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Structural Control on Landscape Development of Barak Valley, Northeast India

A. Alam Laskar[1] and P. Phukon[2]
[1]Indian Statistical Institute, North-east Centre, Tezpur – 784 028
[2]Department of Geological Sciences, Gauhati University, Guwahati - 781 014
Email: laskar.alam@yahoo.co.in

Abstract: The Barak Valley, comprising a contiguous region of three south Assam districts of Cachar, Hailakandi and Karimganj, represents a ridge and valley province with meridional to sub-meridional anticlinal hills and synclinal valleys. Thin skinned tectonics resulted in the deformation of Neogene clastics which is manifested in the form of a series of anticlines and synclines. These structural elements have profound control on the development of present-day landscape in Barak valley. Structurally controlled fluvial erosion produced a series of cuesta ridges and strike valleys which were further subjected to erosional dissection leading to development of numerous topographic highs. Along the northern part of Barak valley adjoining Barail range, three terrace levels stand out with topographic offsets of upto ~10 m. These terraces are linked to tectonic adjustments along Haflong-Disang Thrust that traverse along the Barail foothills. Numerous wetlands linked to fluvial activities and also isolated from the fluvial domain form a significant element of the Barak valley landscape. Some of these wetlands have their origin to tectonic activities of the region. While the trunk channel of the region follows a nearly E-W trend, all the major tributaries join it at nearly orthogonal position following the prevailing structural trend.

Keywords: Landscape development, Structural control, Barak valley, Assam.

INTRODUCTION

The Barak valley, named after the large alluvial river Barak, comprises a contiguous region of three South Assam districts namely, Cachar, Hailakandi and Karimganj. The Barak basin occupies about 39390 sq. km. spread into Bangladesh (7780 sq. km), India (30770 sq. km) and a small part of Myanmar (840 sq. km) (Fig.1). This river system drains into the Bay of Bengal and is independent of the Brahmaputra basin with Shillong Plateau-Mikir hills forming the topographic divide between the two. From the geological point of view, the study area forms part of the Tripura-Cachar-Mizoram frontal fold belt within the greater Assam-Arakan geosynclinal basin. The total sediment cover in the area is about 10-12 km with Neogene rocks forming the bulk. Regonal structural disposition and tectonic activity in the region have significant effect on the landscape development during late Quaternary period. Most of the landforms are formed as a result of tectonic activity or are carved out from the pre-existing structural landform by erosional processes.

Structural control on landscape evolution for the fold mountain belts including Appalachian, Zagros, Urals, Andes, Alps and Himalyan foothills have been studied by many workers (Makunina 1974; White and White 1979; Clark and Ciolkosz 1988; Schlunegger 1999 Bissig et al. 2002; Burberry et al. 2008; Requelme et al. 2008). However, information on the landform evolution of this area, particularly, their relation to the existing structural and tectonic setup is very scanty. There is a perceptible information gap in geomorphology of Barak valley and more particularly, on landscape development vis-à-vis tectonic evolution. This paper presents an account of the Barak valley landscape and the structural and tectonic control on their evolution. Limited morphometric analysis is done to substantiate the role of active tectonics in the development of the present day landscape.

GEOLOGICAL SETTING OF BARAK V ALLEY

Cachar-Tripura-Mizoram Frontal Fold Belt within the greater Assam-Arakan Tectono-Sedimentary basin is part of a foredeep accretionary basin between the Indian craton and Indo-Burma plate collision zone. The general depositional events of the area consist of a repetitive succession of Neogene arenaceous and argillaceous sediments, known as rhythmites, with thinning upward sequence (Nandy, 2001). The rhythmites of marine origin are followed later by fluvial deposits. The entire sedimentary

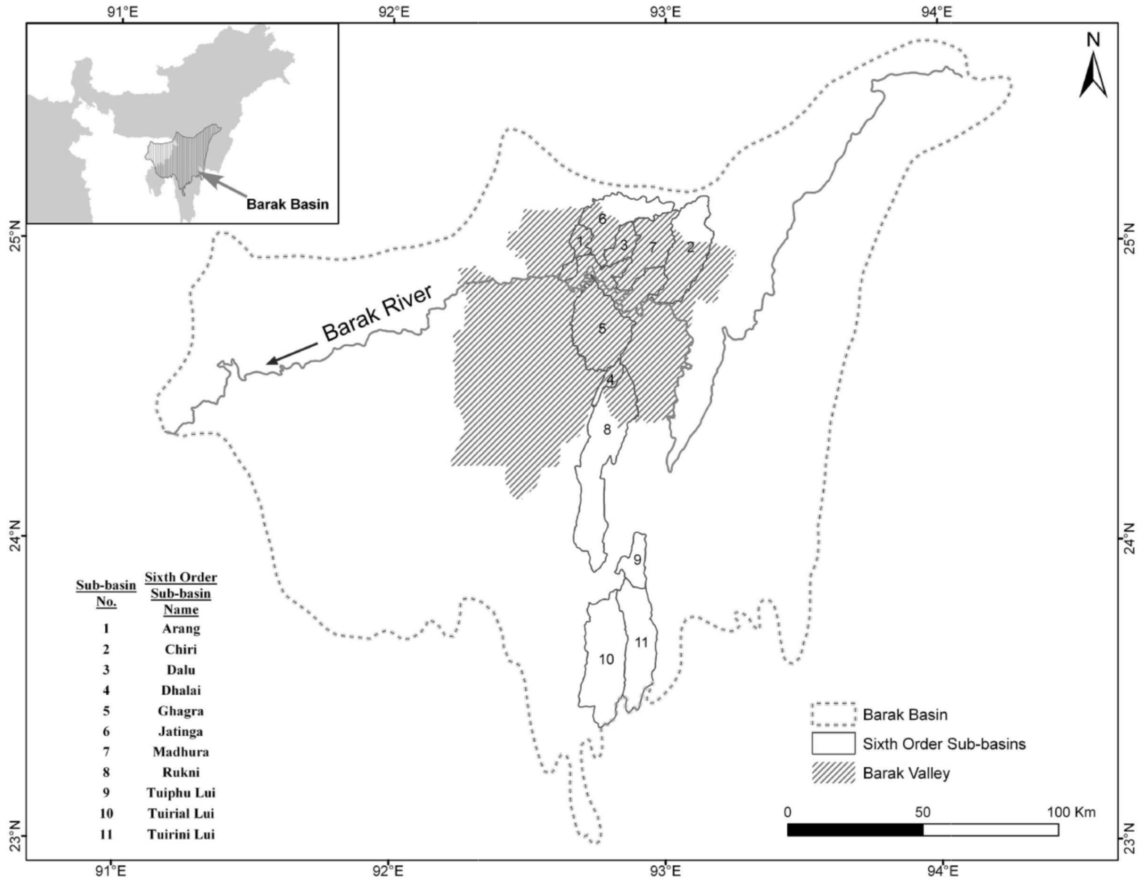

Fig.1. Location map of Barak basin and Barak valley (shaded area) showing eleven sixth order sub-basins considered under the present study

column of the area is made up of sandstone, siltstone, shale, mudstone, conglomerate, unconsolidated sediments ranging in size from clay to boulders. All these formations are not exposed throughout the area, but are present at various depths due to folded nature of the rocks. The oldest rock of this area belongs to Disang Group (Eocene) followed by Barails (Oligocene), Surma (Miocene), Tipams (Mio-Pliocene), Dupi Tila (Plio-Pleistocene) and Dihing Group (Pleistocene). These are followed by Alluvium of Pleistocene to Recent age.

Structurally the area is characterised by a series of meridional to sub-meridional, arcuate, elongated, doubly plunging, asymmetric folds arranged in an en-echelon pattern, trending N-S to NNE-SSW with slight convexity towards west (Ganguly, 1983, 1984). The regional geology and the tectonics have been recorded in a number of earlier works, mostly inspired by exploration for hydrocarbon in the region (Evans, 1932, 1964; Mathur and Evans, 1964; Brunnschweiler, 1966; Raju, 1968; Ganguly, 1975; Rangarao, 1983; Desikachar, 1974; Dutta and Saikia, 1976; Nandy, 1982; Seshavataram et al. 1998). The fold belt region is tectonically bounded towards the north by the Dauki Fault and Haflong-Disang Thrust, in the east and in the south by Arakan-Yoma Fold Belt, while, in the west it is bounded by the Hail-Haka-Lulu Lineament and Chandpur-Barisal High (Nandy et al. 1983). In general, the tightness of folding increases towards east as it approaches the Arakan-Yoma collision zone. The Oil and Natural Gas Corporation Limited (ONGC) has been involved in hydrocarbon exploration since early part of the twentieth century and it has so far discovered seven major types of folding (Seshavataram et al. 1998) (Fig.2).

a) Adamtila-Patharia
b) Longai-Chorgola
c) Chhatachura-Kanchanpur-Chandipur-Badarpur-Hilara-Narayanchara-Shahbazpur
d) Bhairabi-Masimpur-Indranagar
e) Rengte-Pathimara
f) Teidukhan-Ramphan-Tukbai
g) Bhuban-Digli

Out of the 26 anticlinal structures, a few are concealed, while, others have well discernible morphological expression. The steeper flanks of the anticlines in the western

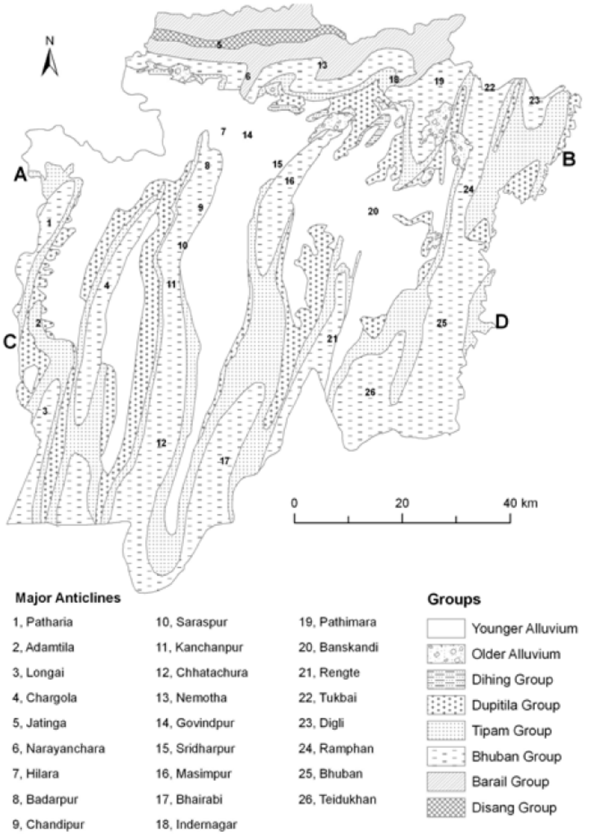

Fig.2 Generalized geological map of Barak valley showing the locations of the anticlinal structures (*after* Das Gupta and Biswas, 2000 and references therein; Sheshavataram, 1998).

part as well as in the eastern part are generally dislocated by longitudinal listric reverse faults (Fig.3) which have maximum throw near the anticlinal culminations and plunge down and disappear towards periclinal extremities (Ganguly, 1983, 1984). Internal complexities in some individual structures in the form of cross-faults, oblique-faults and lineaments trending NW-SE and NE-SW to ENE-WSW directions divide these structures into separate blocks (Ganguly, 1983). These cross faulting lead to upward warping of the synclinal troughs, also termed as structural inversion. As a result a pseudo-anticline is formed at the trough of the syncline as in the case of Bhubandar (Kamaraju, 2010).

The E-W trending Dauki fault running along the southern margin of Shillong Plateau is almost straight up to a point a little east of Sonapur (92°22' E-25°06' N) and it shows a clear morphological expression of a normal fault with southern block down-thrown relative to the northern block as interpreted from satellite image and digital elevation model (DEM) derivatives. Beyond that point, further east the morphological expression of the occurrence of the fault is not clear. On the other hand the Haflong-Disang thrust has a clear morphological expression beyond Haflong towards west and it extends up to Sonapur, where it ends against the Dauki fault. The Haflong-Disang thrust separates the less deformed northern block from the more deformed south block which overrides the northern block. In this part, i.e. west of Haflong, as the trend of the thrust becomes E-W it shows oblique-slip nature with a dextral strike-slip component. The dextral strike-slip nature of the Haflong-Disang thrust is also supported by the eastward swing of the northern part of the N-S trending folds of Cachar region. Another important structural feature of the region is a number of splays branching out of the Haflong-Disang thrust (Fig.4). These splays branch out in a south-western direction and have nature of movements similar to that of the Haflong-Disang thrust. The morphological expression of these splays ends along a linear zone along the Barail foot-hills. A probable fault may exist along this zone which is also evident from the facts that there is distinct elevation difference across this zone, the nature of folding across this zone is also different and three levels of terraces are formed along this zone. The block between the Haflong-Disang thrust and the probable fault south of it has been faulted into smaller blocks by connecting splays forming a contractional strike-slip duplex (Twiss and Moores, 1992) as shown in Fig.5.

GEOMORPHOLOGICAL SETUP

The Barak valley exhibits a unique landscape of ridge and valley with low-lying hills and intervening valleys. The area is bound to the north by Barail range, to the east by Bhuban and Manipur hills, to the south by Mizoram fold belt and to the west by the Bangladesh plains. On an average the elevation increases towards north and east reaching 800-1000 m amsl. The Barail form the highest hill range in the north with elevation more than 1000 m amsl. There is, however, difference in the trend of the hill ranges with Barail range having an E-W trend, while the southern hills spread across Barak valley and Manipur-Mizoram border have N-S to NNE-SSW trend. Their geometric and geographic disposition is in conformity with the regional structural trend. The valleys are, however, have a general lower gradient with elevation mostly between 20-30 m amsl. Present day geomorphic processes have carved out diverse erosional landforms from the prevailing first order landform features. Six major landform features are recognized in the area. These are: anticlinal hills, linear ridge and strike valley, denudational hill, fluvial terrace, alluvial plain and active flood plain.

Anticlinal hills in this area are important landform

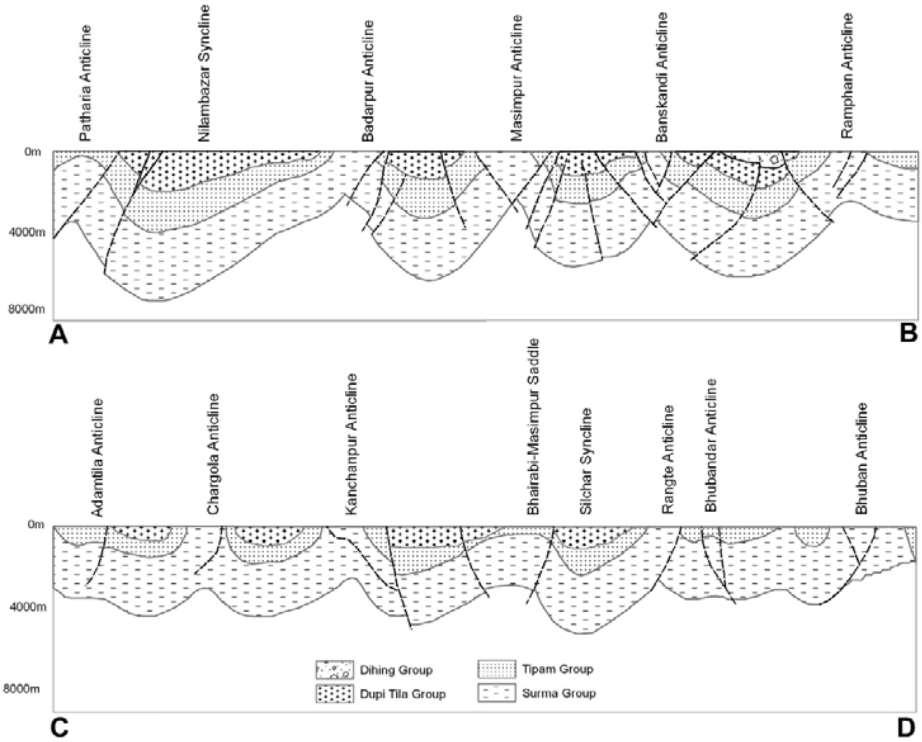

Fig.3. Geological cross-sections across Barak valley (*after* Seshavataram et al. 1998)

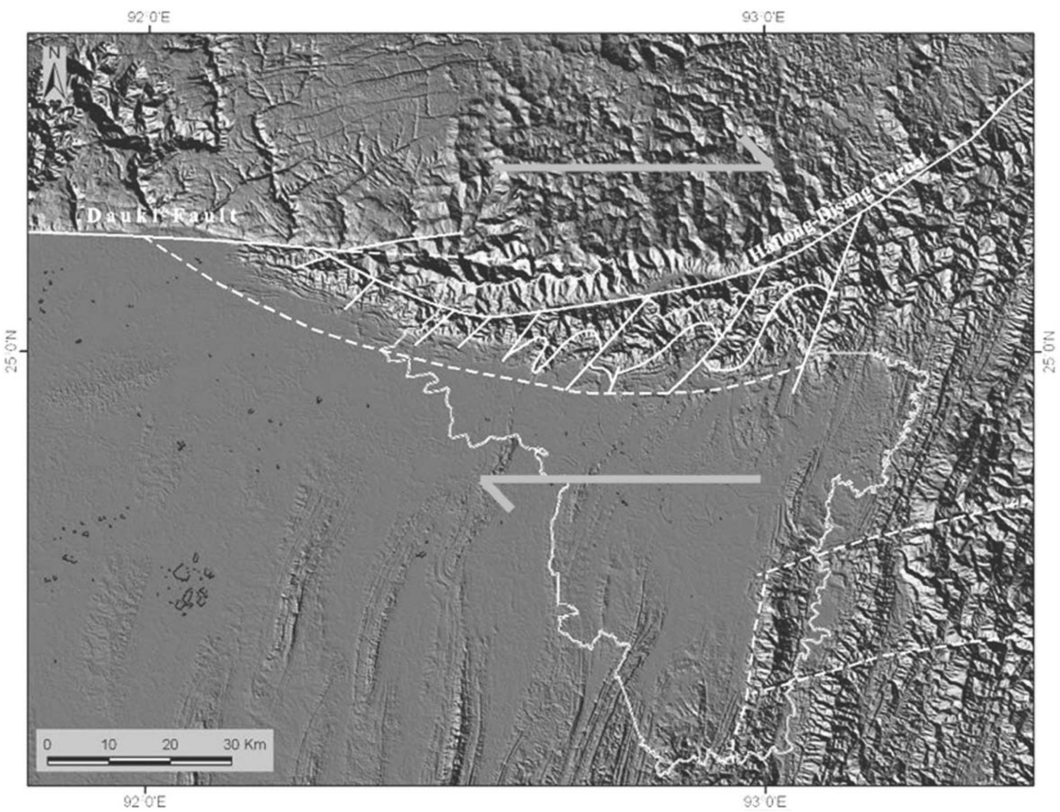

Fig.4. Overlay of Dauki Fault and Haflong-Disang Thrust and related fault positions on SRTM DEM indicating the formation of contractional strike-slip duplex structure.

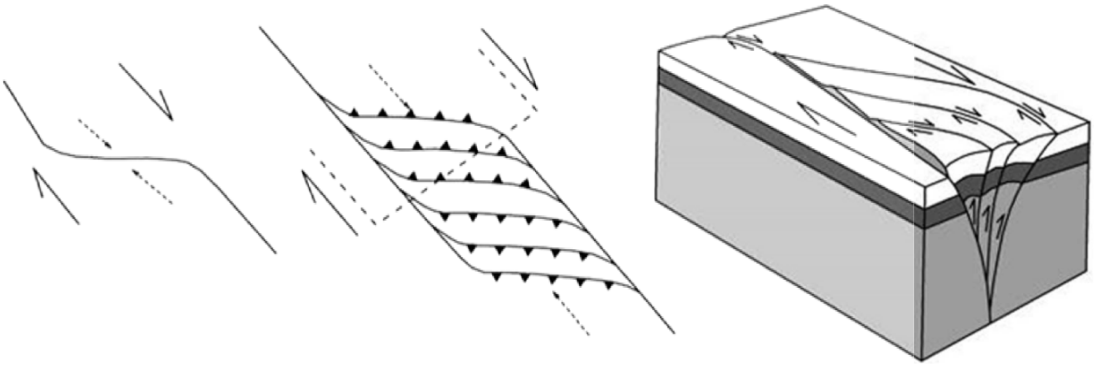

Fig.5. Formation of contractional strike-slip duplex as given by Twiss and Moores (1992).

features, which are formed as a result of folding of the Neogene sedimentary strata. The anticlines give definite geomorphic expression as structural hills characterised by well-defined bedding trend dissected to various degrees by erosional processes forming the most conspicuous land form features in the study area. The hill ranges are mainly composed of sandstones and intervening shale beds belonging to Barail Group of Oligocene age and Surma Group of Miocene age. Present day morphological expression of this hill range is found as structural hills occupying the highest topographic levels. The prominent structural hills of the study area are Barail, Bhuban, Bhairabi, Badarpur, Chatachura etc.

The anticlinal hills have been subjected to differential erosion into various litho-structural units resulting in the development of a series of geomorphic features like linear cuesta ridges and strike valleys. The flanks of the anticlines, which are made up of a sequence of sandstone and shales belonging to Bhuban, Bokabil, Tipam and Dupi Tila depict narrow linear ridges and intervening valleys. They are well discernible on satellite images as well as in DEM (Digital Elevation Model) (Fig.6). Sandstone beds usually develop into cuesta ridges in trend with general strike and having asymmetric topographic profile with a steper erosional limb and a gentler limb representing dip of the original bedding planes, while strike valleys are commonly developed due to higher degree of erosion of the argillaceous lithounits in between cuesta ridges.

Denudational hills are the remnants of the structural hills and linear ridges. These forms have lowered topographic surface than the original surface. The imprints of structural disposition are usually blurred due to erosion. However, on a regional scale they form definite pattern and on reconstruction found to be part of erstwhile structural hills. They are more common in areas composed of Tipam and Dupi Tila Group of rocks (Fig.7).

In the northern part along the foothills of Barail range some isolated patches of terrace gravels are identified (Fig.8). The gravels are massive, well rounded and poorly sorted with little matrix support. By and large the

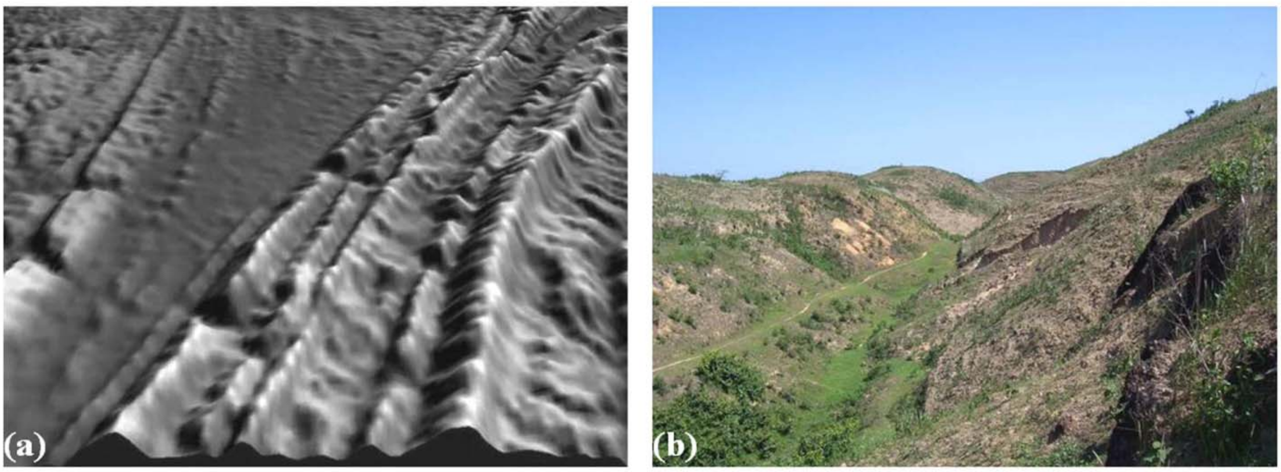

Fig.6. Linear ridge and strike valley developed as a result of differential erosion of the alternating sand-shale sequence. (**a**) 3-d perspective in SRTM DEM and (**b**) the same feature as observed in the field.

Fig.7. Erosional dissection of the linear ridges has led to the development of a series of denudational hills (**a**). Further erosion led to the development of isolated hillocks having low altitude (**b**)

composition of the clasts is grey to brown coloured sandstone. At a few places three levels of terraces are observed, which are separated by scarp faces of up to 10 m.

Broad alluvial plains have developed along the synclinal troughs between consecutive anticlines and also along eroded valleys in between cuesta ridges. Numerous static water bodies, genetically linked either to fluvial action or tectonics, are found dotting the alluvial plain. A unique type of water body found in the area and locally called *Haor* contain water for three to four months during the rainy

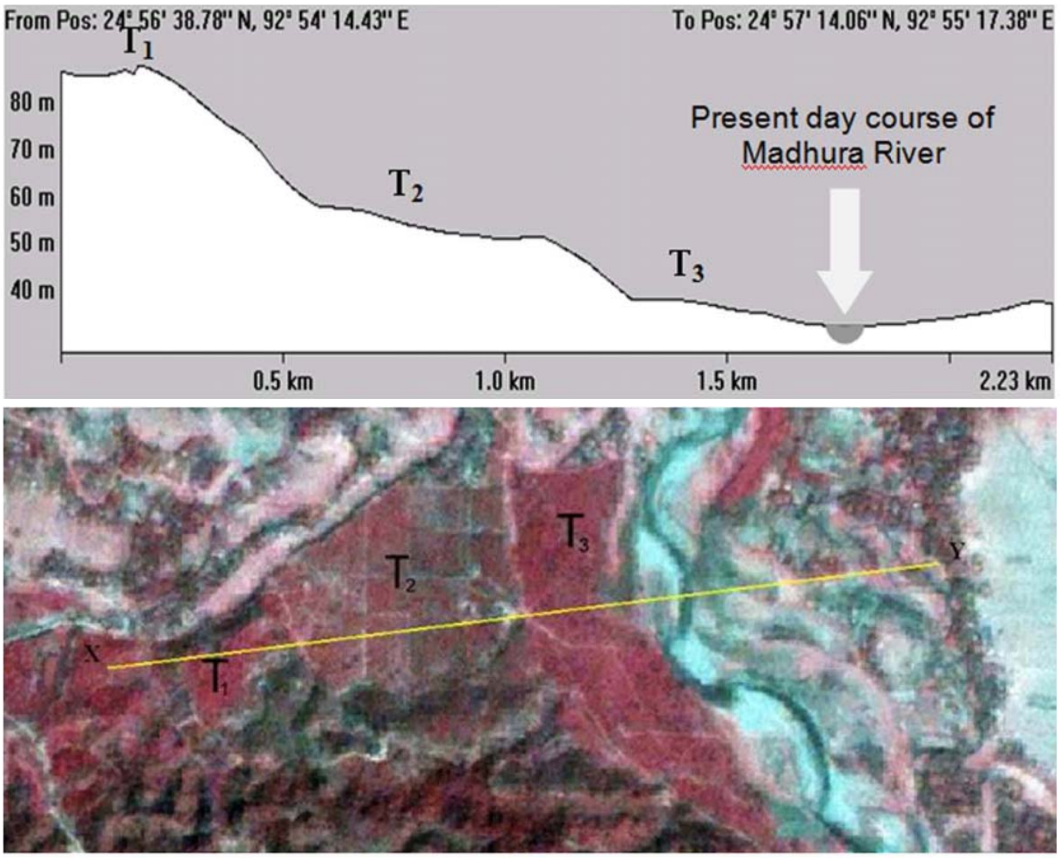

Fig.8. (**a**) Topographic profile showing three levels of terraces developed along the Barail foothill region by Madhura River. (**b**) Line of the profile overlaid on the satellite imagery.

season and remains almost dry during rest of the year. They are fen or swamp not directly fed by any river system. When the water levels in the rivers rise above the fen, the muddy water with heavy silt swell the marshes into wide lake and when the rivers recede, water from the fen drain out. The muddy water deposits silt raising the fen bed.

Active floodplains occupy the lowermost topographic position about 20 m above mean sea level (amsl), which have very low gradient. They are subjected to frequent flood inundation, fluvial depositional processes and are characterized by a host of minor landform features viz., ox-bow lake, natural levee, back swamp, ridge and swale, sediment bar, etc. Although small N-S trending flood plains have developed along most of the tributaries, the E-W trending Barak river floodplain is the most prominent one. The Barak River and its tributaries are predominantly meandering in their planform and have developed narrow, elongated flood plains, which, are often restricted by bedrock exposures. In other cases the floodplain development is restricted due to overall lithotectonic control.

DISCUSSION

Landscape evolution in Barak valley is strongly influenced by the structural and tectonic set up of the foreland fold belt and linked to tectono-sedimen-tary history of the accretionary basin. The first order topography of anticlinal hills and synclinal valleys are formed as a direct consequence of folding of the sedimentary strata composed of alternative arenaceous and argillaceous beds. Differential erosion of the sand-shale sequence of these anticlinal hills has led to the development of cuesta ridges and strike valleys. More resistant arenaceous formations form the ridges, while easily erodible argillaceous sequences form the strike valleys in between the ridges (Simms, 2004). Further, dissection of these ridges has led to the development of individual low lying mounds locally known as 'tila'.

Formation of different levels of terraces can be accounted with Post-Dihing tectonic activities along Haflong-Disang thrust. Although some other factors such as change in the base level, change in climate etc. might play a role in the formation of different levels of the terraces, tectonic uplift plausibly played a major role in the formation of these terraces. Their occurrence in the north bank along a linear belt indicates tectonic uplift along that zone which has resulted in the change of the bed level of the existing rivers. The poorly sorted, grain supported, massive gravels represent huge sediment flux from the nearby hills more as a mass flow, rather than by fluvial processes. Further, a few of the larger patches show clear southward slopes, which indicates that these are remnants of alluvial fan formed along the active zone. These alluvial fans may have formed during or after the deformation of the Dihing beds.

Most of the major tributaries flow along the synclinal valleys and join the trunk channel orthogonally (Fig.9). The planform morphology and spatio-temporal variability of Barak river is modulated by the sporadic exposure of bed-rock. Many small segments of these rivers including the Barak, at places flow along fault trace as indicated by their straight courses. Drainage development of the area is also structurally controlled and more than half of the area is covered by either trellis or sub-dendritic pattern.

Plots of longitudinal profile on a simple logarithmic scale of Chiri, Madhura, Dalu and Jatinga, which, originate from Barail range in the north, show convex upward nature (Fig.10) with average gradient indices of 299, 386, 414 and 129 gradient-meter respectively, while the profiles of other streams show variation in index from source to mouth with average SL index within 50 gradient-meter with exception of Rukni river which has its source in the Lusai Hills of

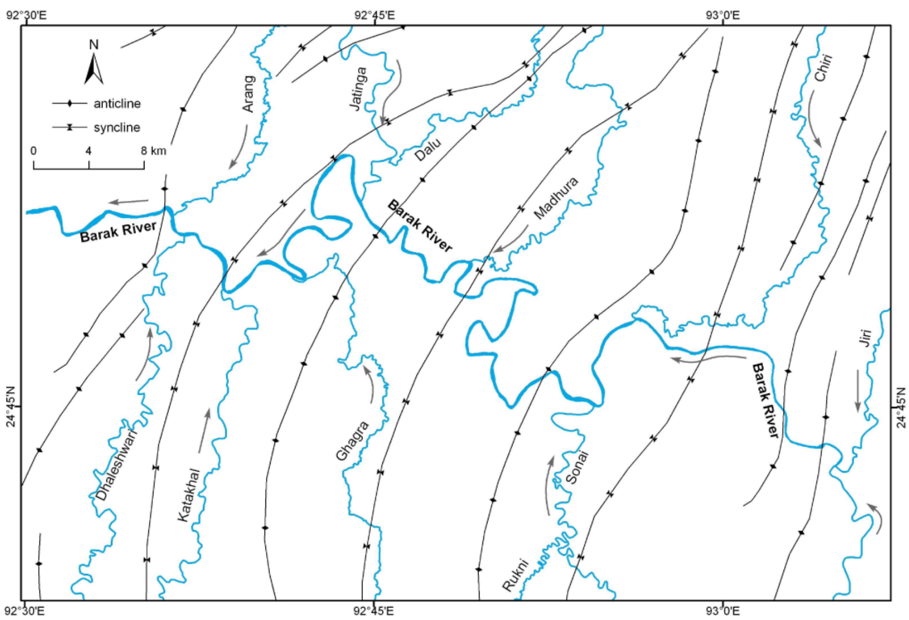

Fig.9. Spatial arrangement of Barak River and its major tributaries. The tributaries flowing along synclinal valleys join orthogonally from both north and south to the westerly flowing Barak River

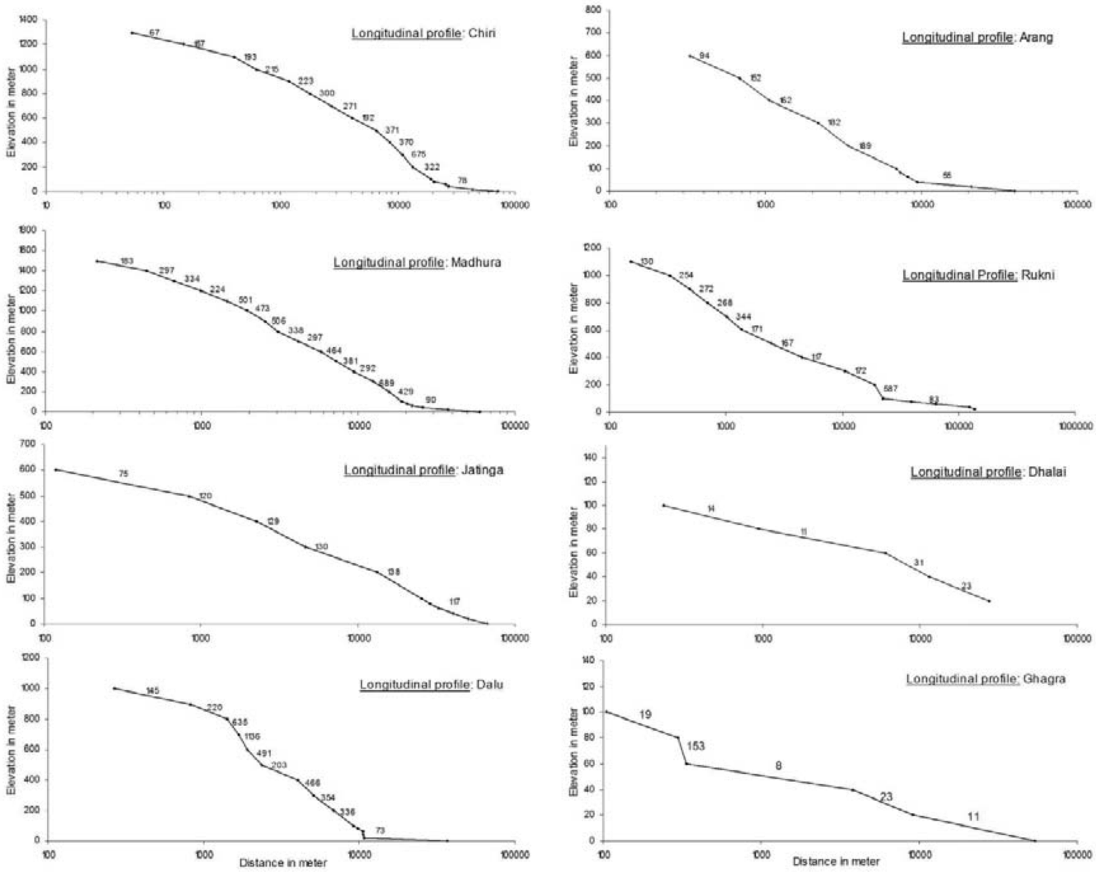

Fig.10. Longitudinal profiles (Keller and Pinter, 1996) of the rivers of northern part (Chiri, Madhura, Jatinga and Dalu) show convex upward nature with high SL Index indicating rapid uplift in the source area while others (Arang, Rukni, Dhalai and Ghagra) show variation from source to mouth.

Mizoram. Plots of SL index for northern part show a distinct anomaly around Haflong-Disang Thrust indicating prevalence of active tectonics along this zone. This suggests differential uplift of the region with more rapid upliftment in the north than in the south.

The vast alluvial plain and intermontane valleys are dotted with numerous static water bodies of different dimensions. Many of these are formed as a result of blockage of drainage due to post-Neogene tectonics. The blocked drainage forming large linear wetlands along some of the strike valleys is also suggestive of continued neotectonic activities in the area. Various fluvial processes such as channel migration, bank erosion, meander bend migration etc. are directly related to the structural disposition of the region.

CONCLUSION

Barak Valley exhibits a unique structurally controlled landscape characterized by folded Neogene rocks developing into a ridge and valley terrane and a set of erosional and depositional landform superimposed on it. Landscape development in the area shows the distinct imprints of lithological and tectonic control. Late Quarternary surface geomorphic processes carved out and modified a predominantly first order topography with anticlinal hills and synclinal valleys. Formation of three levels of terraces in the northern part indicates Post-Dihing tectonic activity along Haflong-Disang Thrust resulting change in the bed level of the existing rivers. Most of the rivers are of consequent type, flowing along synclinal trend, while the Barak river that forms the trunk drainage follows a transverse trend. Continued neotectonic activity has also resulted in the formation of large linear wetlands in some of the strike valleys by blockage of drainage.

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