Original Research Article

Sedimentary structures and lithofacies found in a channel bar of Brahmaputra River in Panikhaiti, Kamrup District, Assam

ABSTRACT

Accumulation of sediments in river channels often leads to the formation of sediment bars. They form prominent elevated regions during the non-flood period within the river channel, and contain characteristic bedform features and internal stratification. These features reflect the hydrodynamic conditions prevailing during the deposition of the sediments. The present study deals with the recognition and interpretation of various bedform features and lithofacies that had developed in a channel bar of the Brahmaputra River, in Panikhaiti near Guwahati, Kamrup district, Assam. The different bedform features that are identified are small and mega ripples, water level cut marks, mud cracks, worm track and trails and raindrop imprints. Internal stratification was identified in trenches of depth ranging between 1.80m and 2.25m. in which eight varieties of lithofacies were identified. These are Trough cross-bedded sand (St), Planar cross-bedded sand (Sp), Horizontally laminated sand (Sh), Climbing ripple lamination (Sr), Convolute bedding (Fc), Flaser bedding (Sf), Massive sand (Sm) and Massive Mud (Fm). The lithofacies associations indicate deposition of sediments under multiple episodes of flood, and characterized by multiple migration from low flow regime conditions to high flow regime conditions.

Keywords: *Bedform features, lithofacies, channel bar, Brahmaputra River, Panikhaiti, Kamrup District, Assam.*

1. INTRODUCTION

The Brahmaputra River is a classic example of a braided river and is highly susceptible to channel migration and avulsion. It is one of the largest sandy braided rivers in the world and is characterized by large seasonal discharge and sediment load in its lower reach (Reineck and Singh, 1980), and development of channel bars comprising of fine-grained materials. Coleman (1969) described in detail the processes and various depositional features of the Brahmaputra River in its lower reach in the deltaic plains of Bangladesh. Das and Borthakur (1995) presented a fluvial facies model of the

Brahmaputra River near Nimatighat. Patgiri and Laskar (1996) worked on a channel bar near Guwahati and described different lithofacies types and sequences. Borkotoky (2015) published a paper on bedforms and lithofacies and the interpretation of depositional environment of Brahmaputra River near Nemati, Jorhat, Assam.

The study area of the present bar is confined to parts of a bank-attached bar of the Brahmaputra River near Panikhaiti, Guwahati, Assam. This bank-attached bar is bounded within coordinates $91^0$52'20.97" and $91^0$53'44.55" E and $26^0$13'5.20" and $26^0$13'39.14"N. The location of the bar is shown in Figure 1. The maximum length of the bar is about 2 km and average width is about 0.5 km. The bar is elongated in shape and acquires a pointed shape towards its downstream end.

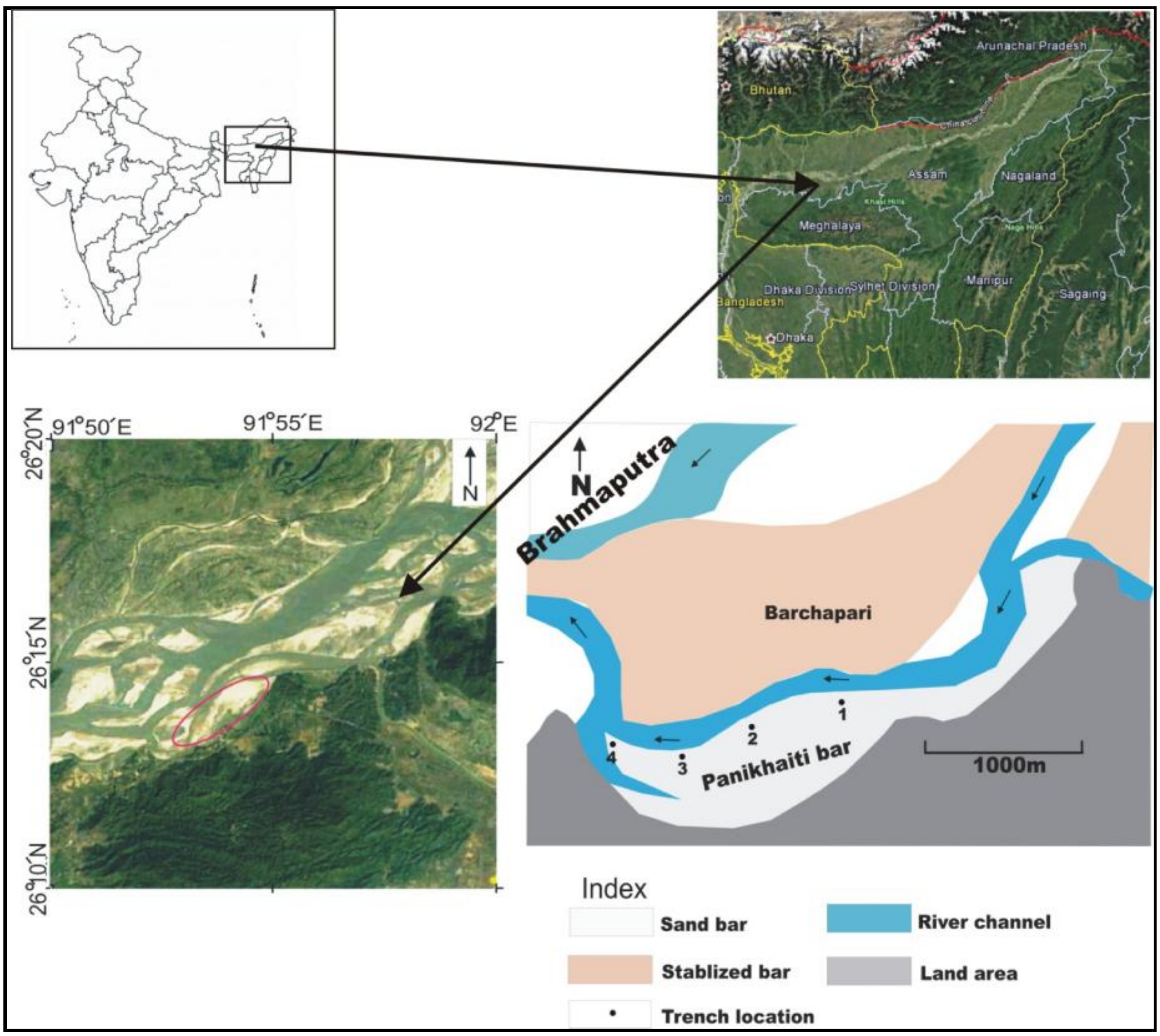

Fig. 1. Location map of the study area (Google Earth Image).

2. METHODOLOGY

The present study is concerned primarily with identification and recognition of various bedform features and lithofacies developed on the channel bar, together with their environmental significance. For this purpose trenches were dug at four suitable locations along the bar margin with one trench-face aligned parallel to flow, and with another face aligned perpendicular to the flow direction. The trenches varied in depth between 1.7m and 2.25m. Various lithofacies types and their characteristics were identified in these trenches. Measurement of thickness and inclination of internal stratification were also recorded during the course of field investigation in the trenches studied. The bedform features, as well as lithofacies associations so identified, were interpreted from the point of view of the hydrodynamic conditions prevailing during the deposition of the sediments at various stages of development of the bar.

3. OBSERVATION AND DISCUSSION

BEDFORM STRUCTURES

Various sedimentary structures have been observed on the bar surface. The structures are mainly ripple marks, (small and mega ripple), water level marks, mud cracks, raindrop imprints, and worm track and trails.

Small ripples

Most of the ripples are of lingoid type (Fig. 2A). They are discontinuous, isolated and are broken with forward closures. Ripples range in length between 3 cm to 7 cm whereas the height varies between 5 cm to 15 cm. They are produced as a result of the interaction of waves or currents on the sediment surface (Reineck and Singh, 1980).

Mega ripples

Mega ripples are of a larger height, greater length and asymmetrical crests and are undulatory in nature. The wavelength of the mega ripples are greater than 4.5m, ripple index is found to be above 15 and the height varies from 35cm to 58cm. Their crests are asymmetrical (Fig. 2B).

Water level cut marks

Water level cut marks are also called micro-terrace (Picard and High, 1973). They are usually developed at the contact between water level and a sloping sediment surface and look like small steps

(Fig. 2C). Well developed water level cut marks are observed along the edge of the channel bar in the study area.

Mud cracks

Mud cracks form when mud is dewatered, shrinks and leaves a crack. Mud cracks of varied dimensions are recorded in the area. They are polygonal in shape. The average thickness of individual cracks range from 2.5 cm. to 30 cm. while the depth of the cracks varies from 0.5 cm to 65cm (Fig. 2D).

Raindrops imprints

They are found on the top surface of loose sediment in the study area and are formed in wet mud or loose fine sand and are circular in outline (Fig. 2E). Their circular nature indicates low wind conditions during the rainfall spell.

Worm tracks and trails

They are produced by various organisms on the bar surface. Movement of organisms on the surface of loose and soft sediment may cause the development of worm tracks and trails. (Fig. 2F). They occur as a network of ridges composed of sediments a few millimetres high.

Fig. 2. (A) Lingoid ripples. Current direction is from top right corner to down left corner, (B) Mega ripples with undulatory crest line. Current direction from right to left, (C) Water level cut marks. Scale is 30 cm, (D) Mud cracks, scale is 30cm, (E) Rain drop Imprints, (F) Worm tracks and trails, scale is 10 cm.

LITHOFACIES ANALYSIS

The term “Lithofacies” is used to describe various depositional units from the point of view of their characteristic internal stratification and structure, grain size and other physical properties like colour, mottling, bioturbation etc. Different structures in a sedimentation unit may develop either due to variations in the energy condition of the depositional environment or due to the variation of grain size of the available material for sedimentation in a constant energy condition (Fritz and Moore, 1988). Based on sedimentary structures and grain sizes, 8 (eight) lithofacies varieties are recognized and coded following Miall (1978, 1996), and are described below.

1. Trough cross-bedded sand (St)
2. Horizontal laminated sand (Sh)
3. Planar cross-bedded sand (Sp)
4. Climbing ripple laminated sand (Sr)
5. Convolute bedding (Fc)
6. Flaser bedding (Sf)
7. Massive sand (Sm)
8. Massive mud (Fm)

1. Trough cross-bedded sand (S_t)

A cross-bedded unit where bounding surface is curved and the units are trough-shaped is called trough cross-bedded (Reineck and Singh, 1980). This facies consist of fine to very fine sand. It is further sub-divided into two types St_1 and St_2 on the basis of their dimension. Facies St_1 represent trough cross-bedding with set thickness greater than 4 cm, while St_2 represents trough cross-bedding with set thickness less than 4 cm. The thickness of the facies units vary between 15 cm and 80 cm (Fig. 3A). The trough cross-bedded sand indicates their deposition under increasing flow strength in lower flow regime conditions and produced by migration of three dimensional bedforms.

2. Horizontal Laminated Sand (S_h)

This lithofacies is composed of very fine sand (Fig. 3B) and range in thickness between 8 cm and 70 cm. This facies represents deposition under high-velocity condition in the plane bed phase of upper flow regime (Parkash et. al. 1983).

3. Planar Cross-bedded sand (S_p)

This facies is composed of medium sand and the beds are tabular to wedge-shaped. The foreset angle varies from 25° to 45°. The thickness of the beds varies from 7 cm to 30 cm (Fig. 3C). Planar cross-bedded sand forms due to the migration of straight crested large or small ripples on the surface of the bar supplying sand, which has slipped down and was deposited on the avalanche face of the bar (Singh and Bhardwaj, 1991).

4. Climbing –Ripple Laminated Sand (S_r)

Climbing ripple lamination are the internal structure formed in non cohesive materials from migration and simultaneous upward growth of ripple produced either by current or waves. Climbing ripple laminations, particularly Type-II (drift type) (Reineck and Singh, 1980) are found in abundance in the study area. They indicate a relatively high rate of sediment deposition in comparison to transportation (Mckee, 1966). They range in thickness from 20cm to 30 cm (Fig. 3D).

5. Flaser bedding (Sf)

Ripple bedding in which mud streaks are preserved completely in troughs and partly in crests is known as Flaser bedding (Reineck and Singh, 1980) (Fig. 3E). The thickness of the bed varies from 5 cm to 25 cm.

6. Convolute bedding (Fc)

Convolute bedding is a structure showing marked crumpling or complicated folding of laminae of a well-defined sedimentation unit (Kuenen, 1953; Potter and Pettijohn, 1963).This facies is well developed in very fine sand. The convolute are asymmetry and the axial plane inclined to the down current direction. The thickness of the bed is 18 cm (Fig. 3F).

7. Massive sand (Sm)

This lithofacies is characterized by massive nature and does not show any internal stratification and average thickness of strata is about 15 cm (Fig. 3G). The massive units are possibly post-depositional products of local nature formed by underwater slumping in still-soft sediment (Ray, 1976).

8. Massive Mud (Fm)

Facies Fm is composed of homogeneous massive mud layers composed of variable amounts of silt and clay. The thickness of the beds varies from 5 cm to 30 cm. They are formed during the waning stages of flood by vertical accretion of fine suspended sediments under quiet environment (Fig. 3H).

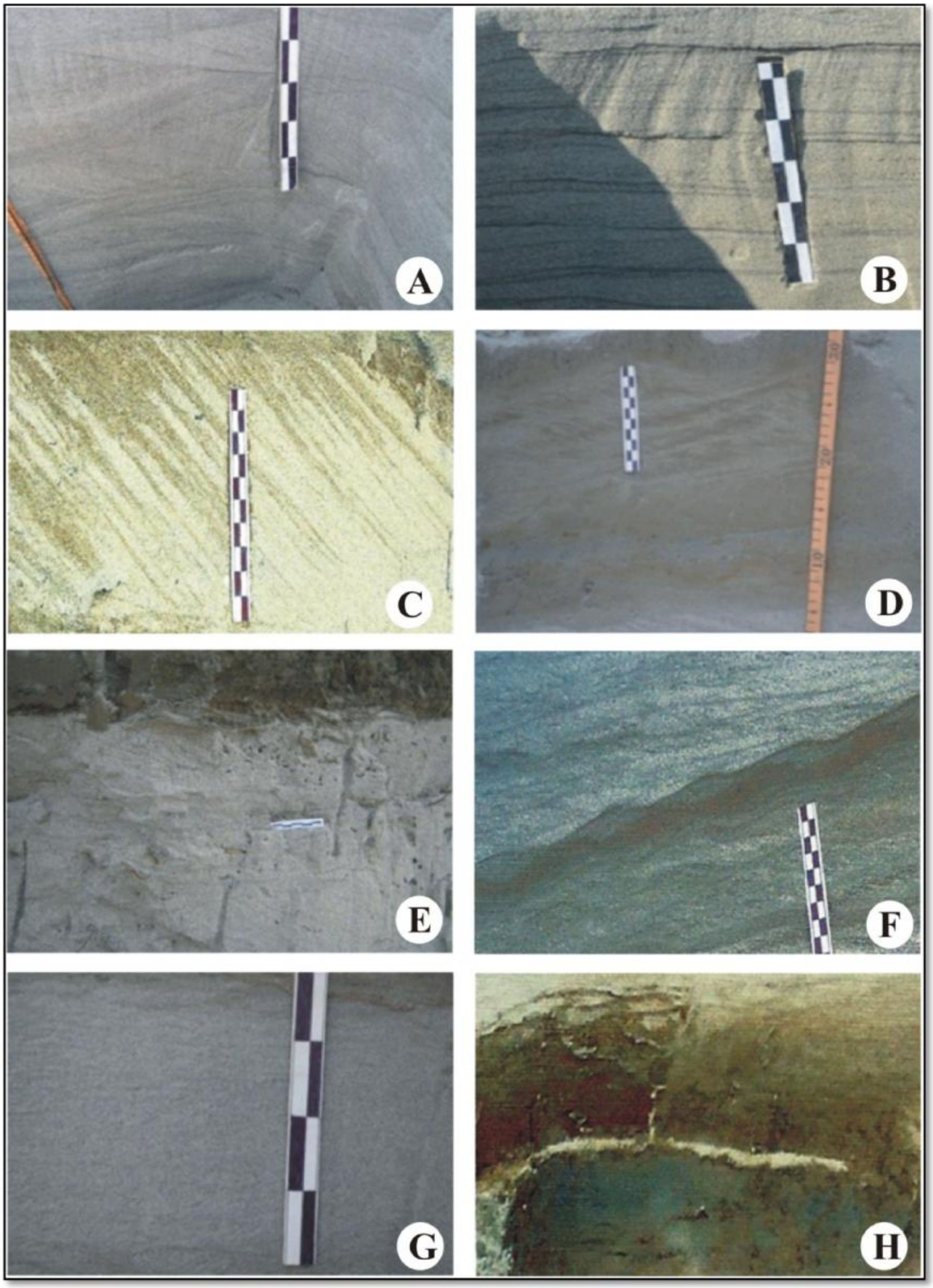

Fig: 3 (A) Trough cross bedded sand, (B) Horizontal laminated sand, (C) Planar cross bedded sand, (D) Climbing ripple laminated sand, (E) Flaser bedding, (F) Convolute bedding, (G) Massive sand and (H) Massive mud.

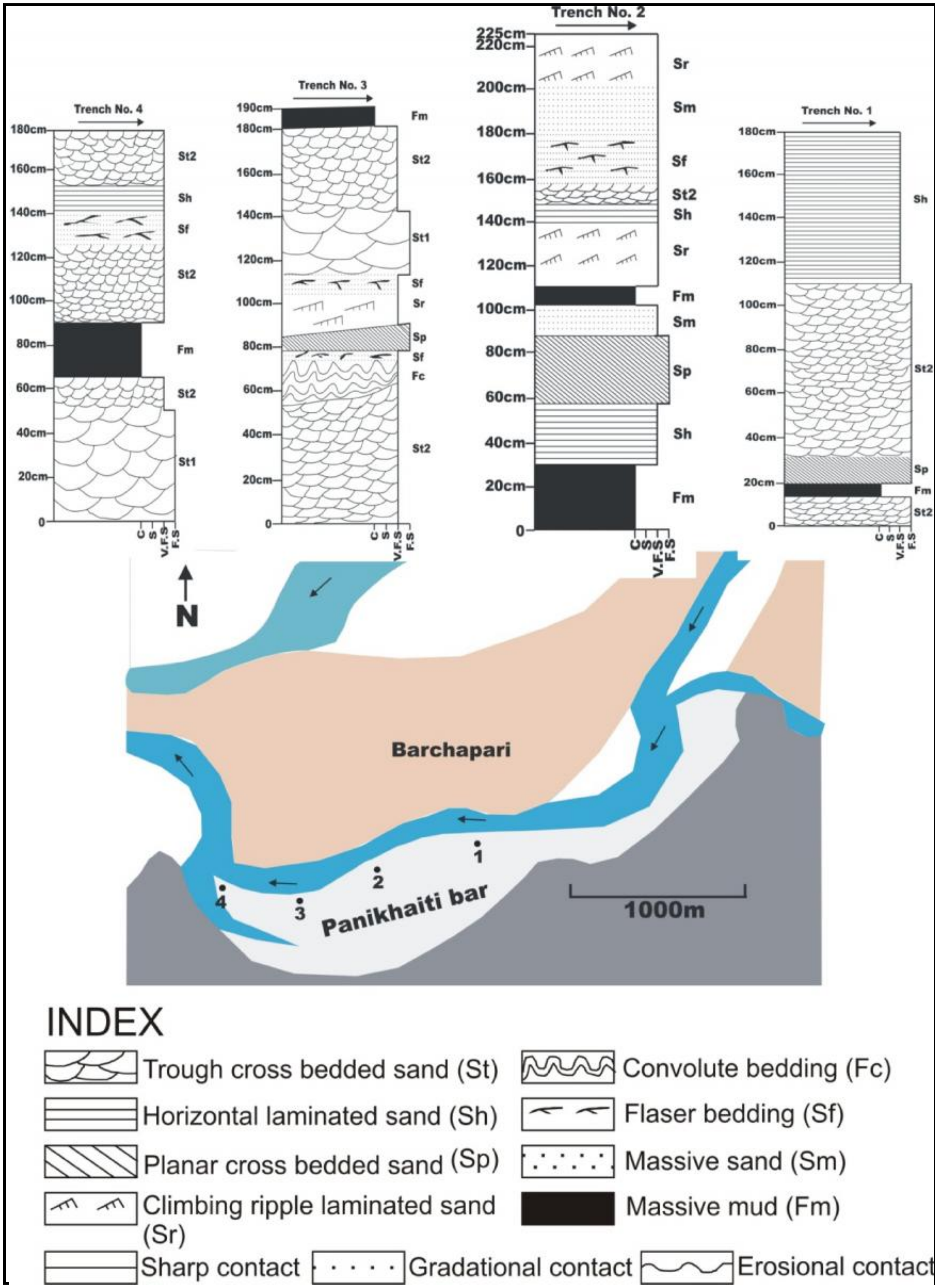

Fig. 4. Vertical profile section showing distribution and association of various lithofacies types.

LITHOFACIES ASSOCIATION

Fig. 4 shows the vertical and lateral distribution of the lithofacies of the bar. **Trench 1** represents a 180 cm thick sequence from the upstream portion of the bar. The lower portion of the sequence is composed of small scale trough cross bedded sand (St_2). This facies is overlain by massive mud (Fm) which marks the end of a flood cycle. Facies Fm is overlain by planar cross bedded sand (Sp). Again Sp is overlain by small scale trough cross bedded sand (St_2) facies. The foreset laminae angle of facies Sp varies from 30° to 35°. They are deposited by migration of large two dimension ripples in lower flow regime condition. Facies St_2 is overlain by horizontal laminated sand (Sh) which develops under upper flow regime conditions.

The facies association reflects a gradual transition from lower flow regime conditions to an upper flow regime condition in the upstream portion of the bar. Fining upward sequences is also seen..

Trench 2 represents the middle portion of the bar where the sedimentary sequence becomes 225 cm thick. The lower portion of the sequence contains massive mud (Fm). This facies is followed by horizontal laminated sand (Sh) which represents deposition under upper flow regime conditions. Facies Sh is overlain by planar cross bedded sand (Sp). Sp is in turn overlain by massive sand (Sm) followed by Fm. These facies associations represent a complete flood cycle. Climbing ripple laminated sands (Sr) occur above Fm. Facies Sr is subsequently overlain by Sh which indicates a change from lower flow regime to upper flow regime condition. A drop in flow velocity is indicated by the occurrence of Facies St_2 above Facies Sh. Flaser bedding (Sf) is found above Facies St_2. Facies Sf is subsequently overlain by massive sand (Sm) and Facies Sr, which indicates prevalence of lower flow regime condition during the deposition of the most recent sediments. Almost three flood cycles are identified. Coarsening up to fining up sequences is also seen in this sequence.

Trench 3 represents the middle portion of the bar where the sequence becomes 190 cm thick. The lower portion of the sequence is composed of small scale trough cross bedded sand (St_2) which is followed upwards by convolute bedding (Fc) and Flaser bedding (Sf). Facies Sf is overlain by planar cross bedded sand (Sp). They indicate a lower floor regime condition. Facies Sp is further overlain by climbing ripple laminated sand (Sr) and flaser bedding (Sf). This facies is followed by large scale trough cross bedded sand (St_1). St_1 is overlain by small scale trough cross bedded sand (St) and finally by massive mud (Fm) unit. The finer facies such as ripple laminated sand (Sr), convolute bedding (Fc), flaser bedding (Sf) anf massive mud (Fm) were deposited during the falling stage of the flood.

A complete flood cycle along with fining upward sequences is also seen in this sequence.

Trench 4 is located in the downstream portion of the bar and is 180 cm in thickness. The lower portion of the sequence is composed of large scale trough cross bedded sand (St_1) and is followed upwards by small scale trough cross bedded sand (St_2) and massive mud (Fm). Facies Fm is overlain by facies St_2 followed by flaser bedding (Sf). Sf is overlain by horizontal laminated sand (Sh) which indicates an upper flow regime condition. This facies is overlain by facies St_2 and indicates a drop in current velocity during their deposition. Two flood cycles are identified. In the lower portion a beautifully developed a fining upward sequence.

4. CONCLUSIONS

The present study, various bedform features are identified. they are represented by small and mega ripples, water level cut marks, mud cracks, rain drop imprints and worm tracks and tails. Eight different types of lithofacies could also be identified in the bar. These are Trough cross bedded sand (St), Horizontal laminated sand (Sh), Planar cross-bedded sand (Sp), Climbing ripple laminated sand (Sr), Convolute bedding (Fc), Flaser bedding (Sf), Massive sand (Sm) and Massive mud (Fm). The lithofacies associations indicate deposition of sediments under multiple episodes of flood, and characterized by multiple migration from low flow regime conditions to high flow regime conditions. The lithofacies associations also show development of both complete as well as incomplete fining–upward flood sequences. Incomplete flood sequence show association of fewer lithofacies types and indicate the simultaneous erosion and deposition by floods. Different lithofacies types and association in the study area indicates their deposition under different hydrodynamics conditions.

REFERENCES

1. Borkotoky A. Study on Bedforms and Lithofacies Structures and Interpretation of Depositional Environment of Brahmaputra River near Nemati, Assam, India, The International Journal of Engineering and Sciences. 2015;4(7):14-20.

2. Coleman JM. Brahmaputra River, Channel Processes and Sedimentation, Sediment Geol. 1969;3(2 & 3):129-239.

3. Das PK, Borthakur J. Fluvial Facies Model of the Brahmaputra River Sediments around Nimatighat, Jorhat, Assam; Bull Pure and Applied Sci. 1995;14(1& 2):63-69.

4. Fritz WJ and Moore JN. Basics of Physical Stratigraphy and Sedimentology, John Wiley & Sons Inc; 1988.
5. Kuenen Ph H. Significant Features of Graded Bedding, Bull Amer. Assoc. Petrol. Geologist. 1953; 37:1044-1066.

6. McKee ED. Significance of Climbing Ripple Structures, Prof Paper, U.S. Geol Survey, 550-D, 1966;94-103.

7. Miall AD. Lithofacies Types and Vertical Profile Models in Braided Rivers, A summery, In Fluvial Sedimentology, A.D Miall (Ed). Canadian Soc Petrol Geol; 1978.

8. Miall AD. The Geology of Fluvial Deposits. Springer-Verlag, Berlin Heidelberg; 1996.

9. Potter PE, Pettijohn FJ. Palaeocurrents and Basin Analysis, Berlin-Botingen-Heidel-berg.Spinger; 1963.

10. Picard MD, High (Jr.) LR. Sedimentary Structures of Ephemeral Streams, Elsevier Scient. Publ. Co., Amsterdam-London-New York; 1973.

11. Patgiri AD, Laskar J. Lithofacies Types and Sequences of Channel Bar deposits: A Case Study of Brahmaputra River near Guwahati, Assam, Journ. Indian Association of Sedimentologists.1996;15:165-176.

12. Parkash B, Awasthi AK, Gohain K. Lithofacies of the Markanda terminal fan, Kurukshetra district, Haryana, India, Spec. Publs. Int. Ass. Sediment. 1983;6:337-344.

13. Ray PK. Structure and Sedimentological History of the Overbank Deposits of a Mississippi River Point Bar, Jour Sed Petrol. 1976;46(4):788-801.

14. Reineck H E, Singh IB. Depositional Sedimentary Environment, Spinger-Verlag, New York; 1980

15. Singh A, Bhardwaj BD. Textural Attributes Depositional Processes and Heavy Mineral Study of the Ganga Sediments between Haedwar and Kachhla, Bull Ind. Geol. Assoc. 1991;24(1):41-54.