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An account on bed form features and lithofacies types of the Brahmaputra River found in Kakari Kata Bar, Majuli District, Assam

Suman Saikia* and Jayanta Jivan Laskar
Department of Geological Sciences, Gauhati University Gopinath Bordoloi Nagar,
P.O. Gauhati University,Jalukbari, Guwahati, Assam, INDIA
Mob- 8822638664 Email: sumansaikia1991@gmail.com

Abstract: Brahmaputra river, one of the argest river in the world flows from Himalaya and debouches its enormous sediment into the bay of Bengal. During its journey through Assam it exhibits braided pattern and forms various bars. One of such bar is Kakarikata present in the district of Majui which is got separated from the main land area of Majuli by a second order channel of the Brahmaputra river. The present study focuses on the study of various bedform features and lithofacies types on both the northern as well as southern part of the stabilized bar. The bedform features found in the study area are ripples, megaripples, scours, mud cracks etc. The lithofacies types found on the channel channel sediments of both sides are Sh, St, Ms, Sr whereas the lithofacies types found on the bank sediments of both side are Fm, St, Sp,Sr, Sm, Fl and Sh. On the bank sediments alteration of mud and sand layer were found.

Keywords : Bed Form, Brahmaputra River, Kakari Kata Bar

Introduction: Braided Rivers and their deposits are important components of the Earth's surface (Bridge et al., 2005). They are characterized by high rates of sediment transport, deposition and erosion combined with frequent channel shifting and rapid bank erosion (Mosley et al., 1982). Braiding results from changes in flow regime due to systematic sorting and deposition of sediments with sizes it is no longer capable of carrying. The continued deposition of sediments in an area will result in formation of different types of bars and bed forms, which in turn would impede and divert the flow (Miall, 1982).

The Brahmaputra River is one of the largest rivers in the world and displays a braided pattern in its middle part during its journey through Assam. It has a large discharge with heavy sediment load, active lateral migration (Coleman, 1969) and a hierarchy of channels exists in the river resulting various channels with different orders (Bristow, 1987). Because of a high amount of sediment coming during the rainy season, the river builds up channel bars which migrate actively during floods, mainly due to migration of various bed forms (Borkotoky, 2015). One of the most conspicuous feature of the alluvial reaches of the Brahmaputra River is the presence of large alluvial islands ; several of which are more than a century old and inhabited as well (Lahiri et al., 2014).One such island, Majuli, located in the upper reach of the Brahmaputra valley has been recognized as the largest riverine island in the world(Lahiri et al.,2014).

In the western part of Majuli, near Lahalial, a 2nd order channel cuts the main land and forms a stabilized bar named Kakari Kata (Fig 1).The southern bank of Kakari Kata bar comes directly under the influence of the main channel of Brahmaputra River. The present study aims to examine the characteristics of various bed form features and lithofacies types occurring in both the northern and southern part of the stabilized bar.

Location: The study area is located towards the western part of Majuli, between Burha Chapori and Borgayan no 1. The approximate length of the stabilized bar is 6km and breadth is about 2.6km. A 2nd order channel of the Brahmaputra river flows through the northern margin of the stabilized bar with an approximate width of 50m. The present study focused on the characteristics of the bedform features, channel sediments and over bank deposits in the northern and southern bank of the stabilized bar.The coordinates of study location in the 2nd order channel, north of stabilized bar is about 26°55'40.0N, 94°06'31.8''E and in the south of stabilized bar near the present day water level is 26°54'29.4N, 94°06'41.8".

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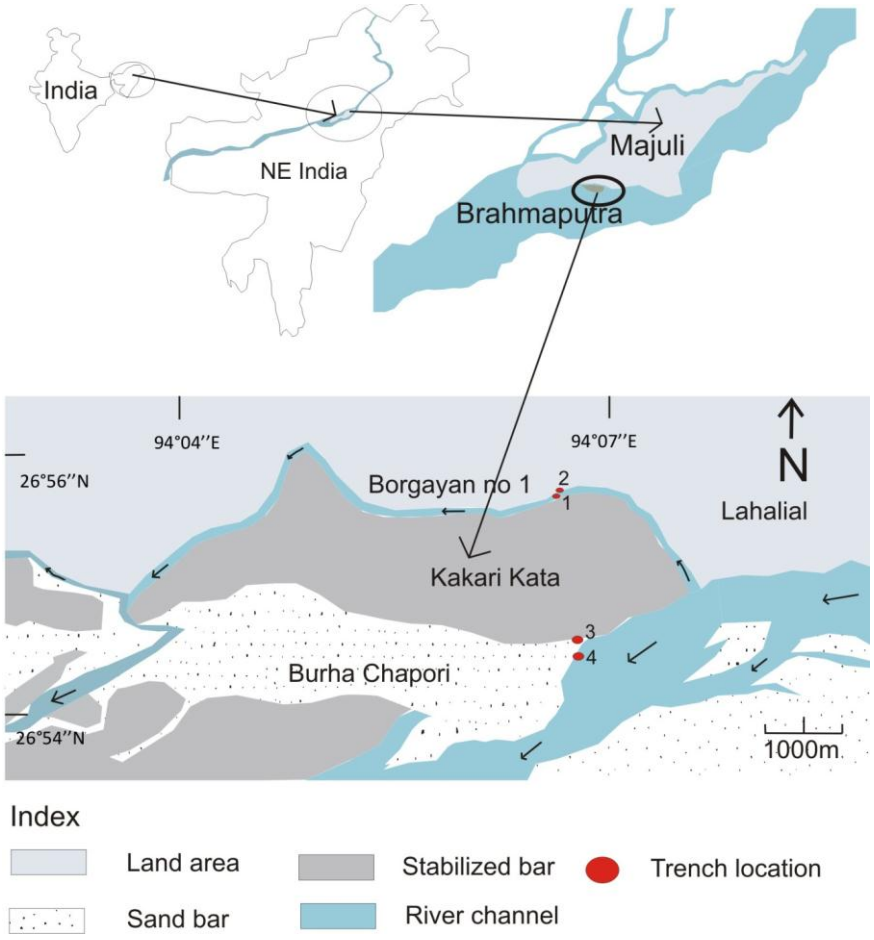

Fig 1: Location map of the study area.

Methodology: The field survey was carried out in the month of February, 2017 after the recession of the monsoon floods. Fresh bed form features and channel deposits are exposed during this time, which makes it convenient for their study and interpretation. The various bed form features were identified, measured and their salient characteristics were described. The location coordinates were recorded with the help of a hand held GPS receiver (Garmin-e-Trex). To study the lithofacies types, their assemblage and their internal structure, trenches were dug in 'L' shaped pattern with one direction perpendicular to the river flow direction and the other parallel to the water flow. Various parameters like thickness, colour, grain size, internal stratification, nature of contact between different lithofacies units were noted and their dimensions were measured with measuring tape and a brunton pocket transit. The lithofacies types were identified following the lithofacies classification scheme proposed by Miall,1978. Representative sediment samples were collected from various lithofacies units following the methods of Spot Sampling and Channel Sampling. Spot sampling was carried out in strata of thickness less than 15 cm while channel sampling procedure was undertaken in strata with thickness greater than 15 cm. The samples were carefully packed in labeled sample bags for laboratory analysis.

Observations and Interpretations:

The study was undertaken in the northern and southern part of the stabilized bar. The northern part (trench no 1&2) comprises of sediments deposited by the 2nd order channel. Trench-1 is located within the 2nd order channel while Trench-2 is situated in the right bank of the 2nd order channel. In the southern part of the stabilized bar, two trenches were dug (trench no 3&4). Trench-3 was dug in the southern bank of the stabilized bar, and Trench-4 was dug in the sediments deposited on the sand bar further south of Trench-3. It is located adjacent to the present day river bank.

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Northern part of the stabilized bar is composed of sediments deposited by a 45m wide second order channel flowing towards S63W (Fig 2a). The sediment surface contains Mega-ripples and large scours. The megaripples have undulatory crest lines with amplitudes of about 1m.The troughs of these megaripples are marked by deposition of mud, which appear dark due to presence of high amount of moisture. No mud cracks are found on the surface of these muddy layers. A second set of mega ripples are found on the stoss side of the pre-existing megaripples with amplitude of 25 to 55cm. Ripple index (L/H) of these megaripples is about 26. There is development of several scours in the area. They are about 6.6m in length, 3m in width and 40cm in depth and trend towards SW (Fig 2b).

Fig: 2a. 2nd order channel of the Brahmaputra River in the study area

Fig: 2b. Scours observed on the top surface of mega ripples.

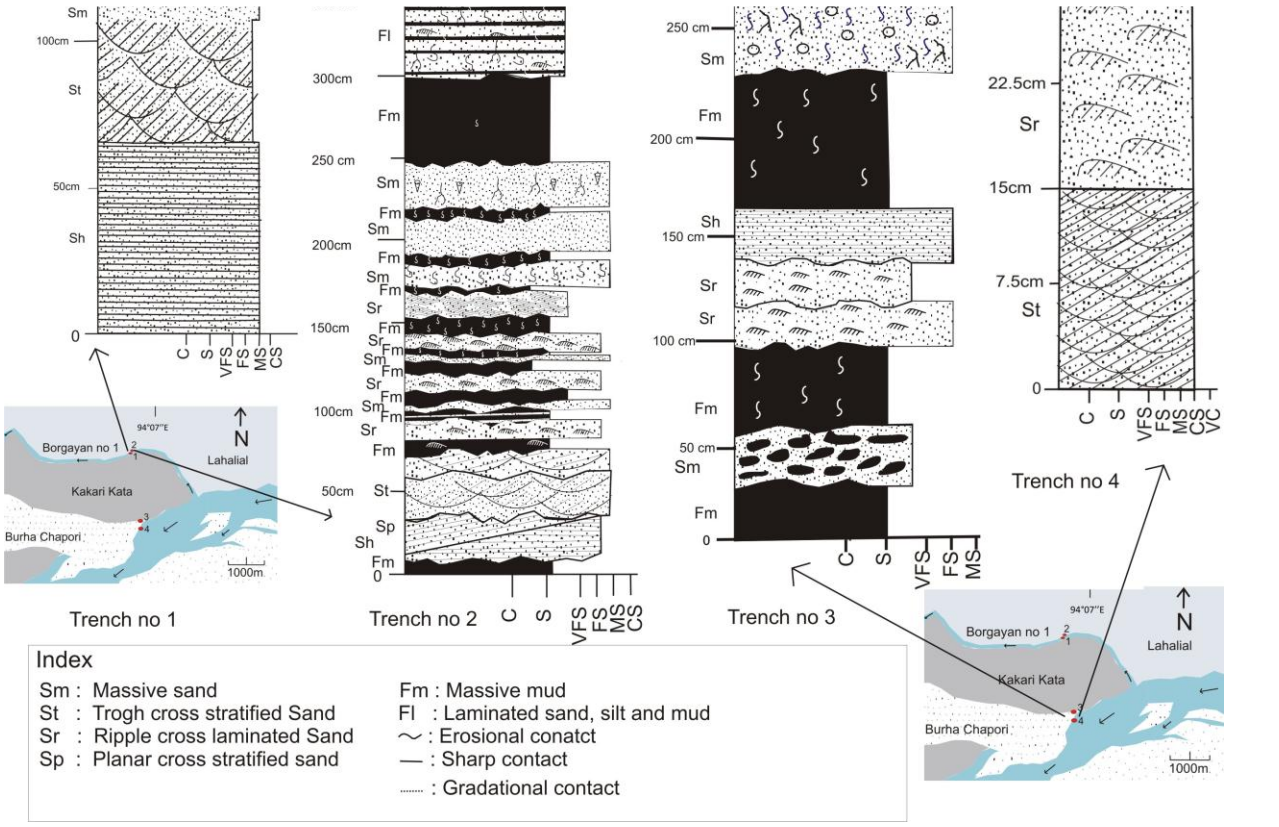

Fig 3: Lithofacies associations at different locations in the study area. Arrow marks indicate flow direction.

Trench number 1(Fig 3) consists of channel deposits of about 1.15m thickness. The sediments are medium sand and consist of three lithofacies varieties, namely, horizontally stratified sand (Sh), trough cross stratified sand (St) and massive sand(Sm). The lower portion of the sequence is composed of medium sands and shows horizontal stratifications. This layer is overlain by low angle trough cross stratified sand (St) with a sharp boundary, and is composed of fine to medium sand. The fore set angle within each trough dips between 14^{o} and 20^{o}. The length of the troughs is about 2m. Lithofacies St is overlain by medium grained Massive sand facies (Sm) through a gradational contact. This layer occurs as a layer of unconsolidated sediments on the topmost portion of channel surface.

The presence of a thick sequence of Sh in medium sand indicates transition from lower flow regime to upper flow regime conditions. The presence of lithofacies St above Sh indicates a drop in kinetic energy and a change from upper flow regime conditions to lower flow regime conditions. St had developed due to the migration of 3d dunes. The sharp contact between Sh and St indicates a short switch-over time from upper flow regime to lower flow regime conditions. The deposition of Sm above St in a small channel might be the result of further drop in stream power.

Trench number 2(Fig 3) was dug on the right bank of the 2^{nd} order channel and is approximately 3.5m in depth. Six types of lithofacies were identified in this trench. They are Sm (massive sand), Fm (Massive mud), Sr (Rippled sand), St(Trough cross stratified sand), Sp(Planar cross stratified sand) and Sh(Sand with horizontal stratification).The entire sequence is composed of alternations of sand and mud layers. The lowermost layer comprises of massive mud, Fm which forms due to deposition of suspended silt and clay due to drop in velocity during the receding phase of a flood episode. Fm is overlain by Sh, which in turn is overlain by Sp. The planar cross stratified layer was overlain by trough cross stratified layer, where the coset thickness decreases from 25cm to 14cm towards the top of the unit. The foreset laminae of the larger cosets (coset thickness ~ 25cm) have a thickness of 1-3mm and dip at 34°. Towards the top portion of St, the bounding surfaces become distinct due to high concentration of opaque minerals. Here the foreset laminae dip at 11°→ 294° and have an average thickness of 3mm. This layer is overlain by Fm which contains traces of poorly preserved ripples. It marks the end of another flood episode. This layer is again overlain by medium-grained rippled sand (Sr). The foreset thickness ranges from 1 to 2mm and dips at 24° → 290°. The coset thickness ranges between 6mm-12mm dipping at 4° → 111° Facies Sr is overlain by mud (facies Fl) containing irregular sand laminae. Ripples with foreset thickness of 1mm are found within the sand laminae. Facies Fl is overlain by a 25mm thick layer of fine to medium sand containing irregular mud pellets. The mud pellets may have been derived from erosion of pre-existing mud layers. A 9cm thick sandy mud layer containing ripples with forest thickness 1-2mm overlies this layer. The contact between the two layers is marked by a contorted sandy layer. This layer is overlain by a 8cm thick rippled sand facies (Sr). Muddy sand (Sm) overlie the layer and contains type-2 ripple (Reineck et al.,1980). Fine to medium sand Sm of 16mm thickness overlies this layer with an erosional contact, which is marked by the presence of mud pellets. This layer is overlain by a layer of bioturbated mud and a 13.6cm thick muddy sand layer containing climbing ripple type-2 whose foreset thickness are 1mm and dip at 14 → 254. The set thickness varies between 8-12mm and dip 9→108. Reddish mottling is seen within the bioturbated mud layer. A bioturbated poorly preserved trough cross stratified sand (St) layer overlies the previous layer. Massive mud (Fm) is found to occur above the previous St layer. Again this layer is overlain by 20cm thick massive sand (Sm) with an erosional boundary. The Sm is overlain by massive mud (Fm), which is subsequently overlain by massive sand (Sm) containing small amounts of mud chunks. Traces of animal activity is found in this layer in the form of worm burrows. Brown massive mud (Fm) overlie this layer with an erosional boundary. The topmost layer of this lithofacies sequence is composed of fine to medium massive sand (Sm), which displays development of bioturbation, thin mud streaks and irregular ripples. Mud shows greater amount of bioturbation with presence of spherical mud-pellets and insect burrows. The layer is marked by development of ill preserved ripples where cross stratification is occasionally observed. The thickness of forest laminae is 2mm and forest angle dip at 20° → 264.

The lithofacies assemblage in this vertical profile comprises of alterations of sand and mud, indicating fluctuations in the energy level of the transporting media. The repetition of sand and mud layer is the result of multiple episodes of flooding. The occurrence of sand with horizontal cross stratification indicates upper plane bed condition. Miall, 1996 reported that lithofacies Sh occurs under two different conditions, lower velocities at shallow depth and during flash floods, when flow

conditions may remain in the critical stage for periods of many hours. Sp formed in the lower flow regime conditions by the migration of 2 D dunes (Miall, 1996). With subsequent increase in water velocity there was formation of trough cross stratification in the overlying sand layer, a portion of which was subsequently eroded off. The overlying alternations of rippled sand and mud layer, indicates development of rippled sand during the flood stage, and deposition of mud during the waning stage of flood within the 2nd order channel. The presence of climbing ripple lamination in the trench is the result of migration and simultaneous upward growth of ripples produced by currents (Reineck et al., 1980). Type-1ripples indicate that at the time of formation of these ripples the amount of suspended load in the river water was less. There was development of various layers of type 1 ripple cross laminated sand and there was development of one layer type 2 ripples also. The formation of type 2 ripple after episodes of different flood cycle forming type 1 ripple indicates that the during the formation of these layer the amount of suspended sediment was much higher than the previous flood cycles(Reineck et al., 1980). As we move upward from about 200cm there was development of bioturbation in almost each layer which indicates sub areal exposure of these deposits. The massive mud layer represents overbank deposit and the top of the profile is characterized by ripple laminated sand, silt and mud mixture with development of bioturbation,burrows, abundant vegetative material which indicates natural levee sequence(Miall, 1996).

The southern part of the stabilized bar comes directly under the influence of the main channel of River Brahmaputra. The bed form features identified in this location are undulatory to lingoidal ripple, obstacle scour (Fig.4b), and thin mud drape layer. Regions in the vicinity of present day river bank are characterized by mega ripples with wavelengths ranging between 7.5 and 10m, and amplitude 20 to 30 cm.

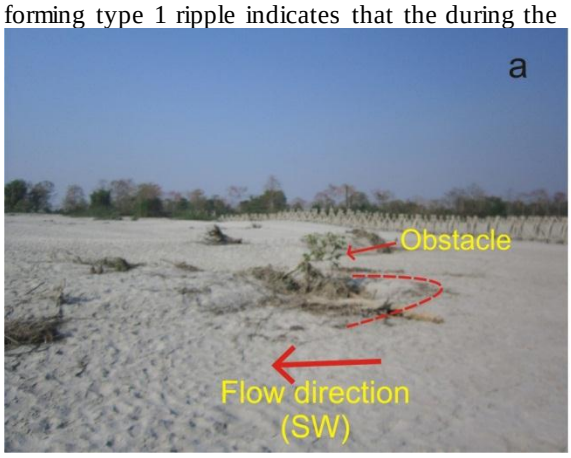

Fig:4a. Obstacle scour and its flow direction

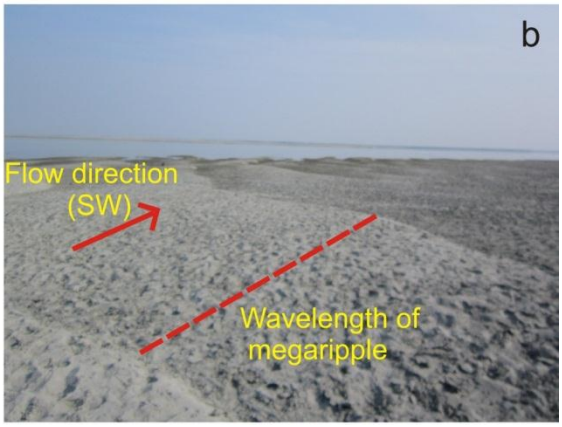

Fig4b. Mega ripples with undulatory crest line along the present day river bank

Trench number 3(Fig 3) is located towards the southern bank of the stabilized bar and is directly affected by the action of flow of the present day main channel of Brahmaputra river. The lithofacies assemblage is composed of four varieties, namely massive mud (Fm), massive sand (Sm), rippled sand (Sm) and horizontally stratified sand (Sh). The lowermost portion of the lithofacies sequence is composed of a massive mud layer of thickness about 30cm. This layer is overlain by muddy sand which contains irregular patches of mud eroded from muddy layers situated in upstream locations. This layer is overlain by a massive bioturbated mud (Fm) layer of thickness 27cm. Indistinct rippled fine sand layer (Sr) of thickness 40cm overlie this layer, which in turn is overlain by muddy sand containing ripples (Sr). About 22cm of fine sand showing horizontal stratification (Sh) overlies this layer. A thick layer of sandy mud (Fm) overlies Sh with a sharp boundary. This layer is affected by bioturbation, vegetative materials are abundant and formation of spherical pellets within the mud have been observed.The top most portion of the lithofacies sequence is composed of Massive fine sand (Sm) which contains insect burrows, vegetative material and the lower portion contains mud.

The alteration of various mud and sand layers in this section indicates occurrence of multiple cycles of flood episodes. The massive mud layers were deposited due to drop in water velocity and the sand layers were deposited during the peak stage of water current velocity. Formation of irregular patches of mud within the sand layer indicates that they are probably the result of eroded chunks coming from the upstream location. The

occurrence of type 1 cross laminated sand in this profile indicates that at the time of formation of these ripples the amount of suspended sediment load was not high. The development of horizontal stratification in medium to fine sand above the ripple laminated sand indicates increase in water velocity and hence indicates upper flow regime. The top of the sequence is affected by bioturbation. This indicates occasional sub areal exposure of the sediments. The topmost layer of the vertical section is characterized by the development of sandy layer with little amount of mud containing abundant vegetative material, rootlets, burrows, bioturbation indicates over bank deposit.

Trench number 4(Fig 3) is located in the bank of the Brahmaputra river at present day water level. The lithofacies sequence is composed of two units. The lower portion of the sequence is composed of trough cross stratified sand (St). The set thickness is 18cm and foreset dips at 24° → 260. The sediments are composed of coarse sand. Above this unit there is development of rippled coarse sand (Sr). Both the units are separated by a sharp boundary. The formation of trough cross stratification in the lower layer is due to the result of migration of 3-dimensional dunes (Miall, 1978), whereas the presence of Sr type 1 in the upper portion of the sequence indicates their development due to migration of ripples with a low rate of sedimentation from suspension(Miall, 1996).

Conclusion: The study reveals the types of bed form features and lithofacies units of a stabilized bar formed by the Brahmaputra River in Majuli district, Assam. The various bed form features found are ripples, mega ripples, scours, mud cracks etc. The lithofacies types indicate both upper and lower flow regime conditions. The bank deposits of the stabilized bar are formed by alteration of both sand and mud layer indicating different episodes of flood cycles. Thus the study reveals that the lithofacies types found in the area were formed in different hydrodynamic conditions of the Brahmaputra River.

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