Bank erosion of the Brahmaputra River and Neotectonic activity around Rohmoria Assam, India

Erosão das margens do Rio Brahmaputra e actividade neotectónica em Rohmoria Assam, Índia

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Abstract: Bank erosion of the Brahmaputra River and geomorphology around Rohmoria area in Assam, India, are found to be related to neotectonics as revealed by a study carried out using GIS based on topographic maps surveyed in 1916 and 1963, seismotectonic map as well as remote sensing data of 1983, 1996, 2001, 2007 and 2009. There is a neotectonic fault located just north of Rohmoria area. The Brahmaputra River was 6 km away from Rohmoria in 1916, but by eroding it south bank continuously it reached this place in 1996. During the six time periods under study, i.e., 1916-1963, 1963-1983, 1983-1996, 1996-2001, 2001-2007 and 2007-2009, the amount of bank area eroded by the river around Rohmoria in km² were 51.372, 18.522, 34.507, 1.468, 1.321 and 1.289, respectively. The rate of bank erosion in km²/year were highest (2.731) during 1983-1996 and lowest (0.220) during 2001-2007 and 0.645 in the present years during 2007-2009. Subsidence due to movement along the neotectonic fault during these two periods of higher bank erosion was the main cause of rampant bank erosion of Rohmoria area, which is augmented by direct action of the river current and presence of a thick unconsolidated sand horizon at the base of the bank.

Keywords: Bank erosion, Bankline, Neotectonic scarp, Rohmoria.

1. Introduction

The Brahmaputra is a large river which flows for 2880 km through China, India and Bangladesh, out of which it has a course of 640 km through Assam, India. The Brahmaputra River has been causing severe bank erosion along different parts of its alluvial banks in Assam. Among the localities afflicted by severe bank erosion in Assam (such as Majuli, Morigalola, Kaziranga, Laharighat, Palasbari, Gomi, Mokalmau and Bogribari), Rohmoria area has the highest rate of bank erosion in the south bank of the Brahmaputra (Sarma and Phukan, 2006). This paper is aimed at giving an idea of the graveness of the erosion problem using spatial data and geomorphic evidences and its interrelation with a neotectonics fault.

Rohmoria area is located on the plains of eastern part of Assam, on the left (south) bank of the Brahmaputra in Dibrugarh district. According to Survey of India (SI) topographic map of 1916 (1924 edition) there were two villages named Rohmoriagon 1 & 2 (gaon=village), a tea garden (TG) named Rohmoria (Fig. 1). The Rohmoria area (Rohmoriagon 1 & 2) spanned 3.2 km and centred on 27°32′/N latitude and 95°08′/E longitude. Rohmoria area is situated at a distance of about 23 km to the east of Dibrugarh town. The entire area situated to the north of Rohmoria comprised several small settlements, swamps and dense mixed jungles till 1996. The Dibrugarh-Rangagarga-Tinsukia (DRT) Road, a historical highway, passes through and links Rohmoria with both Dibrugarh and Tinsukia townships by regular transport services. But the Brahmaputra River had not only eroded away all those resources along with the DRT road, but also has been eroding presently the villages around Rohmoria. The erosion of the Brahmaputra at Rohmoria has resulted in a 4-5 m high vertical erosional scarp (Fig. 2), which spans linearly at a stretch for about 9 km.

2. Previous work

Studies on bank erosion of the river Brahmaputra and many of its tributaries using topographic maps and satellite data have been done by many workers (Sarma & Basumallick 1984, Kotoky et al. 2005, Sarma & Phukan, 2004, 2006, Sarma et al., 2007, 2011). Important studies on neotectonics of the eastern part of Assam include the works of Roy (1975), Goswami and Kar (1978), Mazumder et al. (2001), Luirei and Bhakuni (2008), DPR DLHWP (2008) and CISMHE (2009). In these studies attempts were made to correlate subsurface active structure with drainage

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patterns and drainage anomalies. In the present study an attempt has been made for the first time to evaluate the role of a neotectonic fault on rapid bankline migration vis-a-vis bank erosion of the Brahmaputra River around Rohmoria locality of Assam. Pant et al. (1992) and Hodges (2000) had studied neotectonics of parts of the Himalayass. Pant et al. (1992) and Hodges (2000) had studied neotectonics of parts of the Himalayas.

Fig.1. Location map of Rohmoria area.

Fig.1. Mapa de localização da região de Rohmoria.

and the Newer Alluvium superimposed over the Older Alluvium close to the foothills occur as fans and within narrow flood plain of the present rivers defined by their paleo banks as Low Level Terraces. Geologically the Rohmoria area comprises Newer Alluvium on the paleo bank of an ancient river, presently known as the Maijan River located south of Rohmoria. A generalized lithostratigraphic succession of the Quaternary deposits of Brahmaputra Basin after Kar et al. (1997) is given in Table 1.

Table.1 Generalised lithostratigraphy of the Quaternary deposits of the Brahmaputra basin (after Kar et al. (1997))

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation/Unit</th>
<th>Lithostratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>Newer Alluvium</td>
<td>Channel Alluvium (T₃)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terrace Alluvium (T₁)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terrace Alluvium (T₂)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alluvial Fan (T₄)</td>
</tr>
<tr>
<td>? Middle</td>
<td></td>
<td>Disconformity</td>
</tr>
<tr>
<td>to Upper Pleistocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Pleistocene to Lower Pleistocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Older Alluvium</td>
<td>Older Terrace Alluvium (T₃)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Older Terrace Alluvium (T₁)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Older Terrace Alluvium (T₂)</td>
</tr>
<tr>
<td></td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kamin (Upper Siwalik) and Dihing Formation</td>
</tr>
</tbody>
</table>

2.2. Neotectonics

One neotectonic fault scarp, named Okland-Guijan scarp, which extended in E-W and ENE-WSW direction for about 32 km immediately north of Rohmoria, was mapped in all studies carried out prior to 1996. Locally, this scarp is called Rangagara - Ranga=Red (reddish-yellow soil), gara=Scarp. But Brahmaputra and one of its major tributary, the Lohit, which presently joins the former at Balijan on the east of Rohmoria, both advanced southward by eroding their banks and reached the scarp in the year 1996.

This scarp is shown in the SoI maps of 1916 and 1963 and is observed as a lineament in satellite data prior to 1996. The location of the scarp coincides with an ENE-WSW trending neotectonic fault located just northeast of Dibrugarh and south of the river Dibru (Fig. 3) as shown in the Seismotectonic Atlas of India (Nurula et al., 2000). Geomorphologically the area to the north of the scar was 2 to 6 m lower than the southern part. Correlation of subsurface lithologic units across the scarp, as revealed by drilling, suggested a vertical displacement of 3 - 4 m to the north across the scar (Goswami et al., 1984). This scarp followed the trend of the isoseimal line no. IX of the Assam Earthquake of 1950 (magnitude - 8.6 in Richter scale with epicentre near the Indo China border at Rima 26.60 N; 96.50 E) as shown by Poddar (1950), Ray (1953), and Reddy et al. (2009). The ENE-WSW, NW-SE and NE-SW trending fractures present in Achaean Group of Meghalaya and Mikir Hills plateaus are extending into the basement lying under the alluvium (Das Gupta et al., 1964). Moreover, diastrophism or deformation has taken place so recently in Assam that there has not been enough time for erosion and mass wasting to destroy the effect of the same and hence the topographic high may also be a structural high (Roy, 1975). This fault is a normal fault as confirmed by correlation of subsurface lithologic units across the scar as mentioned above (Goswami et al., 1984). This region bears imprints of change in the landscape by faulting, fracturing, subsidence and upheaval by the great Assam Earthquake of 1950 (Poddar 1950, 1952, Ray 1953, Das Gupta, 1977, Goswami and Kar, 1978).

2.1. Regional geology

The eastern part of the Brahmaputra Valley in Assam is known as Upper Assam Valley, which evolved during middle Pleistocene within the depression formed between Sub-Himalaya and the Precambrian massif of the Shillong Plateau and uplifted Naga-Patkai folded belt due to Post-Siwalik Himalayan orogenic movement. Its development is linked with the phases of uplift, glaciations (?), erosion of the Himalayas and basement tectonics affecting Shillong-Mikir massif and the basin of deposition (Balasundaram and Murthy, 1977). Kar et al. (1997) had classified the Quaternary sediments of the valley into Older Alluvium and Newer Alluvium. The Older Alluvium form High Level Terraces.
2.3. Geomorphology

Brahmaputra River has an overall braided channel in Assam. But it develops an anabranching reach just north of Rohmoria area due to the consistent southward shifting of its channel. The mean annual discharge of the Brahmaputra near Rohmoria is about 257270 Mm³ or 8157.97 m³/sec. Geomorphologically the area to the north of the scarp is a continuation of neighbouring Saikhoa surface (T1 surface) included in low level terrace alluvium replete with small streams and swamps, whereas the area to the south of the scarp is an extension of the Dangori surface (T2 surface), included in higher level terrace alluvium with paleochannels and misfit streams, which occurs 2 - 4 m higher than the Saikhoa surface. Stratigraphically the Saikhoa surface is called Saikhoa Formation comprising unoxidized sediments of very fine sand, silt and clay of recent flood plain origin and the Dangori surface is called Dangori Formation comprising moderately to highly oxidized sand and clay of older flood plain deposits (Goswami et al., 1984, Kar et al., 1997).

![Image](309x105to551x274)

Fig.3. Neotectonic fault (F – F) shown in bold lines on the northeast of Dibrugarh and just south of the Dibru River as shown in the Seismotectonic Atlas of India. Positions of the rivers Brahmaputra and Dibru are shown according to the map of 1916. Geomorphologically this fault exactly coincides with Oakland – Guijan neotectonic scarp. (Reproduced in modified form after Narula et al., 2000).

![Image](282x260)

Fig.3. Falha neotectônica (F – F) mostrada em linhas carregadas a nordeste de Dibrugarh e imediatamente a sul do Rio Dibru, como evidenciado no Atlas Sismotectônico da Índia. As posições dos Rios Brahmaputra e Dibru são mostradas de acordo com o mapa de 1916. Do ponto de vista geográfico, esta falha coincide com a escarpa neotectônica Oakland – Guijan. (Reproduzido e modificado a partir de Narula et al., 2000).

3. Database and methodology

The amount of erosion of Rohmoria area has been estimated using S‘I topographic map no. 83 M/2 of 1924 edition at 1: 63,360 scale surveyed in 1916 and of 1967 edition at 1: 50,000 scale surveyed in 1963, Landsat satellite data of 1983 as well as IRS satellite data of 1996, 2001, 2007 and 2009. The SoI maps have been scanned in A0 scanner. The scanned map and the images are exported to format compatible to PCI Geomatica V 8.1 GIS software and were georeferenced using a projection system (Lat.- Long., Ellipsoid - Everest - E006). The bankline of the Brahmaputra around Rohmoria area for each data was digitized individually and then banklines of all data were superimposed on the same scale. The superimposed bankline layers of two consecutive years were then converted to area layers and the areas eroded in between the two consecutive data years have been estimated progressively for the entire period of study. The geomorphic features of the area were studied from the S‘I topographic map, satellite data and field survey. Previous literature helped to know about the neotectonic aspects of the area (Goswami & Kar, 1978, Goswami et al., 1984, Nurula et al., 2000, Reddy et al., 2009).

4. Results

4.1. Geomorphology of the area during 1916

According to S‘I map surveyed in 1916 the Brahmaputra River had a braided channel on the north of Rohmoria area having an average width of 7.12 km. At that time the westernmost extension of the nearly E-W trending Oakland-Guijan scarp was only up to Bogoritoli (95009/10//E), located about 2 km east of the centre of two Rohmoria gaons (Fig. 4). There was a conspicuous difference in geomorphology and land use practices on both sides of this scarp - the northern side had sparse small settlements, forests, and bamboo groves, whereas the southern side had dense large villages, cultivated land and tea gardens. The river Dibru, a tributary of the Brahmaputra, flowed from east to west, nearly parallel to the latter, by about 2.5 km to the north of Rohmoria area as well as the scarp. There were several small reticulate streams surrounding the intricately meandering-cum-anastomosing Dibru River and three small swamps (bil) formed on abandoned river channel in the area in between the river Brahmaputra and the scarp. The general slope of the area was from northeast to southwest. The elevation of the area varied from 359 ft (109.4 m) to 355 ft (108.2 m) on the north of the scarp and from 381 ft (116.1 m) to 374 ft (114 m) on the south of the scarp. Hence the area to the north of the scarp was about 5.8 m to 6.7 m lower than the southern counterpart. The Brahmaputra River flowed by about 3.5 km to the north of the river Dibru. Hence in 1916 the distance from Rohmoria area to the river Brahmaputra was about 6 km and the river was about 5 km wide just on the north of Rohmoria.

![Image](274x285)

Fig.4. Geomorphological features of the area in 1916 with an inset of location map of the study area.

Fig.4. Características geomorfológicas da área em 1916 com o enquadramento da localização da área estudada.
4.2. Geomorphological and spatial changes in the area during 1916 – 1963

Comparing the map surveyed in 1963 (Fig. 5) with that of 1916 the spatial changes that occurred during 47 years have been assessed, because no map is available for the intermediate period. The Brahmaputra encroached southward from 1.14 km to 4.25 km further south till 1963 and wiped away vast area on the north of Rohmoria (Fig. 6). Therefore, the width of the river increased to 10.88 km. The main cause of triggering the erosion of Rohmoria might be the 1950 Assam Earthquake of magnitude 8.6 in the Richter scale. Erosion was alarmingly high during 1954-1955, when the entire south bank of the Brahmaputra from the west of Dibrugarh town up to Saikhoaghat for a stretch of nearly 80 km had been subjected to severe erosion due to bank collapse (Sarma and Phukan, 2006, CISMHE, 2009). In the S’1 map of 1963 Oakland-Guijan scarp stretches continuously up to Brahmaputra River through Oakland TG, which indicates that the scarp extended further west for about 11 km from its earlier position of Bogorioli in 1916. The elevation of the area varied from 111 m to 107 m on the north of the scarp and from 114 m to 112 m on the south of the scarp, confirming that the southern part of the scarp was still higher than the northern part as mapped in 1916.

The western projection of this scarp was close to the northern boundary of the then Dibrugarh town, northern part of which collapsed into the Brahmaputra River after the Assam Earthquake of 1950 (Kar et al. 1977, CISMHE, 2009). It appears from these evidences that the Oakland-Guijan scarp existed prior to 1916 and it was probably extended southwestward as a consequence of the great Assam Earthquake of 1950, with an elevation difference of about 2 m and subsidence of the area north of the scarp with southward tilting of the subsided block (Goswami et al. 1984).

By 1963 about 12 km of the downstream course of the river Dibru was engulfed by the Brahmaputra. Moreover, the distance between the rivers Brahmaputra and the Dibru became only 1.1 - 3.2 km (Fig. 5). In the 1963 map the area between the rivers Dibru and the Brahmaputra is shown as a low swampy land with tall grass and the area to the south of the river Dibru and north of the scarp is also shown as depressed land teeming with swamps, usually flooded from April to September. Forest cover reduced in 1963 as compared to 1916. These facts also lead to infer that the area to the north of the scarp had undergone some subsidence due to the 1950 Assam Earthquake resulting in an increase of low-lying swampy land in place of forest areas as compared to 1916.

Fig.5. Geomorphological features of the area in 1963. The area on the north of the scarp (Oakland-Balijan) and south of the Brahmaputra river channel represents Saikhoa surface (T1 surface). The area on the south of the scarp represents Dangori surface (T2 surface) and the channel bed of the Brahmaputra represents T0 surface.

Fig.5. Características geomorfológicas da área em 1963. A área a norte da escarpa (Oakland-Balijan) e a sul do canal do Rio Brahmaputra representa a superfície Saikhoa (superfície T1). A área a sul da escarpa representa a superfície Dangori (superfície T2) e o leito do canal do Brahmaputra representa a superfície T0.

Dibru and the Brahmaputra is shown as a low swampy land with tall grass and the area to the south of the river Dibru and north of the scarp is also shown as depressed land teeming with swamps, usually flooded from April to September. Forest cover reduced in 1963 as compared to 1916. These facts also lead to infer that the area to the north of the scarp had undergone some subsidence due to the 1950 Assam Earthquake resulting in an increase of low-lying swampy land in place of forest areas as compared to 1916.

Fig.6. The banklines of the Brahmaputra River around the Rohmoria locality in the years 1916, 1963, 1983, 1996, 2001 and 2009.


4.3. Spatial changes of the area during 1963 -1983

The spatial changes that occurred from 1963 to 1983 have been detected using a Landsat 4 image of 1983 with 80 m ground resolution. The Brahmaputra encroached further south varying from 0.60 km to 1.60 km from 1963 to 1983; therefore, by 1983 the mouth of the Dibru had shifted further 3.5 km to the east.

4.4. Spatial changes of the area during 1983 -1996

The spatial changes subsequent to 1983 have been assessed by using IRS 1B LISS III data of December 1996 with 36.25 m ground resolution. During this period of only 13 years the amount of southward shift of the Brahmaputra on the north of Balijan, Rohmorigaonas, Garhparaagon and Oakland-Nagaghuli were 5.5 km, 4.5 km, 1.8 km, and 0.2 km, respectively. Therefore, the width of the Brahmaputra increased to 16.20 km and the mouth of the Dibru River shifted further 8 km to the east up to Balijan from its position of 1983. The entire area to the north of the Okland-Guijan scarp, comprising sixteen small settlements was then swallowed up by the Brahmaputra, which continued to flow along the side of this scarp, i.e., the scarp became the river bank. Moreover, in the year 1996 the Lohit River avulsed and diverted its flow (which amounts to 1447.66 m/sec as mean annual discharge) through the rivers Dangari and Dibru to join the Brahmaputra River at Balijan (Fig. 7) (Sarma, 2005).

4.5. Spatial changes in the area subsequent to 1996

The LISS III data of IRS 1B LISS 1D of December 2001 with 23.6 m ground resolution depict the changes that took place from 1996 to 2001. By 2001 the areas on the northern parts of Oakland TG, Garhparaagon and Rohmorigaonas were eroded away. The...
The Brahmaputra River reached Kachuanigaon on the west and Bagaritoli on the east of Rohmoriagaons. The encroachment by the Brahmaputra during this time span varied from 200 m to 750 m.

The IRS P6 LISS III data acquired in December 2007 with 23.5 m ground resolution show that the southward migration of the south bank of the Brahmaputra continued unabated up to 200 m around Rohmoriagaons during 6 years from 2001 to 2007. Cartosat 1 data of 2.5 m ground resolution acquired on November 2009 have confirmed that the bank erosion has been uninterrupted and the maximum encroachment of about 107 m took place from 2007 to 2009. The Brahmaputra River became 17.02 km wide by 2009. A field visit on January 10, 2011, confirmed that the erosion has been continuous throughout and maximum amount was 20 m in the year 2010.

The total bank area being eroded away by the Brahmaputra from 1916 to 2009 along the 17 km segment around Rohmoria area was estimated at 109.479 km². If this amount is divided by the time span of (2009-1916=) 93 years then the rate of erosion in this reach becomes 1.177 km²/year and when this amount is divided by the length of the segment (17 km), the bank erosion per unit length of the river Brahmaputra at Rohmoria is nearly 0.069 km²/km per year, which is highest for the entire south bank of the Brahmaputra (Sarma and Phukan, 2006).

### Table 2 Amount of bank erosion in different periods

<table>
<thead>
<tr>
<th>Period</th>
<th>Time span in years</th>
<th>Total area eroded in sq km</th>
<th>Rate of erosion in sq km/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916–1967</td>
<td>51</td>
<td>51,372</td>
<td>1.007</td>
</tr>
<tr>
<td>1967–1983</td>
<td>16</td>
<td>18,722</td>
<td>1.158</td>
</tr>
<tr>
<td>1996–2001</td>
<td>5</td>
<td>1,488</td>
<td>0.294</td>
</tr>
<tr>
<td>2001–2007</td>
<td>6</td>
<td>1,372</td>
<td>0.229</td>
</tr>
<tr>
<td>2007–2009</td>
<td>2</td>
<td>1,289</td>
<td>0.645</td>
</tr>
</tbody>
</table>

4.7. Causes of bank erosion at Rohmoria

The S1 map of 1963 reveals that the amount of low land increased significantly on the northern part of the Oakland-Guijan scarp as compared to 1916, which may be an evidence suggesting that the area to the north of the scarp had subsided due to the great 1950 Assam Earthquake. As the scarp represent the plane of a normal fault having its downthrown block to the north, the area to the north of the scarp might be subjected at times to vertical movement due to neotectonic causes. There might have been another subsidence to the north of the same scarp just before 1996, because by this time two very remarkable events took place. Firstly, the rapid southward migration of the south bank of the Brahmaputra and concomitantly highest rate of bank erosion that occurred in this period. Secondly, avulsion of the Lohit River took place towards southwest in 1996, which captured the lower courses of the Dangori and Dibru Rivers and converted Dibru-Saikhoa reserved forest (RF), situated on the north of the Oakland-Guijan scarp, into a large island (Fig. 7) (Sarma, 2005). The subsidence of the area to the north of the Oak-Hu-Guijan neotectonic fault might have resulted in development of an arcuate semicircular bend of the entire braided belt of the ENE-WSW flowing Brahmaputra river channel abruptly towards SW on the north of Rohmoria (Fig. 7). Here the primary and two secondary channels of the Brahmaputra flow in SW direction and strike the bank at about 45° and flow along the bank for about 9 km up to Nagaghuli causing severe bank erosion and then the flow turns towards NW direction beyond Nagaghuli. The easternmost channel of the Brahmaputra is being reinforced by the present flow of the river Lohit through the course of the Dibru River that joined the Brahmaputra at Balijan in 1996. The next and the major cause of erosion is the presence of about 2 m thick layer of medium to coarse grained loose sand below the thick layer of cohesive top soil of the bank (Fig. 8). During high flow the river current undermines the bottom unconsolidated sand layers of the bank; as a result the overhanging top soil layers lose support and tumble down to be carried away by river current very easily.

![Image of satellite IRS Liss III data of 2007 showing the arcuate course of the Brahmaputra with its primary and secondary channels striking the bank at about 45° and flowing for about 9 km along the bank of Rohmoria area.](image)
As the only preventive measure of bank erosion of the Brahmaputra at Rohmoria area, Oil India Limited (OIL), Duliajan, had proposed to install 200 dampeners with used steel drill-pipes along entire 9 km erosion-prone bank of Rohmoria. But only 35 dampeners have so far been put up since 2005 at certain parts of the eroded bank. Only a few of these dampeners have been successful to control bank erosion and the rest are damaged by the river current. In order to prevent bank erosion at Rohmoria locality it is necessary to divert the southwestward flow of the Brahmaputra towards WSW along the middle part by adopting training measures, which will prevent the main flow from hitting the banks directly.

Fig.8. A trench dug across the erosional scarp of Rohmoria shows light coloured loose sand layer at the bottom below cohesive brownish top soil.

Fig.8. Uma trincheira ao longo da escarpa erosiva de Rohmoria mostra areaia de cor clara e solta na base por debaixo solo de topo coeso de cor castanha.

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References


