Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 10, pp.21954-21961, October, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ACTIVE TECTONICS ALONG THE FRONTAL PART OF HFT, IN AND AROUND PASIGHAT, EAST SIANG DISTRICT, ARUNACHAL PRADESH

***Manash Protim Baruah and Devojit Bezbaruah**

Department of Applied Geology, Dibrugarh University- 786004, Assam, India

ARTICLE INFO

Article History:
Received 10th July, 2015
Received in revised form
29th August, 2015
Accepted 15th September, 2015
Published online 31st October, 2015

Key words:
Pasighat, Terrace,
Warping,
Earthquake.

ABSTRACT

The study area in and around Pasighat is bounded between two major collision originated orogenies, NE-SW trending Himalayan orogene and NW-SE trending Mishimi Hills. Evidence such as discontinuous mountain front, different levels of terrace in the rivers, presence of number of cross-faults implies that the whole area is in transient state and active tectonics is modifying the geomorphology of the area. In the present study, mapping of the terraces present in the frontal part of the area is carried out and different level of terraces area marked. By observing the local gradient of each level and compared with that of the present river bed, it is inferred that most of the terraces undergoes considerable degree of warping and post depositional tilting has occurred in those particular locality. Further, occurrence of earthquakes having magnitude > M5 in the vicinity of the crossfaults also testify the activeness of the region.

Citation: Manash Protim Baruah and Dr. Devojit Bezbaruah, 2015. "Active tectonics along the frontal part of HFT, in and around Pasighat, East Siang District, Arunachal Pradesh", *International Journal of Current Research*, 7, (10), 21954-21961.

INTRODUCTION

The Himalayas results from Indian–Eurasian collision are the highest, youngest and one of the most tectonically active regions of the world. Himalayan rocks are subjected to progressively increasing compression due to continued convergence of India with mainland Asia. The fault that demarcates the boundary of the Himalaya and the alluvial expanse of the Brahmaputra Plains is the youngest of the faults of the Himalayan province. It was first recognized and named Himalayan Frontal Fault (HFF) by Nakata (1972) in southern limit of Dehradun domain. The HFF had originated in the later Pleistocene between 1.5 and 1.7 Ma when the foreland basin in front of the emergent Himalaya was intensely compressed, resulting in its breaking up into the rising hilly Siwalik domain and the subsiding Sindhu-Ganga-Brahmaputra depression (Valdiya, 1998). This boundary fault of tremendous importance that remained undetected (and untraced) until quite recent, has been describe by different names by different workers- as Foothill Fault by Karunakaran and Ranga Rao (1979), and Thakur (1993); as Main Frontal Thrust by Gansser (1991) and as Himalayan Foothill Boundary by Raiverman *et al*.,(1993). Presently the HFT is the most active among the three major Himalayan thrusts (Thakur, 2004). For this reason it has attracted the attention of geomorphologists for several decades.

**Corresponding author: Manash Protim Baruah*
Department of Applied Geology, Dibrugarh University- 786004, Assam, India

Ongoing tectonic activity is well indicated by prominent tectonically controlled geomorphic indicators (Malik *et al*., 2007). Although numerous studies in the Himalayan domain have recorded geomorphic expressions like displaced and warped late Pleistocene and Holocene surfaces along active faults in the frontal zone (Nakata, 1989; Valdiya *et al*., 1984; Valdiya, 1992; Yeats *et al*., 1992; Wesnousky *et al*., 1999; Lave´ and Avouac, 2000; Kumar *et al*., 2001; Malik and Nakata, 2003; Malik *et al*., 2003). The compressional Himalayan regime is responsible for strain build up continually and hence three major thrust MCT, MBT and HFT are associated with large seismicity.

The location of the studied area is confined to Pasighat, the headquarters of East Siang district in the Indian state of Arunachal Pradesh bounded between 27º 43' and 29º20' North latitudes and 94º 42' and 95º 35' East latitudes (Fig. 1). Detail geological mapping, terrace and lineament analysis are done in order to assess the active tectonics and their role in the late Pleistocene-Holocene river terrace development of the area. The area is sandwich between two major collision originated orogenies i.e. NE-SW trending Orogeny in the extreme eastern Himalayan and NW-SE trending Mishimi Hills. The active tectonics in the region is evident by warping of river terrace, orientation of lineaments in the area, steep scarps towards the northern part of Ruksing and Miram village and other ground evidence.

Regional setting of the study area

The Himalaya can be divided into four geographic belts, from south to north: sub-Himalaya, Lower/Lesser Himalaya, Higher/Greater Himalaya and Tethyan Himalaya (Gansser, 1964; LeFort, 1975). These belts are comprised of Paleoproterozoic to Cenozoic rocks, with the latter occurring mainly in the sub-Himalaya. 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 lithotectonc succession of the area is given in the Table 1.

intensely deformed and are dissected by number of thrusts and cross faults. The Himalayan Frontal Fault- 2 (HFF-2) thrusted High level terrace deposits over the Recent Alluvium of the Brahmaputra plain while Siwalik Group of rock of Mio-Pliocene override High Level Terrace Deposit along HFF-1. Four NW-SE trending strike slip faults Viz. Siba Fault, Siang Fault, Miku Korang Fault and Sileng Fault cut HFF-1, HFF-2 and MBT which are shown in the geological map of the area (Fig. 2).

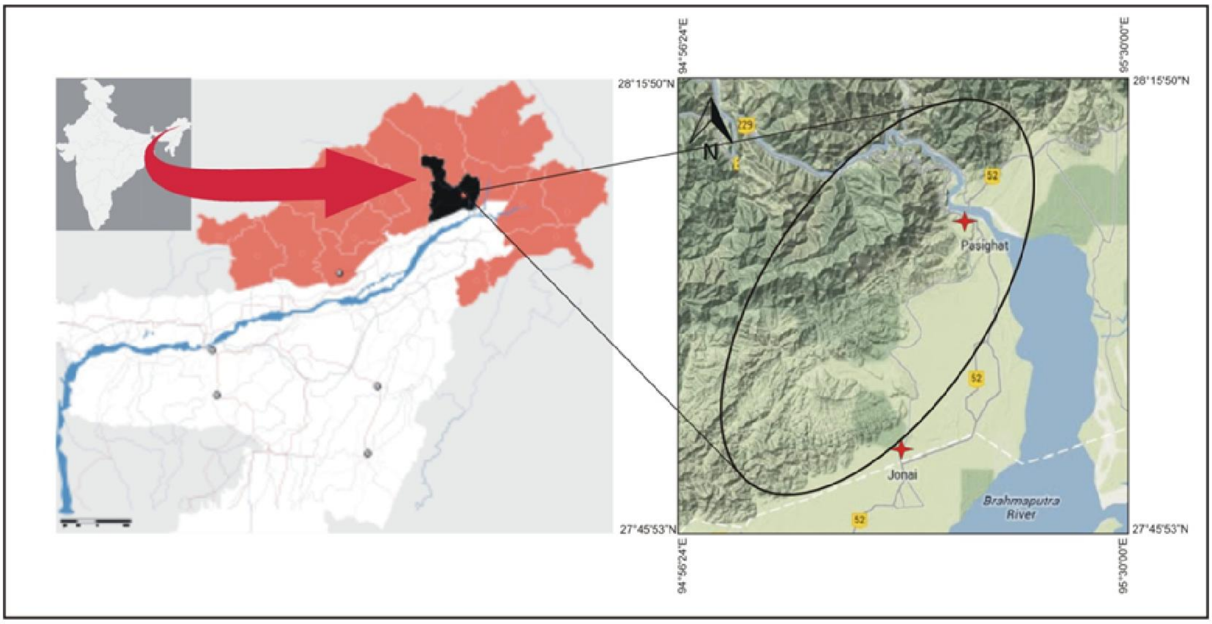

Fig 1. Location map of the study area

Table 1. The Lithotectonic succession of the study area

Age	Lithotype
Recent to Sub-Recent	Alluvium and River terraces
Plio-Pleistocene	Kimin Formation: Soft sandstones, silty shale, sand silt, gravels and conglomerates, etc.
Middle to Upper Miocene	Subansiri Formation: Coarse to medium grained, massive to poorly bedded, pebbly micaceous soft friable sandstone.
Middle to Lower Miocene	Dafla Formation: Fine to medium grained silty sandstone, shales, claystones, mudstones and carbonaceous shales.
Eocene	Yingkiong Group: Shale, limestone, marl and sandstone which are intruded by basic rock.

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 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 the 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 is associated with different basic intrusive rocks. Apart from these major litho unit, towards North of HFT, older alluvium comprises of river terraces are exposed which are bounded by sub thrust of the Fronal Fault. Further North recent alluvial sediments of the Brahmaputra plains are present. These Eocene and Siwalik groups of rocks are

MATERIAL AND METHODS

Adjustment of the landforms with the tectonic activity can be evaluated by warping of terrace and lineament analysis. The geomorphic responses to the tectonic activity can be substantiated by detail geological mapping of folds, faults and presence of different levels of river terraces. Satellite images from Google Earth are used to understand the nature of the terrain of the area of interest. Latitude and 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 Survey of India of 1:50,000 scale, SRTM data and satellite imageries downloaded from Google Earth have been used. For this mapping spherical geographical co ordinates along the edge of the terraces is taken with the help of hand GPS. These points are jointed to mark the boundaries of individual terraces.

In the present study the whole area is divided into six blocks viz Dikari River and Leku stream near Jonai town (AA'), Rime stream and Mike stream near Miram village (BB'), Miku stream and Siang River near pasighat (CC'), Siang River and Siku stream (DD') (Fig:3) which are separated by cross fault that dissected the mountain front and block on right and left bank of Siang River separated by Siang Fault. All the lineaments are marked using Survey of India (SOI) toposheet having scale 1:50,000 and lineament study is done in all these segments separately (Fig 5). Orientation of the lineaments is usually analyzed by Rose Diagrams which is prepared using Rozetta software. To verify the recent activities along the HFT in the study area past earthquake events that occur in the area are collected from United State Geological Survey (USGS), Earthquake Hazard Program as secondary data and are superimposed in our present context.

Mapping of terraces and their degree of warping

Terrace surfaces are formed as river flood plains. Because they are in equilibrium when formed, terraces have graded longitudinal profile unless they have been subsequently deformed. Deformation will alter the profile of the terraces compared with the longitudinal profile of the modern channel. The shape of deformed terraces reveals the character of deformation. An assumption implicit in this comparison is that the original terrace profile was same as the profile of the modern channel. Changes in sediment load; discharge or bedrock substrate strength may invalidate this assumption. Climatically or lithologically controlled variations in profile are unlikely to progress systematically through time, although they may do in certain situations (Keller and Pinter, 1969).

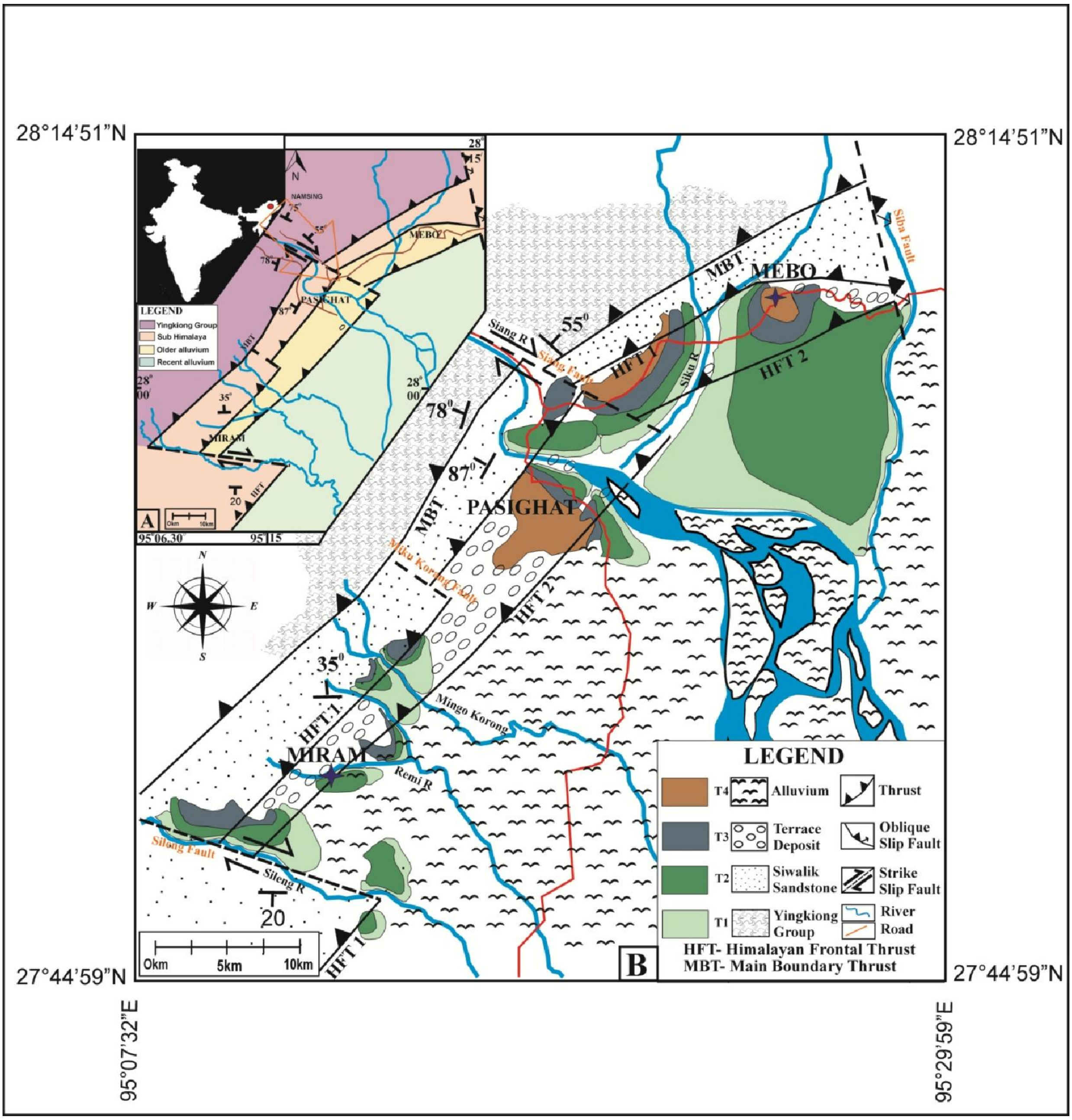

Fig. 2. A) Regional Geological map of Pasighat Area showing major lithotectonic unit of Himalaya. B) Tectonic and lithologic map of the study area between Main Boundary Thrust and Himalayan Frontal Thrust showing different level of terraces and intervening thrust

Therefore, attempt have been made to study the deformation of the terrace present in the area by comparing longitudinal profile of the terrace with the longitudinal profile of the modern channel.

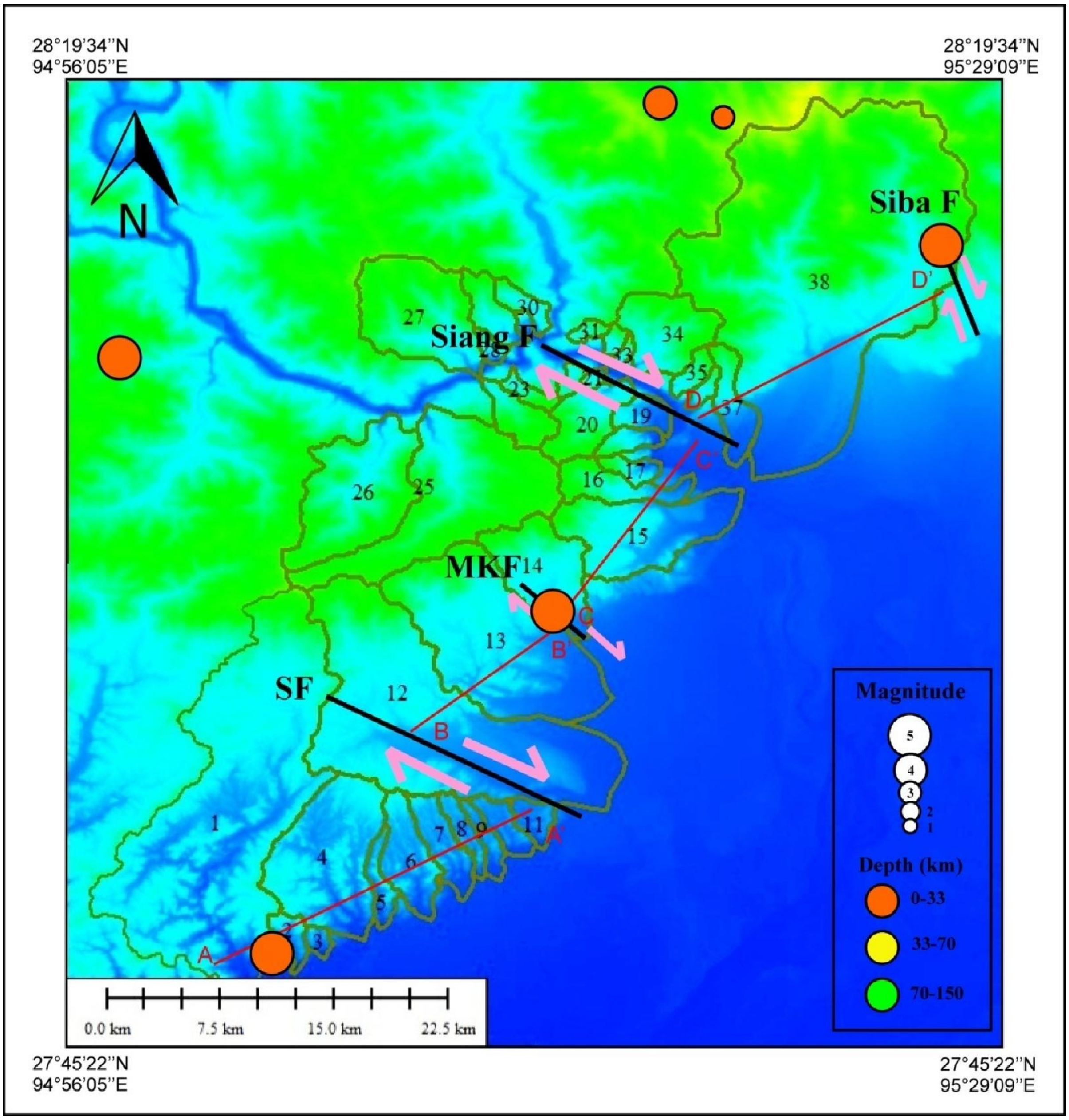

Fig. 3. Topographical map of the study area showing 38 river basins, location of the cross faults (SF- Seling Fault, MKF- Mingo Korong Fault, Siang Fault and Siba Fault), the segments (AA', BB', CC' &DD') and also the location of the epicenter of the earthquake events (sources from USGS, Earthquake Hazard Program) that had occurred in the study area till date

In the area 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 T1, T2, T3… respectively in the increasing order of their elevation from the present level of active flood plain (T0) (Fig. 2B). Five levels of river terraces are present in the area. The degree of warping of terrace is mainly determined by taking elevation data from SRTM maps. Here the elevation of different levels of terraces and its corresponding nearest value of elevation of the active river channel is recorded for a fixed distance and is plotted. In the Excel worksheet the elevation of terraces and the active river channel is plotted along Y-axis and the distance along which these elevations are obtained is plotted on X-axis. The graph so obtained gives the picture of warping of different level of terrace from the present course of the river profile (Fig. 4).

Lineament Analysis

Tectonically active regions show higher intensities of lineaments than tectonically quiet zones. According to (Cracknell *et al*., 1993), "Lineaments are the terrain surface expression of fractures, jointing and other linear geological phenomena that occur anywhere from the terrain surface down to possibly great depths." Not only the lineaments can be tectonic features such as faults, folds, joints and fractures, but they can also be other natural features, such as steep to vertical strata, rivers, vegetation and some cultural features such as roads and boundaries between areas of different agricultural use. Analyses of lineaments in an area where exposures are poor and covered by thick vegetation typically can provide indications of tectonic activities.

segments (AA', BB', CC' and DD') which are separated by cross faults as delineated earlier Fig. (5). The aim of the study is to understand the tectonic regime and structural geomorphic responses that have influenced the present day geological set up of the area. Orientation of the lineaments is usually analyzed by Rose Diagrams. These diagrams display frequency of lineaments for regular intervals. Different lineament density plots or Rose Diagrams using Rozetta Softwere is prepared for all the four segments. Fig. (6)

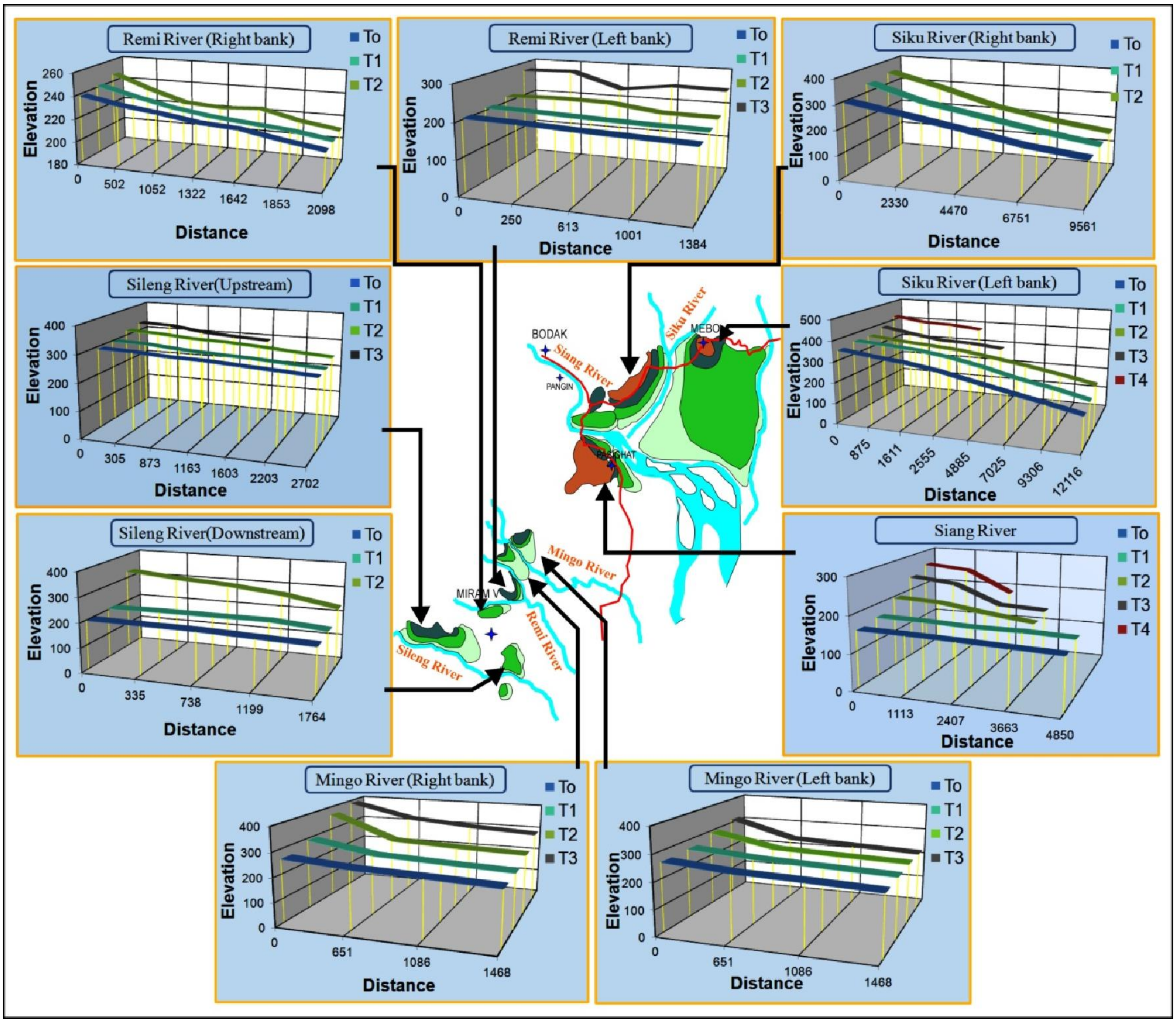

Fig 4. Different level of terraces and their degree of warping from the present river bed. Moving clockwise from Sileng River (Downstream), successive terrace profiles are Sileng R (Upstream), Remi R (Right Bank), Remi R (Left Bank), Siku R (Right Bank), Siku R (Left Bank), Siang River, Mingo R (Left Bank) and Mingo R (Right Bank)

These surface characteristics are often influenced by structural features, such as folds, faults, and joints. The surface features making up a lineament may be geomorphological, i.e. caused by relief. Straight stream valleys and aligned segments of a valley are typical geomorphological expressions of lineaments. Together with a detailed structural analysis and understanding of the tectonic evolution of a given area it provides useful information for geological mapping and understanding of groundwater flow and occurrence in fractured rocks (Aaro, 1960, Hung *et al*., 2005, Anudu *et al*., 2011). In the present study, Lineament study is done separately in all the four

Earthquake epicenter plot of the area

The past earthquake data collected from the USGS databank is plotted in our existing tectonic map showing location of the identified cross faults Fig (3). Three of the six events having magnitude M>5 occur along the HFT. Out of this three event two are directly coincide with the present location of the two cross faults present viz Mingo Korong Fault (MKF) and Siba Fault. The earthquake along MKF having M5.6 occurred in 22-08-1956 at 19:40:18 UTC having Location of the epicenter 27.974ºN & 95.211º E and depth of Focus at 15 km. The next event that occurs along the Siba Fault having 5.5M occurred in 16-10-1950 at 15:42:35 UTC is located 28.220ºN and 95.457ºE occurred at a depth of 25 km. indicates that there has been tilting of the terraces after its deposition. The movement along Sileng fault might have deformed terraces present in that area.

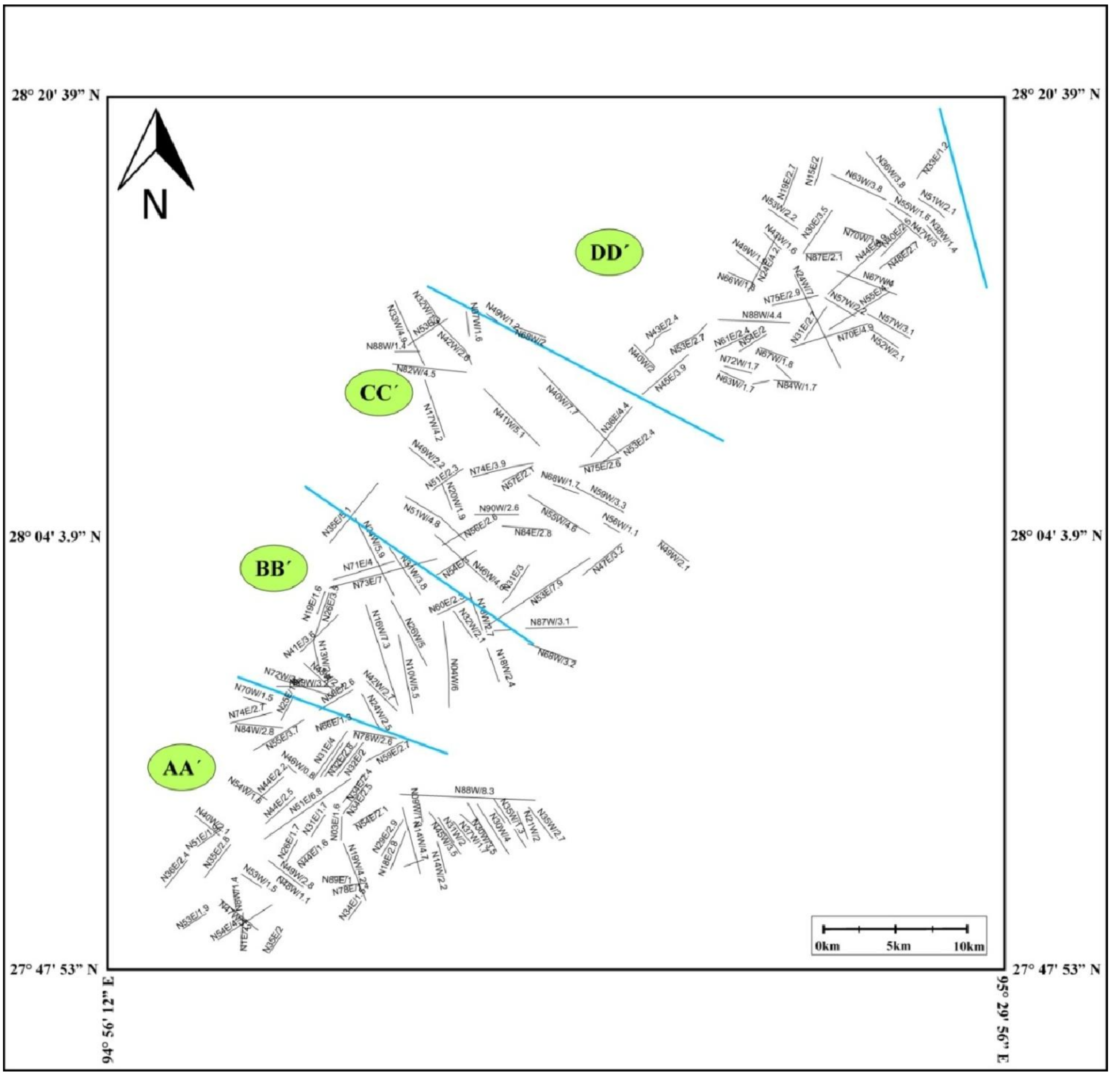

Fig. 5. Photo interpreted Lineament map of Pasighat Area, East Siang District, Arunacal Pradesh

The last event along the HFT is of M 5.1 in the date of 1982-11-26 13:26:29 UTC and having depth of the focus at 33 km. Apart from these major events the study area also witnessed no of earthquake in the upper reaches via M5.7 1950-08-16 16:36:01 UTC, M 3.7 in 2001-11-27 13:47:04 UTC and M 4.1 in 2008-06-13 11:16:04 UTC. The locations of all these events are shown in the Fig. (3) in accordance of their magnitude and depth of occurrences.

RESULT AND DISCUSSION

Warping of Terraces

The profiles of all the three level terraces present in the upstream of the Sileng River, near to the mountain front are parallel. This indicates that the area has been uplifted but no deformation has occurred in the terrace after its deposition. In the terraces present in the downstream, it has been observed that the slope of T2 terrace is more than that of T0. This

Terraces present in both bank of the Remi river show considerable amount of warping. In the right bank, the slope of T2 is more than that of T1 and T0. On the other hand, in the left bank, slope of T2 and T3 is more than that of T1 and T0. This unpaired terraces indicate that the whole area have been uplifted and been tilted after deposition of these terraces. In the bank of Mingo River three levels of unpaired terraces are present. The terraces T2 and T3 of both the bank are deformed near to the mountain front but terrace T1 is more or less parallel to the river bed. Therefore, it can be inferred that the area was deformed before deposition of T1 level of terrace. In the left bank of Siku River five levels of terraces are present while in the right bank three levels of terraces are present. T4, T3 and T2 level of terraces are deformed in the left bank. In the right bank both T1 and T2 are deformed.

The terraces of Siang River in the Pasighat area shows considerable amount of warping. By observing the slope of different level of terraces, it is cleared that the terrace T4 shows greatest degree of warping followed by T3 and T2. The slope of lower level terrace T1 is more or less parallel to the river bed. This indicates that the whole area was uplifted and deformation episode might take place after the deposition of T4, T3 & T2. Therefore, study of warping of terrace present in the area indicates that there was a deformation prior to the deposition of T1 level of terrace.

In the block BB' majority of the lineament shows SSW-NNW trend and some lineaments aligned in the NE-SW direction. This change of the major trend from NE-SW to SSE- NNW might be due to the presence of the cross faults at both the edge of the segment BB'. The relative movement of the cross faults might drag the lineaments from SE-NW direction to SSE-NNW.

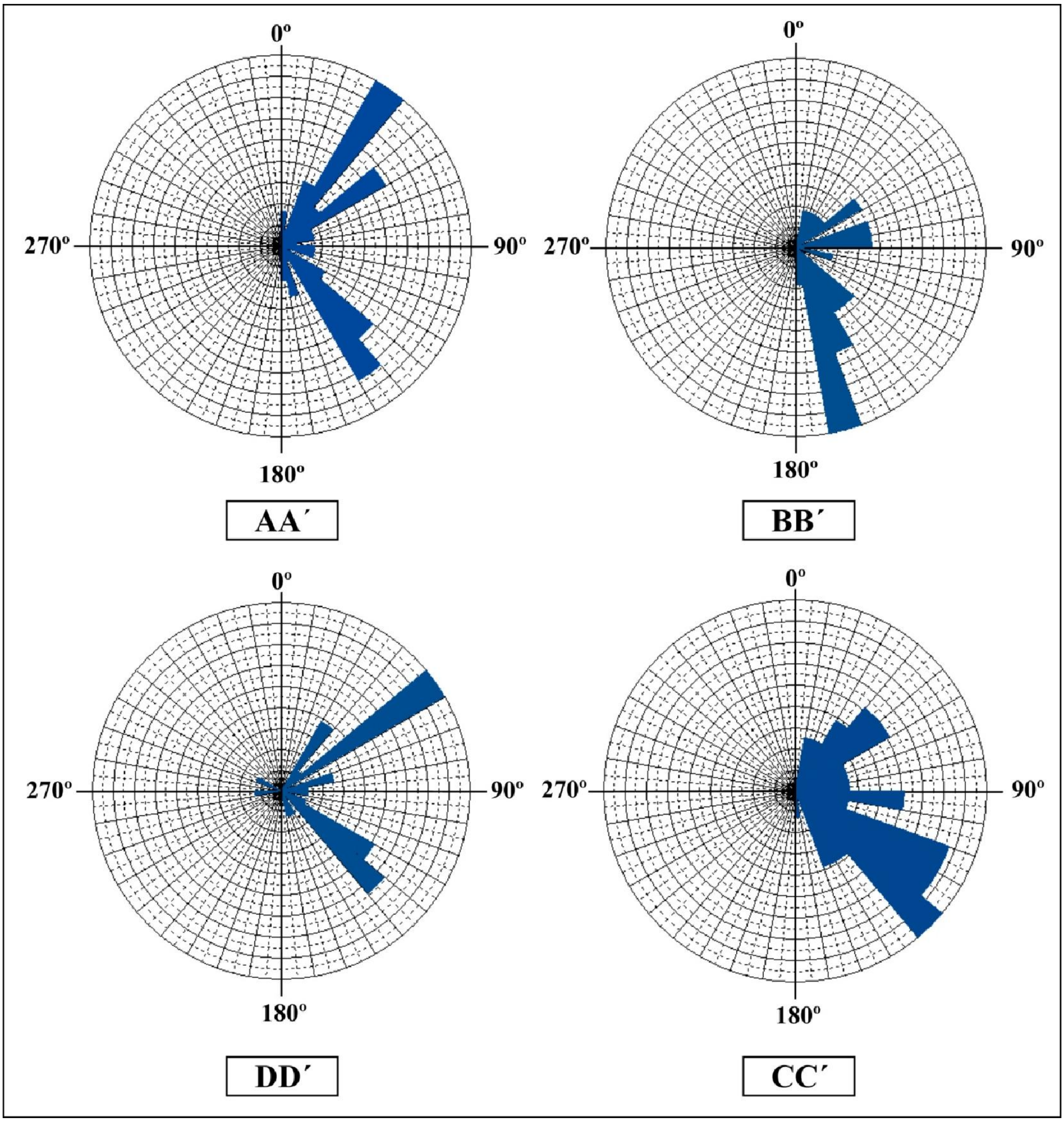

Fig. 6. Different lineament density plots or Rose diagrams for segments AA´, BB´, CC´ and DD´

Lineament Analysis

It has been observed that there is variation in trends of lineaments in four blocks which are separated by strike slip faults. The dominant trend of the lineament in the block AA' is towards NE-SW direction, which is parallel to the HFT and MBT. Some of the lineaments have SE-NW trend which are parallel to strike slip faults those dissected the mountain front.

The segment CC', lies between the Siang Fault and the Miku fault, the dominant trend of the lineaments is parallel to the HFT & MBT i.e, towards NE-SW direction. Some lineaments in the area shows SE-NW trend which is parallel to the Siang fault. In the block DD', which lies between the Siang fault and the Siba fault, majority of the lineament shows NW-SE trend. Thus the relative movement between this Siang and Siba fault may lead to the dominance of the trends towards NW-SE direction. Some of lineaments are showing NE-SW trend. Therefore, trend of lineaments in the area is governed by similar tectonic processes which give rise to major thrusts and strike slip faults of the area. Again the results inferred from the past earthquake epicenter plot of the area strongly suggests the higher activity along the frontal fault (HFT) till last 60 to 100 years back.

Conclusion

The ongoing tectonic deformation in the study area has resulted in the southward propagation of various branching faults like MCT and MBT. The HFT is one of the most prominent branching fault of MBT. Further movement along the Frontal Fault leads to the deformation of siwalik sediments and were thrusted over recent alluvium. This episode involved the activation of another fault which branched out of HFT-1 and named as HFT-2, (Fig.2.B). Further, the mountain front in the study area is dissected by number of strike slip fault. These may probably developed due to difference in resistance for thrust movement in the frontal part. These Strike-Slip faults displaced HFT-2, which indicate that the age of the Strike Slip fault is late Pliestocene to post Pliestocene (Fig.2.B). Hence it can be concluded that The Himalayan Mountain Front could be in a state of expanding southward.

The manifestations of the active tectonics are warping of river terraces present in the study area. Here post depositional upliftment affects prior to the deposition of next lower level terraces as shown by the degree of warping of higher level terraces present in the Sileng, Remi, Mingo, Siang and Siku Rivers. Study of warping of terrace present in the area indicates that there was a deformation prior to the deposition of T1 level of terrace. In the study area, correlation of the various lineament density indices map prepared reveals that the area is tectonically controlled and most of the geomorphic lineament may be the resultant of tectonics. The presence of cross faults in the study area, affects the alignment of the lineaments, which is inferred from the rose diagram of Lineament. Again relative movement between Sileng and Miku Korong cross faults, drag the lineaments from SE-NW direction (in segment AA′) to SSE-NNW direction (in segment BB′) (Fig.6). Therefore there have to be some oblique movement between these two cross faults in the area. The relative movement between the cross fault can also be inferred from the warping of the river terraces present nearby.

REFERENCE

Aaro, E. A., 1960. Graphical Statistical Analysis of Fracture patterns in rock encountered in engineering projects, *Bulletin of the Geological Society of America*, 71: 1719-1720.

Anudu, G. K., Essien, B. I., Onuba, L. N. and Ikpokonte, A. E. 2011. Lineament analysis and interpretation for assessment of groundwater potential of Wamba and adjoining areas, Nasarawa state, Northcentral Nigeria, *Journal of Applied Technology in Environmental Sanitation*, 1B 185-198.

Cracknell A. and Hayes, L., 1993/ Introduction to Remote Sensing, Taylor & Francis.

Keller, E. A. and Pinter, N., 1969. Active Tectonics, Prentice-Hall, Upper Saddle River, 338 pp.

Gansser, A. 1991. Facts and theories on the Himalaya. Ecol. Geol. Hel., 84: 33-59.

Hung, L.Q., Batelaan, O. and Desmedt, F., 2005: Lineament extraction and analysis, comparison of Landsat ETM and ASTER imagery. Case study: Suoimuoi Tropical Karst catchment, Vietnam. (Remote Sensing for Environmental Monitoring, GIS Applications, and Geology V, edited by Manfred Ehlers, Ulrich Michel, Proc. of SPIE Vol. 5983, 59830T, (2005) 0277-786X/05/$15· doi:10.1117/12. 627699).

Karunakaran C. and Ranga Rao, A., 1979. Status of exploration for hydrocarbon: The Himalayan region. Misc. Publ. Geol. Surv. India, 41: 1-66.

Láve, J., Avouac, J.P., 2000. Active folding of fluvial terraces across the Siwalik Hills, Himalayas of central Nepal. *Journal of Geophysical Research* 105, 5735–5770.

Le Fort, P., Himalayas: 1975. The collided range. Present knowledge of the continental arc, *Am. J. Sci*., 275A, 1-44.

Malik, J. N. and Mohanty, N., 2007. Active tectonic influence on the evolution of drainage and landscape: Geomorphic signatures from frontal and hinterland areas along the Northwestern Himalaya, India. *Journal of Asian Earth Sciences,* 29, 604–618.

Malik, J.N. and Nakata, T., 2003. Active faults and related late Quaternary deformation along the NW Himalaya Frontal Zone, India. *Annals of Geophysics*, 46 (5): 917-936.

Nakata, T., 1989. Active faults of the Himalaya of India and Nepal, *Spec. Pap. Geol. Soc. Am*., 232: 243-264.

Nakata, T., 1972. Geomorphic History and Crustal Movements of the Himalayas. Institute of Geography, Tohuku Univiversity, Sendai, Japan, 77p.

Raiverman, V., Srivastava, A. K. and Prasad, D. N., 1993. On the Foothill Thrust of Northwestern Himalaya, Jour. Him. Geol., 4: 237-256.

Thakur, V. C., 1993. Geology of Western Himalaya, Pergamon, Oxford, 366p.

Thakur, V. C., 2004. Active tectonics of Himalayan Frontal Thrust and seismic hazard to Ganga Plain. *Curr Sci*., 86:1554–1560.

Valdiya, K. S., 1984. Aspects of Tectonics: Focus on Southcentral Asia, Tata Mc-Graw Hill, New Delhi, 319p.

Valdiya, K. S., 1998. Dynamic Himalaya, University Press Hyderabad, 178p.

Valdiya, K. S., 1992. The Main Boundary Thrust Zone of Himalaya, India, *Ann. Tecton*., 6: 54–84.

Wesnousky, S. G., Kumar, S., Mohindra, R. and Thakur, V. C., 1999. Tectonics., 18: 967–976.

Yeats, R.S, Nakata, T., Farhan, A., Fort, M, Mirza, M.A, Pandey, M.P and Stein, R.S , 1992. The Himalayan Frontal fault system, Sp.Is., 6: 85-98.

****