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Facies association and paleo depositional environment of the exposed Neogene succession in the Sitapahar Anticline of Rangamati Area, Chittagong Tripura Folded Belt (CTFB) region, Bengal Basin, Bangladesh

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ABSTRACT

Neogene sedimentary rocks are exposed in the Chittagong Tripura Folded Belt (CTFB) Region in Bengal Basin. Sitapahar anticline is situated in the middle part of the CTFB Region. In this structure, eleven litho-facies have been identified in fluvial, overbank, shallow marine, deltaic, and deep marine depositional environments. Surma Group is composed of Bhuban and Boka Bil formation during Miocene time and was deposited in shallow marine, deltaic, and deep marine environments and characterized by the identification of interbedded shale facies (ShI), fine sandstone facies (SFs), lenticular laminated silty shale to shale facies (Zw), wavy bedded sandstone siltstone facies (Slsh), flaserbedded sandstone siltstone facies (Sxhs), ripple laminated sandstone facies (Sr), black Shale facies (Shb) and nodular shale facies (Zn). While, Pliocene Tipam group and Plio-Pleistocene Dupi Tila Formations were deposited in fluvial intervention and characterized by crossbedded sandstone facies (Sxbt), mudstone facies (Mf), interbedded mudstone and sandstone facies (MI).

Keywords: Facies association, paleo-depositional environment, facies analysis

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INTRODUCTION

Tertiary sediments are well exposed in Chittagong Tripura Folded Belt (CTFB) region, Bengal Basin, Bangladesh. The Surma Group comprises the Bhuban and Boka Bil Formations, which were deposited during the multiple marine transgressions and regressions (Sikder and Alam, 2003). The Upper part of the Bhuban Formation is considered the submarine fan deposit (Roy et al., 2006). Then the Boka Bil Formation was deposited dominantly under the estuary to tidal flat environment and sometimes the depositional environment shifted from a continental slope to a marginal shallow marine environment (Haque and Roy, 2021). The Surma Group mainly comprises sandstone, siltstone, silty shale, and shale throughout both flanks of the anticline. (Evans, 1932; Khan, 1991; Reimann, 1993; Gani and Alam, 2003). The Tipam Group is mainly composed of Tipam sandstone Formation and Girujan clay Formation. The Tipam sandstone is mainly composed of yellowish-brown to reddish-brown, coarse-grained, cross-bedded sandstone with minor siltstone, deposits dominantly of braided river systems (Johnson and Alam, 1991; Sikder and Alam, 2003). Girujan clay is brown to blue and gray in color and it was deposited in over bank deposits and Dupi Tila sandstone is pink to yellowish brown in color and is considered as channel fill deposits the of meandering river system (Johnson and Alam, 1991).

GEOLOGICAL SETTINGS AND STRATIGRAPHY

The Bengal Basin is located at the juncture of three interacting plates namely the Indian plate, the Tibetan plate, and the Burmese sub-plate (Alam et al., 2003) (Fig. 2). The Sitapahar anticline is situated in the eastern part of the Chittagong Tripura Folded Belt (CTFB) region of Bengal Basin (Fig. 1), which is subduction-related orogeny. The Indian plate is subducting the Burmese sub-plate in this area (Alam et al., 2003). The eastern limb is well exposed in the road cut east and further divided into two sections: Baraichari-Kaptai east section and Rangamati-Ghagra west section. The western limb was also divided into two sections such as the Baraichari-Kaptai section, Rangamati- Ghagra section. Curray (1990) stated that at the onset of the India-Asia collision, the Asian plate (Tibetan plate) rotated clockwise and made a collision with the Burmese sub-plate (Baral et al., 2019; Lin et al., 2022). Due to the collision between the Indian plate and Burmese sub-plate, the subduction complex of the Indo-Burma arc system had already emerged above sea level during the Oligocene time (Dasgupta and Nandy, 1995).

Convergent-oblique movement of the Indian plate relative to the Burmese sub-plate creates an accretionary prism in the CTFB region during Miocene (Murphy, 1998; Sikder, 1998) and forms regional strike direction in the NNW-SSE (Khan et al., 2017). The folding of CTFB had started during the late Miocene-Pliocene time (Hiller, 1988; Lohman, 1995). The Pliocene upliftment of Shillong Plateau change the ancient flow path of the Brahmaputra River to 300 km west, which flowed over the Surma basin (Johnson and Alam, 1991).

Extensive geological fieldwork was carried out in Chittagong Tripura Folded Belt (CTFB) region as far as the boundary to the Indian state of Mizoram and Burma by the Geological Survey of Bangladesh. The result of the collected samples contributed much of the present knowledge of lithology, facies, and stratigraphic succession of this area (Table 1). The Bhuban is considered the oldest exposed rock in the CTFB region (Reimann, 1993). The Bhuban Formation is mainly composed of sandstones, siltstones, and shales (Reimann, 1993). The Boka Bil Formation is composed of shales, siltstones, and sandstones (Reimann, 1993). Both the Formation was deposited during the Miocene time shown in Table 1 and Figures 3, 4. Pliocene Tipam sandstone is composed of cross-bedded massive coarse-grained sandstone and Girujan clay is composed of brown, purple, and pale–blue mottled clay (Reimann, 1993). The Dupi Tila Formation is composed of variegated, coarse-grained, cross-bedded sandstone with intercalations of clay horizons (Hiller, 1988) (Figs. 3, 4).

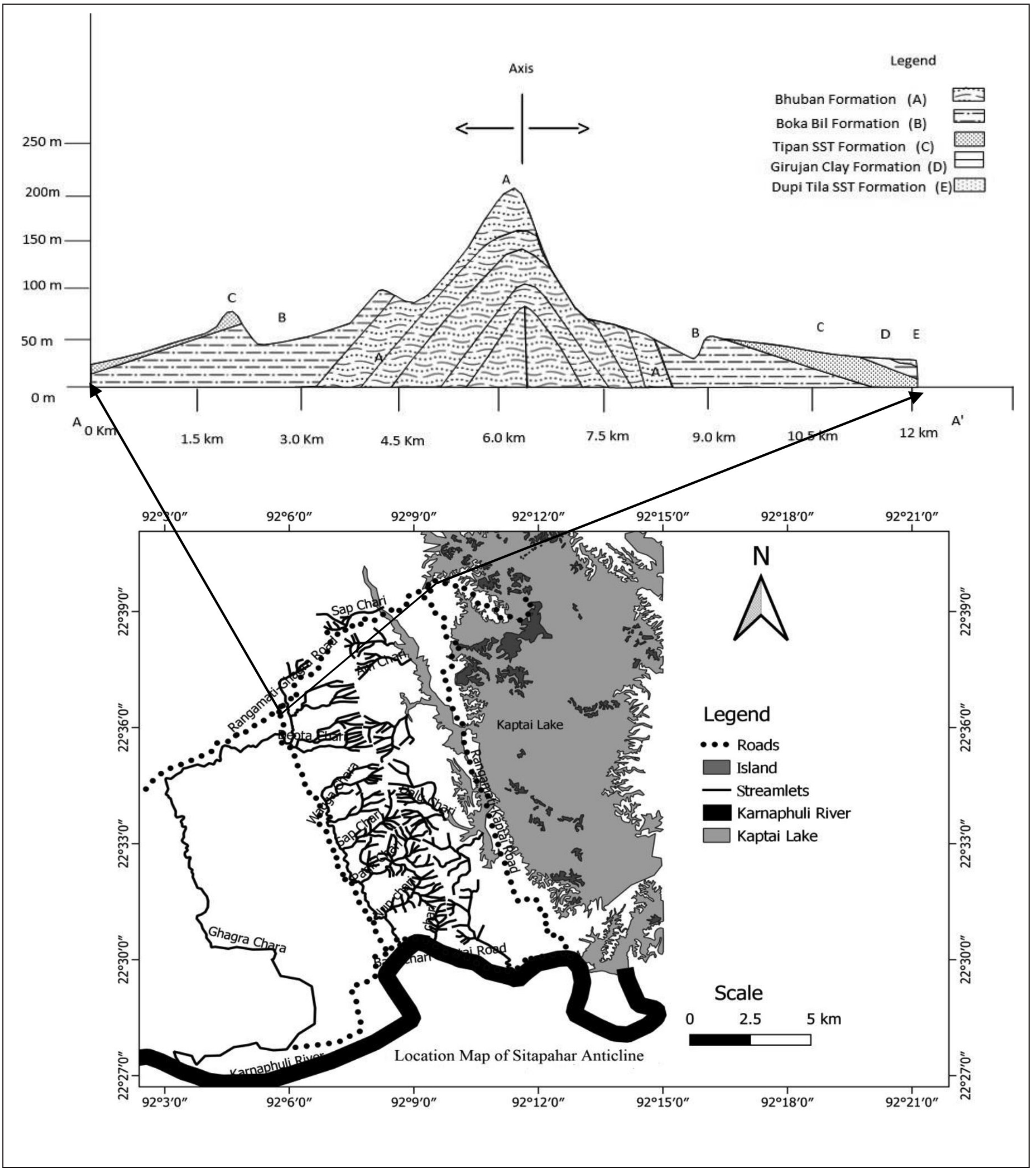

Fig. 1: Location map and cross-section view of Sitapahar Anticline.

Table 1: Stratigraphic succession of Sitapahar anticline (after Evans, 1932; Reimann, 1993; Gani and Alam, 2003).

Age (approx.)	Group	Formation	Lithology	Depositional environment
Recent	Alluvium	Alluvium	Sand, silt, clay	Fluvial
Plio-Pleistocene	Dupi Tila	Dupi Tila	Pink sandstone, bluish-gray clay	Meandering channel fill deposit
Pliocene	Tipum Group	Girujan Clay	Brown, purple, and pale–blue clay, sandstone, and siltstone.	Overbank
		Tipam Sandstone	Yellowish brown coarse to medium and fine cross-bedded sandstone, shale	Braided river deposits
Miocene	Surma Group	Boka Bil	Dark gray to light gray medium to fine sandstone and shale	Shallow marine and deltaic
		Bhuban	Dark gray to light gray medium to fine sandstone and shale	Shallow marine and deltaic

MATERIALS AND METHODS

Detailed fieldwork was carried out in the Sitapahar Anticline in both limbs of the structure by compass clinometer traverse method. The rock specimens were observed by necked eye as well as pocket lenses and used HCL for determining cementing material of the rocks. Based on their texture, color, and sedimentary structures different types of lithofacies were identified. The thickness of the bed was measured by the equation $\sin \delta = t/s$, t = thickness of the bed, δ = angle of dip of the bed, s = distance of outcrop at right angles to the strike line, measured along a horizontal surface following the methods by Billings (1961).

RESULT AND DISCUSSION

Types of lithofacies

There are eleven types of lithofacies in the study area which are described as;

Cross-bedded sandstone facies (Sxbt)

Cross-bedded sandstone facies (Sxbt) are comprised of pink and yellowish brown to brown colour, medium to coarse-grained sandstone (Fig. 5a,b). Cross-bedding is formed by the downstream migration of bedforms such as ripples or dunes (Boggs, 2006). The current flow continuously formed and destroyed bedforms like ripples and dunes and creates cross

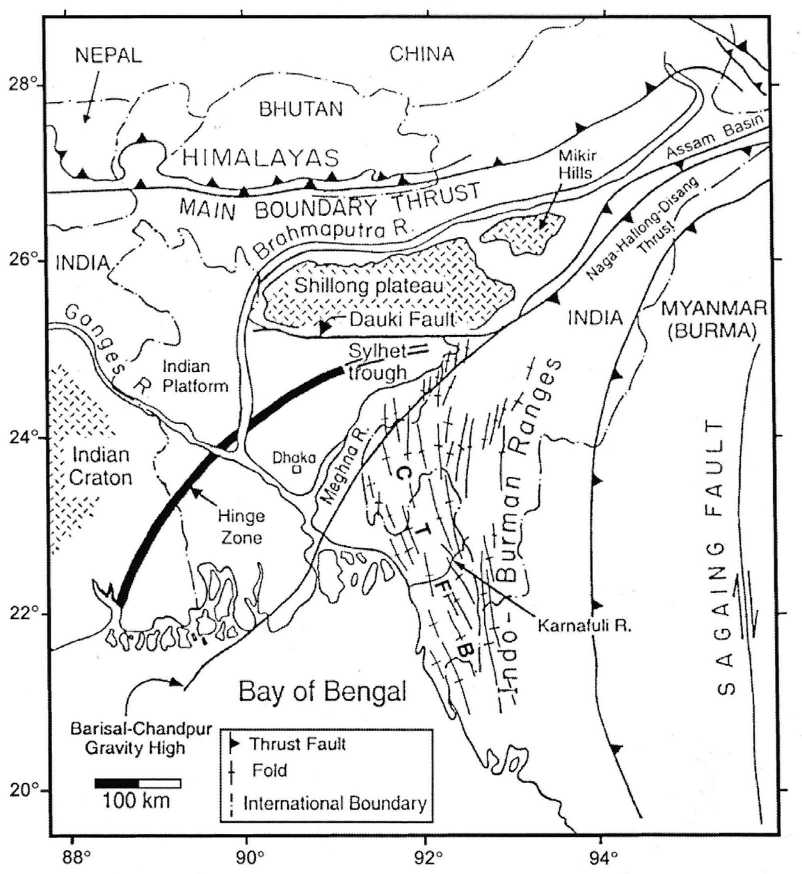

Fig. 2: Tectonic map of Bengal Basin (after Uddin and Lundberg, 1998).

stratification structures in sandstone. Cross-bedding evolved through the migration of underwater dunes. Generally, the succession of cross-bedded sandstone accumulated during the migration of subaqueous dunes in a sandy bar (Nichols, 2009). The Tipam sandstone of the Tipam group in Sitapahar Anticline shows the cross-bedding and it is considered as the braided river deposit.

Mudstone facies (Mf)

Mudstone facies comprises bluish gray to gray color molted clay and silty clay (Fig. 5a). This facies is observed in the easternmost part of the eastern limb of the anticline. Over-bank deposits occur when the discharge exceeds the channel capacity and water flows over the banks. Most of the sediments that carried out suspended load clay and silty clay (Nichols, 2009). The Mf facies is mainly observed in the Girujan clay Formation of the Tipam group and is considered over-bank deposit.

Interbedded mudstone and sandstone facies (MI)

Interbedded mudstone and sandstone facies (MI) comprise brown sandstone and clay (Fig. 5c). The facies is observed in between Girujan clay and Tipam sandstone area. MI facies shows the abrupt change in water current velocity. The brown

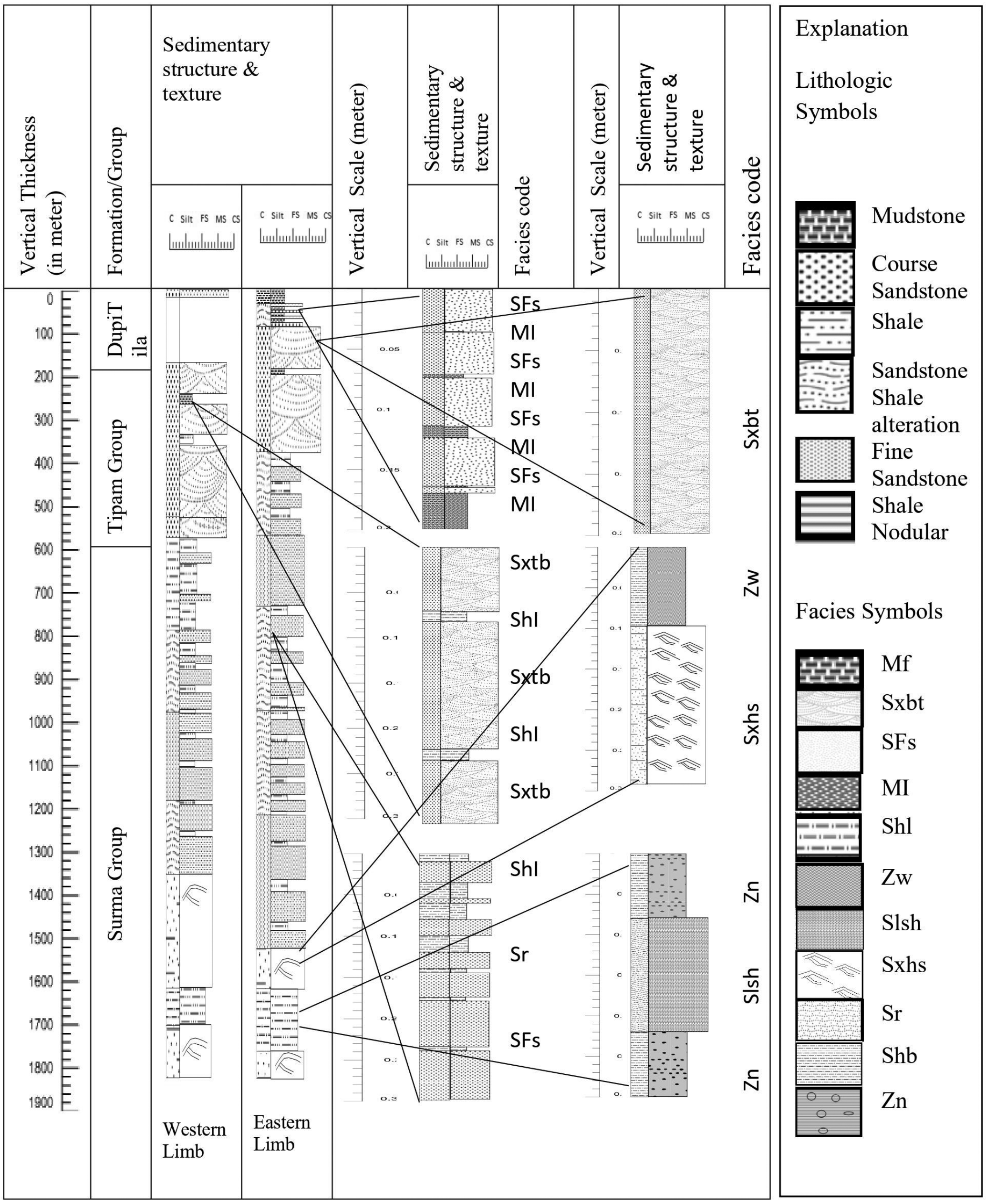

Fig. 3: Vertical litho-stratigraphic succession and facies association of Baraichari-Kaptai road cut section of Sitapahar anticline. The litho-log represents the summarized features in successions of sedimentary rocks and sedimentary structures as well as facies associations.

sandstone shows high energy water flow velocity and the clay shows low energy of flow velocity or suspended load sediment deposits. The facies indicates the changing environment from braided river deposit to overbank deposit.

Interbedded shale facies (ShI)

Interbedded shale facies (ShI) comprises light gray to dark gray shale in between sandstone facies (Fig. 5d). The facies is observed in the transition zone of the Tipam sandstone Formation and Boka Bil Formation which indicates the change of environment from low energy to high energy.

Fine sandstone facies (SFs)

SFs facies are composed of brown to light brown color fine to very fine grain sandstone. Some very thin clay lamina is present (Fig. 5e). Thickness of the facies varies from a few centimeters to tens of meters. According to Nichols (2009), fine-grained sandstone can accumulate in the distributary mouth bar of deltas showing the SFs facies may be associated with the deltaic environment.

Black shale facies (Shb)

This facies is composed of dark gray shale with a very thin laminated silt layer (Fig. 5f). Black shale facies is deposited in a calm and quiet environment. The silt lenses are deposited due to the higher flow velocity of the water. This facies is deposited in the deeper part of the marine environment.

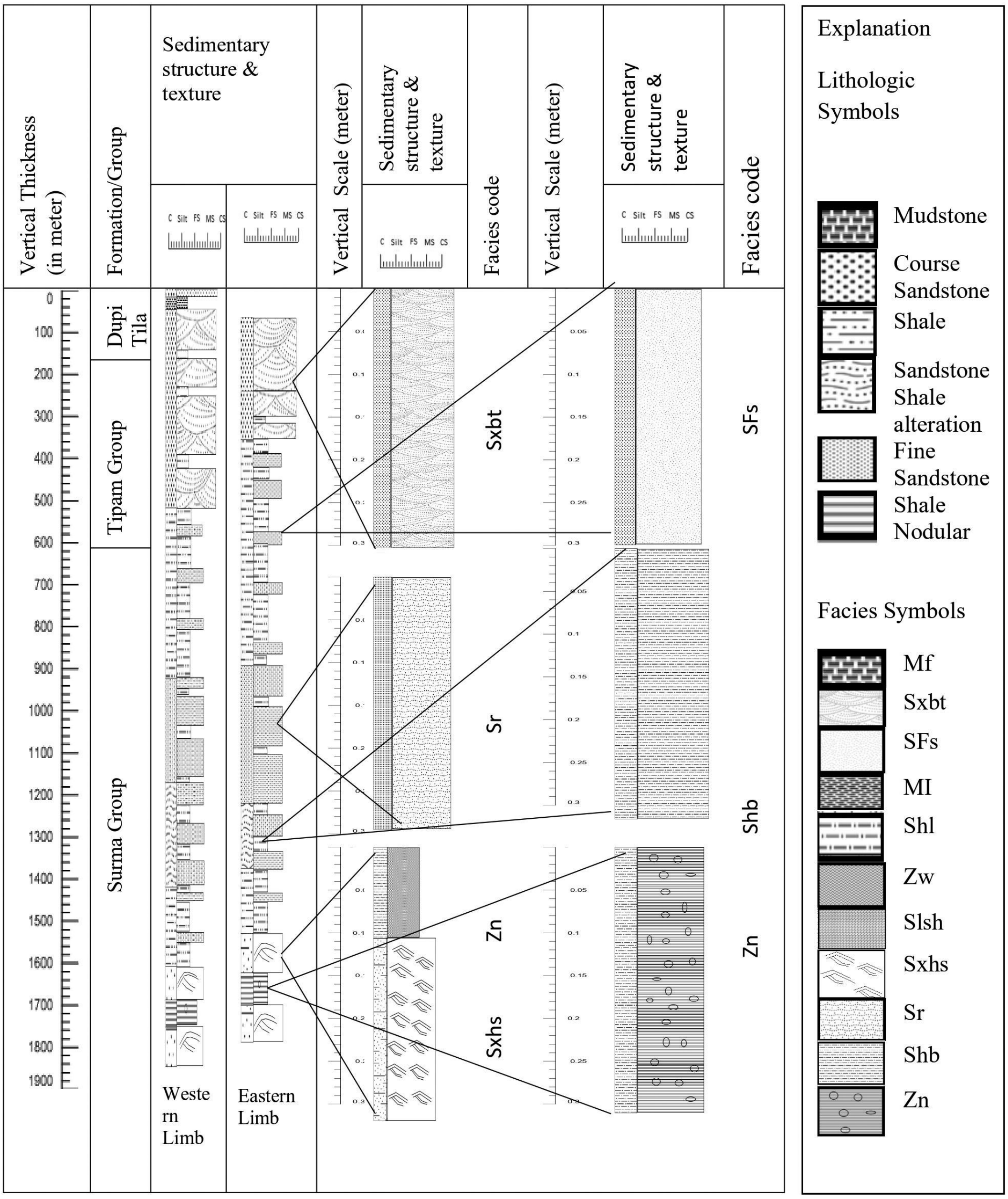

Fig. 4: Vertical litho-stratigraphic succession and facies association of Rangamati-Ghagraroad cut section of Sitapahar Anticline. The litho-log represents the summarized features in successions of sedimentary rocks and sedimentary structures as well as facies associations.

Lenticular laminated silty shale to shale facies (Zw)

Figure 5g shows that lenticular laminated silty shale to shale facies (Zw) is composed of isolated ripples of sandstone completely surrounded by mudstone (Nichols, 2009). This facies is interbedded sandstone and mudstone facies but the percentage of sandstone is lower than the mudstone. The mudstones are dark bluish-gray in color, hard and compacted, and blocky in nature. The facies associated with quiet water of shelf to the offshore region (Sultana and Alam, 2001; Alam, 1993).

Wavy bedded sandstone siltstone facies (Slsh)

Wavy bedded sandstone siltstone facies (Slsh) composed of approximately equal proportions of sandstone and mudstone (Fig. 5g). This facies consists of a few millimeters to a few cm thick and straight to slightly wavy laminated bluish gray to gray shale and ripple laminated siltstone and sandstone. The facies is associated with offshore to tidal regions under low to moderate energy conditions.

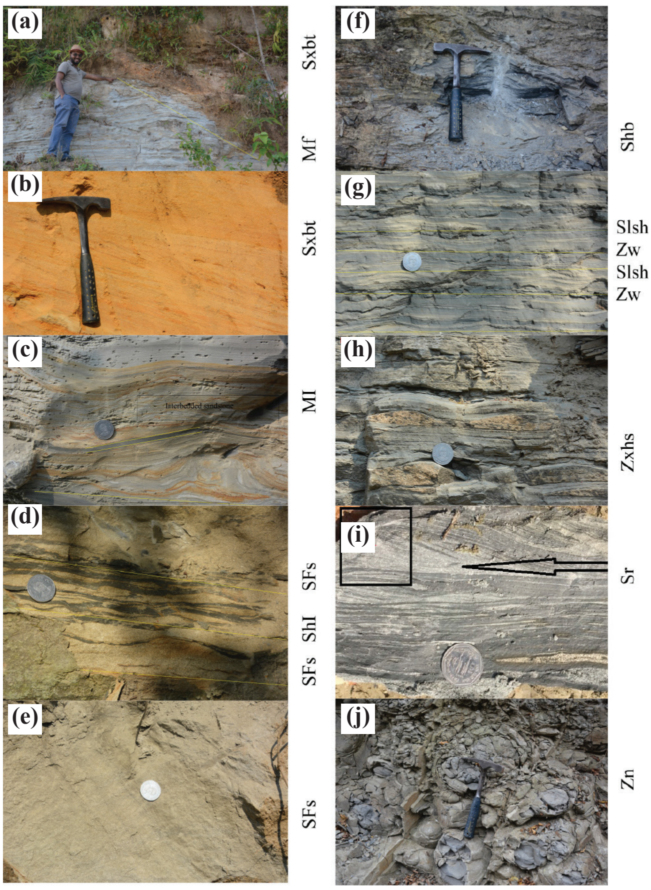

Fig. 5: The field photographs show different types of sedimentary facies. (a) Cross bedded sandstone facies (Sxbt) and mudstonefacies (Mf), (b) cross bedded sandstone facies (Sxbt), (c) interbeded mudstone and sandstone facies (MI), (d) shallow marine Interbeded shale facies (ShI) and fine sandstone facies (SFs), (e) fine sandstone facies (SFs), (f) black Shale facies (Shb), (g) shallow marine wavy bedded sandstone siltstone facies (Slsh) and lenticular laminated silty shale to shale facies (Zw), (h) flaser bedded sandstone siltstone facies (Sxhs), (i) ripple laminated sandstone facies (Sr), (j) deep marine nodular shale facies (Zn).

Flaserbeded sandstone siltstone facies (Zxhs)

Flaser bedding is composed of isolated mudstone completely interbedded with sandstone. The Flaser bedding is characterized by isolated thin drapes of mudstone amongst the cross-lamina of sandstone (Nichols, 2009). In the sandstone of this section, sometimes herring-bone cross-stratification is observed (Fig. 5h). This facies is interbedded sandstone and mudstone facies with a higher percentage of sandstone than the mudstone. The facies is related to lower intertidal to sub-tidal regions (Alam, 1993; Rahman, 1999).

Ripple laminated sandstone facies (Sr)

Ripple and ripple cross-laminated sandstone comprises grayish to white color fine-grained sandstone (Fig. 5i). The facies is deposited in the turbidity current origin of the marine environment.

Nodular shale facies (Zn)

Nodular shale facies (Zn) is composed of dark gray shale. This facies looks like an onion structure (Fig. 5j) and is deposited in a calm and quiet environment in the deeper part of the marine environment. It is located close to the axis of the anticline area.

Paleo-depositional environment

The Sitapahar structure consists of mainly Surma group (Bhuban and Boka Bil Formations), the Tipam group (Tipam Sandstone and Girujan Clay Formation), and Dupi Tila Formation (Reimann, 1993). The Surma group was deposited during the Miocene time (Reimann, 1993). At Miocene time this area has gone under multiple sea level transgression and regression. During this time, this area belongs to a shallow marine, deltaic, and deep marine environmental condition (Fig. 6). The older part of the Surma group is composed of Bhuban Formation in which sandstone was deposited in the channel under the deltaic environment and shale was deposited under outer neritic environment (Reimann, 1993). Shallow marine wavy bedded sandstone siltstone facies (Slsh) and lenticular laminated silty shale to shale facies indicated that the depositional environment was shallow marine (Fig. 5g). Flaser bedded sandstone siltstone facies (Sxhs) was formed due to bi-directional energy flow. This sedimentary structure is a typical example of a tidal depositional environment (Fig. 7). Black shale facies (Shb) is an example of a deep marine calm and quiet depositional environment. During the Miocene time, the depositional environment of this area was marine and deltaic and after the end of the Miocene, this area had been replaced by a fluvial environment. Both the Tipam sandstone and Dupi Tila sandstone show dominantly cross-bedded sandstone facies (Sxbt) further indicating the depositional environment was fluvial.

Mudstone facies (Mf) is very much common in cross-bedded sandstone facies. The facies is composed of pale–blue mottled clay which is considered as suspended load sediment deposits.

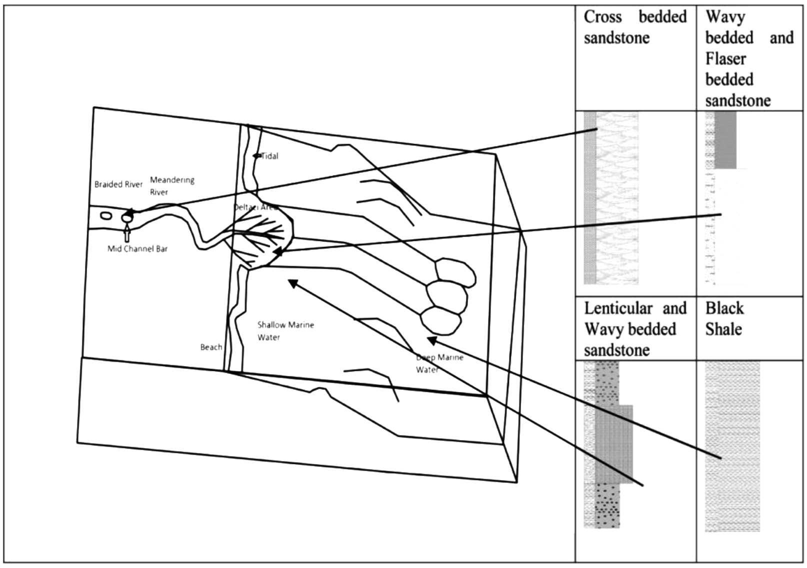

Fig. 6: Schematic block diagram showing the relationship between facies and depositional environment of Sitapahar anticline.

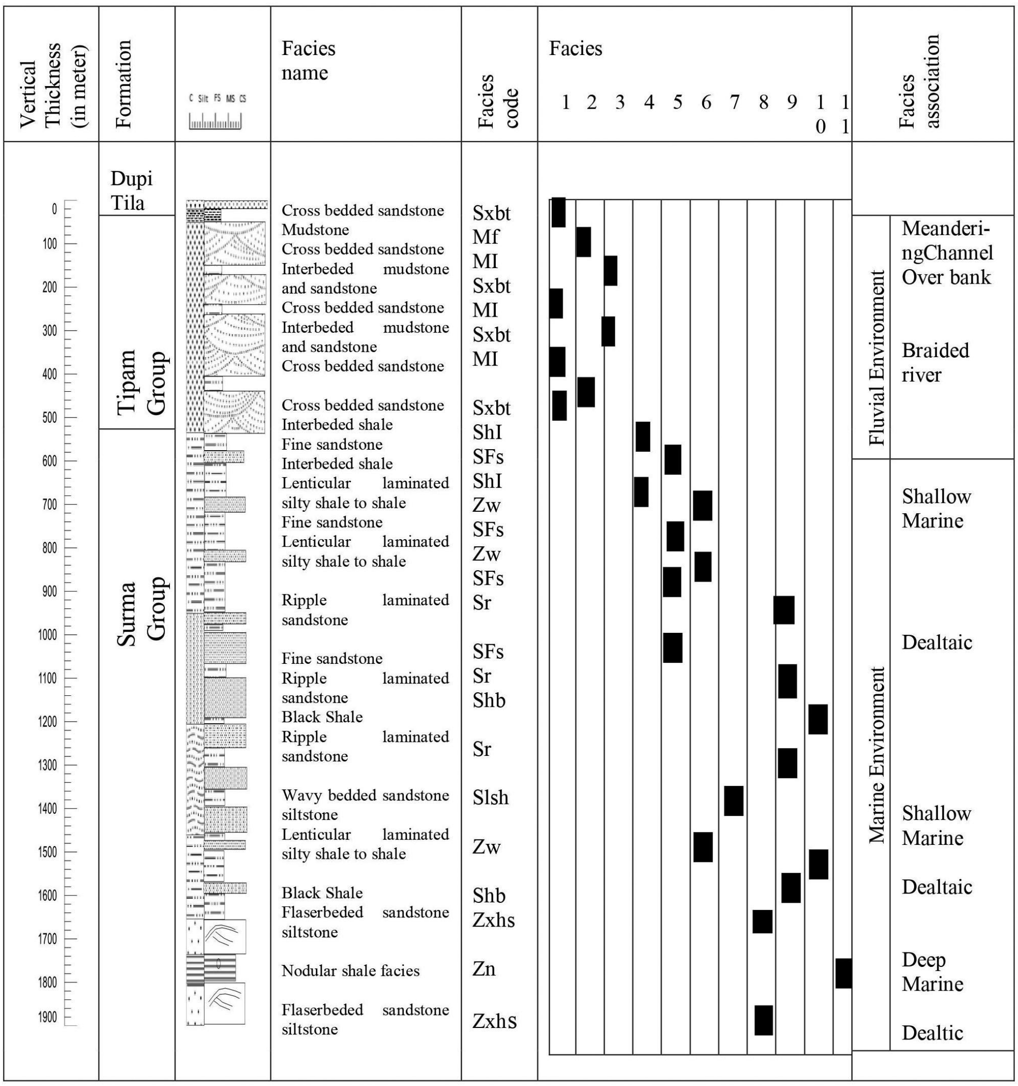

Fig. 7: A graphic sedimentary log with facies information as well as facies association. The name of the facies is usually descriptive and facies codes are used and an abbreviation of the facies codes is found in the description. The use of columns for each facies allows for trends and patterns in facies and associations to be readily recognized.

CONCLUSIONS

The Surma group is the oldest exposure among the Neogene succession exposed in the Sitapahar Anticline. This Group is subdivided into two formations: Bhuban and Boka Bil formations. In this group, several facies have been identified such as ShI, SFs, Zw, Slsh, Sxhs, Sr, Shb, and Zn. The Surma group was deposited in a shallow marine environment, deltaic environment as well as deep marine environment. The Tipam group comprises Tipam sandstone and Girujan clay formation have been characterized by Sxbt and mudstone facies further illustrating the depositional environment was braided and fluvial. Dupi Tila Formation, which is the youngest of this succession was deposited in the fluvial environment. The marine confluence ended after the end of Miocene time and from the Plio-Pleistocene onwards the fluvial environment prevailed.

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