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# Evidences of Neotectonic Activities as Reflected by Drainage Characteristics of the Mahananda River Floodplain and Its Adjoining Areas, Bangladesh

Bazlar Rashid<sup>1, \*</sup>, Sultan-Ul-Islam<sup>2</sup>, Badrul Islam<sup>2</sup>

<sup>1</sup>Geological Survey of Bangladesh, Dhaka, Bangladesh <sup>2</sup>Department of Geology and Mining, University of Rajshahi, Rajshahi, Bangladesh

#### **Email address**

bazlarrashid@ymail.com (B. Rashid)

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#### Abstract

The drainage pattern in the Bengal Basin as a whole has been greatly controlled by the tectonic features of the basin. Considerable evidence of significant tectonic movements has been recorded within and along the boundary of the basin in Late Tertiary and the Quaternary times. This paper tried to unveiling the signatures of neotectonic activities in the Mahananda River floodplain and its surrounding areas with the help of drainage characteristics. To carry out this interpretation historical maps, satellite imagery and earthquake records were used. The interpretation implies that the area is being structurally controlled. Changing of river courses, shifting of rivers, restriction of the Punarbhaba, Tangon and Kulic River valleys against the comparatively narrow Mahananda River, abrupt change in the sinuosity of the Mahananda River at a particular area and presence of large number of depressions/sag ponds are clear indication of the structural control of the area. In the recent past few earthquakes occurred in this region which also supports the same view about neotectonics. All these features and evidences strongly support the structural control of the area.

### **Keywords**

Mahananda River Floodplain, Drainage Characteristics, Neotectonics

### 1. Introduction

In ancient time, most of the rivers provide cheap and convenient means of transport and communication. So, all the flourishing cities, trade centers or big villages are situated on the banks of the rivers. Any changes in their courses have changed the position of the prosperous cities, thriving trade centre and villages of ancient Bengal (e. g. [52]). During last four or five hundred years, great changes have taken place in the course of some of the important rivers of Bengal as well as settlement, cities and trade centers along the courses of the rivers (e. g. [52]). In the present study area, the major rivers have also changes their courses and some cases obstructed dramatically.

The drainage is the connecting link between the erosional and depositional parts of the system and therefore the drainage significantly influences the morphology of an area (e. g. [16]). The morphology of rivers reflects a balance between the erosive power, the stream flow and the erosional resistance of the bed and bank materials. Morphological changes of an alluvial channel can occur as a result of changes in water discharge, sediment load, sediment type and gradient. Tectonic activity also significantly controls river patterns and their behaviors (e. g. [17], [25], [29, [39], [59], [66], [69]). Many of the major rivers of the world follow structural laws and major geo-fracture systems and have adjusted to tectonic activity (e. g. [43], [50]). The present study tried to unveiling the signatures of neotectonic activities in the Mahananda River floodplain and its surrounding areas with the help of drainage characteristics.

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The study area lies between latitudes  $24^{\circ}20'-2530'$  N and longitudes  $88^{\circ}00'-88^{\circ}30'$  E (Fig. 1). A part of this area belongs to the exposed Pleistocene deposits (Barind Tract), and rests are either the floodplain, channels, flood basins of the number of rivers flowing through the area.



Fig. 1. Location map of the study area.

### 2. Materials and Methods

Satellite images, topographic maps, historical maps have been interpreted for the preparation of physiographic, topographic, drainage maps and to identify the neotectonic signatures. Details of the data used in the study are given below:

a) *Satellite Imagery*: Hard copy SPOT Panchromatic images of scale 1:50,000 (1990) and Landsat ETM + digital image of 1999 have been visually interpreted for physiography and drainage characteristics of the area.

b) *Topographic Maps*: Topographic maps covering the study area at the scale of 1: 50,000 published by the Survey of Bangladesh have also been used to prepare the topographic and physiographic maps.

c) Ancient Drainage Maps: Ancient drainage maps of northwestern part of Bangladesh have been used to delineate the shifting characteristics of rivers in the areas in historic times.

d) *Earthquake Data*: Data recorded during recent and past earthquakes have been used to delineate the tectonic activity in the area.

The maps have been prepared by 'Adobe Illustrator 10' software'. All the maps along with ancient drainage maps and earthquake data have been used to understand the drainage characteristics, their pattern, distribution, shifting and evolution of drainages in historic times in the areas and to identify the neotectonic signatures.

# 3. General Geology

The Bengal Basin occupies a major part of Bangladesh. Tectonically, this part of the Bengal Basin is divided into two major divisions (a) the Precambrian Rangpur Platform and (b) the Bengal Foredeep (Fig. 2). The study area is located at the northwestern part of Bangladesh falls in the Precambrian Rangpur Platform of the Bengal Basin. This platform is a buried Precambrian basement rock, and connects the exposed Indian Shield in the west with the Shillong Massif in the east (Fig. 2).

## 4. Physiography

The study area fall into two major physiographic surfacesthe Pleistocene Barind Tract and Holocene Channel-Floodplain Complexes (Fig. 1). The Barind Tract is exposed on a slightly elevated land (about 20-40 m amsl) in comparison to the surrounding floodplains. It forms inliers within floodplain and is criss-crossed by different rivers having highly dissected topography. The Tract is mainly an alluvial terrace, which abruptly merged into Recent floodplain. The Holocene Channel-Floodplain Complexes are lies along the Ganges (Padma), Mahananda, Punarbhaba, Kulic and Tangon Rivers. The elevations of these floodplains are ranges from about 15-20 m. All the floodplains of the study area are deeply inundated annually.

## 5. Drainage of the Area

The Ganges (Padma), Mahananda, Punarbhaba, Kulic and Tangon are the main rivers in the study area (Fig. 1). All the rivers are flowing roughly N-S, NW and SE directions (Fig. 1). The Barind Tract shows the tightly meandering channels with dendritic drainage pattern, whereas, the rivers in the floodplain are either meandering, braided or anastomosing drainage channels (Fig. 1). Large number of tributaries meet the Mahananda, Punarbhaba and Tangon Rivers in the east and west respectively (Fig. 1). In the area between the Ganges (Padma) and Mahananda Rivers, numerous channel scars, loop, scrolls and abandoned channels are present (Figs. 3, 7-9). All these features are coincides with the Padma River pattern. The Tangon and Punarbhaba Rivers are single channel meandering rivers. But these rivers show multichannel meandering i.e anastomosed river system within their valleys (Fig. 4). Although the Tangon and Punarbhaba valleys are similar or larger in dimension in comparison to the present Padma River Valley, but these valleys do not continue upto the present Mahananda River (Figs. 1, 3).



Fig. 2. Generalized tectonic map of Bangladesh and adjoining area (compiled from (e. g. [5], [27], [33], [34] [45], [53], [61]).



Fig. 3. Interpretation of Landsat ETM+ (digital) image of 2001 showing the shifting characteristics of the Padma and Panar Kosi Rivers in this region and also used as index map of Figs. 7-9.

### 6. Discussion

Alluvial rivers are those which flow between banks and on a soft sedimentary bed and are composed of transported sediment, sensitive to changes of sediment load, water discharge, and variation in valley floor slope. Neotectonic movements are reflected only in those geomorphic features that react to smallest changes of slope. When stream channel and terraces are offset along faults these exhibit remarkable effects (e. g. [67], [72]). Drainage system adapts to the changes of surface slope and these have the potential to record information about the evolution of structure like, faults and folds (e. g. [37], [48]). Fluvial anomalies, such as local

development of meanders or braided pattern, local widening or narrowing of channels, anomalous ponds, marshes or alluvial fills, variation in levee width or discontinuous levees, and any anomalous curve or turn etc. are possible indicators of active tectonics in an alluvial plain (e. g. [21], [22], [30], [38], [48], [49], [63]). Migrating and alternating bars forming, a sinuous thalweg, a highly sinuous channel of equal width, frequent transition of meander-braided natures etc. are also the indicators of active tectonics (e. g. [21], [22], [30], [38], [48], [49], [63]).

Structural implication in the study area is reflected by drainage characteristics. The Punarbhaba, Tangon and Kulic Rivers valleys are present in the northwestern Barind Tract (Figs. 1, 3). It is interesting that the widths of the valleys are not less than that of the present Ganges (Padma) River valley. But these valleys do not continue up to the present Mahananda River. Large numbers of abandoned channels, channel scars, scrolls, loops, ox-bow lakes etc. are present in these valleys and anastomosing channels (Fig. 4, 5).



Fig. 4. Anastomosing drainage pattern of the Tangon and Punarbhaba valleys.



Fig. 5. SPOT image (Sheet No.78 D/5) of 1990 showing a number of abandoned channels and channel scars in the Punarbhaba valley (Scale 1: 50, 000).

These valleys might be obstructed and did not maintain their continuity, which favours the formation of anastomosed pattern in the Tangon and Punarbhaba Rivers. From the interpretation of paleo-drainage systems and recent (in this decade) satellite imagery reveals that once upon a time the Padma River was flowing through the present Mahananda River and the Tista, Punarbhaba, Mahananda, Kulic, Tangon and Kosi Rivers were directly fall into the Padma River in the south. Previously the Mahananda River was fall into the Padma River at the place where the Kulic River presently meets the same river (Figs. 3, 6, 7). Once upon a time the Mahananda, Tangon, Punarbhaba and Kulic Rivers followed the course which has been abandoned and became the present course of the Mahananda River due to the upliftment of the Barind Tract and westerly shifting of the Padma River. Large numbers of tributary channels of the Barind Tract also have not head ward continuity to the main channels (Fig. 1), and this might be due to the upliftment of the Barind Tract.

Presence of abandoned channels, channel scars and oxbow lakes and their trends indicate that the Panar Kosi River (in India) flowed through the old channel of the Padma which is now the Mahananda River (Figs. 3, 8). But this river shifted towards northwest and presently falls into the Padma River at about 40 to 45 km (Figs. 3, 8) northwest from the Mahananda River. It has been identified that the mouth of the Panar Kosi River shifted from north to south-southwesterly and successively joined the Mahananda River (Fig. 3, 8). Six paleoflow of the Panar Kosi River can still be identified from the interpretation of recent satellite images (Fig. 8). But at present this river totally shifted from the Mahananda River and directly falls into the Padma River (Figs. 3, 8). Priyadarshi (2009) studied that the Kosi River is building up a large delta of its own through which its channels have wandered for centuries (e. g. [51]). This river originally joined the Mahananda, a river coming from the Darjeeling Himalayas. It is known that the Kosi flowed by Purnea (Bihar) 200 years ago, but its present course is about 160 km to the west of that place, having swept over an area of 10,500 sq. km on which it has deposited huge quantities of sand and silt (e. g. [35]).



Fig. 6. Ancient drainage map of the northwestern part of Bangladesh (compiled from Rennell, 1783 (e. g. [55])).

Wells and Door Jr. (1987) also mentioned that the Kosi River at the foothills of the Himalayas in Bihar, India, has shifted 113 km westward over the Kosi Fan in 228 years (e. g. [73]). Bose *et al.*, (2009) indicated that neotectonism and local isostatic adjustments are responsible for migration of the Kosi River (e. g. [15]). The channel also showed a marked affinity of lineaments and faults. It now coincides with the Bhawanipur Fault, while an eastern branch of the river trends towards the Malda-Kishanganj Fault (e. g. [15]). Agarwal and Bhoj (1992) also indicated that the migration of the Kosi River is related to the active Malda–Kishanganj Fault (e. g. [2]).

Tectonic influences on the alluvial sedimentation in the Gangetic plains have also been suggested in different works (e. g. [62], [63], [64], [65]). Jain and Sinha (2005) also interpreted the active nature of these subsurface faults in the eastern Gangetic plains (e. g. [30]). Earlier studies on the Ganges River system have highlighted the manifestation of regional E–W thrusts as knick points in the longitudinal profiles of the rivers in north India and the role of Meghalaya block uplift on the Brahmaputra (e. g. [60], [67]). On the basis of some geomorphic observations, such as the rivers flow above the general level of the ground, frequent flooding and

extensive silting, marshy land, and reduction in delta building activity in Bengal it was interpreted that the geomorphic change in the Ganges occurred due to epirogenic movement (e. g. [3]). Geophysical surveys and deep drilling also proved most of these hypotheses (e. g. [32], [54], [56]). The Gangetic plains, of which the Kosi megafan forms a part, is bound by E-W faults, which on analogy with the main boundary thrust faults. The Kosi megafan is bound on the west by a NE trending prominent sinistral fault causing an offset of some 20 km of the Siwaliks juxtaposed against the Gangetic alluvium (e. g. [51]).



Fig. 7. Interpretation of Landsat ETM+ (digital) image of 2001 showing shifting of the Padma River from the Mahananda River to the west (Ref. Index Map Fig. 3).

The Mahananda River is a typical meandering river. This river shows low to moderate sinuosity (sinuosity value 1.3 to 1.58) having almost same line of flow for long period (Figs. 1, 3, 9). But the sinuosity of this river abruptly increases (sinuosity value about 2.58) at Chapai-Nawabganj District in Bangladesh (Figs. 1, 3, 9). Generally, meandering rivers are characterized by symmetrical and sinusoidal bends, but bend asymmetry may occur because of river confinement (e. g. [28]). Any kind of tectonic disturbance may also result in asymmetry of river bends and anomalously high sinuosity because of compression and such compressed meanders are one of the common geomorphic markers of tectonic disturbance (e. g. [29], [59]). Compressed meanders form when a straight channel is forced to meander because of perturbation of channel by faulting, and the meanders tend to straighten in over time. Although these have been commonly observed in bedrock channels, such types of meanders have also been reported in alluvial plains of the Nile River and have been interpreted to reflect tectonic effects (e. g. [57], [59]). Jain and Sinha (2005) worked about the channel characteristics of the Baghmati River, a tributary of the Kosi River in eastern India and suggested that the compressed meanders in the Baghmati River and a major avulsion in the same region have been triggered by active tectonics (e. g. [30]).



Fig. 8. Interpretation of Landsat ETM+ (digital) image of 2001 showing shifting of the Panar Kosi River from the Mahananda River to the west and its successive paleoflow (Ref. Index Map Fig. 3).

In the area between left bank of the Mahananda River and western margin of the Barind Tract several number of depressions/sag ponds are present (Fig. 9). Localization of the Mahananda Rivers with its tight sinuous channel, presence of depressions/sag ponds and abrupt termination of the Punarbhaba and Tangon valleys, and even Kulic River (Figs. 1, 3, 9) strongly suggest the presence of fault which restricted the water limit of the Barind Tract, both in Bangladesh and India. In this area, Malda–Kishanganj Fault also follows the same line of Mahananda river course (Fig. 2). This fault may be similar in nature to those present along the western boundaries of the Madhupur Tract and Lalmai hill (Fig. 2). It is interesting that the wider valleys of the Kulic, Tangon and Punarbhaba Rivers became restricted and seems to be beheaded against the present course of the Mahananda River having much narrower vallies. It is much more logical to state that these river valleys might have been truncated previously against larger valley and that was obviously the Padma River. So, truncation of these valleys, variation of their topography and elevation, and dimension of the Mahananda River suggest that the Padma River was previously flowed through the area now occupied by the Mahananda River and the lower Mahananda course is the structurally controlled abandoned course of the Padma River formed due to the upliftment of the Barind Tract and southwestern shifting of the Padma River.



Fig. 9. Interpretation of Landsat ETM+ (digital) image of 2001 showing large number of depressions between left bank of the Mahananda River and western Barind Tract and its tight sinuous channel (Ref. Index Map Fig. 3).

A number of subsurface faults trending NW and NE, transverse to the trend of the Himalaya, were reported and most of these faults are known to be seismogenically active (e. g. [20], [26], [35], [66]). An earthquake with magnitude 4.1 occurred on Bangladesh-India border in 5 July, 2008, which

was felt in parts of Rajshahi as well as parts of West Bengal in India. The epicenter was located 6.4 km W-NW of Rajshahi (e. g. [19]), which also indicates the active nature of the areas. Another earthquake with magnitude 4 occurred on Rajshahi-Naogaon border in 29 July, 2011, which was felt in Naogaon, Bogra, Joypurhat and Gaibandha Districts, Bngladesh (e. g. [9], [10]). A powerful earthquake with magnitude 7.9 occurred in Nepal in 25 April, 2015 and sent tremors through northern India, China, Bhutan, Pakistan and Bangladesh (e. g. [6], [7]). About 7000 people were died and 5 million were directly affected (e. g. [6], [7]). Another two major earthquakes with magnitude 6.7 and 7.3 also occurred in Nepal in 26 April and 12 May, 2015 which also felt in the same region (e. g. [6], [7]). These are clear indication of the tectonically active nature of the region. In the recent past some others earthquakes also occurred in this region (e. g. [8], [31], [40]) which also indicates the same view about neotectonics. The tectonic activities in and around Bengal Basin are also reported in different literatures (e. g. [4], [11], [12], [13], [14], [18], [23], [24], [41], [42], [44], [46], [47], [59], [68]).

### 7. Conclusions

The study implies that the area is being structurally controlled. Shifting and changing of river courses like Kosi and Padma rivers, restriction of the Punarbhaba, Tangon and Kulic River valleys against the comparatively narrow Mahananda River, abrupt change in the sinuosity of the Mahananda River at a particular area with large number of depressions/sag ponds are clear indication of the structural control of the area. Presence of Malda–Kishanganj Fault and some recent past earthquakes in this region also reflect the same view about neotectonics.

Finally, from the drainage characteristics, earthquakes activities and presence of Malda–Kishanganj Fault it can be concluded that the area is tectonically active.

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