The Brahmaputra River in Assam: The Outsized Braided Himalayan River

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Abstract

The Brahmaputra is a very large braided river, which flows though a narrow intermontane valley in Assam with low gradient. It is the fourth largest river in the world in terms of average discharge, but its discharge is mainly contributed by its tributaries. The river is ranked second in sediment load. The river is the backbone for economy of Assam State and Bangladesh. Characteristic fluvio-geomorphic features of the river are channels of various orders, channel bars, side bars, unit bars, crevasse splays, natural levees, swamps, palaeochannels, etc. Floods, bank erosion, and natural dam-burst floods are major hazards of the river. The Brahmaputra River is an antecedent river as it is older than the Himalaya that are rising since the Miocene times. The sediments from the Himalaya and the southern hills were deposited in the Assam Valley giving rise to full development of the braided pattern in recent times.

Keywords

Assam • Brahmaputra • Braiding • Large floods • Sediment load • Bank erosion • Avulsion

1 Introduction

The Brahmaputra is one of the largest braided rivers in the world. It is an international river as it flows through Tibet in China as the Tsangpo (Yarlung Zangbo), India as the Siang/Dihang and Brahmaputra and Bangladesh as Jamuna. The river flows both as single thread and braided channel through Tibet, but it becomes totally braided in India and Bangladesh. The most distinguishing characteristic of the Brahmaputra River in Assam, India, is its channel size vis-à-vis its valley width, and large unstable and dynamic braids. The Brahmaputra Valley in Assam is about 35–90 km wide, whereas the width of the Brahmaputra River channel itself varies from 1.1 to 18.6 km. Hence, the outsized river occupies a large part of its valley (Fig. 1).

The river originates in Tibet, where climate is cold and dry (annual rainfall ~400 mm) temperate steppe variant. Flowing easterly for about 1,600 km with moderate gradient (1.6 m/km), the river then takes a sharp bend and flows southward through deep bedrock gorges cutting across the Higher and Lesser Himalaya and the Siwalik Hills with high gradient (4.3–16.8 m/km) over a series of precipitous cataracts and falls before entering the plains near Pasighat in India (Fig. 2a). About 600 m wide river in the Himalaya becomes 10 km wide just 12 km downstream of Pasighat due to sudden decrease in the channel gradient to 0.27 m/km. The river has a wide braided course throughout Assam with an average gradient of 0.16 m/km, except for three locations where it becomes narrow as it cuts through hard granite and gneissic rocks. Downstream, in Bangladesh, it is about 12 km wide. The total length of the Brahmaputra is about 2,880 km and the contributing drainage area up to the

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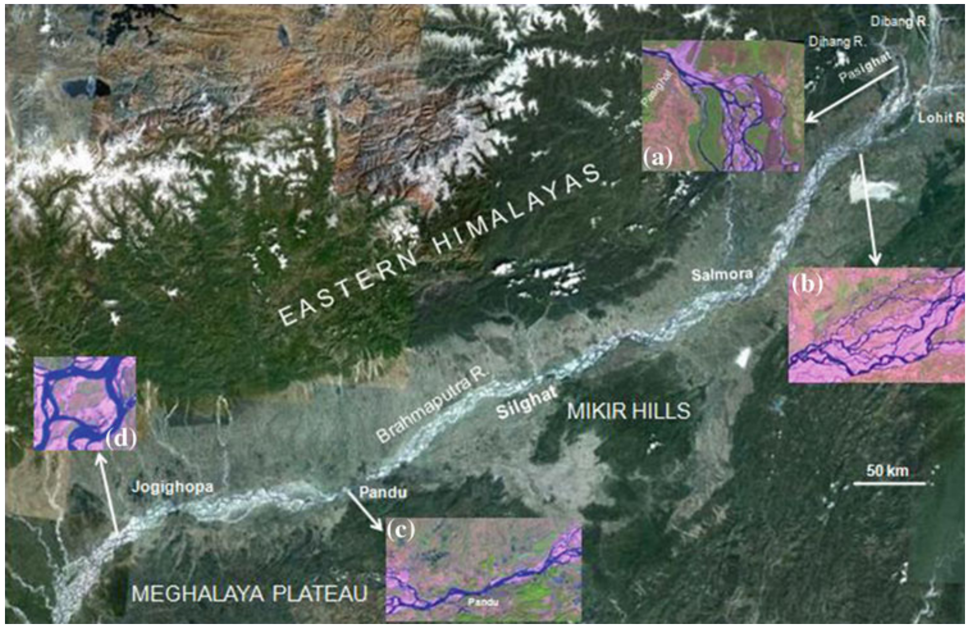

Fig. 1 Satellite image of the Brahmaputra River through Assam valley. *Insets* **a** single channel of the Dihang River enters into the plains near Pasighat and immediately develops braiding, **b** anabranching-cum-braided channel on the north of Rohmoria, **c** narrowest reach at Pandu with wide braided channel at both the ends, **d** a single large channel gets symmetrically divided into two smaller channels near Dhubri. R represents river

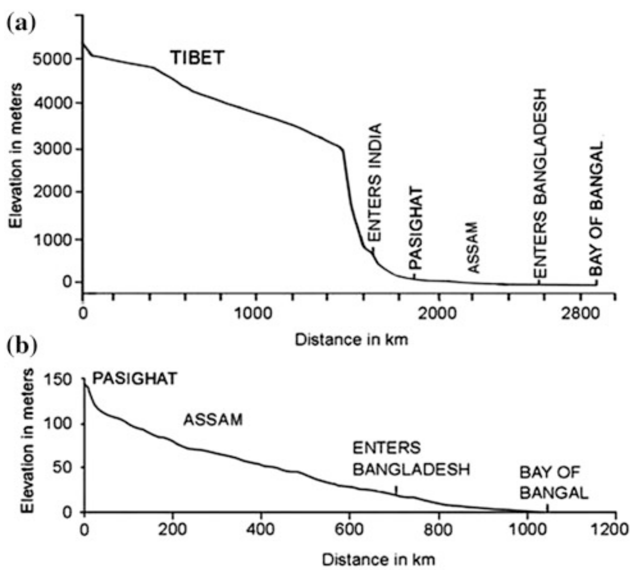

Fig. 2 Longitudinal profiles of the Brahmaputra River. **a** From the source to the Bay of Bengal, **b** From Pasighat through Assam and Bangladesh to the Bay of Bengal

confluence with the Ganga at Goalundo in Bangladesh is ~580,000 km^2.

The course of the Brahmaputra River from Pasighat to Indo-Bangladesh border is through an intermontane valley locked from three sides by hills and plateaus, whereas it flows through alluvial and coastal plains of Bangladesh with further low gradient (0.079 m/km) (Fig. 2b). Although it is navigable over the Tibetan Plateau, it is not so in the Assam Valley due to heavy siltation. The river is the backbone for the economy of Assam and Bangladesh. Its basin has the highest biodiversity hotspots in India. Although ravaged by annual floods since time immemorial, the fertile soils and pleasant climate of Brahmaputra Valley have attracted people from various corners to settle here permanently.

2 Channel Hydrology

The Brahmaputra is the fourth largest river in the world in terms of average flow discharge at its mouth with a flow of 19,830 m^3/s (Goswami 1985), although the river ranks 22nd in terms of drainage area. Hence, discharge per unit drainage area is amongst the highest in the world. At Pandu, near Guwahati, the flow in the Brahmaputra yields 0.0306 m^3/s/km^2. The mean annual flow of the Brahmaputra at Pasighat is ~5,869 m^3/s, which increases to ~17,030 m^3/s at Jogighopa, situated about 610 km downstream, implying that the discharge increases progressively downstream. About 68 % of the discharge of the Brahmaputra is contributed by its tributaries, such as Dibang (6.6 %), Lohit (7.9 %), Subansiri (7.9 %), Jia Bhareli (4.9 %), Manas (5.5 %), Sonkosh (2.8 %), and Burhi Dihing (1.9 %). The mean monthly discharge is highest in July (18.9 % of the total annual discharge) and lowest in February (1.7 % of the total annual discharge). The annual mean rainfall in Assam is ~3,000 mm.

3 Flood Hazard

The Brahmaputra is well-known for its severe and devastating floods. The highest flood discharge (73,000 m^3/s) was recorded in 1962 near Guwahati. The average annual flood

Fig. 3 Google Earth image of a part of the Brahmaputra River around Kaziranga showing features of the Brahmaputra River channel and adjacent valley. The channel is about 8–10 km wide. *1* second order channel, *2* third order channel, *3* mid-channel bar, *4* side bar, *5* sand, *6* bars with vegetation (islands, *chars*), *7* water body (swamp), *8* tributary, *9* abandoned channels, *10* natural levee. Flow of the river is from *right* to *left*

discharge at Guwahati is about 50,000 m^3/s with a recurrence interval of 2.6 year. The bankfull discharge is ~35,000 m^3/s, which occurs every year. Large floods with flows of the order of 70,000–100,000 m^3/s have a return period of 100 years. More than 10,000 km^2 of land (~12 % of Assam), is annually affected by floods. The flash floods of the Himalayan tributaries contribute huge peak discharges leading to flooding of the plains.

4 Sediment Load

Among the world rivers, the Brahmaputra is ranked second in sediment load that amounts to one billion tonnes of clastic sediment and 100 million tonnes of dissolved matter annually. At Pandu, the river transported an average annual suspended sediment load of ~402 million tonnes during 1955–1979 (Goswami 1985). About 70 % of the sediment of the Brahmaputra is derived from the Higher Himalaya. Using a sediment budget, Goswami (1985) estimated an overall aggradation of the 607 km Assam reach of the Brahmaputra from Pasighat to Jogighopa during 1971–1979 as 16 cm. The north bank Himalayan tributaries contribute enormous volumes of sediments; the chief contributions are from Beki and Jia Bhareli as 305 and 297 million tonnes, respectively.

5 The Channel Reaches: Width and Braiding Index

The Brahmaputra River channel in Assam is a classic example of braided river (Fig. 3) The river displays three types of reaches—(1) braided (island/bar)—83 % (2) anabranching-braided—13 %, and (3) narrow single channel reach (node)—4 %. The longest anabranching channel is the Kalang Suti (165 km).

The Brahmaputra flows in a single channel for three short rocky reaches at Silghat, Pandu and Jogighopa (width 1–2 km) (Fig. 4). At Pandu (near Guwahati) the river is narrowest (1.1 km), where the water depth varies from 18 to 27 m. The channel becomes wider downstream of the constricted reaches, for example, ~20 km downstream of Pandu it widens to 18.6 km.

Larger braid channels are between 0.6 and 1.5 km wide, and the depth varies from 2 to 9 m during dry season. Usual anabranching channels display sinuous thalweg

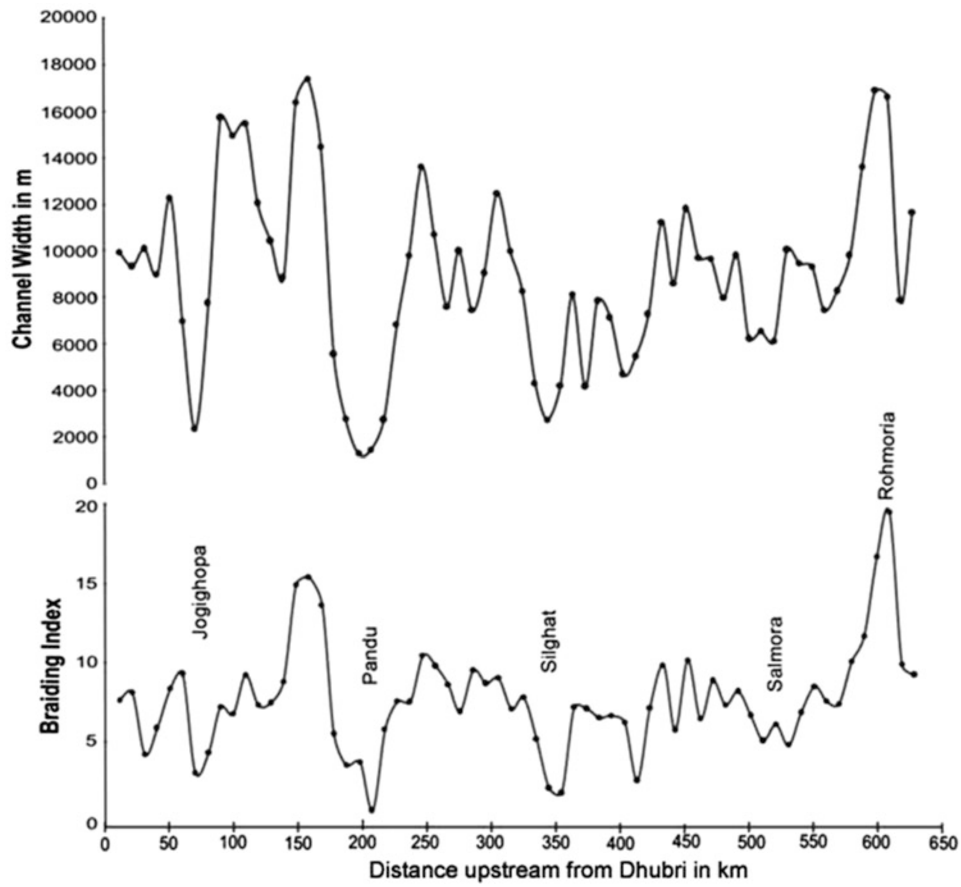

Fig. 4 Variation of channel width (w) and Braiding Index (BI) of the Brahmaputra in Assam from Dhubri to Kobo. Note that both w and BI are low at Jogighopa, Pandu, Silghat and Salmora and high at Rohmoria and downstream of Pandu. $BI = 2(\Sigma L_I)/L_r$, where ΣL_I is the length of all the islands and/or bars in the reach, and L_r is the length of the reach measured midway between the banks of the channel belt

with alternate bars. Their length ranges from 22 to 35 km, and the width varies between 265 and 622 m. The smaller braid channels ($\sim$100 m wide) occur on top of the bars.

The width of the Brahmaputra River channel has shown a constant increasing trend. The mean width of the river measured at 64 equally spaced segments in 1916–1925 was only 5,949 m, which increased to 7,455 by 1966–1972 and then to 9,012 m in 2009. The braiding index of the Brahmaputra River in Assam in different segments varies from 1.21 to 17.33, with an average between 7 and 8. It has shown minor changes with time. The channel width and braiding index are directly interrelated (Fig. 4).

6 The Channel Bars and Islands

Four types of bars are observed in the Brahmaputra, namely mid-channel braid bars, lateral or side bars, tributary mouth bars and unit bars (Figs. 3 and 5). Mid-channel bars are generally elongated, rhombic or triangular in shape with the longer axis aligned parallel or perpendicular to the direction of the main channel. Tributary mouth bars are small in size. Islands (*chars*) are diamond shaped, they have mature vegetation, settlements and are relatively stable. About 70 % of the channel bars have length between 0.8 and 1.0 km. Side bars are both elongated and triangular in form and are attached to the banks. The unit bars are rhombic or lobate and emerge only during low flow stage. At low flow stage, large areas of the bar tops ranging in length from a few tens of meters to 18.4 km, are exposed.

The Majuli Island (26° 57′ 2″ N and 94° 10′ 11″ E) of Brahmaputra River is the largest inhabitated river island in the world. But Majuli is not a braid bar island, it was a piece of land called Majali on the southern bank of the Brahmaputra till 1750, when the Brahmaputra partly avulsed southward to capture one of its *parallely* flowing tributary, the Dihing, converting the land area in between into an island, which is now called Majuli. In 1917, the island had an area of 751 km^2, but in 2011, it was reduced to 492 km^2 because of erosion by the Brahmaputra. Majuli is perennially devastated by floods.

7 Floodplain Features

The alluvial plain of the Brahmaputra varies in width in different portions of the Assam Valley, the widest part across Sivasagar is 95 km and the narrowest part across

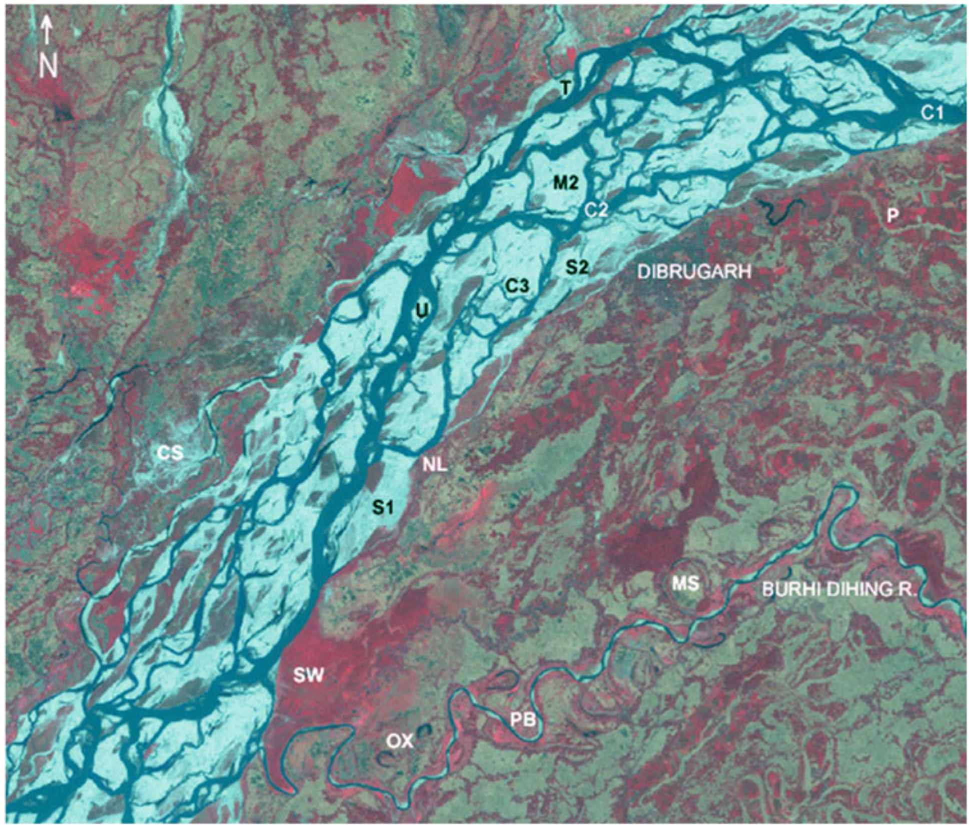

Fig. 5 Indian Remote Sensing 1D satellite FCC image (December 2002) of the Brahmaputra River near Dibrugarh showing Brahmaputra main channel and floodplain features. Large (C1) and small (C2) second order channels, third order channel (C3), mid-channel bars (M1 and M2), tributary mouth bar (T), unit bar (U), side bars (S1 and S2), swamp (SW), natural levee (NL), crevasse splay (CS), palaeochannel (P), and ox-bow lake (OX), point bar (PB), meander scroll (MS) and the meandering tributary Burhi Dihing River. Length of the reach of the Brahmaputra in the image is about 56 km

Silghat is 35 km, with an average width of about 75 km. The valley width to channel width ratio is 7.6 across Dibrugarh in the upstream, 7.5 across Dhubri in the downstream, 4.2 across Silghat due to narrow valley, 4.5 at Palasbari due to widest channel, and 64.5 at Guwahati due to narrowest channel.

Natural levees occur as wedges along the banks, breaching of the same during flood results in crevasse-splay deposits. Large swamps are developed behind the levees on the floodplain. All of the south-bank tributaries are meandering rivers. Meandering tributaries develop ox-bow lakes, meander scars, point bars, channel bars, side bars, point-bar islands, natural levees and deferred tributaries (Figs. 3 and 5). The north-bank tributaries show development of braiding near the foothills of the Himalaya. The interfluves comprise many palaeochannels (former old channels, now abandoned), which were formed due to piracy of the headwaters (Fig. 5). Some misfit streams now occupy the palaeochannels. The Kaziranga National Park (26° 40′ 0.1″ N and 93° 20′ 59″ E) is forest-edged riverine grassland inhabited by the world's largest population of one-horned rhinoceroses having an area of 430 km^2. There are about 204 swamps within this park; most of these swamps represent earlier abandoned river courses.

8 Fluvial Processes

8.1 Bank Erosion, Bank Materials and Causes of Bank Failure

High rate of bank erosion of the river results from frequent failure of its banks (Kotoky et al. 2005). Bank materials in the Brahmaputra River are mostly fine sand and silt with clay fraction less than 5 %. Shear failure in the upper bank materials seems to be by far the most widespread mode of bank failure. It is caused by currents undercutting the upper bank levee materials during high flows, due to which large blocks of natural levee sediments are sheared off into the river. Failure can also occur by over-steepening bank materials (Fig. 6a) because of the migration of the main flow closer to the bank during falling flood stages or where the flow approaches the outer bank at an angle. Large scale slumping is observed during falling stages of the river and highly saturated clayey silt will liquefy and tend to flow towards the channel causing bowl-shaped shear failure of the overlying silty deposits (Fig. 6b).

Between 1912 and 1996 the net bank erosion of the Brahmaputra was ~870 km^2 (Sarma and Phukan 2006). During this period, higher amount of shift in the bankline

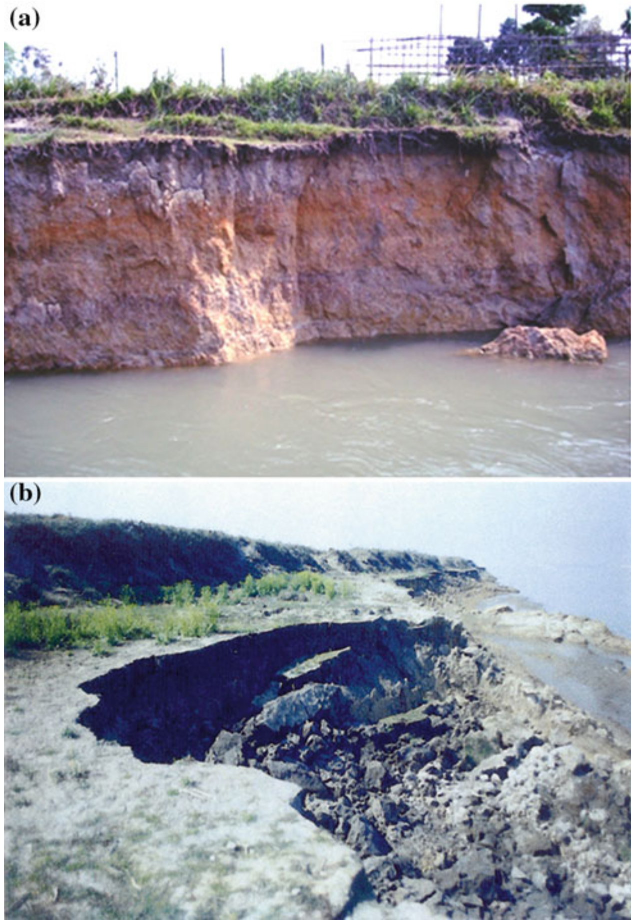

Fig. 6 **a** Erosional scarp due to over-steepening bank materials at Rohmoria. **b** Bowl-shaped shear failure on silty bank materials at Nimati Ghat, near Jorhat (Reproduced from Kotoky et al. 2005, with permission)

was between 60 and 130 m/year. In Bangladesh, both the banks have shown a shift of ~90 m/year (Thorne et al. 1993).

8.2 Landslides-Dam Failure Floods

Being situated in a tectonically active zone, occurrence of landslides is frequent, which, in turn, are responsible for great morphological changes on Tsangpo, Dihang, Dibang, Subansiri and Lohit Rivers and their tributaries. Failure of landslide-dammed lakes on these rivers was responsible for flood havocs downstream. For example, the natural dam across the Subansiri, caused by the 1950 Assam earthquake, burst four days later and a 6 m high wave swept across many villages and caused 532 deaths. Breaching of a natural dam formed across Yigongzanbu, a tributary of the Tsangpo, on 10th June 2000 washed away all large bridges of the Siang and flooded Pasighat.

8.3 Avulsion

When a river abandons its earlier course and forms a new channel it is called avulsion. It is the most important change shown by the Brahmaputra. The Brahmaputra avulsed to join the Dihing, thereby creating Majuli Island, around 1750 CE. A large bend of the Brahmaputra was straightened between Pandu and Hazo around 1532 CE. Dibru-Saikhowa reserved forest (RF) was earlier situated on the southern bank of the Brahmaputra and Lohit Rivers. In 1995, an avulsion of the Lohit near Saikhowaghat diverted its flow to join a small river, the Dangori, which captured the Dibru and through it joined the Brahmaputra River (Sarma 2005). Thereafter, Dibru-Saikhowa RF has been converted into an island similar to the Majuli, comprising an area of ~322 km^2.

As per the 1779 map of Rennel, the Brahmaputra flowed southwesterly along the base of the Garo Hills through Jamalpur, Nasirabad, Maimansingh to meet the Meghna River at Bhairab Bazar. The Brahmaputra avulsed into its present course along the Jamuna to the south probably around 1787 (Bristow 1987) . The former course of the Brahmaputra was about 10 km wide and is presently occupied by the Old Brahmaputra, a small meandering river of about 200 m in width, which is active only during the flood season.

9 Evolutionary History

The Brahmaputra River is an antecedent river, as it is older than the Himalaya. The present valley is believed to have taken shape after the rise of the Himalaya during late Miocene. There is evidence to suggest that the river flowed due south, before it occupied the present Assam Valley sometimes in the late Miocene following capture of Tsangpo-Irrawaddy in mid Miocene (Fig. 7). The southern course of the river was blocked by the rise of the Barail Range. As the Himalaya achieved their full height, the rivers draining the southern slopes of Himalaya vigorously eroded the rocks producing enormous amount of sediments. Simultaneously, a long, narrow furrow was formed in front of the mountain. Into this furrow now flowed the Brahmaputra towards west. With the Brahmaputra deflected west, a new drainage network evolved in Assam. The south-flowing independent rivers of long-standing such as the Subansiri, Manas, Jia Bhareli, Sonkosh, etc. now joined the Brahmaputra as tributaries and on the left bank the river received streams rising in the newly uplifted Patkai and Naga Hills and Meghalaya (Shillong) Plateau. Immediately after traversing Assam the course of the Brahmaputra is determined by a fault zone (Dhubri Fault) trending north-south along the border of the Garo Hills, formed in the early

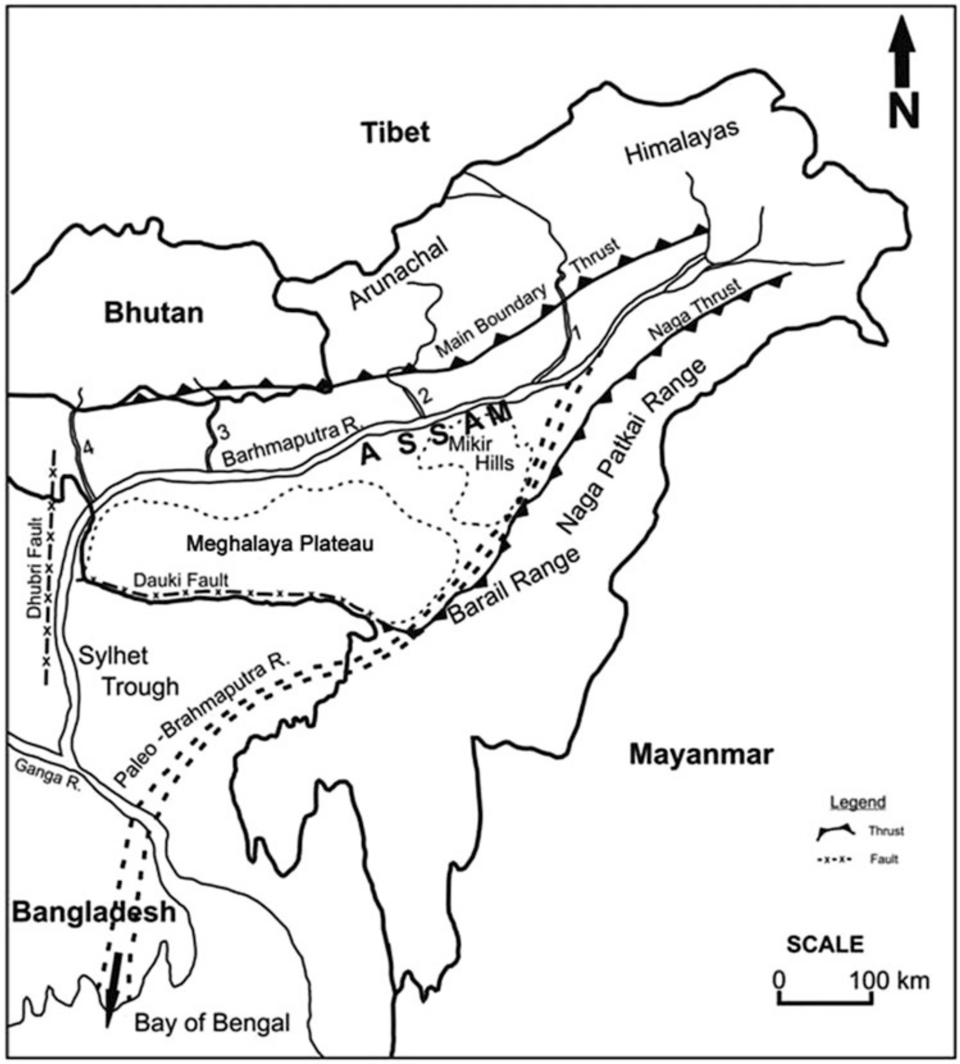

Fig. 7 The present course of the Brahmaputra River and probable ancient southerly course of the paleo-Brahmaputra, prior to rising of the Barail Range. *1* Subansiri, *2* Jia Bhareli, *3* Manas, *4* Sonkosh

part of Miocene. The sediments from rising Himalaya and the southern hills were deposited, raising the valley floor rapidly. By Quaternary, the valley floor was raised to such an extent that the river was unable to carry its entire load to the sea. Consequently, the river started depositing its sediments within the channel, giving rise to full development of the braided pattern in recent geological past.

10 Conclusions

The Brahmaputra is one of the largest braided rivers in the world. It is an outsized river because it is up to 18.6 km (average 9 km) wide and occupies most of its 35 to 90 km wide valley. Remarkable variation of slope of the channel from 16.8 to 0.16 m/km occurs as the river enters Assam Valley thereby intensifying development of braiding pattern. Geological evidence suggests that the Brahmaputra has occupied the elongated Assam Valley since about late Miocene times. Hydrologically, the river has some unique characteristics. The discharge per unit drainage area in the Brahmaputra is the highest in the world. Further, the Brahmaputra is ranked second in terms of sediment load. The high discharge and immense sediment load are responsible for the dynamic nature of channel. Changes in the braid bar morphology and bankline migration are common during the monsoon season. The Brahmaputra has a very high rate of bank erosion and bank migration. Avulsion of the main Brahmaputra and its large tributaries had been giving rise to the creation of very large islands, such as Majuli, and new river like the Jamuna in Bangladesh. The river is highly flood-prone and frequently experiences large floods. More than 12 % of the geographical area of the floodplain is annually affected by monsoon floods of the Brahmaputra and its tributaries. Each year its floods provide water for agriculture and fisheries on which some millions of people and a variety of wildlife depend. Not surprisingly the mighty river is known as the lifeline of Assam (India) and Bangladesh.

References

Bristow CS (1987) Brahmaputra River: channel migration and deposition. In: Ethridge FG, Flores RM, Harvey MD (eds) Recent development in fluvial sedimentology. Soc Eco Paleo Miner Special Pub 39:63–74

Goswami DC (1985) Brahmaputra River, Assam, India: physiography, basin denudation and channel aggradation. Water Resour Res 21:959–978

Kotoky P, Bezbaruah D, Baruah J, Sarma JN (2005) Nature of bank erosion along the Brahmaputra River channel, Assam, India. Curr Sci 88:634–640

Sarma JN (2005) Channel form and morphology of the river Brahmaputra in Assam, India. Geomorphology 70:226–256

Sarma JN, Phukan M (2006) Bank erosion and bankline migration of the river Brahmaputra in Assam, India, during the twentieth century. J Geol Soc India 68:1023–1036

Thorne CR, Russell APG, Alam MK (1993) Planform pattern and channel evolution of the Brahmaputra River, Bangladesh. In: Best JL, Bristow CS (eds) Braided rivers. Special Pub. Geol. Soc. London 75:257–276