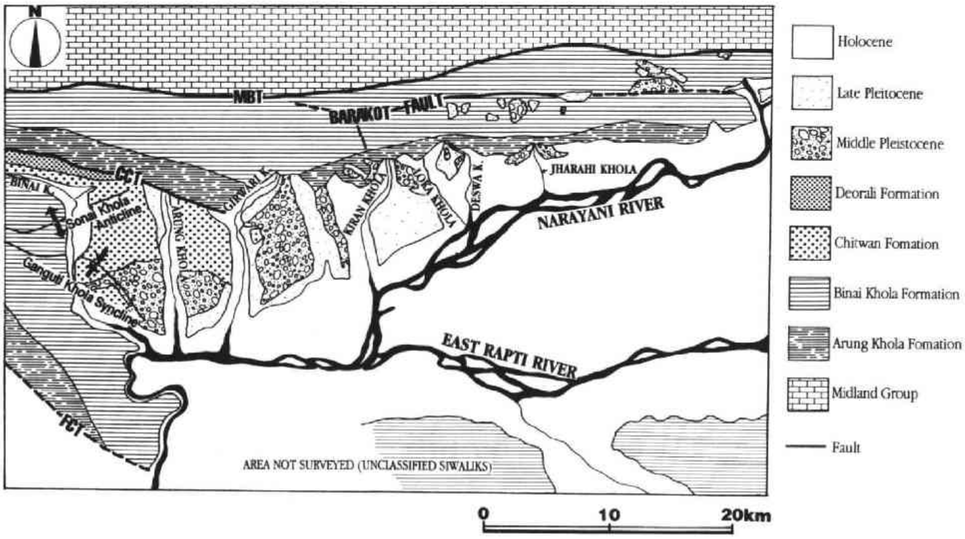


Fig. 2 Simplified geological map of the western part of the Chitwan Dun.
Midland group is the Palaeo-Mesozoic metasediment forming the Mahabharat Range. Arung Khola Formation is dominated by the middle Miocene siltstone, which is the lowest part of the Siwalik Group. Binai Khola Formation is chiefly composed of the Mio-Pliocene sandstone correlated to the Middle siwalik. Chitwan Formation is early Pleistocene conglomeraate consisting of well-rounded cobble. Deorali Formation is boulder conglomerte accumulated in early Pleistocene age. Chitwan Formation and Deorali Formation are correlated to the Upper Siwalik. The middle-late Pleistocene are remained in western part of the dun as terraced debris and alluvium. The Holocene is the present aluvium transported by Narayani River and its tributaries. Four north-dipping reverse faults, the Main Boundary Thrust (MBT), the Barakot Fault, Central Churia Thrust (CCT) and Frontal Churia Thrust (FCT) from north to south, stretch in E-W or NW-SE direction. Map modified from Department of Mines and Geology (1982) and Tokuoka *et al.* (1990). The south margin of the dun is not surveyed because it is the restrict area (Indo-Nepal Border).

strate that the Arung Khola Formation correlates the age between the Chron 8 and 15 (8.5-14.5 Ma) and the Binai Khola Formation corresponds from the Gauss Normal Epoch to the Chron 8 (2.5-8.5 Ma).

The Siwalik belt is bounded by two thrust systems: the Main Boundary Thrust (MBT) on the north and the Frontal Churia Thrust (FCT) on the south. Pre-Tertiary Himalayan bedrocks are in fault contact with the Siwaliks by the MBT, which is dipping 50-80° towards north and striking E-W. The FCT is delineated between the south-branch of the Churia Range and the Gangetic Plain with NW-SE trend (Tokuoka *et al.* 1994).

The Siwaliks surrounding Chitwan Dun are subdivided into the north belt and the south belt by the Central Churia Thrust (CCT, Tokuoka *et al.* 1986). The south belt consists of the Arung Khola Formation through the Deorali Formation. The Binai Khola Formation of the south belt has a set of syncline and anticline, the Ganguti Khola Syncline and the Sonai Khola Anticline. The Chitwan Formation and later sediments, including Quaternary basin fills, accumulated on the Ganguti Khola Syncline. The Deorali Formation, which is characterized by huge subangular boulder-conglomerate derived from the Arung Khola Formation and the Binai Khola Formation (Deorali-type conglomerate), is only observed along the foot of the CCT. The Deorali-type conglomerate regarded as the synorogenic sediment related with thrusting (Tokuoka *et al*. 1986). The north belt is composed of the Arung Khola Formation and the Binai Khola Formation, which are monoclinally dipping 40-70° northwards. The Churia Range in the study area belongs to the north belt with their homoclinal ridges. The CCT is in accordance with the topographic boundary between the Churia Range and the Chitwan Dun in the Binai Khola Drainage. The fault, however, is not traceable to the valley floor.

The author recognizes two sub-parallel lineaments in the northern part of the study area. They forms splay faults striking E-W orientation (Figs. 2, 3). The north

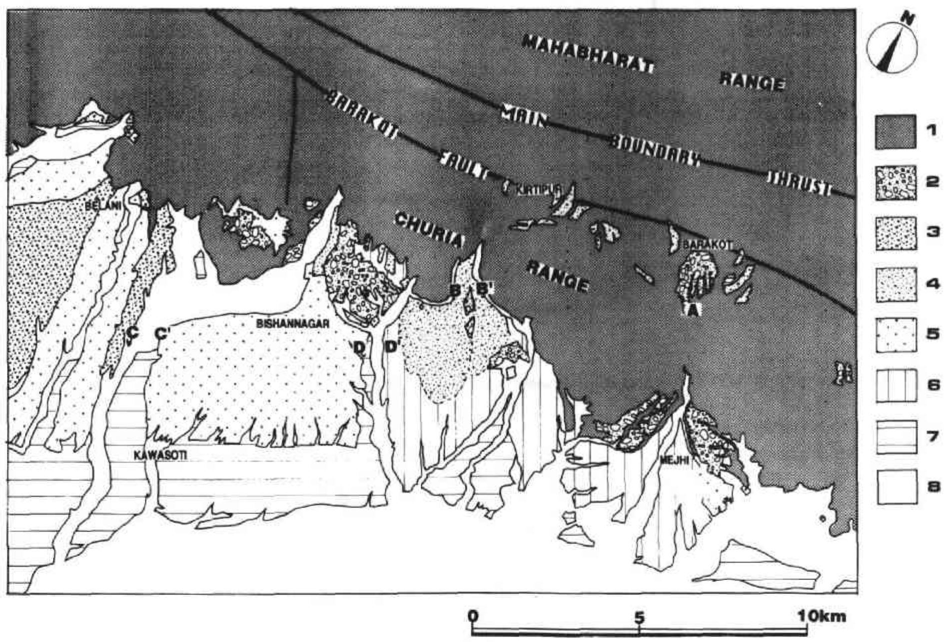


Fig. 3 Distribution of terraces in the study area.
1: Mountain Slope, 2: Barakot Terrace (Upper Debris Terrace), 3: Belani Terrace (Upper Fluvial Terrace), 4: Kirtipur Terrace (Lower-1 Debris Terrace), 5: Bishannagar Terrace (Lower-1 Fluvial Terrace), 6: Mejhi Fan (Lower-2 Debris Fan), 7: Kawasoti Terrace (Lower-2 Fluvial Terrace), 8: Flood Plain, A-D: locality index for Fig. 4-7

one is mapped as the MBT (Department of Mines and Geology, Nepal, 1982). The south branch has not yet reported, thus, this paper calls it the Barakot Fault. The summit level of the Churia Range falls hundreds metres. Its shatter zone extends along the bedding plane (40-60° dipping towards north) of sandstone and siltstone. Therefore, the Barakot Fault is a north-dipping (around 50°) reverse fault, which has a character of dip-slip fault. Its foot wall is covered with unconsolidated boulders, which will be mentioned later.

3 Geomorphic surfaces and Quaternary deposits

The dun floor is predominated by the present floodplain created by the Narayani

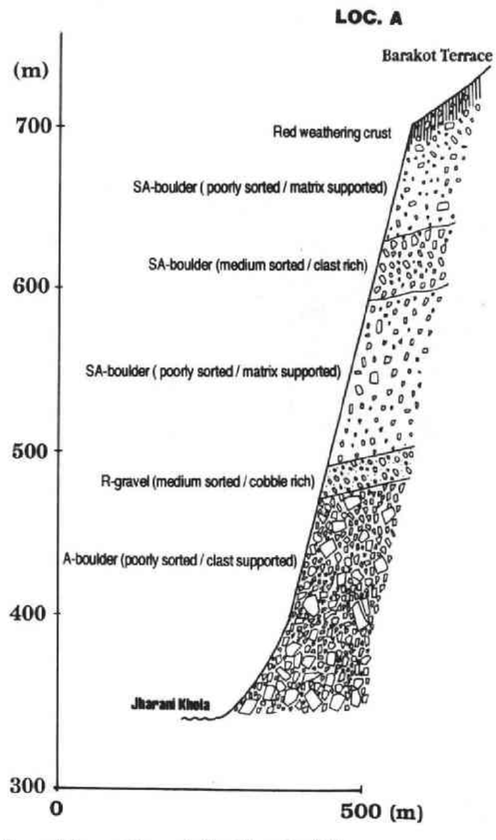


Fig. 4 Morphostratigraphic section of the Barakot Terrace.
The Barakot Terrace Deposit is developed more than 300 m in thickness. Angular to sub-angular boulders including huge block are dominant in the deposit. (Loc. A in Fig. 3; A=angular, SA=subangular, SR=subrounded, R=rounded. Illustrated patterns are not in scale.)

River. Post-Siwalikan terraced deposits, which are termed the Dun Gravel (Sharma 1990, *etc.*), are preserved with their fill-top surfaces at the margin of the dun (Fig. 2). Three stages of morphostratigraphic units, the Upper, Lower-1 and Lower-2 Terraces, are recognized in the study area. Each unit includes two types of terraces. One of them is steeply slanted debris slopes developing from the Churia Range towards the dun. The other is flat lying fluvial surfaces distributing in the basin floor. The debris slopes are designated, from oldest to youngest, the Barakot Terrace, the Kirtipur Terrace and the Mejhi Fan. Fluvial terraces are classified into the Belani Terrace, the Bishannagar Terrace and the Kawasoti Terrace in descending order. Correlation of terraces is based on topographic continuity, degree of soil colour rubification using the Munsell colour system, and surface dissection (Coates 1984 ; Lowe & Walker 1984 ; Boardman 1985 ; Iwata & Nakata 1985). Distribution of geomorphological surfaces in the study area is shown on Fig. 3. Morphostratigraphic relationships between terraces and Quaternary deposits are illustrated on Figs. 4-7.

3.1. Upper terraces

The *Barakot Terrace* is distributed along the foot of the Barakot Fault and is traceable towards the dun. The terrace surface attains about 650-750 m.a.s.l. (320-430

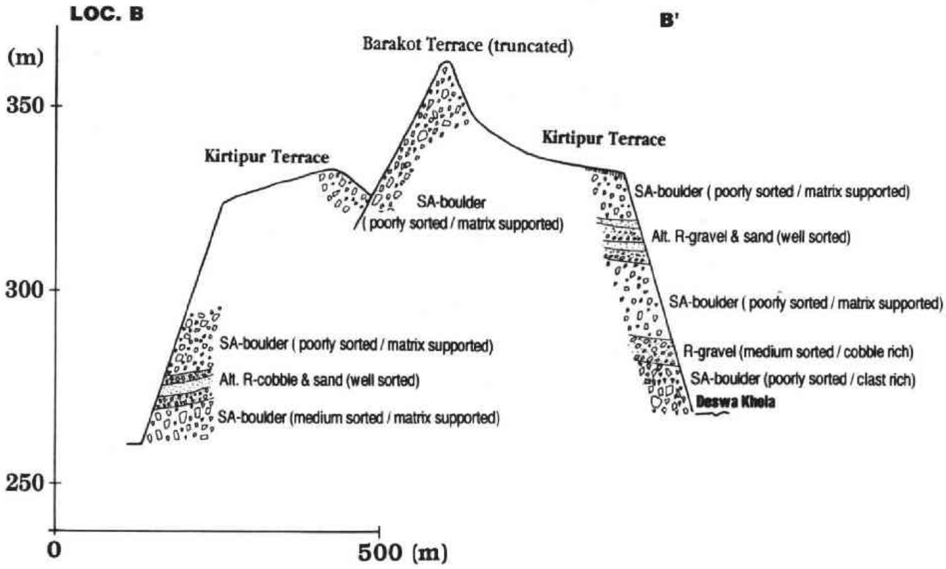


Fig. 5 Morphostratigraphic relation between the Barakot Terrace and the Kirtipur Terrace.
The Kirtipur Terrace Deposit is abut with the dissected Barakot Terrace Deposit. (Loc. B in Fig. 3 (viewed from south) ; A = angular, SA = subangular, SR = subrounded, R = rounded. Illustrated patterns are not in scale.)

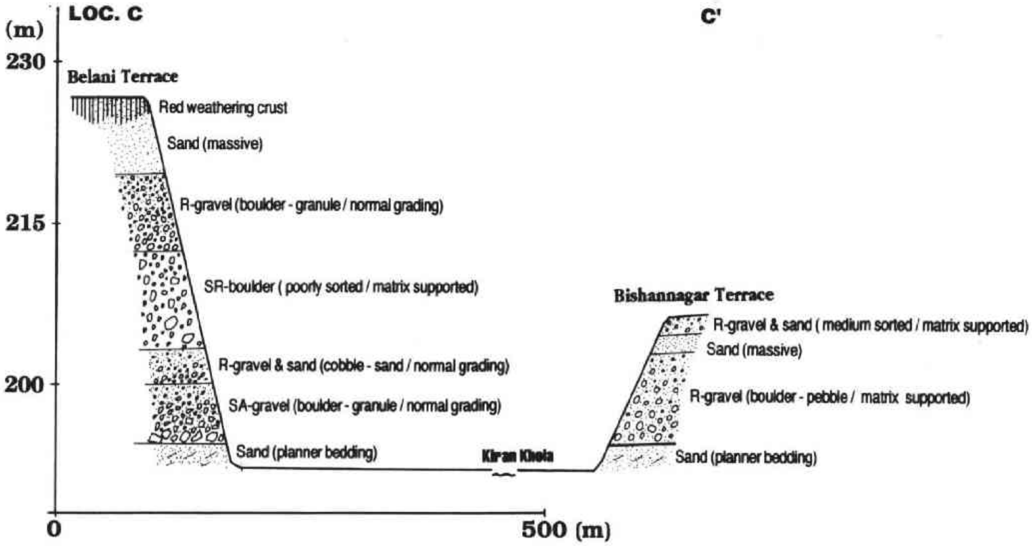


Fig. 6 Morphostratigraphic relation between the Belani Terrace and the Bishannagar Terrace.
The Bishannagar Terrace Deposit was accumulated in the valleys formed in the Belani Terrace Deposit. (Loc. C in Fig. 3 (viewed from south); A = angular, SA = subangular, SR = subrounded, R = rounded. Illustrated patterns are not in scale.)

metres above the present stream level) in the Churia Range and it is buried or truncated by younger morphostratigraphic units in the valley floor. The terrace deposits are unconformably underlain by the sandstone of the Siwaliks. They are composed of three conformable members, clast-supported angular boulder beds (about 120 m in thickness), thin alternating beds of well-rounded gravel and sand (total thickness is about 10 m), and matrix-supported, poorly-sorted subangular gravel layers (more than 250 m in thickness) including huge blocks, in ascending order (Fig. 4). The facies of the lower member show that the boulders are scree or dry avalanche deposits and their source area is close to the depositional area. The middle member is the channel deposit including the gravel derived from the Lesser Himalayan Metasediments. The upper member is debris flow deposit. Similar to the Deorali-type conglomerate (Tokuoka *et al.* 1986), lithology of the boulders of the upper member is dominated by the soft sandstone. Their facies, thick-bedded, matrix-supported and non-stratified gravelly strata including huge blocks of several metres in diameter, are also similar to that of the Deorali-type conglomerate. However, unlike the Deorali Formation, the terrace deposits are not yet consolidated and the original sedimentary surface still remains. These difference in diagenesis and geomorphic characters suggest that the Barakot Terrace Deposits are younger than the Deorali

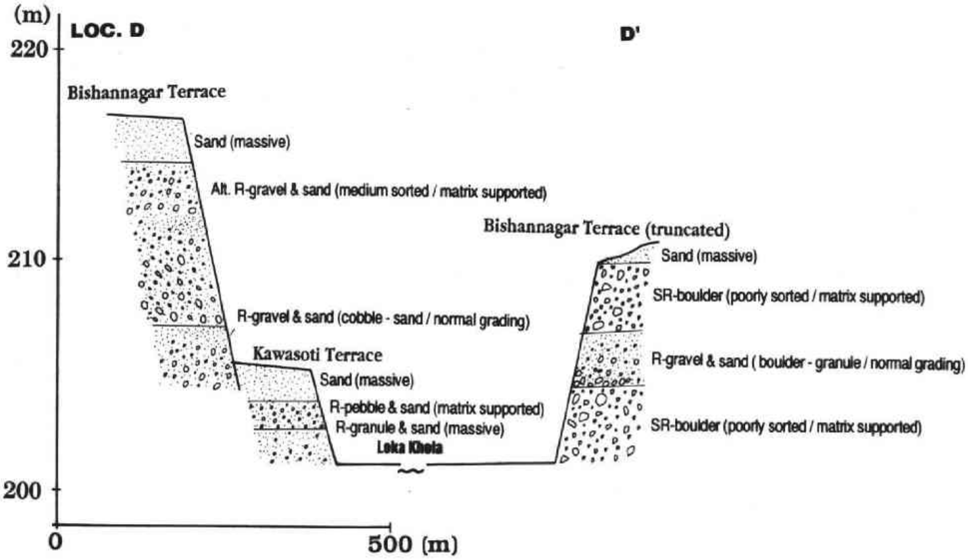


Fig. 7 Morphostratigraphic relation between the Bishannagar Terrace and the Kawasoti Terrace.
The Kawasoti Terrace is narrowly developed in the valleys carved in the Bishannagar Terrace Deposit. (Loc. 4 in Fig. 3 (viewed from south); A=angular, SA=subangular, SR=subrounded, R=rounded. Illustrated patterns are not in scale.)

Formation. The Barakot Terrace is characterized by well-preserved undulating sedimentary surface and a well-developed red weathering crust with 10R to 5YR hues. The red soil is 5 metres in thickness. According to Iwata and Nakata (1985), the age of the Highest and Higher Terraces, which are distributed to the east of the study area, is estimated 200 to 120 ka on the basis of the surface weathering and dissection. The Barakot Terrace could be correlated with those terraces, which have thick red weathering crust.

The fluvial *Belani Terrace* is locally distributed in the western part of the study area and extends westwards. Relative height from river bed attains around 40 m at the foot of the Churia Range and decrease towards the valley centre. The terrace deposits, unconformably overlapping the Chitwan Formation, are alternating beds of medium-sorted rounded gravel and sand (Fig. 5). The Chitwan Formation was deposited on the Ganguti Khola Syncline (Tokuoka *et al.* 1986). Therefore, the Belani Terrace Deposit is also accumulated on the structural depression. Sandy layers have planner bedding structures. Gravelly beds include well rounded cobbles derived from the Siwaliks and the Lesser Himalayan Metasediments. Palaeocurrent directions indicates that the terrace deposits were supplied by channels flown from N-NE to S-SW. These features show that the Belani Terrace was chiefly formed by the tributaries of the Narayani River. Well-developed weathering crust, which is from 3 to 10 metres and 10 R to 5 YR hues, is observed on the terrace surface. The terrace surface is dissected by the gorges of several hundreds metres long from their margin. These characters suggest that the Belani Terrace should be correlated with the Higher terrace represented by Iwata & Nakata (1985) as developed in 200–120 ka.

3.2. Lower-1 terraces

The *Kirtipur Terrace* is scattered along the foot wall of the Barakot Fault in the Churia Range, and is also distributed as an elevated piedmont fans along the Deswa Khola in the dun. The relative height of the terrace is about 70 m in maximum on the hills, and is decreased towards the basin floor. The terrace deposit, abutting with the Barakot Terrace Deposits, is chiefly composed of massive matrix-supported boulder beds (Fig. 6). The boulder is dominated by soft sandstones derived from the Siwaliks. The litho-facies are similar to that of the upper member of the Barakot Terrace Deposits. Thus the Kirtipur Terrace was formed as terraced debris. Overall volume of the debris is, however, far smaller than that of the Barakot Terrace Deposit. Red weathering crust is immature on the terrace and the surface soil colour ranges from 7.5 YR to 10 YR hues. The depositional surface is well preserved except along the Deswa Khola. Judging from these surface features, the Kirtipur Terrace is correlated with the Lower 1 Terrace in the Dang Dun, which had been formed in the age between 16,000 and 26,000 yrs B. P. (C-14 dating, Yamanaka and Yagi 1984).

The fluvial *Bishannagar Terrace*, standing 5–20 m above the modern stream level, is well developed between the Loka Khola and the Kiran Khola, and around the Belani Terrace. Although their margins, faced towards the Narayani River, are dissected by some gullies, most of the original surfaces are well remained. Alternating beds of well-rounded gravel and sand, whose total thickness is 10–20 m, are underlying the terrace surface (Figs. 6, 7). The deposits truncate or onlap the Belani Terrace Deposits. Their lithology, which is dominated by metamorphic rocks, shows that they were derived from the Lesser Himalaya through the Narayani River. The surface soil colour ranges from 7.5 YR to 10 YR hues as same as that of the Kirtipur Terrace. Therefore, the Bishannagar Terrace is considered to have emerged from the flood plain during the Late Pleistocene.

3.3. Lower-2 terraces

The *Mejhi Fan* is situated at the present boundary between the Churia Range and the Chitwan Dun. At the top of the fan, the surface is slanted almost parallel to the present talweg within 2 metres heights. Its margins, though, are dissected by gullies extending from Narayani River. Coarse gravel within the Mejhi Fan only exposes near the surface, and their base level is below the river bed. The deposits consist of rounded boulders with sandy matrix derived from the Siwaliks. Shape of the surface and the litho-facies of the deposits show that the Mejhi Fan is typical foothill alluvial fan. Red weathering crust is not observed on the surface, and the colour of top soils ranges from 10 YR to 2.5 Y hues similar to that of the flood plain. Thus the Mejhi Fan has been formed in the Holocene.

The *Kawasoti Terrace* is well developed along the right bank of the Narayani River. Its surface stands within 3 metres above the floodplain of tributaries and ranges from 3 to 8 metres at the bank of the Narayani River. Fresh sandy beds with common cross bedding facies are associated with the terrace. The distribution of the surface and the facies of the deposit suggest that the Kawasoti Terrace was formed by the main stream of the Narayani River. The fine sediments of the terrace are interfingered with the Mejhi Fan Deposits. The colour of the terrace surface soil, which is around 2.5 Y hue, expresses that they have been accumulated in the recent time.

4 Geomorphic features as tectonic implications

4.1. Terraced debris and the Barakot Fault

The profiles of range crests, terraces and streams are integrated with the field data to assess the Quaternary crustal movement in the study area. They are assembled along the Jharahi Khola (Fig. 8), the Deswa Khola (Fig. 9) and the Kiran Khola (Fig. 10) using contour information, obtained from topographic maps (1 : 50,000 ; 100 feet contour interval), and relative height data obtained by altimeter and hand levelling.

As shown in Figs. 8-10, summit elevation decreases from the Mahabharat Range towards the dun. Crest level is clearly step down on the MBT and on the Barakot Fault. Both areas, separated by the Barakot Fault, are underlain by loose sandstone. Any special differences in rock character are observed in between the hanging wall and foot wall of the fault. Thus the differential denudation, induced by rock control, is rejected as the primary cause of the changes of the summit level. This means that the crest step on the Barakot Fault could be regarded as a fault scarp. The two units of the terraced debris are only developed on the foot wall of the Barakot Fault. This distribution pattern of the debris suggests that the both debris were derived from the scarp of the Barakot Fault. Therefore the Barakot Fault was active and formed steep fault scarp prior to the formation of the Barakot Terrace Deposit. Thick debris beds consisting of boulders, which unconformably overlay the bedrock of the foot wall of a reverse fault, are generally regarded as synorogenic deposits (*e.g.* Huzita 1983 ; Nichols 1987). Similarities in facies and distribution pattern between the Deorali-type conglomerate (Tokuoka *et al.* 1986), which is a typical synorogenic sediment in the Siwalik belt, and the Barakot Terrace Deposits supports those interpretation. Thus

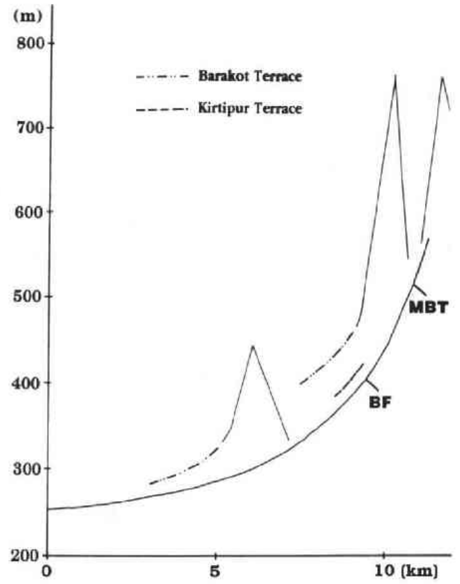


Fig. 8 Topographic pofile along Jharahi Khola. Crest profile is clearly stepped down on the Barakot Fault. Debris terraces are distributed on the foot wall of the fault. (Horizontal-axis shows the distance from Narayani River. MBT : Main Boundary Thrust, BF : Barakot Fault)

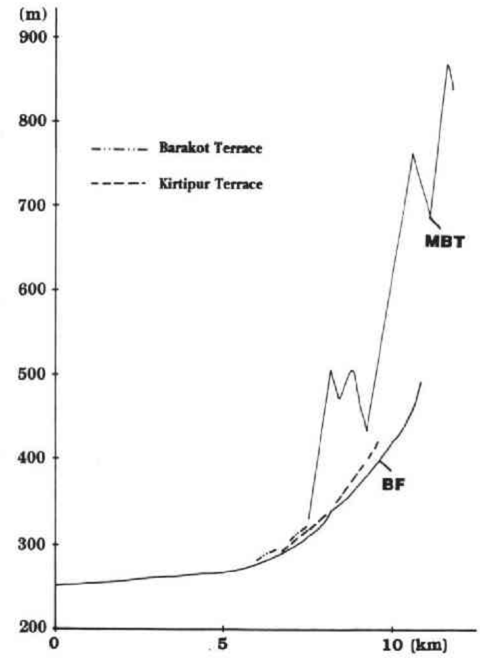


Fig. 9 Topographic profile along Deswa Khola. Two steps, which are located on the MBT and the Barakot Fault, are recognized in this crest profile. The Barakot Terrace and the Kirtipur Terrace are intersected on the dun floor. (Horizontal-axis shows the distance from Narayani River. MBT : Main Boundary Thrust, BF : Barakot Fault)

the Barakot Terrace Deposits implies an activity of the Barakot Fault in the age close to the formation of the terrace. However, detailed chronological data are still insufficient to discuss the beginning and displacement of the fault.

On the other hand, the origin of the scarp along the MBT could not be resolved with one reason such as faulting. If the MBT is still active, slopes around the fault should be instable. Some topographic indicators of crustal movement, which are debris foot slope, land slide, dislocation of geomorphic elements and so on, should be observed around active faults. In spite of the existence of steep scarp, debris, landslide, no other markers of crustal movement could be observed on the foot of MBT. Although information is not sufficient to discuss the recent activity of the MBT, it should be emphasised that the slopes surrounding the MBT are more stable than those of the Barakot Fault. This implies that the MBT is less active than the Barakot Fault since late Pleistocene time.

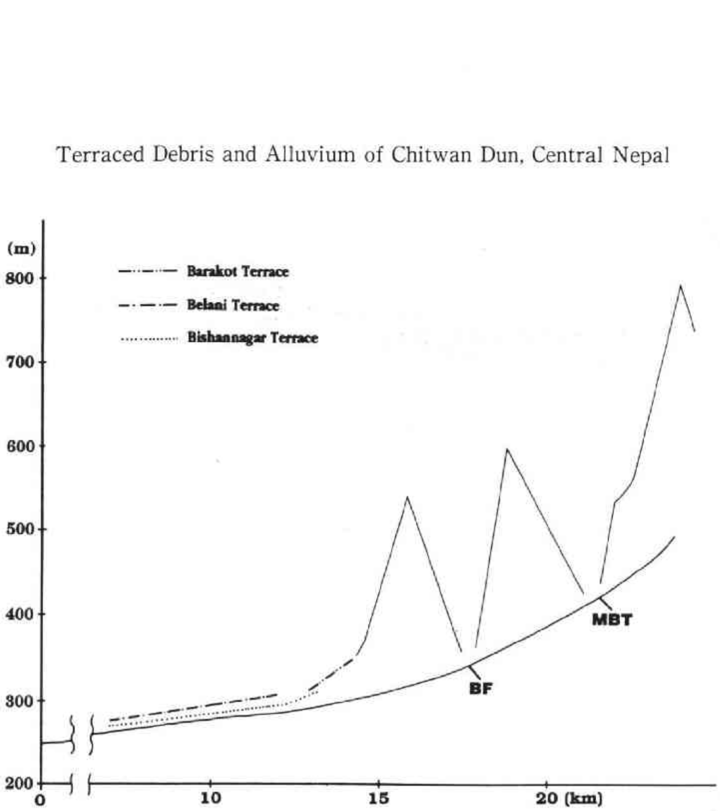


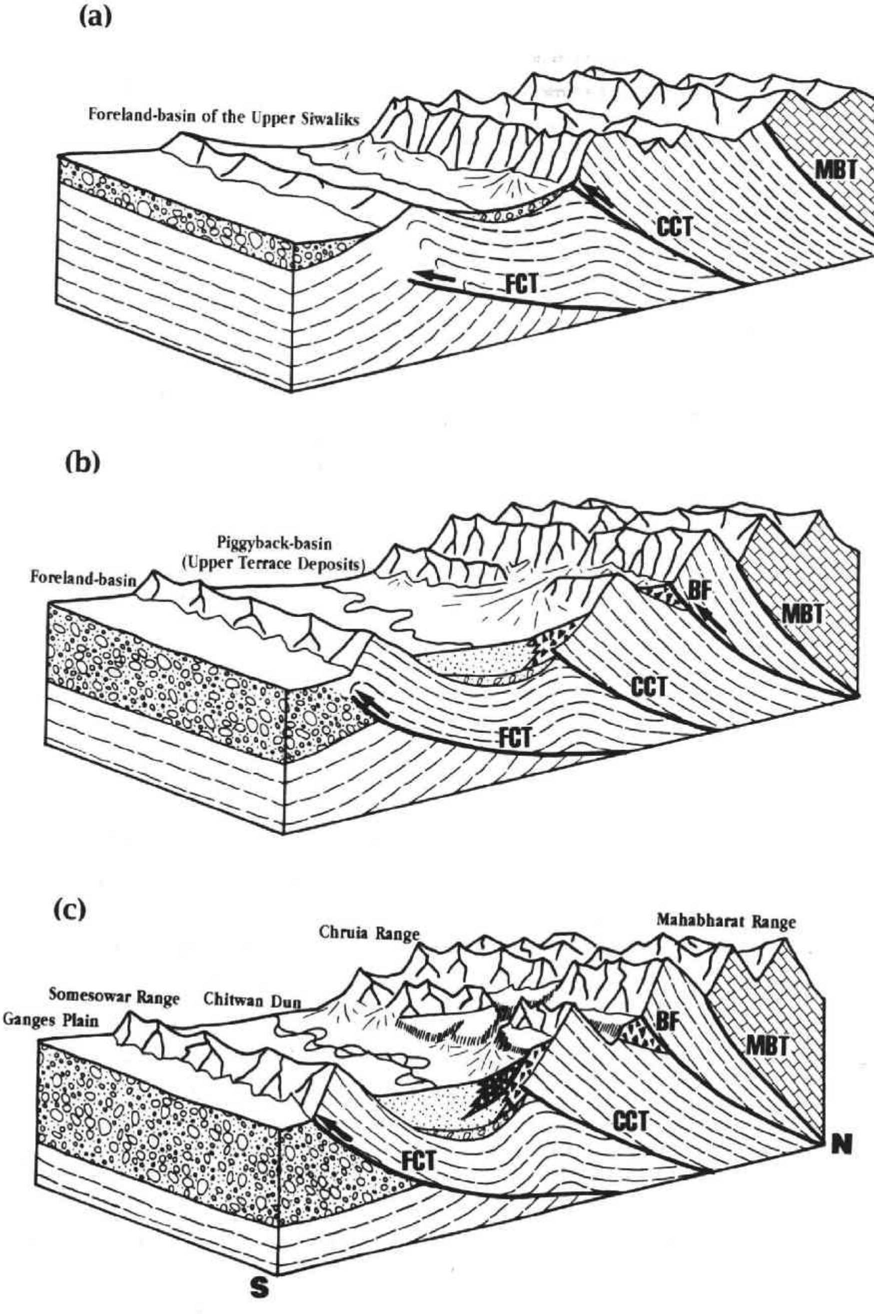
Fig. 10 Topographic profile along Kiran Khola.
Crest step is observed on the MBT. Fluvial terraces are gently slanted towards the depo-centre of the dun and are sub parallel each other. (Horizontal-axis shows the distance from Narayani River. MBT : Main Boundary Thrust, BF : Barakot Fault)

4.2. Profiles of geomorphic elements

As mentioned above, the Chitwan Dun is characterized the valley floor dominated by the present floodplain. In contrast, valley floors of other duns such as the Dang Dun and the Hetauda Dun, are mostly terraced (Yamanaka & Yagi 1984 ; Kimura 1994). The post-Siwalikan deposits in the Chitwan Dun were accumulated on the Ganguti Khola Syncline, which has formed since the Latest Siwalik Stage (Tokuoka *et al.* 1986). The deposits in the most part of the Chitwan Dun are overlain prevalently by the present alluvium except the terraced sediments. The stratigraphic relationship was formed in the condition of constantly greater rate of accumulation than the rate of uplift (Burbank & Verge 1994).

Relative height of the Belani Terrace of Middle Pleistocene age, which is less than 40 metres above the stream level and it decreases towards south and east, is exceptionally low compared with the equivalent terraces in the Dang Dun (Yamanaka & Yagi 1984) and the Hetauda Dun (Kimura 1994). Similarly younger terraces stand less in height than those of the other duns. This means that changes of the base level of deposition in the Chitwan Dun is smaller than that in other duns.

Longitudinal profiles of streams and fluvial terraces are respectable indicators for


(a)
Foreland-basin of the Upper Siwaliks
MBT
CCT
FCT
(b)
Piggyback-basin
(Upper Terrace Deposits)
Foreland-basin
BF
MBT
CCT
FCT
(c)
Chruia Range
Mahabharat Range
Somesowar Range
Chitwan Dun
Ganges Plain
BF
MBT
CCT
FCT
N
S

tectonic deformation (*e.g.*, Sugimura 1967 ; Yamanaka & Yagi 1984 ; Iwata & Nakata 1985). Fluvial landforms, the Belani Terrace, the Bishannagar Terrace, the Kawasoti Terrace and the present floodplain, are gradually slanted towards the depo-centre of the dun, and they are almost parallel to each other (Fig. 10). Fluvio-lacusrine terraces in other duns are tilted as a rule ; older surfaces are slanted steeper towards the basin centre than younger surfaces reflecting the mode of crustal movement (Yamanaka & Yagi 1984 ; Kimura 1994). The longprofiles in the Chitwan Dun show that the movement has not deformed the terraces.

Likewise the Chitwan Dun is less affected by tectonic deformation than the other intermontane basins in the Nepal Sub-Himalaya. These facts suggest that the Chitwan Dun is still subsiding as an intermontane basin through the late Quaternary.

5 Concluding remarks

As synthesized the discussions above and privious studies, the following morphostructural development is presented.

As growing the thrust ramp of the FCT, the molassic sediments was going to be trapped on the foot of the Himalayas. This is the origin of the dun (Fig. 11-a). The timing of the dun formation is unknown from morphostratigraphic analysis, however, Tokuoka *et al.* (1994) illustrate that an intermontane basin has generated between the FCT and the CCT since Early Pleistocene time.

The depo-centre of the Belani Terrace Deposits is in accord with the hinge of the Ganguti Khola Syncline, which is situated on the thrust sheet of the FCT (Tokuoka *et al.* 1986). This means that the dun had been commenced to be developed as a piggy-back basin by Middle Pleistocene age. In the same stage, the Barakot Terrace was formed on the foot wall of the Barakot Fault. The debris terrace formed a series of valley floor associated with the Belani Terrace. This means that the northern margin of the dun had expanded towards the Barakot Fault in Middle Pleistocene age (Fig. 11-b).

The present topographic boundary between the dun and the Churia Range has outlined since the Lower Terrace Stage (Fig. 11-c). The northern boundary of the dun

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Fig. 11 Schematic block diagram showing the morphostructural evolution in the western Chitwan Dun.
(a) The stage of the formation of the dun and frontal thrust ramp. It is correlated to Early Pleistocene time (Tokuoka *et al.*, 1994). (b) The stage of the Upper Terraces (Barakot Terrace and Belani Terrace). In this stage, it may be Middle Pleistocene time, sedimentary area of the Chitwan Dun was expanded northwards. The CCT was buried by the deposit, and the Barakot Fault was a boundary fault between hills and the basin. (c) The stage of the Lower Terraces-present time. (MBT : Main Boundary Thrust ; CCT : Central Churia Thrust ; FCT : Frontal Churia Thrust ; BF : Barakot Fault ; not in scale)

might be slightly shifted southwards in comparison with that of the Upper Terrace Stage. The vast floodplain of the basin shows, however, that the dun well maintains its sedimentary area. The evidence suggests that the Chitwan Dun is still subsiding against the uplifting trend of the Sub-Himalaya (Nakata 1972 ; Delcaillau *et al.* 1987 ; Kimura 1994 ; Chalaron *et al.* 1995).

The neotectonics of the Himalayas are characterised by the southwards shifting of the active front (*e.g.* Kizaki 1988). Tokuoka *et al.* (1994) also point out that the thrusting in the area around the Chitwan Dun has occurred, from older to younger, at the MBT, the CCT and the FCT. Those thrusts are regarded as a system of thrust imbricate (*e.g.* Schelling 1992 ; Srivastava & Mitra 1994). Generally, the evolution of the Chitwan Dun doesn't conflict with this trend.

The specific geostructure of the Barakot Fault is, however, extraordinary in the structural development of the Sub-Himalaya. Because the fault seems to be newly appeared in the "hinterland" of the active front. Kimura (1994) reports that subordinate fold-and-thrusts, which appeared later than the CCT and the Himalaya Front Fault (HFF=FCT), has commenced to uplift on the valley floor of the Hetauda Dun. Chalaron *et al.* (1995) illustrate that the Main Dun Thrust (MDT=CCT) in the Midwestern Nepal, shows an irregular trajectories associated with transverse faults and tear faults. According to them, the main active faults are located in the boundary between basin and hills, and the transverse faults and the tear faults, which are distributed in the hinterland of the main boundary fault, displace the hillslopes during the development of the dun. In the both cases, those subordinate faults occurred with northwards expansion (or migration) of duns. Similarly the Barakot Fault had appeared by the stage that the northern boundary of the Chitwan Dun was shifted towards its hinterland. The northwards expansion of the duns are resulted from the growth of frontal thrust ramp. It reflects severe shortening of an existing thrust-sheet. Therefore, the activities of those subordinate faults in hinterland may be general episodes in the neotectonics of the convergent plate boundary. In addition the author supposes that the load of the dun gravel (deposits of piggy-back basin) affect to break the tectonic balance of the existing thrust-sheet. However, there is not sufficient data at present to discuss this problem more in detail. These intra-Siwalik fault systems should be reexamined to understand the mechanism of the neotectonics in the Himalaya and its front.

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