International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2015 Vol. 5 (3) September-December, pp. 118-126/Baruah and Bezbaruah
Research Article

TECTONIC CONTROLS ON QUATERNARY ALLUVIAL TERRACES PRESENT IN THE FRONTALPART OF HFT, BETWEEN SILENG RIVER AND SIKU RIVER NEAR PASIGHAT, EAST SIANG DISTRICT, ARUNACHAL PRADESH, INDIA

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ABSTRACT
The Himalayan domain have recorded geomorphic expressions like displaced and warped late Pleistocene and Holocene surfaces along active faults in the frontal zone. An active deformation showing warping of river terraces, development of steep scarps and upliftment of Siwalik over recent alluvium indicates that the Himalayan Frontal Thrust (HFT) tectonically the most active zone across the Himalaya. Further, continuous compression in the Himalayan domain leads to the reactivation of number of Subthrusts in the frontal part that ultimately affects the general trends in slope of Quaternary sediments. In the present study an attempt has been made to study the deformation of the terraces present in the area between Sileng River and Siku River near Pasighat, East Siang District and to decipher the effect of the subthrusts on slope modification in the frontal part of the study area.

Keywords: *Warped, HFT, Slope, Quaternary, Pasighat*

INTRODUCTION
The Himalayas are the highest and youngest mountain ranges in the world. The mountain ranges belong to the Alpine-Himalayan orogenic belts which extend between two old continental masses, Gondowana land to the south and Laurasia to the north (Wadia, 1964). The topography, geologic structure and earthquake of the Himalaya and surrounding regions are a consequence of the northward progression and collision of India into Eurasia (Wesnousky *et al.*, 1999), a processes that has accommodated an estimated 2000-3000 km of convergence since the Late Cretaceous (Molnar and Tpponnier, 1977) and continues today at a rate of about 55 to 60 mm/yr (Demets *et al.*, 2001; Bilham *et al.*, 1997,1998). The strong neotetonic behaviour of the outer Himalaya (Hodges *et al.*, 2001) is recently brought out by numerous examples. Several workers (e.g. Nakata, 1989; Yeats and Lillie, 1991; Yeats *et al.*, 1992; Mukul, 2000; Valdiya, 2001; Malok *et al.*, 2003; Joshi, 2004; Philip and Virdi, 2006) have shown that the major faults, especially those of the Outer Himalaya, are presently active. The river system of Himalaya has brought down and deposited boulders and gravels at the foot of the ranges, and formed alluvial fans and river terraces during the last orogeny or thereafter. Formation and deformation of such geomorphic surfaces along the Himalayan Foot hills suggest that the last orogenic movement of the area is still active and highly morphogenic (Gansser, 1964). In the orogenic belt of Himalaya, the study of Pliestocene-Holocene fluvial deposits has addressed a close relationship between uplift, climatic variation and erosion (Lave and Avouac, 2000; Bookhagen *et al.*, 2005; Wobus *et al.*, 2005; Suresh *et al.*, 2007; Srivastava *et al.*, 2008; Sinha *et al.*, 2010). Although effect of syndepositional and/or postdepositional tectonic events on the development of Pleistocene-Holocene fluvial deposit particularly in the north eastern part of Himalaya still remains the least studied part.
In the present study an attempt has been made to decipher the effect of collision originated active tectonics on the slope modification in the frontal part of HFT. This work is one of the initial studies on the terrace mapping using GPS and satellite imagery of the eastern extremity of the NE Himalayan Foot-hills regarding their evolution and tectonic movements. This type of study is important not only because the work will fulfil lack of information on the landforms of the area consisting of Post Siwalik deposits in the non-glaciated areas, but also because the work will contribute the fundamental data on the Himalayan geology left by geologists.

The present area of study lies in and around Pasighat area between Sileng river and Siku river, East Siang District of Arunachal Pradesh in SOI Toposheet No. 83M/1, 83M/5, 82P/4 and 82P/8 bounded by latitude $27^0$45’00” to $28^0$15’00” and longitude $95^0$00’00” to $95^0$30’00”(Figure 1)

Regional Geological Settings of the Study Area

Regional setup of the study area is very complex. Mainly two of the four major tectonic zones are exposed in the vicinity of the study area. The sub-Himalayan zone rising abruptly from the Brahmaputra Plains along a tectonic plane- Himalayan Frontal Thrust (HFT). The Lesser or Lower Himalayas comprises of Yingkiong Group and some patches of Gondowana in the right bank of Siang bounded by Main Boundary Thrust (MBT) towards north and continues Northward. The Sub Himalayan part present in this area is very narrow in comparison to the western part of Arunachal Himalaya. The Sub Himalaya comprises of Siwalik sediments, deformed between MBT towards north and HFT towards south. North of the narrow Siwalik belt lies the Yingkiong Group of Paleocene-Eocene age, which are associated with different basic intrusive rocks. Apart from these major lithounits, to North of HFT, older alluvium comprises of river terraces are exposed which are bounded by subthrust of the Frontal Fault. Further north, recent alluvial sediments of the Brahmaputra plains are present. Four NW-SE trending strike slip fauls viz. Siba Fault, Miku Korong Fault and Sileng Fault cut HFT-1, HFT-2 and MBT which are shown in geological map of the area (Figure 2).

MATERIALS AND METHODS

Methodology

The geomorphic responds to the tectonic activity can be substantiated by detail geological mapping of folds, faults and presence of different level of river terraces. Satellite images from Google Earth are used to understand the nature of terrain of the area of interest. Latitude Longitude data obtained in the field with the help of GPS are uploaded in Google Earth to get a better resolution of data’s collected from the field. The fluvial terraces present in the area is mapped using hand held GPS. For the purpose of mapping toposheet of SOI of 1:50,000 scale, DEM data and satellite imageries downloaded from BHUVAN GEO-PORTAL have been used. For this mapping spherical geographical coordinates along the edge of the terraces is taken with the help of hand GPS. These points are joined to mark the boundaries of individual terraces.

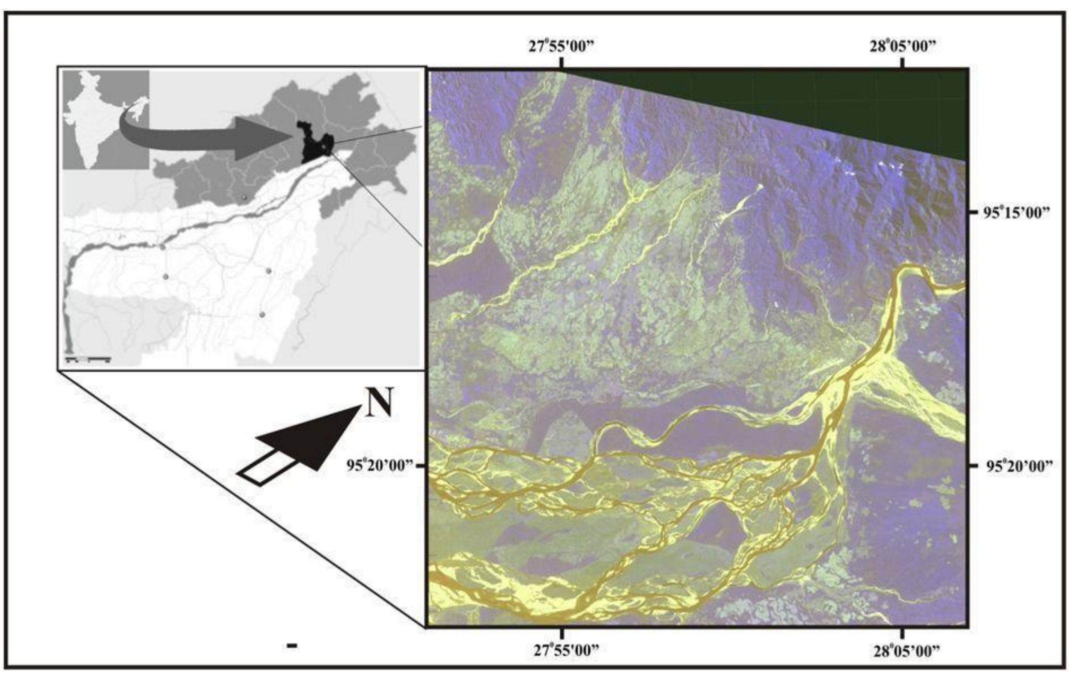

Figure 1: Location Map of the study area

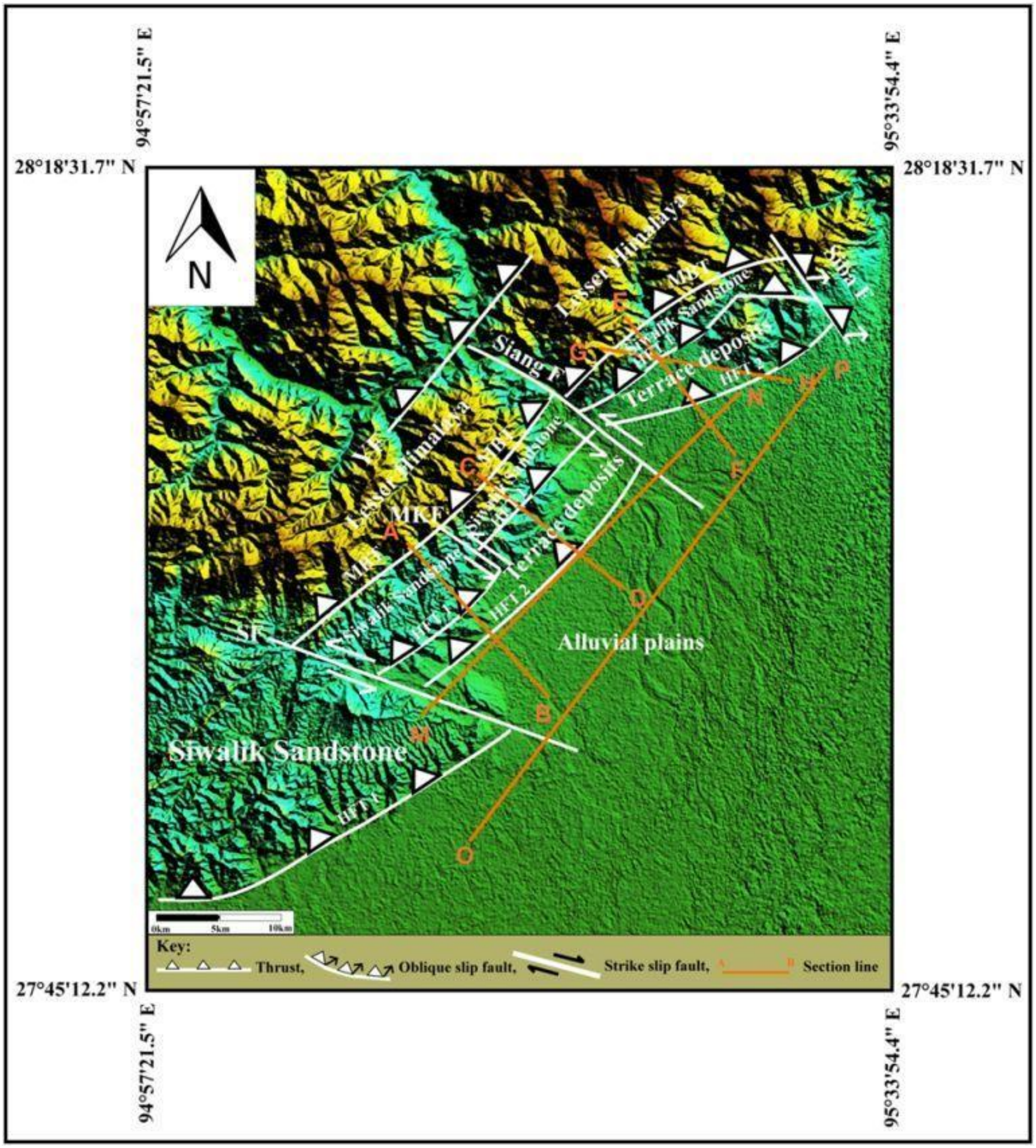

Figure 2: The Cartosat-1 Digital Elevation Model (CartoDEM) Version-3 R1 imagery of the study area showing major thrusts and lithologies in the frontal part of the study area. Lines AB to OP are sections along which topographic profiles are shown. MBT: Main Boundary Thrust; HFT: Himalayan Frontal Thrust; SF: Sileng Fault; MKF: Mingo Korong Fault; YF: Yamnee Fault; Siang Fault and Siba Fault

RESULTS AND DISCUSSION

Mapping of Terraces

The fluvial terraces present in the area are mapped using hand held GPS and SRTM (DEM) data. We mapped the terraces for all the rivers present, viz Sileng, Remi, Mingo, Siku and Siang River. Different level of terraces are marked and are termed as T_1, T_2, T_3,... respectively in the increasing order of their

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evolution from the present level of active flood plains (T_0) (Figure 3). Five level of river terraces are present in the area.

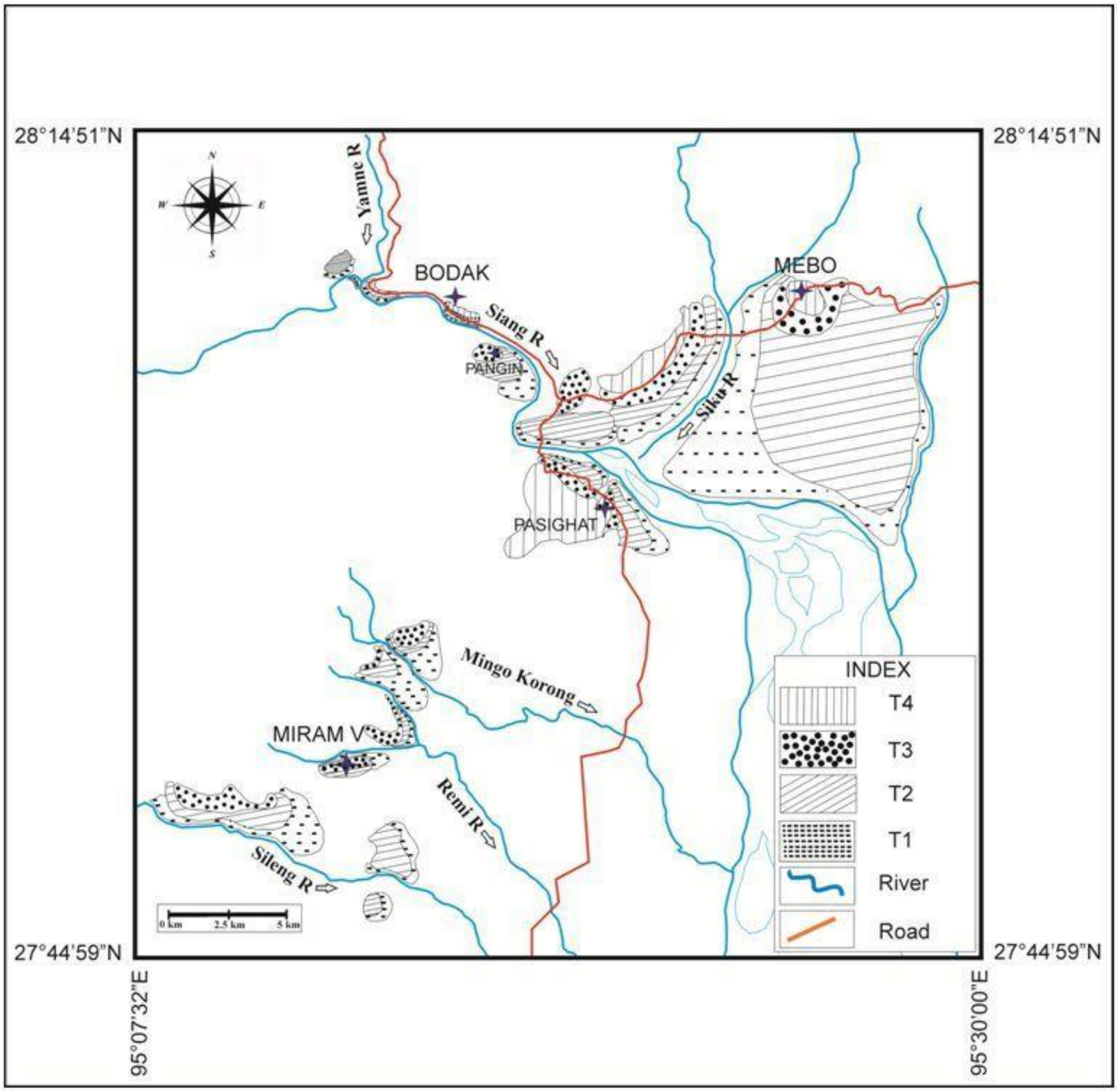


Figure 3: Terrace map of the study area

Inference from the River Terraces

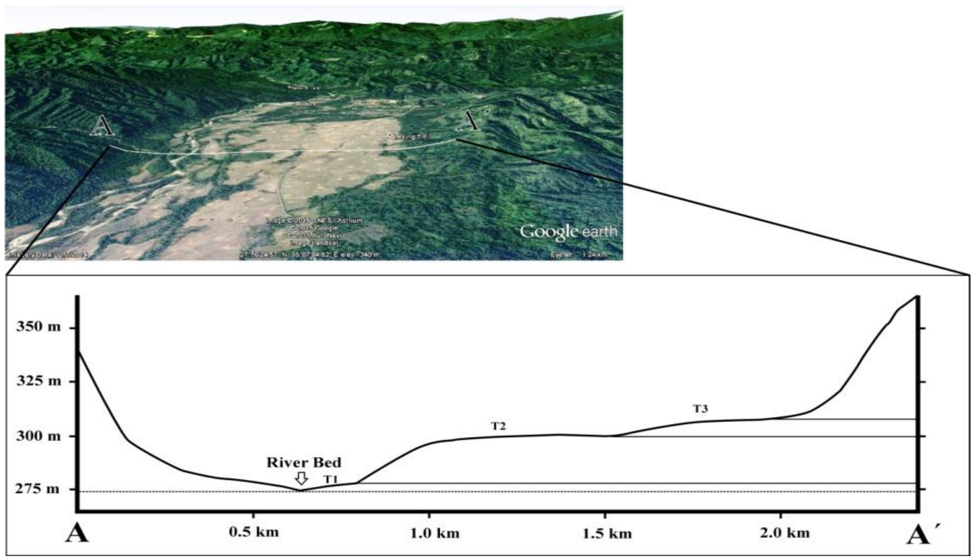
The profile drawn from Google Earth in the upstream of Sileng River, near the mountain front shows development of three level of terraces in the left bank via, T_1, T_2 & T_3 successively from the present river bed T_0. But in the right bank, only T_1 level is exposed. This unpairedness of the terraces is mainly related to the cross fault present alog the Sileng River (Segment AA' in figure 4.1).

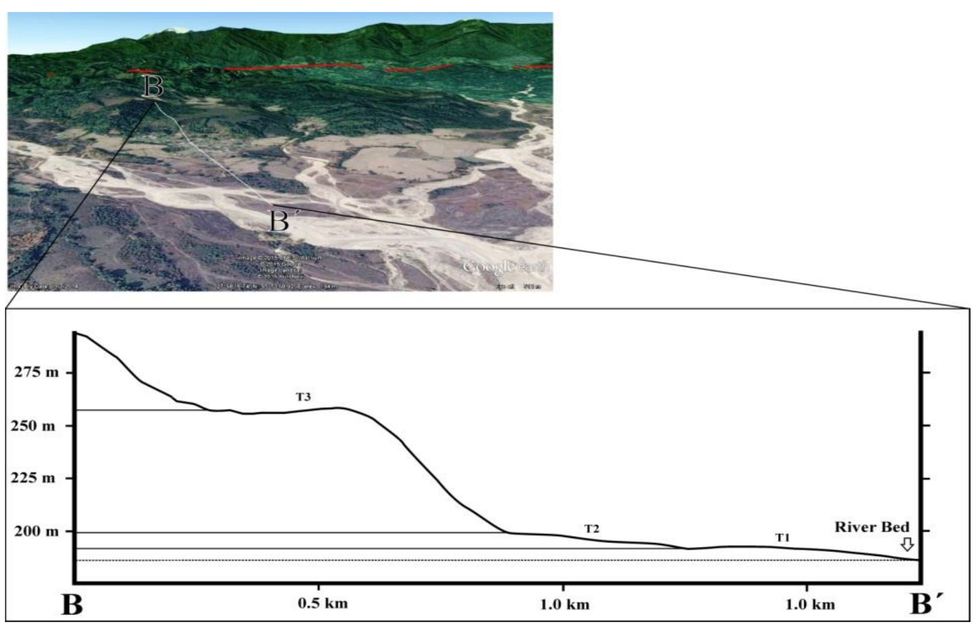
Terraces of Remi River show development of three levels of terraces from the river bed. T_3, the highest level present in the area occur at a height of 50m from the T_2 level below. This unusual rise of the terrace surface from the regional slope of the area is mainly due to the effect of the sub thrust HFT2 (BB' segment in Figure 4.1).

The terrace profile of the left bank of Mingo River shows gradual development of terrace surface from T_1 near the river bed to T_3 at an average elevation of 30m from T_0. This unpaired terraces and steepness of the slope indicate that the area is uplifted and has been tectonically disturbed after the deposition of the terraces (CC' segment in Figure 4.1).

Terraces of Sian River are located in the right bank near Pasighat town. It has five levels of terraces including the present river bed. T_4 is the highest level present in the area. It has a maximum elevation of 290m from the msl and 140m from the river bed. The next level (T_3) present at a maximum elevation of 270m above msl and 120m from T_0. T_2 is the next level terrace having maximum elevation 238m above msl and 88m from the Siang river bed. The Pasighat town is located above this. T_1 in the area is present at a maximum elevation of 178m from msl and 26 m from the river bed. The Dhobi ghat area is located above this (DD' segment in Figure 4.1). Transverse section across the river bed reveals the unpairedness of this terrace. This unpaidness is directly related to the differential upliftment of the area along Siang cross fault and also to some extent by the effect of the Sub thrusts of HFT.

In the left bank of Siku River five levels of terraces are developed including the present river bed, but in the right bank T_3 and T_4 are missing. This indicates upliftment along the post depositional deformation in that area. By correlating these data with the tectonic map of the area reveals that the origin of these high level terraces e.g. T_4 & T_3 are directly related to the sub thrust present beneath (EE' segment in Figure 4.1).





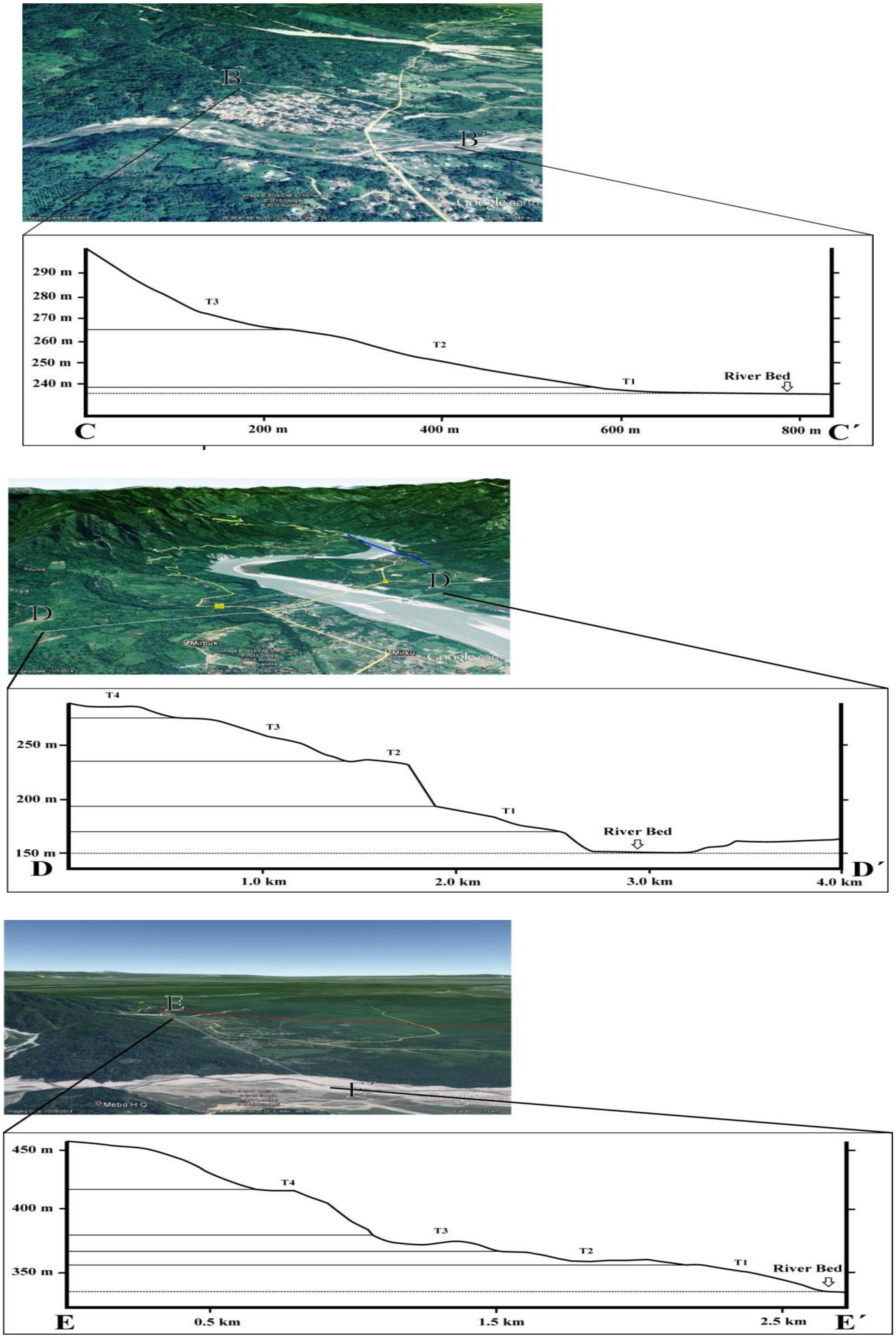


Figure 4.1: Profile of river terraces drawn from Google Earth showing elevation of successive level of terraces for AA': Sileng River, BB': Remi River, CC': Mingo River, DD': Siang River and EE': Siku River

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Topographic Expression of Tectonic Movement

Effect of tectonics in slope modification can be access by constructing profile lines in the frontal part of the mountain front and also in the transverse profile across the front. Topographic profiles are generated using DEM data. Section lines are shown in Figure 2. The tectonic lines are drawn irrespective of dip measurements to highlight topographic expressions of tectonic movements.

Sections Transverse to the Mountain Front

In the area lies between Sileng Fault (SF) and Mingo Korong Fault (MKF) along the section **AB**, between MKF and Siang Fault along the section **CD**, between Siang Fault and Siba Fault along the section EF and in the frontal part of the alluvial fan of Siba River along section **GH** the change in slope of the topographic profile is directly related to the major tectonic planes in the area.

MBT lifted the lesser Himalaya above the sub Himalayans having an elevation above 500m. Sub thrust of MBT, HFT 1 further uplifted the Siwaliks above the older alluvium having average elevation of 250-200 m. HFT 2 an another sub thrust branching out from HFT 1 also affect the slope of the profile and lifted the older alluvium above the regional slope of the piedmont plains.

In the section AB the Lesser Himalaya having regional slope of 55º-60º (approx) in the NNW side was truncated along MBT.

From MBT the slope of the surface changes to 15º-20º due to the effect of HFT 1 towards SSE side. The new frontal sub thrust HFT 2 lifted the terrace deposit and placed at a slope of 5º to 10º above the regional slope of the recent alluvium.

In the section CD also change in slope is observed from NW to SE direction. The topographic slope is changes from 35º-40º to 40º-45º along MBT, 40º-45º to 20º-25º along HFT 1 and from regional slope of the piedmont plain to 20º-25º along HFT 2.

The lesser Himalaya having a slope of 60º (approx) towards NNW side in the EF section abruptly change to 10º-15º in the sub Himalayas along HFT 1. Towards SSE side this slope again changes to 5º (approx) due to the effect of HFT 2.

In the section GH along WSW-ENE across the alluvial fan of Siba River, the major thrust planes are shown irrespective of the dip in order to show the change in slope of the topographic profile. From MBT towards ENE direction the slope changes from nearly 60º to about 8º-10º along HFT 1. This slope is again modified to 4º-5º along HFT 2 towards ENE direction.

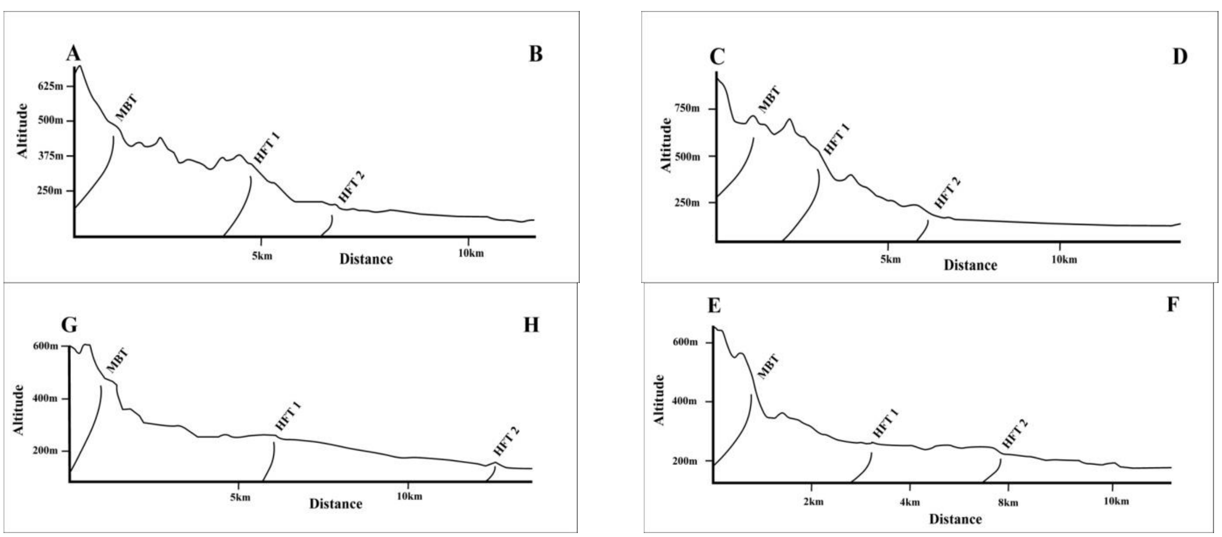

Figure 4.2.a: Topographic profile transverse to the mountain front along lines in Figure 2

Longitudinal Sections Parallel to the Mountain Front

In the sections parallel to the mountain front, topographic highs were observed near to the location of cross faults via Sileng F, Mingo Korong F and Siang F. It has also observed that the slope of the topographic profile is change near to these locations. Hence in both the sections (MN and OP) these changes in slope are mainly attributed to the differential movement along these strike slip faults.

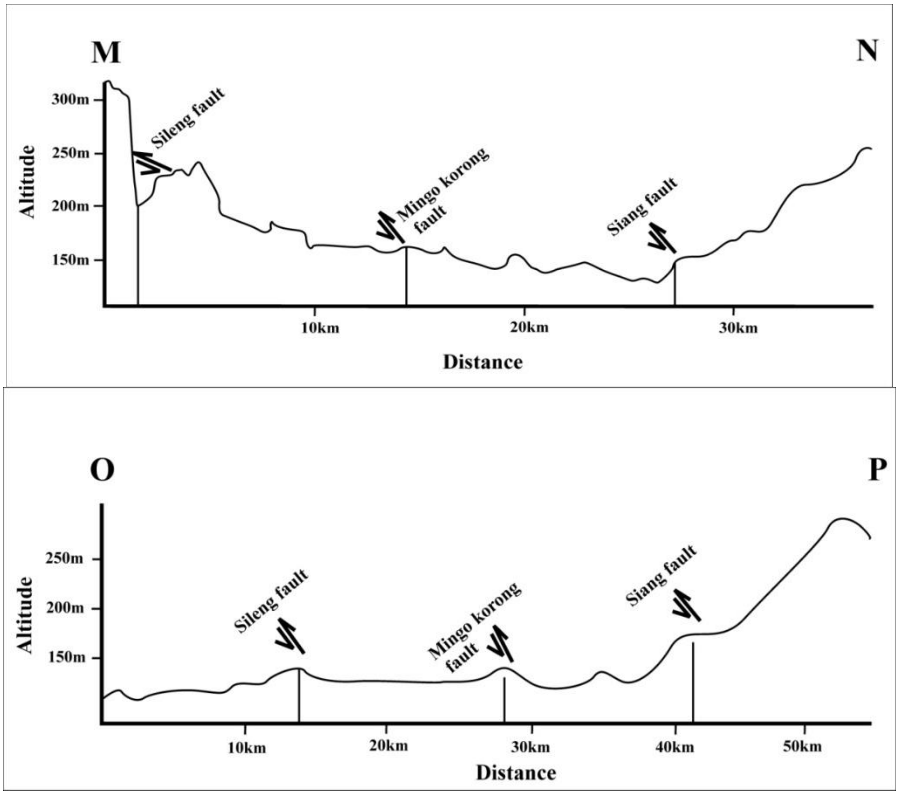

Figure 4.2.b: Topographic profile parallel to the mountain front along lines in Figure 2

Conclusion

HFT, the most prominent branching fault of MBT, is indeed an imbricate thrust in the foreland basin formed due to continued compression of Indian-Eurasian collision, after the deposition of Siwalik sediments in the fore deep basin during the early Miocene period. Further movement along the frontal fault leads to the deformation of Siwalik sediments and were thrusted over recent alluvium. Continuous compression leads to the activation of number of faults which branched out of HFT and named as HFT-1, HFT-2 etc (Figure 2). Hence it can be concluded that the Himalayan Mountain Front could be in a state of expanding southward.

By observing the change in slope of the piedmont zone occurred at the frontal margin of HFT, it has been concluded that the collision originated thrusts, branching out of HFT via HFT-1 and HFT-2, has a dominant role on the slope modification a depicted by the transverse section across the frontal margin. Further in the frontal part of Siwalik foredeep basin the Pleistocene-Holocene sedimentary deposits comprise mainly of river terraces of Sileng, Siba, Mingo Korong, Siang and Siku rivers shows characteristic unpairedness. Hence these unpairedness of the terraces in the whole study area are the direct manifestation of the differential movements along the crossfaults (Sileng Fault, Mingo Korong Fault, Siang Fault and Siba Fault) which dissects the mountain front in the study area.

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