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Lithofacies Analysis of the Tista River Deposits, Rangpur, Bangladesh

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Abstract

Eight (8) distinct lithofacies within the fluviatile reach of the Tista River have been recognized by the detailed study of the sediments as exposed along the river bank and river bars. Genetically, the matrix-supported conglomerate (Gms), massive sand (Sm), Trough cross stratified sand (St), planar cross stratified sand (Sp), ripple laminated sand (Sr) comprise the channel deposits whereas, the ripple laminated sand (Sr), parallel laminated sand (Sh), clay with silt (Fl) and massive Clay (Fm) represent overbank fine deposits. The channel deposits were laid down under relatively high energy conditions compared to the sediments of overbank fines. The stratigraphic succession is indicative of fining upward sequence. The dominance of coarser-grained sediments at the base of the lithostratigraphic unit, especially the matrix supported conglomerate (Gms) suggests that the deposition took place in the proximal part of the Tista Fan, which might be of glacial origin. Massive clay (Fm) is the final stage of vertical aggradations in the overbanks, possibly in the floodplains, flood basins, and back swamps when the velocity of the transporting medium was virtually lean that promotes the deposition of clay materials from suspension. The growth of cracks in the sedimentary succession is resulting from the compaction of the sediments and/or instant change in the paleoslope direction. The unimodal distribution of paleocurrent data with high mode value indicates mainly unidirectional sediment transport. The study of the lithofacies manifests that the deposits are produced by the braided river and debris flows. The modification of the depositional pattern from debris flow to overbank fines discloses the change of climatic condition in the Quaternary period.

Keywords: Lithofacies, Tista, channel deposits, overbank fine or bar top deposits and suspension.

INTRODUCTION

Facies analysis has been an important procedure among sedimentologists for decades. The main basis used for defining facies follow those of Miall (1978, 1996), that have been accepted by many authors. These criteria predominantly concern grain sizes, and sedimentary structure, the geometry of sedimentary bodies, and the presence or absence of identifiable plant or animal remain. Facies moreover occur in predictable patterns in terms of lateral and vertical distribution and can also be linked to sedimentary processes and depositional environments.

The concept of facies has been ever used since geologists, engineers and miners recognized that features found in particular rock units were helpful in correlations and predicting the occurrence of coal, oil or mineral ores.

Facies analysis is significantly applied to the old sedimentary succession for the reconstruction of the depositional environment, paleoclimate. Roy et al. 2004 established three different depositional environments for the Tertiary Dupi Tila formation of Lalmai Hills, Comilla by the detailed examinations of lithofacies. The lithofacies analysis of Gondwana sequences suggests their origin from the sedimentation of fluvio-glacial braided stream to backswamp environments in Bangladesh (Islam and Islam 2006). The lithofacies examinations of modern sediments lay out the 3D view of the stratigraphic succession that is subsequently applicable for the characterization of old sedimentary basins. The Recent fluviatile deposits of the Padma river show the variations in lithofacies compositions while the deposition ranged from channels to backswamps in different seasons of the year (Roy *et al.* 2002).

The present research work is executed with the sedimentology of the transboundary Tista river and is adjoining areas, that is located in the parts Nilphamari, Lalmonirhat, Rangpur, Kurigram and Gaibandha districts of Rangpur division, Bangladesh. The Tista is a fast flowing river and fed by the rainfall, glacial melt and groundwater flow. It emanated from the Himalayan Mountain Ranges and runs through India and Bangladesh (Chakraborty and Ghosh 2010). The landslides are a common incident in the mountainous part of the basin whereas the basin is inundated with seasonal flood events in it lower course in the plain lands (Pal *et al*,. 2016).

The petrographic of analysis of Tista fan sandstone reveals the dominance quartz, feldspar and mica (Akter *et al.* 2003). Chakraborty and Ghosh 2010 worked on the geomorphology and sedimentology of the Tista megafan in Darjeeling Himalaya and concluded the advancement of the paleochannels southwestward after analyzing the paleocurrents data. Chakraborty *et al.* 2018 studied the subsurface lithofacies and they identified seven different lithofacies of fluvial origin in West Bengal, India. Saha *et. al.* 2017 worked on the textural aspects of the deposits as exposed along the banks and bars and reported the dominance of coarse particles especially sand laden with pebbles over the finer sized sediments. The application of illite crystallization index implies that the physical weathering is the prominent process for the production of these sediments (Saha *et al.*2020). The slope and geomorphic characteristics of the Tista river is influenced by the presence of the Tista fault along the course of the Tista river (Sarker et al. 2009). Khan and Islam 2015, deciphers the anthropogenic impacts on the morphology of the Tista river in Northern Bangladesh like the construction of bridges and barrage, bank stabilization, human settlements, intensive agriculture and sand mining. It was reported that the grain size becomes finer vertically upwards and along the downward course of the Tista river.

The wide and rapid spectral variations in sedimentary structures and textures in the Quaternary deposits on the banks of the mighty river Teesta at the Himalayan foothills in Bangladesh bear a snapshot of an extremely unstable depositional regime. The sedimentation entropy involved is further manifested in biogenic responses that include human settlements as well. Recent additions of bridges, barrages, dams, sand mining, cultivation and channel diversions cause modifications of the primary attributes of the deposits. To understand the complex Quaternary sedimentation mileu a holistic lithofacies analysis is attempted in this paper. Lateral and vertical facies transitions are worked out across diastems present in high frequency. Sedimentation continuum is thus studied in piecemeal and then integrated in an evolutionary history which is long awaited.

Study area

The Tista is the fourth main river in terms of discharge in Bangladesh (Khan and Islam, 2015). It is a right tributary of the Brahmaputra (Wiejaczka *et al.*, 2014) (Figure 1a). It originates in the Pauhunri massif (7127m amsl). The Tista River flows through the Tista lineament. The lineament was presumably mapped by remote sensing (Nandy *et al.*, 1993; Mukul *et al.*, 2014). Tista is the principal river of Rangpur district. The area is drained by numerous other rivers like Brahmaputra, Jamuneshwari, Ghaghat, Karatoya, Chikali, Buri Tista etc. The Tista is a braided river in its lower part in Bangladesh. The sedimentation pattern of the river is also influenced by the construction of the barrages in the upper course of the river.

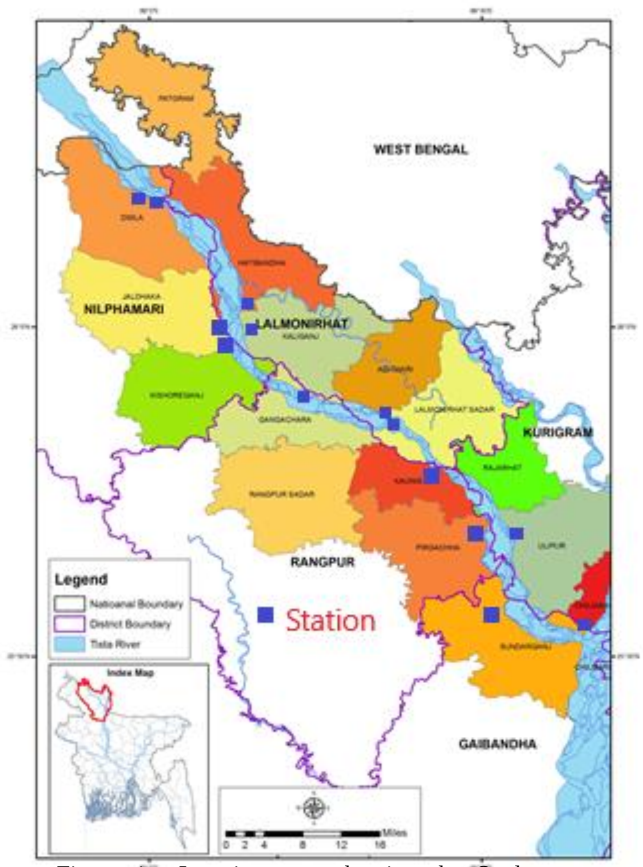


Figure 1a: Location map showing the Study area (modified after Saha et al. 2019

The Tista megafan is a huge triangular sediment body characterized by a radiating drainage pattern (Chakraborty and Ghosh, 2010). The apex of the megafan coincides with the point of emergence of the Tista River from the mountain belt. The Tista River sediments are characterized by the dominance of the sand particles that are mixed with cobbles and pebbles (Saha et al. 2017). The percentage of sand decreases to the downstream direction at expense of an increasing fraction of mud.

Table 1 Stratigraphic succession of the Rangpur Saddle, Bangladesh *(*Modified after Hossain, 1999 and UNDP, 1982*)*

Age	**Group/Formation**	**Lithology**	**Thickness**
Recent to Sub-Recent	Alluvium	Sand, silt and clay	53m.
Late Pleistocene-Holocene	Tista Gravel	Gravels with sand and silt	89 to 97m
Pleistocene	Barind Clay	Clay, sandy clay, yellow-brown sticky	15m
Middle Pliocene to Late Miocene	Dupi Tila Formation	Sandstone with subordinate pebble bed, grit bed and shale	171m.
Early Miocene	Surma Group undifferentiated (?)	Fine to medium grain sandstone, sandy and silty shale, siltstone, and shale.	125m.
Middle Eocene	Tura Sandstone (?) Formation	Gray and white sandstone with subordinate greenish gray shale and coal.	128m.
Late Permian	Gondwana sediments	Feldspathic sandstone, shale, coal beds	475m.
Precambrian	Basement complex	Gneiss, schist, granodiorite, quartz diorite	

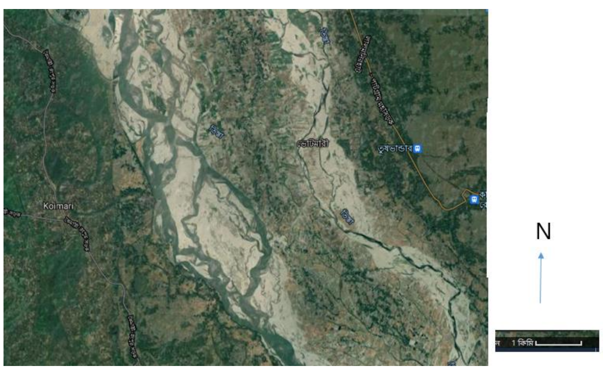
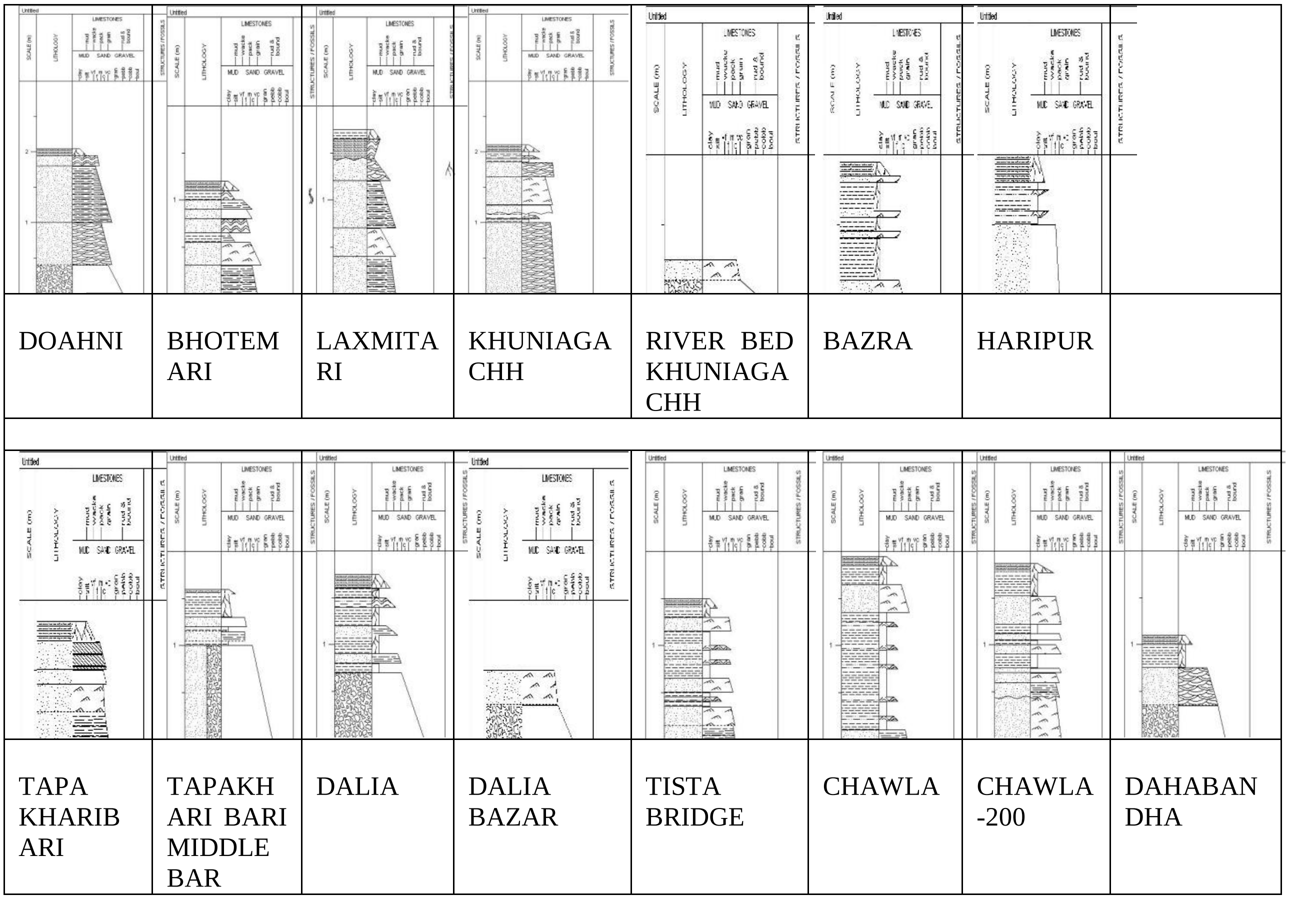


Figure 1b: Satellite image showing the growth of medial bars, Tista river basin, Bangladesh

Table 1 shows the stratigraphic succession of the Rangpur Saddle. The study area composed of Alluvial deposits that contains gravel, sand, silt and clay of Recent age. The aquifers of the Tista Fan, both active fan and inactive, that lie in Rangpur and Dinajpur districts are composed of coarser sediments have the highest transmissivity in Bangladesh that vary from 1000-7000 square meters/day (UNDP 1982; Hussain and Abdullah 2001). The present day Tista river is flowing through the upper part of the megafan. Figure 1b shows the development of the medial bars, which helps to identify the braided nature of the Tista river in Bangladesh.

Methods

The Sedimentary deposits are exposed along the vertical channel banks and medial sand bars throughout the Tista river from west to east. The field work was carried out from February to June in the year of 2014. The lithologies of various stations were examined by the aid of pocket lenses and also tested with the concentric hydrochloric acid to identify the carbonate rocks (Roy *et al.*2012). The attitudes and thickness of the sediments were quantified using clinometer and a measuring tape. The identification of the sedimentary structures was done as described by Collinson and Thompson (1982) and Reineck and Singh (1980). All the field data were recorded in a note book and the lithologs were drawn in situ. Large grains of platy minerals like muscovite was identified with the naked eye. The average thickness of the investigated sections was calculated as 1.34 m. The exposed sediments assigned to number of distinct facies. Facies identifications and interpretations were based on detailed examination of colour, texture, composition, sedimentary structures and bedding characteristics (Miall, 1984; Reading, 1986; Roy *et al.,* 2001). Photographs were taken in the field using digital camera. The stratigraphic lithologs were drawn using a



gure 2: Sedimentological lithologs of the Tista River Basin, Rangpur, Bangladesh

computer software, Sedlog 3.0, Rockworks-17 in the laboratory. The rose diagram was prepared for the interpretation of paleocurrent direction with necessary computer software.

RESULTS

The studied sections show the findings of the detailed stratigraphic and sedimentological analyses of the deposits observed in the sections as exposed along the both banks of the Tista River and its medial bars. An inspection of the sedimentological logs reveals a total of eight facies, which are explained in order of their occurrence from base to top.

The fluvial facies of the Tista River are characterized by normal graded bedding sandstone and conglomerates that fine and thin upward and mudstone. It contains channel and overbank subfacies and occurs in. The channel subfacies include distributary channels, bed form lag deposits, and point bars and the overbank subfacies include natural levees, crevasse splays, and floodplain deposits.

DESCRIPTION OF DIFFERENT LITHOFACIES

Eight different lithofacies were identified in the studied lithosuccession and they are namely Matrix supported conglomerate (Gms), Massive sand (Sm), Trough cross stratified sand (St), Planar cross stratified sand (Sp), Ripple laminated sand (Sr), Parallel laminated sand (Sh), Clay with silt (Fl) and Massive Clay (Fm). These are observed along the river bank and bars within the study area. These are described in order of grain size i.e. coarse grain facies are followed by fine grained facies.

Matrix supported conglomerate facies, Gms

Matrix supported conglomerate facies is a well-developed lithofacies that occurs at the base of the lithocolumn within the area of investigation. The thickness of this facies varies from 10 to 100 cm. The facies is exposed in Doahni, Khuniagachh Bar, Tapa Kharibari Middle Bar, Dalia, Dalia Bazar, and Dahabandha sections. The maximum thickness is recorded in Tapa Kharibari Middle Bar section

Table 2: Lithofacies Scheme of Tista River sediments, Rangpur, Bangladesh

Facies Code	Lithofacies	Sedimentary structure	Thickness	Interpretation
Gms	Matrix supported conglomerate	None	10-100 cm	Debris flow deposit
Sm	Massive sand	Massive	5-50 cm	Rapid deposition from fluidized flow
St	Trough cross stratified sand	Grouped trough cross bedding	20-60 cm	Dunes (lower flow regime)
Sp	Planar cross stratified sand	Grouped planar cross bedded	20 cm	Two-dimensional bed form, sandwaves, linguid and transverse bars.
Sr	Ripple laminated sand	Ripple marks or ripple laminations	5-45cm	Ripple, current generated
Sh	Parallel laminated sand	Horizontal or flat bedding	10-80 cm	Lower flow regime plane bed
Fl	Clay with silt	Ripple laminated	5-50 cm	Over bank/waning flood deposit
Fm	Clay	Massive	5-30 cm	Non channelized swamp deposit

which is 100cm. This gravelliferous deposit is devoid of any sedimentary structures and composed of cobbles, pebbles and granules. The coarser deposits are found in the upstream part of the Tista River within the study area

Interpretation

Matrix supported conglomerate may be the product of debris flow deposits which are promoted by a steep slope, lack of vegetation. Short period of abundant water supply given by heavy rainfall and/or melting, and it is a source providing debris with a sandy matrix (Bull, 1977; Starkel *et al.*, 2015). This flow may be confined to high lobed braided channels but commonly spread out at lobate sheets on the lower reaches of the proximal part of the river forming levees and having characteristics of debris flow deposits (Miall, 1978; Blair and McPherson, 1994). Lack of organized fabric is a common aspect of debris-flow deposits (Rust and Koster, 1984). Because of its high viscosity, the debris flow deposits do not travel a longer distance. Hence these deposits are normally observed in the proximal fan. Short-term fluctuation of precipitation in fan area undoubtedly produces debris flow in a humid area (Curry, 1966; Blair and McPherson, 1994).

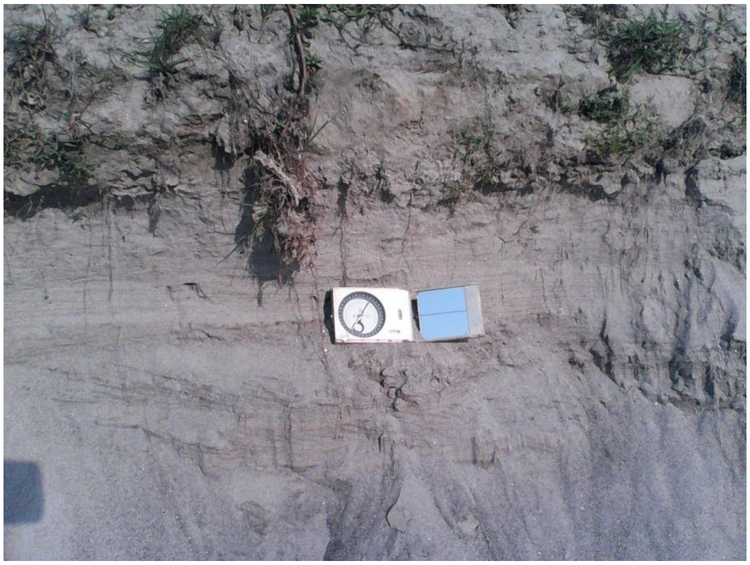


Figure 3: Massive sandstone, Trough cross stratified sand facies (St) as exposed in the Tista River Basin, Sundarganj, Bangladesh.

Massive sand facies, Sm

The massive sand facies consists of fine to very coarse-grained, feldspar bearing sands. The thickness of the facies varies from 5 cm to 50cm, and the maximum thickness is found at the lithocolumn of Haripur (Figure2 and 3). The colour of this is pale to brownish. The sand grains are angular to subrounded and poorly to moderately sorted. Scattered pebbles ranging from 1cm to 2cm in diameter are present at some locations. This facies is unconsolidated and does not exhibit ant sedimentary structure or any fossil.

Interpretation

Massive sandy beds of Sm might be formed in response to depositional processes (McCabe, 1977; Jones and Rust, 1983; Udo and Mode, 2013) or by post-depositional deformation (Allen, 1986). In the present interpretation, deformation is considered irrelevant in the absence of its indicators in any bed associated with Massive sand, Sm. Accordingly, this facies is interpreted as resulting from transport and deposition by short-lived mass flows. This lithofacies has been interpreted as reflecting deposition in a sand-dominated braided fluvial environment (Morton *et al.,* 2011).

Trough cross stratified sand facies, St

Trough cross stratified sand facies (St) constitutes 11% of the total lithosuccession. The thickness of this lithofacies ranges from 20 to 60 cm and the highest thickness was recorded at the lithocolumns of Doahni and Laxmitary. The base of trough cross stratified sand facies is gradational to sharp. The grain size varies from medium to very coarse sand, and sand is dark grayish white in colour. St comprises mainly well to moderately sorted, subrounded to rounded grains of quartz with black and white mica.

Interpretation

Most commonly this facies may have been deposited as migrating sinuous crested dunes or lunate bars on the top of a gravel facies, in association with planar cross bedded sand body (Sp) facies, or in local depressions of mega ripples showing evidence of scour –fill episodes (Miall, 1978; Walker and Cant, 1984). Trough cross stratified sand facies (St) along with the upward as well as down slope of the litho-columns within the present Tista Basin area is interpreted as response to shallowing of water over the gravelliferous bars and active gravelliferous braided channels with a decrease of stream competence, accompanied by or in response to migration of active tract of channels over the fan (Wasson, 1977; Reineck and Singh, 1980).

Planar cross stratified sand facies, Sp

Planar cross stratified sand facies (Sp) is exposed at the lithosuccession of Tapa Kharibari of Nilphamari district and the thickness of the bed is 20 cm. The planar cross stratified sand overlies on massive sand (Sm) with a sharp base. The grain size varies from fine sand to very coarse sand.

Interpretation

The deposition of small scale planar cross-bedded (Sp) facies has been attributed to current migration of linear ripple whereas large scale planar cross-bedding is produced both by linear (two-dimensional) mega ripple and sand waves or migration of three-dimensional medium subaqueous dunes (Ashley, 1990). Sets of planar cross-bedded sand (Sp) facies associated with other finer facies may also represent chute bars in the lower mid to distal part of the alluvial fan (McGowen and Garner, 1970). Low angle planar cross-bedded sand is common in the fining upward litho-column of water-laid deposits (Bull, 1972; Reineck and Singh, 1980).

Ripple laminated sand facies, Sr

Ripple laminated sand facies (Sr) is composed of quartz, muscovite, and biotite minerals. The colour of this facies grayish white, and the thickness varies from 5cm to 45 cm. It is exposed at Doahni, Bhotemari, Laxmitari, Khuniagachch, Bazra, Tapa Kharibari, Dalia Bazar, Tista Bridge, Chawla and Chawla-200 sections and the maximum thickness was recorded at Chawla-200. The grain size ranges from very fine sand to coarse sand.

Interpretation

Ripple laminated sand is developed due to migration of small-scale 2D and 3D ripples during minimum flow strength in relatively shallow water condition (Jopling and Walker, 1968). The ripples may indicate partial abandonment of channels (Gardis and McCade, 1981). These may be deposited partly filled channels in dying stages within unconfined channels or by sheet floods in the alluvial fan (Reineck and Singh, 1980). These ripples may locally present in the sandy layers within the upper part of the stacked channel deposits of lower part and inactive lobes of proximal fan (McGowen and Groat, 1971; Roy *et al.*, 2004a).

Parallel laminated sand facies, Sh

Parallel laminated sand facies (Sh) is constituted gray to yellowish brown parallel, horizontal or flat bedding very fine to very coarse-grained sand. It overlies massive sand, trough cross stratified sand and ripple laminated sand. Sometimes this facies overlies the massive clay facies. The thickness of parallel laminated sand varies from 10 cm to 80cm.

Interpretation

Parallel laminated sand (Sh) facies are product of upper part of lower flow regime when the flow velocity is sluggish (Middleton and Southward, 1978). The coarser nature, unsorted character and faint laminations/horizontal laminations of the sediments are suggestive of flood deposits in the overbank of the Tista River.

Clay with silt facies (Fl)

Clay with silt facies (Fl) comprises silt and clay. Clay constitutes 70-75 percent by volume of this facies. Clay is gray to brownish gray in colour. Silt with certain amount of very fine sand comprises rest of the facies Fl. Silt is gray to grayish white in colour. The thickness of the facies Fl varies from 5 to 50 cm. Silt in the lower part of the facies is parallel laminated, while that in upper part shows current ripple laminations. This facies overlies sharply ripple laminated sand (Sr), parallel laminated sand (Sh), trough cross stratified sand (St) and occasionally over massive clay (Fm).

Interpretation

These deposits are virtually suspension products in slow moving shallow water (Roy *et al.*, 2001). Parallel laminations indicate settling from suspension from slow moving or stagnant water (Roy *et al.*, 2004a). The sediments of Clay with silt facies (Fl) are over bank fine or waning flood deposits. From the field observations, it may be concluded that the coarser sediments (silt and very fine sand) of this facies might have been deposited during the rainy season when the river stage is highest and inundate the floodplains.

Massive clay facies (Fm)

Massive clay facies (Fm) is the dominant facies in the upper part of the litho-column. The material of this facies is generally clay and the colour of the clay varies from bluish gray to grayish white. The clay is sticky when wet. The facies is characterized by mottling nature and ped development. The presence of rootlets is a common feature of the facies, Fm. The facies sharply overlies matrix supported conglomerate, Gms (at Tapa Kharibari Middle Bar, Dalia), massive sand, Sm (at Tapa Kharibari Middle Bar, Chawla-200), trough cross stratified sand facies, St (at Khuniagachh, Dahabandha), parallel laminated sand, Sp (at Tapa Kharibari), ripple laminated sand, Sr (at Doahni, Bazra, Tista Bazar, Chawla, Chawla-200), parallel laminated sand, Sh (at Tapa Kharibari Middle Bar, Dalia, Chawla) and clay with silt, Fl (at Bhotemari, Laxmitari, Khuniagachh, Haripur, Dalia, Tista Bazar). The thickness ranges from 5 to 30 cm and the maximum thickness were found at Bojra (Figure 4), Tapa Kharibari Middle Bar and Chawla sections.

Figure 4: Massive clay facies (Fm) as exposed in the Tista River Basin, Bojra, Ulipur, Bangladesh.

Interpretation

The deposits of Massive clay facies, Fm represent well drained swampy environment (Roy *et al.*, 2004b). Massive clay (Fm) is the final stage of vertical aggradations in the overbanks possibly in the floodplains, flood basins and back swamps when the velocity of the transporting medium was virtually lean that promotes the deposition of clay materials from suspension.

Facies model

The vertical relationship of different facies can be shown by the construction of facies model. The facies model is a useful tool for better understanding of the stratigraphy of an area. It is the most common figure that provides the genetic explanation of the past geologic processes that that played the vital role for the formation of the facies present in the litho-columns of the Tista River basin (Figure 5). A facies model is a general summery of the sedimentary environments represent by the rock record (Walker 1984).

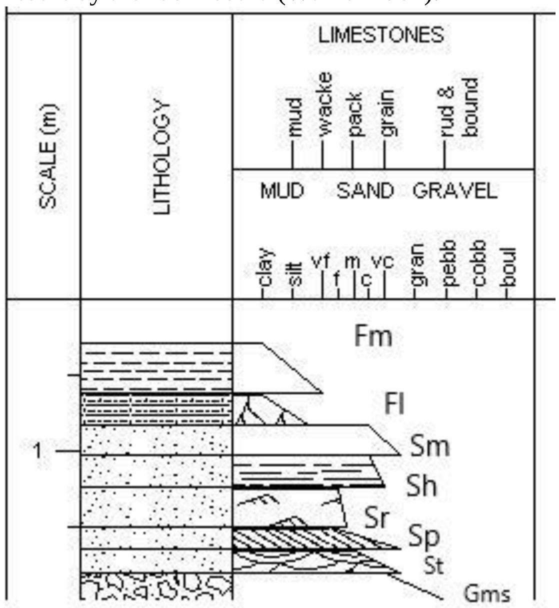


Figure 5: Facies model of the Tista River deposits

The basal facies Matrix supported conglomerate (Gms) is the Oldest facies which is formed under high energy conditions. Trough cross stratified sands (St) is the products of the migration of 3D sub-aqueous dunes in the deeper part of the channel in relatively high energy conditions. Planar cross stratified sand (Sp) has been attributed to current migration of linear ripples. Ripple laminated sand (Sr) is formed due to migration of small-scale 2D and 3D ripples during minimum flow strength in relatively shallow water condition (Jopling and Walker, 1968). Parallel laminated sand (Sh) facies is a product of low energy conditions. Massive sand (Sm) are resulting from transport and deposition by short-lived mass flows. Faintly laminated clays (Fl) are the product when the velocity of the running water is comparatively low in shallow water condition in the overbank. Massive clay (Fm) is a product of flood basins and back swamps when the velocity of the transporting medium is lowest and suspension took place.

Facies association

There are two types of facies association in the sediments of the Tista River under investigation. These are as follows—A) Channel deposits and B) Overbank fines, including flood deposits. The channel deposits consist of Matrix supported conglomerate (Gms), Massive sand (Sm), Trough cross stratified sand (St), Planar cross stratified sand (Sp), Ripple laminated sand (Sr), whereas, the overbank fines, including flood deposits comprise of Ripple laminated sand (Sr), Parallel laminated sand (Sh), Clay with silt (Fl) and Massive Clay (Fm).

A) Channel deposits

The channel deposits are laid down under high energy in the channel. The Matrix supported conglomerate (Gms) deposited under high energy condition having sufficient paleoslopes to carry the sediments. These sediments represent high energy graveliferous river at piedmont alluvial plain or proximal part of alluvial fan.

The Massive sand (Sm) sediments are tractive current deposits under high energy condition and the deposition took place rapidly that did not allow to develop and sedimentary structure. Trough cross stratified sands (St) is the products of the migration of 3D sub-aqueous dunes in the deeper part of the channel in relatively high energy conditions.

Planar cross stratified sands (Sp) are deposits of the migration of 2D sand waves in relatively shallower part of the channel.

Current ripple cross laminated sand (Sr) has been deposited by the migration of small scale 2D and 3D ripples in shallower part of the channel. The channel deposits represent lateral accretion (point bar), downstream accretion (mid channel bar) and channel fill deposits.

B) Overbank fines

The overbank fine sediments are constituted by the facies of Ripple laminated sand (Sr), Parallel laminated sand (Sh), Clay with silt (Fl) and Massive Clay (Fm). occurring in the uppermost part of the lithosuccessions. These deposits represent vertical accretions.

Ripple laminated sand (Sr) represents the shallow deposits of top part of the channel and the deposits of flood on the overbanks. These deposits are represented by 2D ripples; with sufficient supply of sediments the ripples sometimes climb to form climbing cross ripples.

Parallel laminated sand (Sh) is somewhat coarse in grain size and parallel laminated. These deposits are product of upper part of lower flow regime when the flow velocity is sluggish (Middleton and Southward, 1978). The coarser nature, unsorted character and faint laminations/horizontal laminations of the sediments are suggestive of flood deposits in the overbank of the Tista River. Faintly laminated clays (Fl) are the product when the velocity of the running water is comparatively low in shallow water condition in the overbank.

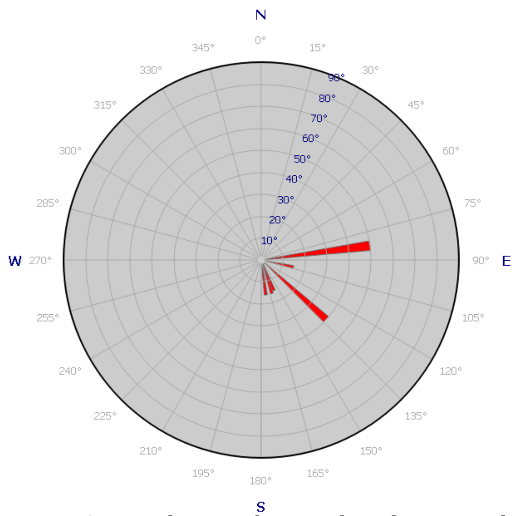


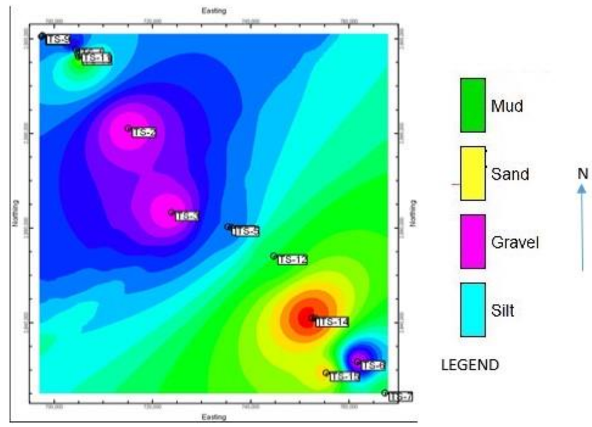
Figure 6: Rose diagram showing the paleocurrent direction

floodplains, flood basins and back swamps when the velocity of the transporting medium was virtually lean that promotes the deposition of clay materials from suspension. These are suspension fall outs of the river and flood in the overbanks. The presence of root/rootlets (in form of small rootlets, decomposed ped marks and coalifed rootlets) are suggestive of short time gap when small scale plants, shrubs and/or grass would grow.

The rose diagram is showing the paleocurrent directions of the investigated area (Figure 7). The calculated vector mean magnitudes are suggestive of northeasterly and southeasterly paleocurrent. The unimodal distribution with high mode value indicates mainly unidirectional sediment transport (Bhattacharyya and Das 2018). The cracks in the sedimentary succession results due to either the compaction of the sediments or the abrupt change in the paleoslope of the depositional basin (Figure 7).

Figure 7: Cracks developed in sedimentary succession at the mouth of the Tista river, Haripur, Sundarganj

Massive clay (Fm) is the final stage of vertical aggradations in the overbanks possibly in the



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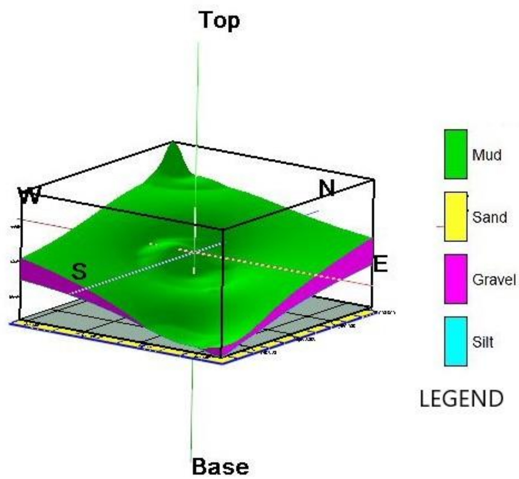

b

Figure 8: a) The distribution spatial of different rocks, b) Sedimentary model of the formation of the Tista river deposits in the Tista Fan, Bangladesh

Figure 8a shows that the coarser gravelliferous deposits are exposed in the upstream directions whereas the finer sediments comprise the areas of downstream. The basal coarser Gms deposits of the sedimentary sequence are poorly sorted and represent debris flow deposit (Meetei et al. 2007). The matrix-supported conglomerate facies belongs to the Tista Gravel formation of Late Pleistocene-Holocene. The three-dimensional inspection of the sedimentary basin reveals that the channel fill deposits are transformed by the overbank fines which is indicative of climatic change in the investigated area during the Quaternary (Figure 8b).

The lithofacies analysis distinguishes their deposition from braided channels and debris flows.

CONCLUSION

Eight different lithofacies were identified in the studied sedimentary succession and they are namely Matrix supported conglomerate (Gms), Massive sand (Sm), Trough cross stratified sand (St), Planar cross stratified sand (Sp), Ripple laminated sand (Sr), Parallel laminated sand (Sh), Clay with silt (Fl) and Massive Clay (Fm). The field observations show that the finer clay sediments are also mixed with sand particles. The colour mottling and colour banding are resulted the mixing of light coloured minerals with dark coloured heavy minerals. Both muscovite and biotite are found in the study area. The channel deposits are laid down under high energy in the channel. The overbank fine sediments are constituted by the facies of Ripple laminated sand (Sr), Parallel laminated sand (Sh), Clay with silt (Fl), and Massive Clay (Fm). occurring in the uppermost part of the sedimentary succession. The presence of root/rootlets (in form of small rootlets, decomposed ped marks and coalifed rootlets) are suggestive of short time gap when small scale plants, shrubs and/or grass would grow. The finer sediments were deposited from the suspension in floodplains or back swamps. The sediments are deposited by the braided river and debris flows. The change in the depositional pattern from debris flow to overbank fines signifies the alteration of climatic condition in the Quaternary period.

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