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Geology and Active Tectonics of the Lalmai Hills, Bangladesh – An Overview from Chittagong Tripura Fold Belt Perspective

Md. Sharif Hossain Khan, Md. Sakawat Hossain* and Md. Azim Uddin
Department of Geological Sciences, Jahangirnagar University, Dhaka-1342, Bangladesh
E-mail: *sakawat@juniv.edu*

ABSTRACT

The Lalmai Hills is a low amplitude anticline with significant variations in landforms, situated along the western fringe of the Chittagong-Tripura Fold Belt (CTFB) and immediate east of the Indo-Burmese deformation front. This fold belt of the Bengal Basin along with more easterly Indo-Burman Range (IBR) developed as a consequence of the oblique collision between Indian and Burmese plates. This neotectonic activity is still continuing and shaping the geomorphology of the area. This study is conducted based on the geomorphological observation of the topo maps and satellite images, and through reconnaissance field work. Stream length gradient index (*SL* Index) and Mountain front sinuosity (S_{mf}) reveals the relative status of tectonic activity. Anomalous *SL* index values confirm the position of the sympathetic minor faults and also relate to the local stratigraphy. A 2D structural model based on the seismic section reveals thrusts controlled wedge-shape upliftment of the central part as pop-up anticlinal structure. The western thrust is the direct result of the collision of the Indian and Burmese plates, and the eastern one is the back thrust of the western fault. Low S_{mf} value found in the western flank signifies recent tectonics and relatively high S_{mf} value in the eastern flank indicates that weathering intensity is relatively greater compared to western flank. Finally, the findings not only enhanced the understanding of geomorphic evolution and active tectonics of the Lalmai Hills area but also the overall tectonic and geomorphic evolution of the western most folded part of the CTFB.

INTRODUCTION

The fundamental processes which have acted to shape the geomorphology of an area are the interactions between tectonic uplift, river erosion and alluvial deposition (Schumm et al., 2002). Analysis of the geomorphic features of an area, therefore, helps to infer the neotectonic activities and related processes. An attempt has been made to decipher the active tectonics of the Lalmai hills and adjacent area. The Lalmai structure popularly known as the 'Lalmai Hills' is situated along the western part of the Chittagong-Tripura Fold Belt (CTFB) (Fig. 1a). The Lalmai Hills and its adjacent area have significant variations in landforms within a very small area consisting of hillocks, piedmont plains, floodplains, paleochannels and rivers. Comilla Town, is located just east of Lalmai Hills, is one of the most prominent cities and district towns of Bangladesh with lots of infrastructures and a considerable number of inhabitants. Comilla university, Comilla Cantonment, and Bangladesh Academy for Rural Development (BARD) are situated in the middle of Lalmai Hills. According to the earthquake zonation map of Bangladesh (Hossain, 1988), Comilla is situated in Earthquake Zone II. The neotectonic activity in the area is manifested by fault scarps, strath terraces, incised streams, river shifting and a few earthquakes in the recent past.

A number of researches have been carried out on the geology (Morgan and McIntire, 1959; Khan, 1991), geomorphology (Bakr, 1977; Brammer, 2012; Islam et al., 2001), structure (Morgan and McIntire, 1959; Hossain et al., 2001; Islam et al., 2001), stratigraphy (Hossain et al., 2001; Monsur, 1995) and sedimentology (Roy et al., 2010; Roy et al., 2012) of the Lalmai Hills. The study is an attempt to integrate the surface geology and geomorphology with the sub-surface geological information to infer the geomorphic evolution, tectonic activity and fault kinematics of the area. Therefore, the purpose of this research will help identify the overall geomorphic evolution and to find out the signature of active tectonics in and around the study area based on field work, topo maps and satellite images, and published seismic reflection data. This study will not only enhance the understanding of geomorphic evolution and active tectonics of the study area but also help comprehend the structural, tectonic and geomorphic evolution of the westernmost folded part of the Bengal Basin as a whole.

GEOMORPHOLOGY, GEOLOGY AND TECTONIC SETTING

The Lalmai hills area (Fig. 1b) lies between the latitudes 23°20' N to 23°30' N and longitudes 91°05' E to 91°10' E. Physiographically, the area is bordered on the east by the Tripura hills of India particularly the Raghunandan hill; on the west by the Meghna river; on the north by the Gumti river; and on the south-southeast by the Dakatia river.

Geomorphology

According to Brammer's (2012) physiographic classification of Bangladesh, the Lalmai Hills area is included in the 'Uplifted blocks' as physiographic unit Q. Bakr (1977) has divided the area into three geomorphic units. From east to west, the units are Lalmai deltaic plain of Pleistocene age, Chandina Deltaic Plain of Early Recent age, and Meghna Flood Plain of Recent age. Lalmai geomorphic unit is also called as Lalmai terrace because of its flat topped and general occurrence as piedmont surfaces much above the recent plains (Bakr, 1977). These geomorphic units/ surfaces are characterized by different elevations: Lalmai Deltaic Plain includes the Lalmai Hills, Chandina Deltaic Plain with an intermediate elevation between Lalmai Deltaic Plain and the Meghna Flood Plain, and the Meghna Flood Plain, which forms the present local base level. The area can be approximately divided into low land areas (Chandina Deltaic Plain and Meghna Flood Plain) and hill areas (Lalmai Hills). The low land areas comprise abandoned channels, floodplains, and rivers. The hilly region is mostly covered by small hillocks. Sloping of the hill sides are actually controlled by the dip of the flanks of the Lalmai structure. The western part of the hills abruptly meets the plain land while the eastern part merges gradually with the adjacent areas.

Topography and relief: The topography of the Lalmai Hills area consists of hillocks (Fig. 1b), floodplains, and rivers. The structure is approximately 17 km long, about 1 km wide in the north and 2.5 km

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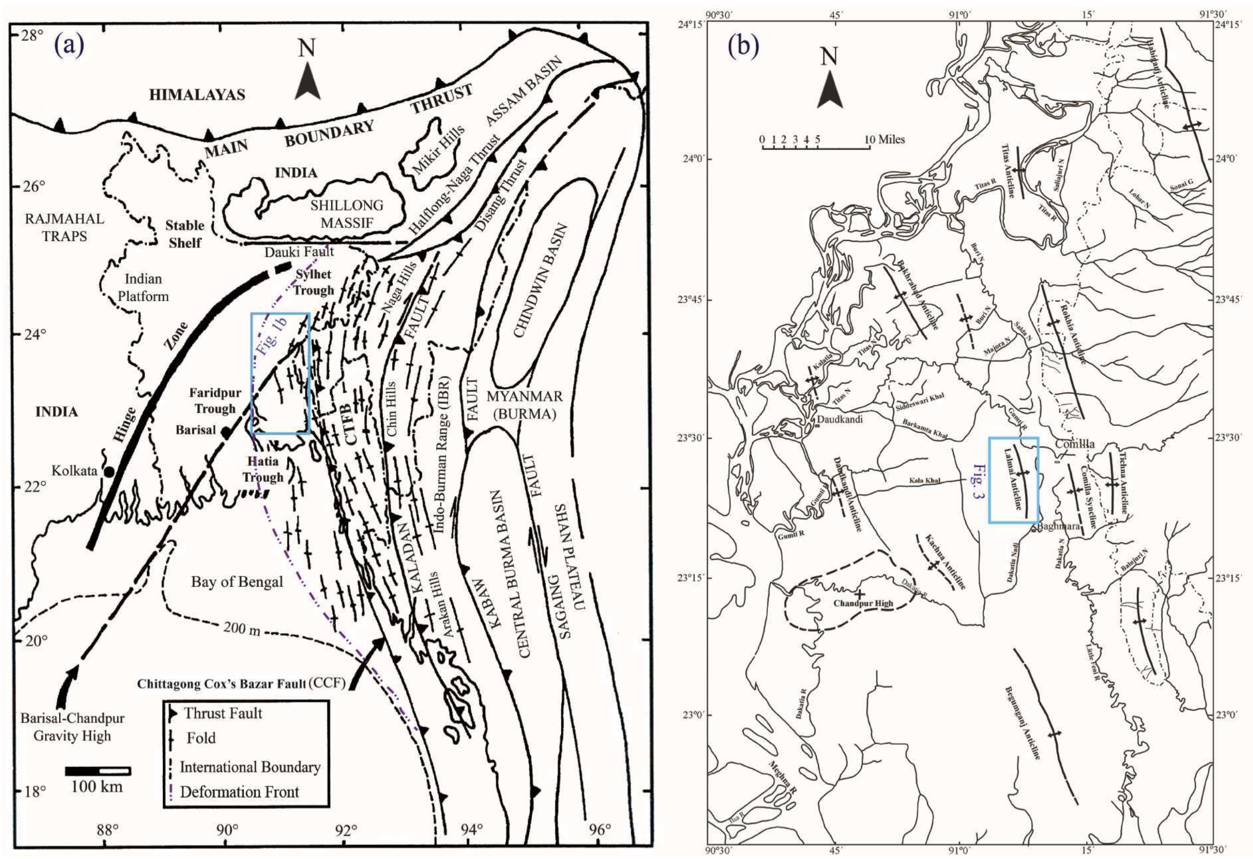

Fig.1. (a) Tectonic elements of the Bengal Basin and its surrounding areas (modified after Bakhtine, 1966; Kayal, 2008) and the location of the study area. **(b)** Local tectonic map of the Lalmai Hills and surrounding areas (after Bakr, 1977) and location of the Lalmai Anticline.

wide in the south, and comprises a number of hillocks. It covers an area of about 33 sq. km. The average elevation of the Lalmai Hills is approximately 30 m above msl but some peaks rise up to 47 m or more. The elevation of the western part of the hill area is relatively higher than the eastern part. The Meghna Flood Plain is situated on the western side of the hill range.

Drainage: Majority of the rivers flowing through the Lalmai and adjoining areas originated from the Tripura hills in the east, and flow towards west, north, and south in consonance with the general slope of the land (Fig. 1b). The area is drained by five river systems, they are: (i) the Titas river in the northern part; (ii) the Gumti river and the Dakatia river in the central part; (iii) the Little Feni river in the south-eastern part; and (iv) the Meghna river in the western part. The Meghna river and Little Feni river meet the Bay of Bengal in the south. The Titas and the Gumti connect at some points; and the Dakatia and the Little Feni join at their heads.

Old meander scars, ox-bow lakes, and paleo-channels mark the area. Bakr (1977) has observed the shifting of Titas and Gumti river courses in the area. Numerous small ephemeral streamlets become active during the periods of heavy rainfall and build up an overall dendritic drainage pattern (Zhang and Guilbert, 2012). More such channels occur in the central and southern parts than in the northern part.

Geology

The Lalmai Hills area is located along the central arcuate bulge of the westernmost part of the CTFB of the Bengal foredeep. CTFB formed due to the still-ongoing collision between the Indian plate and the Burmese plate and exposing the Miocene to Recent deposits (Steckler et al., 2008; Wang et al., 2014; Khan et al., 2015; Khan et al., 2017; Hossain et al., 2018). Monsur (1995) has proposed a Quaternary stratigraphic classification for this area including the Madhupur Clay and Sand Formation consisting three subunits, which are Bhaluka Sand member (bottom), Mirpur Silty-Clay member (middle), and Dhaka Clay member (top). Oxidized reddish brown coloured Madhupur Clay Formation (for convenience, the earlier nomemclature of Morgan and McIntire (1959) is used in this article) capped the hill tops of the area (Fig. 2A). The Madhupur Clay Formation unconformably overlies the Dupi Tila Formation, which is mainly exposed along the streams and channel beds (Fig. 2B, C). Dupi Tila Formation consists of yellowish brown coloured sand containing manganese spots, petrified wood (Fig. 2D), and to some extent lignite/ peaty coal. Roy et al. (2010) and Roy et al. (2012) suggest a varied depositional environment for the Dupi Tila Formation temporally and spatially from a subaerial alluvial fan with a heavily loaded braided river to shallow marine through estuarine and tidal creek-tidal flat. The Chandina Deltaic Plain and Meghna Flood Plain units consist of unconsolidated to semi-consolidated clay, silty clay, silt and sand; and the Meghna Flood Plain is the result of present day building process by the Meghna river and its tributaries. The Madhupur Clay, the Dupi Tila Formation and the recent alluvium constitute the exposed stratigraphy of the area.

Hossain et al. (2001) identified four seismic sequences in the Lalmai area separated by three unconformities. The four seismic sequences from bottom to top are middle Bhuban (SL 4), Upper Bhuban and Boka Bil (SL 3), Tipam Sandstone (SL 2), and Dupi Tila (SL 1) (Table 1, Fig. 7).

The Lalmai structure is a north-south trending anticline. Morgan and McIntire (1959) presumed the structure as a horst block bounded by faults on both east and west margins. Two faults have been identified (Islam et al., 2001) along the western and southern edges of the Lalmai Hills. The western one is longitudinal while the southern one is transverse. The western one is known as 'Mainamati fault' (Islam et

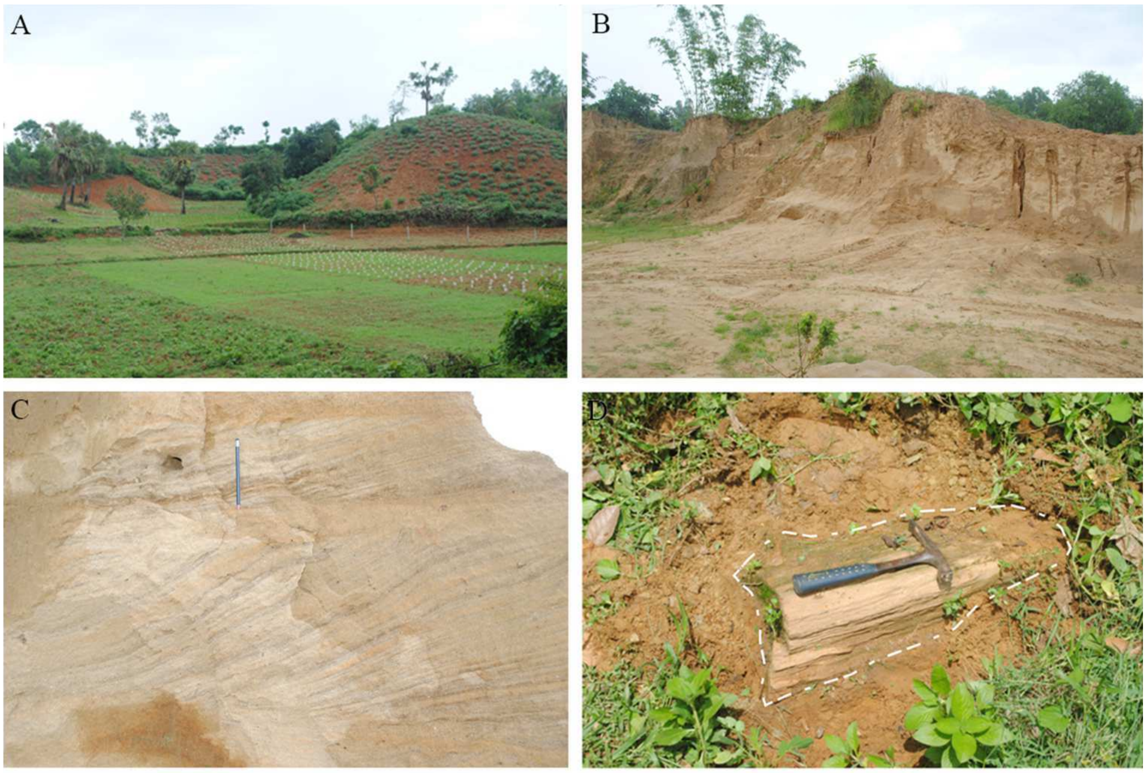

Fig.2. (A) Reddish brown Madhupur Clay capping the hillocks, **(B)** Exposed Dupi Tila Formation, **(C)** Cross-stratification in the Dupi Tila Formation, and **(D)** In-situ petrified wood (outline with broken white line) within the Dupi Tila Formation.

al., 2001). Movements along these faults also produce some geomorphic features, such as fault scarp, hill outcrop, presence of low-lying areas, and an abrupt change in lithology. Hossain et al. (2001) also identifies two faults along the eastern and western borders of the Lalmai Hills. For Mainamati fault, Islam et al. (2001) have considered it as normal fault kinematics, whereas, Hossain et al. (2001) have proposed those as thrust fault.

Regional Tectonic Setting: The Bengal basin is one of the largest collisional foreland basins in South Asia (DeCelles, 2012), which consists a section of Mesozoic and Tertiary deposits covered by Recent alluvium (Hossain et al., 2018). This is one of the thickest sedimentary basins of the world consisting of up to 21 km thick Early Cretaceous–Holocene sedimentary succession (Curray, 1991; Curray and Munasinghe, 1991). Geographically, the major portion of the Bengal basin belongs to Bangladesh and also covers a part of the Indian states of West Bengal, Tripura, and Assam. The Bengal basin is bordered on the west by the Indian Shield, the Shillong plateau to the north, the Indo-Burman Range to the east, and the Bay of Bengal to the south (Fig. 1).

The basin evolution has gone through two major tectonic episodes. In the first episode, it was initiated as an intra-cratonic rift basin within the Gondwana landmass during the Late Paleozoic–Mid Mesozoic time and received the continental Gondwana sediments. This episode of basin development ended with widespread volcanism as continental flood basalts known as Rajmahal Trap covering the Gondwana sediments. The second episode of basin development began in the Late Mesozoic with the break-up of the Gondwana and is still going on (Alam, 1989). In this stage, the tectonic evolution of the greater Bengal basin is fundamentally related to the collision pattern of the Indian plate with the Eurasian plate to the north and Burmese plate to the east forming the Himalayan orogenic belt and the Indo-Burman Ranges, respectively (Alam et al., 2003; Steckler et al., 2008; Wang et al., 2014; Steckler et al., 2016; Hossain et al., 2018).

The peri-cratonic part on the eastern margin has continuously subsided and received a massive volume of sediments from the late Mesozoic through the Tertiary to Recent times. According to Curiale et al. (2002) and Curray et al. (2002), sediment contributions to the basin is primarily from the Himalaya and Indo-Burman Ranges around the Early Oligocene (~35 Ma) and have been prograding southward to the present day. To keep the isostatic equilibrium, the mass of these huge sediments loaded and depressed the underlying lithosphere further, leading to the creation of additional space for deltaic sediments.

By considering the overall regional tectonic setting, the Bengal basin has been divided into three major geotectonic provinces: (i) the stable shelf to the northwest – passive to extensional cratonic margin, (ii) the foredeep to the centre – remnant ocean basin, and (iii) folded belt to the east – the CTFB (Bakhtine, 1966; Matin et al., 1983; Shamsuddin and Abdullah, 1997; Alam et al., 2003; Hossain et al., 2018). The N–S trending fold belt, CTFB of the Neogene molasse sediments forming low hill tracts to the west of the Indo-Burman Ranges (IBR) (Hossain et al., 2014). Hence, the CTFB of eastern Bangladesh represents the less intensely deformed foreland of the IBR (Gilbert, 2001; Acharyya, 2007).

Local Tectonic Setting: Structural and stratigraphic studies carried out in this region indicate that the CTFB has not been developed synchronously; rather, the fold belt has grown progressively westward, toward the present-day deformation front (Fig. 1a) (Steckler et al., 2008; Maurin and Rangin, 2009; Wang et al., 2014; Steckler et al., 2016). This deformation front is represented by some isolated, low amplitude anticlines in the westernmost part of the CTFB. Many of the folds in the western part of the CTFB have been active only from the Late Pliocene (Khan et al., 2005). However, Bakhtine (1966) subdivided the CTFB into three zones- western quite zone of box-like structure, the middle zone of asymmetric thrust faulted structure and eastern narrow ridge-shaped zone. The Lalmai Hills area is the part of the western quite zone which in turn represents the deformation front, an isolated narrow strip of small hills situated along the centre of the westernmost part of the CTFB. These hills together constitute an approximately north plunging anticline known as Lalmai anticline. The Lalmai anticline is delineated to the east by the Comilla syncline and the Tichna anticline; the Kachua and Daudkandi anticlines to the west; the Begumganj anticline to the south; and the Rokhia anticline to the north east (Fig. 1b).

The Lalmai anticline consists of small hillocks; and the western part of the hill area is more uplifted than the eastern part. As a result, the western part of the hill area is steeper than the eastern part. On the other hand, the northern and southern parts of the area gradually merge with the plain land. Steepness along the western part of the hill area probably occurs due to faulting. Hossain et al. (2001) and Islam et al., (2001) have identified three faults along the eastern, western and southern edges of the Lalmai Hills. Except in the east (Tichna anticline), there is no surficial expression of the anticlinal structures in the north (Bangora anticline), south (Begumganj anticline), and west (Kachua anticline) of the Lalmai structure.

STRATIGRAPHY

The overall stratigraphic succession of the area is given in Table 1.

METHODOLOGY

This study attempts to infer the geologic evolution and tectonic activity of the Lalmai Hills area through geomorphological observation from the topo maps and satellite images, and have been checked through the field reconnaissance. Lithologic features and possible location of the faults have been registered along with the stream and surface morphological features. Here, river morphology particularly stream straightness, stream initiation, stream confluence/ convergence, stream bends (Figs. 1b, 3) as well as the surface morphology were carefully observed on the map and have been checked in the field to explore their significance/ causes. These observed nick points of the streams of the mapped area have been further checked to correlate with geology of the area in particular the lithologic control or the structural control. Drainage map (Figs. 3) has been prepared based on the satellite imageries. Mountain Front Sinuosity (S_{mf}) and Stream Length Gradient Index (*SL* Index) have been calculated to understand whether the area is tectonically active or not. Finally, to construct a 2D structural modelling, some procedures have been followed: i) perceiving the regional structural style from the seismic section and previous investigations (Hossain et al., 2001; Sikder et al., 2003; Steckler et al., 2008; Maurin and Rangin, 2009; Hirschmiller et al., 2014), ii) establishing the relationship among the stratigraphic units from sub-surface lithology and well data (Hossain et al., 2001), iii) outlining the distribution of the surface geology and possible location of the faults based on the field work data.

RESULTS

Surface Geology

A surface geological map has been prepared based on the previously published works (Bakr 1977; Roy et al., 2012), the Google Earth Images, and through field reconnaissance survey (Fig. 4). During the field reconnaissance in the Lalmai Hills area, it is observed that if the ground elevation is approximately 20 m or more, the exposed layer is the Madhupur Clay. When the ground elevation is less than 20 m, Dupi Tila Formation is exposed, which means Dupi Tila Formation is mostly exposed along the streams and channel beds of the Lalmai Hills.

Geomorphic Indices

Stream length gradient index (*SL* Index) and mountain front sinuosity (S_{mf}) have been calculated from the Lalmai Hills area to understand/ explore the relative level/ status of tectonic activity.

Stream Length Gradient Index (*SL* index): The *SL* index is used to identify Recent tectonic activity by identifying anomalously high index values on a particular rock (Keller and Pinter, 2002). The following equation is used to calculate the values of *SL* indices:

$$SL = (\Delta H / \Delta L) \times L$$

Where, ΔH is the change in elevation of the reach, ΔL is the length of the reach, and L is the total channel length from the midpoint of the reach of interest upstream to the highest point of the channel. $\Delta H/\Delta L$ is the channel gradient or slope of the reach. Depending upon the morphology of the river, the rock exposures and inferred faults/ lineaments the stream course is divided into different segments (Fig. 5a). Stream length gradient index has been calculated (Uddin, 2015) for those segments (Fig. 5b, c) (Table 2).

Mountain Front Sinuosity: Mountain front sinuosity (S_{mf}) is an index to measure the relative amount of tectonic activity (Keller and

Table 1. Stratigraphic succession of the study area (Hossain et al., 2001; Roy et al., 2012)

Age	Formation	Lithology
Recent	Alluvium	Grey coloured loose siltstone and clay forming soil that support cultivation.
		……..……..………???................................
Pleistocene	Madhupur Clay	Mottled, reddish brown coloured sticky clay.
		……………………..Unconformity………………….
Pliocene	Dupi Tila	Yellowish brown colored sand containing manganese spots, petrified wood and in some extent coal.
		……………………..Unconformity………………….
	Tipam Sandstone	Sandy succession with alternation of siltstone, shale, sandstones, yellowish brown and medium grained, ferruginous, contain numerous intercalations of fine pebble conglomerate
		……………………..Unconformity………………….
Miocene	Boka Bil	Bluish grey shales with intercalation of thick bands of sandstone and siltstone.
		……………………..Unconformity………………….
	Upper Bhuban	Sandy clayey strata; sandstones are massive, bedded fine grained, very compact; lens like concretions of sandstones and siltstones are present
		……………………..Unconformity………………….
	Middle/Lower Bhuban	Predominantly shale with numerous intercalation of siltstones and sandstones; some calcareous band of sandstones are also available

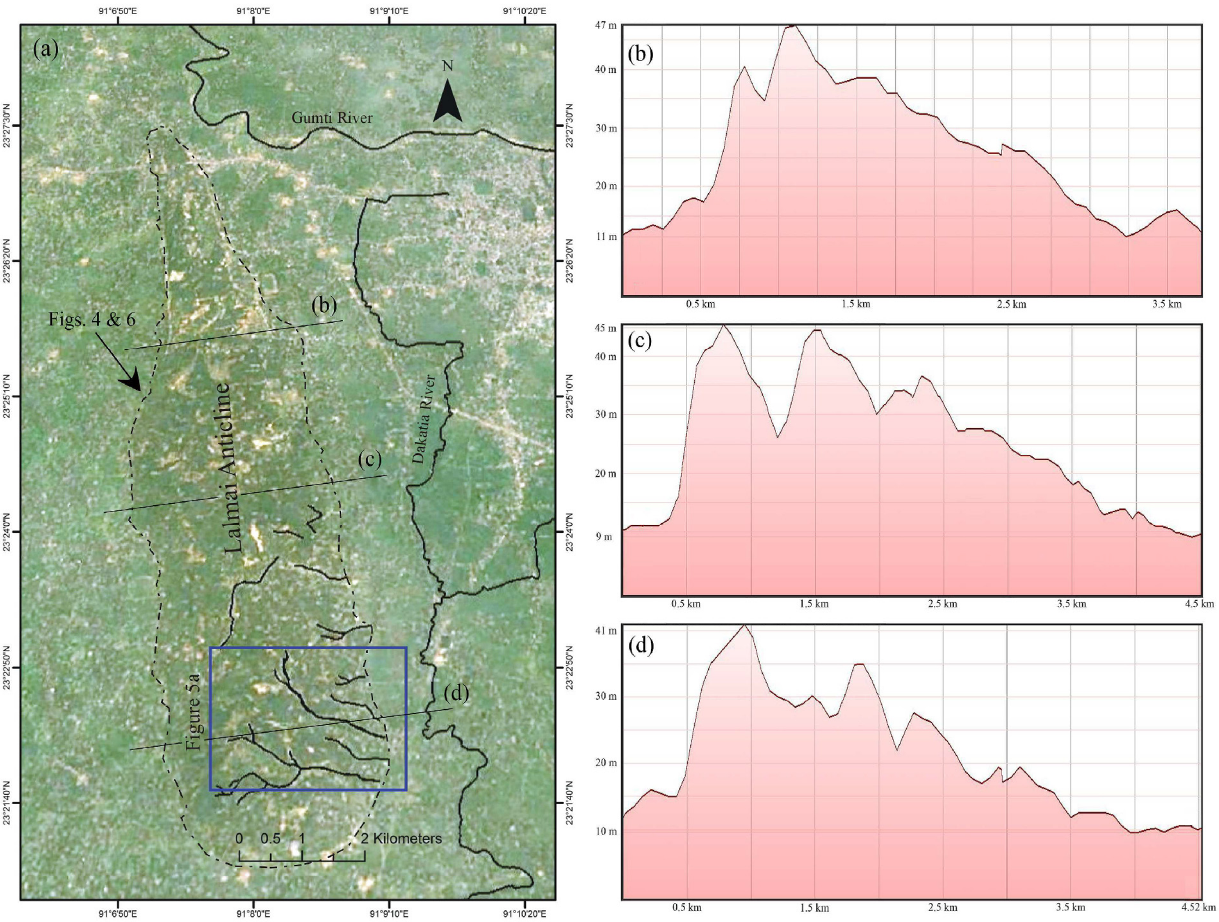

Fig.3. (a) Google Earth Image shows the structural outline and drainage pattern of Lalmai Hills area. Black broken lines outline the Lalmai Anticline. **(b,c,d)** Elevation profiles across Lalmai Hills area along lines b, c, and d, respectively (two times vertically exaggerated).

Pinter, 2002). Mountain-front sinuosity is calculated by the following equation:

$$S_{mf} = L_{mf} / L_s$$

Where, L_{mf} is the length of the mountain front along the foot of the mountain, at the pronounced break in slope, and L_s is the straight-line length of the mountain front. Mountain fronts associated with active tectonics and upliftment are relatively straight and with low values of S_{mf}. If the tectonic activity is less compared to erosional processes, a curve and more irregular mountain front developed with high values of S_{mf}. The most active mountain fronts generally have a S_{mf} value between 1.0 and 1.6. Mountain fronts with lesser activity generally have S_{mf} between 1.4 and 3. Inactive mountain front has sinuosity from 1.8 to greater than 5 (Keller and Pinter, 2002). The calculated value of S_{mf} (Uddin, 2015) of the western front of the Lalmai Hills is 1.22. On the other hand, the S_{mf} value of the eastern front of the Lalmai Hills is 1.79 (Fig. 6).

Table 2. Calculated Stream Length Gradient Index (*SL*) values (Uddin, 2015).

Channel division	*SL* values in meter (From west to east)
Channel (A)	35.83
	12.23
	20.16
	19.17
	4.57
Channel (B)	21.72
	13.51
	29.46
	14.45
	1.46

2D Structural Model of the Study Area

2D structural model has been constructed based on the seismic reflection data along the line KAL-3 (Fig. 4), outlining the distribution of the surface geology and possible location of the faults based on the field work, and perceiving the regional structural style from the seismic section and previous investigations (Hossain et al., 2001; Sikder et al., 2003; Steckler et al., 2008; Maurin and Rangin, 2009; Hirschmiller et al., 2014). The study of seismic section by Hossain et al. (2001) suggests that the faults of thrusting in nature have developed along with folding in very Recent time, which are similar to the regional structural style from the seismic section and previous investigations (Fig. 7). Both the east and west flanks are thrusted and dip towards the core of the structure. In the south, the structure is terminated by a transverse normal fault (Islam et al., 2001). Although there is no surficial expression of the Lalmai structure after the 23°29'20" N line, the observation of seismic line KAL-1 indicates that the structure is continued in the subsurface with very low amplitude to the north (Hossain et al., 2001), indicating that the structure is gradually plunging to the north.

DISCUSSION AND CONCLUSION

The Chittagong Tripura Fold Belt (CTFB) has been divided into three structural compartments (Bakhtine, 1966). Lalmai Hills belongs to the western quite zone which is a low amplitude anticline. Bakr (1977) has divided the area into three geomorphic units from East to West, Lalmai Deltaic Plain of Pleistocene age, Chandina Floodplain of Early Recent Age, and Meghna Floodplain of Recent age. The Lalmai geomorphic unit contains the Lalmai anticline proper and is

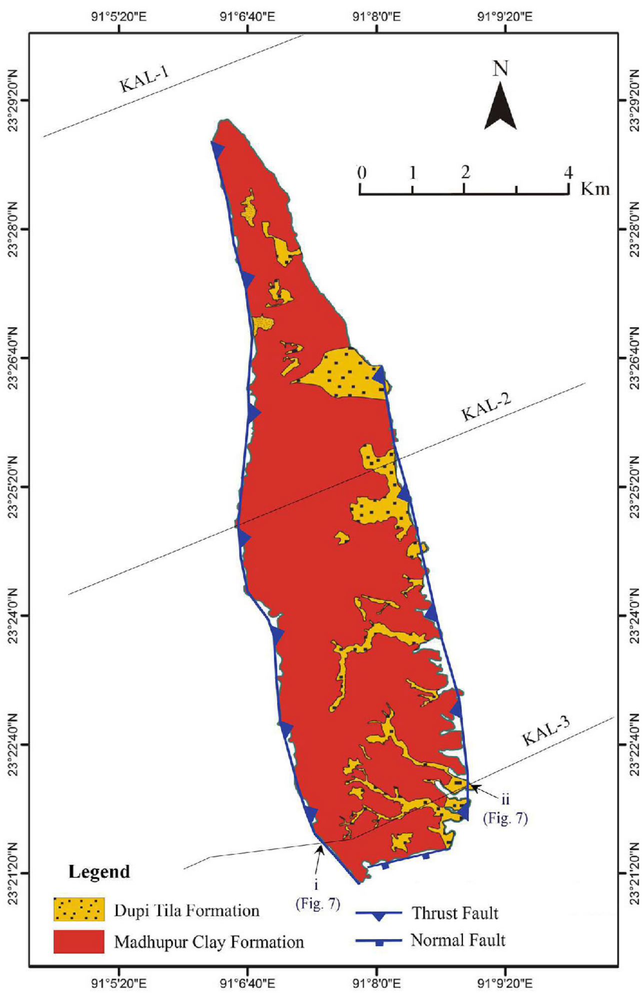

Fig.4. Geological map of the Lalmai structure shows the surface geology and major faults. Black lines on the map (KAL-1 to KAL-3) are the locations of the seismic profiles.

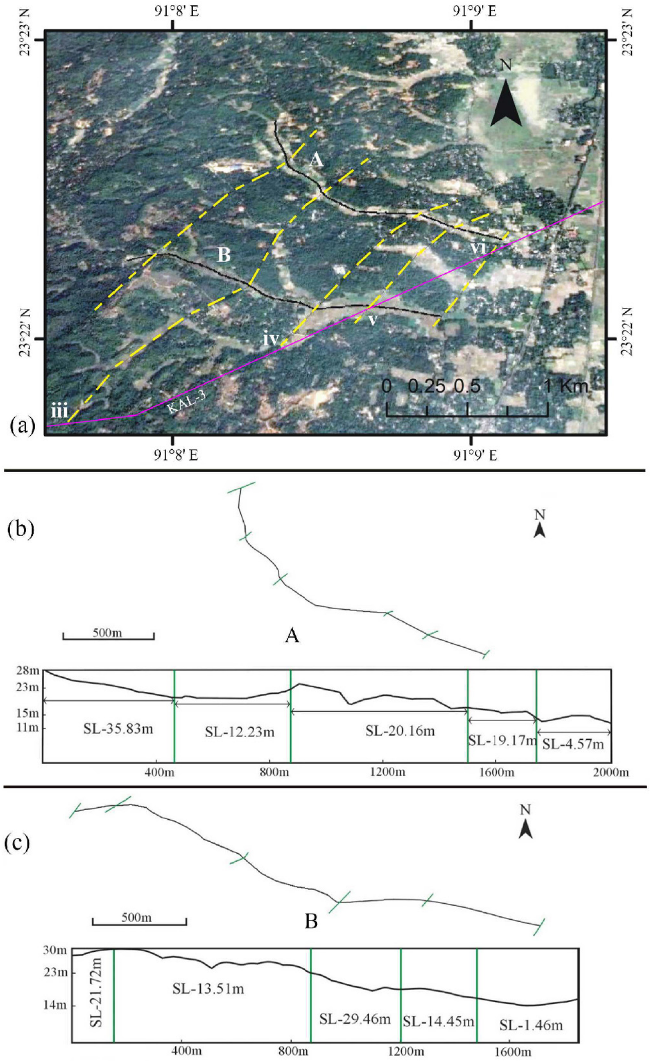

Fig.5. (a) *SL* indices of the channels of the study area. Broken lines represent the inferred faults/ lineaments crossing through the knick points on the streams (disposition of inferred fault/lineaments intersected the line KAL-3 are marked as iii–vi shown in Fig. 7). **(b, c)** *SL* indices of the two channels in the Lalmai anticline.

also called as Lalmai terrace. Roy et al. (2012) has worked on the depositional environment of the Dupi Tila Formation and inferred alluvial fan through estuarine to shallow marine condition.

The Lalmai anticline is surrounded by Comilla syncline in the east, Rokhia anticline in the north-east, Kachua anticline on the southwest, Daudkandi anticline in the far west (Fig. 1b). Keeping in mind the spatial positions of these small-scale structures on the piedmont of the Chittagong Tripura Fold Belt, especially Tripura hills, it is assumed that the Lalmai deltaic plain occupying the area of alluvial fan deposition. Towards the west and south-west, it becomes relatively deeper basinal areas in present Chandina Deltaic and Meghna Flood Plain during the deposition of the Dupi Tila Formation, at least in part. The Dupi Tila Formation contains clay galls and petrified wood (Fig. 2D). These features as well as the sedimentation nature suggest that this is a continental (fluvial) deposition. However, during the deposition of this formation, the area under influence of estuarine condition, at least in part of the Lalmai Hills (Roy et al., 2012). After the deposition of the Dupi Tila Formation, the Madhupur Clay was possibly deposited in a fluvial and swampy environment.

Islam et al. (2001) suggest that there are two normal faults in this area, one is on the western flank and another is in the southern edge of the Lalmai Hills. Whereas, Hossain et al. (2001) identified two thrust faults on the western and eastern boundaries based on seismic section. They also suggest that the core of the anticline is transected by a few minor faults. Pre-field investigation of the present study identified these western and eastern faults based on relief features as the western boundary of the Lalmai Hills is very sharply raised from the adjacent low land, whereas in the eastern part there is a minor relief break and it merges gradually to plain land (Figs. 3, 6). The surface observations, seismic section (Hossain et al., 2001) as well as the structural style of the surrounding area suggest that these two faults are thrust in nature (Fig. 7). The western thrust is the direct result of Indian and Burmese plate collision, whereas the eastern thrust is the antithetic back thrust of the western fault. Continuous tectonic compression has taken place by movement along these thrusts, and resulted wedge-shaped upliftment of the central part as pop-up structure. Few minor faults have been identified during field observations which are correlated with the seismic line KAL-3 (Fig. 5a). These minor faults within the anticlinal core are of sympathetic to the two major faults (Fig. 7), and produced to compensate the movement along these two thrusts. On the other hand, based on the field observation and satellite image analysis, it has been found that the western flank of the Lalmai Hills is in higher elevation than the eastern flank. The S_{mf} of the eastern and western flank are 1.79, and 1.22, respectively (Fig. 6). The result of S_{mf} and the study of seismic section by Hossain et al. (2001) suggest that the faults have been developed along with folding in very recent time. The present study anticipates the development of the faults probably continued even after the deposition of the Madhupur Clay.

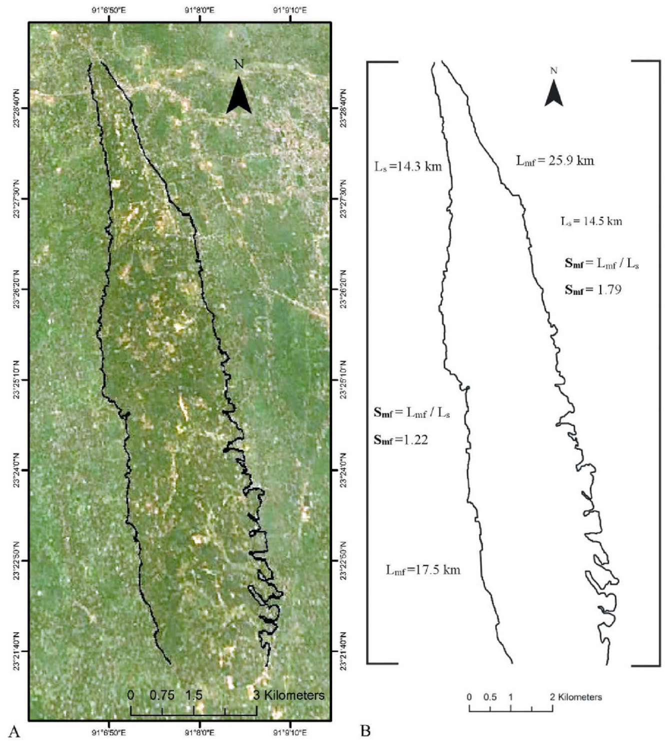

Fig.6. (A) Outline of the mountain front of the Lalmai anticline on the Google Earth Image, and **(B)** Calculated mountain front sinuosity (S_{mf}).

Geotectonically, the Lalmai structure is at the western margin of the CTFB, which is a convergence deformation front. From south to north, this deformation front is represented by some structures with low to moderate amplitude, e.g., Dakhin Nhila, Inani, Maheskhali, Jaldi, Lalmai, Habiganj, Sylhet. The seismic reflection profiles across a few of these anticlinal structures reveal growth strata that constrain the initiation of folding (Mandal et al., 2004; Steckler et al., 2008; Najman et al., 2016). The age of the growth strata of the Sylhet, Habiganj, Jaldi, and Kutubdia structures constrain the initiation of anticlinal growth to the Pliocene or younger (Johnson and Alam, 1991; Steckler et al., 2008; Maurin and Rangin, 2009; Wang et al., 2014). According to Khan et al. (2015), Dakhin Nhila structure is tectonically active and showed different uplift rates spatially and temporally for the last 55,000 years as the structure is faulted. More recent activity is recorded from Maheshkhali and Jaldi anticlines (Khan et al., 2005).

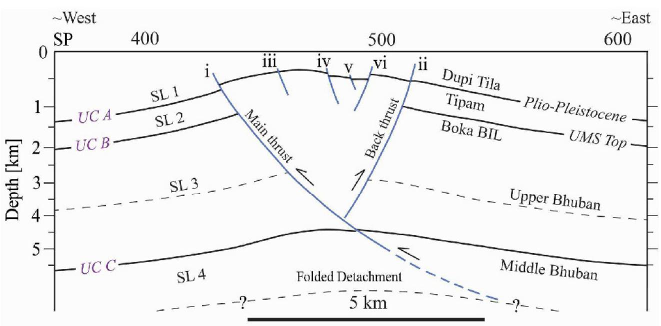

Fig.7. 2D structural model of the Lalmai Hills area along the line KAL-3 (see location in Figs. 4 & 5a). Faults are labelled as i-vi in which i and ii are the two boundary thrusts to the west and east of the structure, respectively (planar view shown in Fig. 4). Faults iii-vi are minor sympathetic faults (planar view shown in Fig. 5a), modified after Hossain et al. (2001). Note: UC-Unconformity, UMS-Upper Marine Shale, SP-Shot Point.

On the basis of young-aged soils from the crestal portion of these anticlines, Khan et al. (2005) suggest the uplift in the Maheshkhali anticline during the past 18,000 years and in the Jaldi anticline during the last 35,000 years. Farther north, the upper surface of the Sandwip structure is estimated to be about 7000 years old as indicated by radiocarbon date (Goodbred and Kuehl, 1999). Similar young neotectonic activities are also reported by Ansary et al. (2000) and Steckler et al. (2008) in this area. Moreover, the northern-most part of the deformation front is limited by the Dauki Fault, one of the active and largest boundary fault of the Bengal Basin (Biswas et al., 2007; Hossain et al., 2016). In the eastern part, to the immediate south of the Dauki Fault, some small hillocks present in the Jaintiapur area, Sylhet which are capped by the Dihing Formation. The Optically Stimulated Luminescence (OSL) dating of this formation indicates young depositional age (73-24 ka), and variable uplift rate (Khan et al., 2006). The authors suggest that the area is tectonically active and gone through a differential upliftment in the recent past. As the Lalmai structure is situated at the middle of the same deformation front, therefore, we can rightly assume that the deformation age of this structure is quite recent and still going on.

In the Lalmai anticline proper, there are a number of charas or streamlets which are incised. Whenever the incision deeps below 20 m amsl, they expose the Dupi Tila Formation. But, when they have not incised below 20 m amsl, they generally expose the lower part of the Madhupur Clay (Fig. 4). The *SL* index values of two minor channels within the Lalmai anticline range from 35.83 m to 1.46 m (Fig. 5). The high *SL* values are generally found at a higher elevation or close to 20 m. Up to this elevation, the Madhupur Clay Formation is exposed. But where the value is low, stream is exposing the Dupi Tila Formation (Fig. 4). As the rocks of both the formations have similar resistance, the authors anticipate the stream incision/ exposer of the Dupi Tila Formation is controlled by the minor faults running across the stream course which are correlated with the seismic line KAL-3 (Fig. 5a). It should be mentioned here that Bakr (1977) has shown a number of shifting episodes of Gumti and Dakatia rivers flowing through the northern and southern edges (Fig. 3) of the structure during the recent past which is not only because of climate fluctuation but also due to recent tectonics.

Active tectonics have defined the geomorphology and sedimentation patterns as well as the structures of the Lalmai Hills area. In the eastern front, the S_{mf} is relatively higher than the western front, because of the antithetic back thrust and weathering have taken over the tectonics. Weathering and erosion are comparatively higher in the eastern part.

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