

A Review on the Quaternary Characteristics of Pleistocene Tracts of Bangladesh

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With regards to the origin and evolution of the Pleistocene tracts (Lalmai, Madhupur and Barind tracts) of Bangladesh, two trends of thoughts are common. Most of the authors believed that the Madhupur, Barind and Lalmai tracts represent tectonically uplifted surface. Some researchers have different opinion and they believed that the Lalmai hills and the Madhupur locality represent tectonically uplifted blocks but the whole Barind tract and the major portion of the Madhupur tracts are not tectonically uplifted, rather these are originated by erosional-depositional processes. In order to solve the problems associated with origin and evolution of Pleistocene tracts of Bangladesh, further study is needed. Borehole data may be collected and fusion images can be prepared from aerial photographs and satellite images to detect neotectonic imprints and geomorphological signatures of the areas. Elaborate laboratory analysis of sediment deposits, radiocarbon dating may indicate a new dimension about the origin and evolution of these tracts.

Key words: Bangladesh, Lalmai Hill, Barind Tract, Madhupur Tract, Neotectonics, Aerial photographs, Satellite Image, Fusion Image.

I. Introduction

Geologically, the Madhupur and Barind tracts belong to Plio-Pleistocene Terrace deposits. The Madhupur and Barind tracts are underlain by unconsolidated Madhupur Clay. These tracts are broken into several fault blocks, the surfaces of which are a few meters higher than the nearby floodplain land. Five kinds of relief pattern, namely, level, poorly-drained areas (occupies most of the Barind Tract and a few small areas of the Madhupur Tract), high uplifted areas (15m high western edge of the Barind Tract), broadly dissected areas (mostly on the Madhupur Tract, minor areas in the Barind tract), closely dissected areas (on the Madhupur Tract only) and broadly dissected valleys (on the Madhupur Tract) (Banglapedia, 2000).

Most of the authors including Fergusson (1863), Hirst (1916), Morgan & McIntire (1959), Rizvi (1975), Khandoker (1987&1989), Huq et al. (1991), Coates et al. (1988, 1990 &1991), Alam (1988 & 1995) and Kamal (1998, 2005) believed that the Madhupur, Barind and Lalmai tracts represent tectonically uplifted surface. Some researchers including Monsur (1995) opined that the Lalmai hills and the small portion of Madhupur (locality) represent tectonically uplifted blocks but the entire Barind and the major portion of the Madhupur tracts are originated by erosional processes rather than structural.

Morgan & McIntire (1959) considered the red deposits exposed in the Madhupur, Lalmai hills and Barind areas as the 'Pleistocene terrace' but could not establish conclusively the existence of multiple terrace

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system in the Bengal plain. They indicated two terrace levels in the Barind tract but it was not known whether the surfaces are an indication of multiple terraces or if they reflect the structural activity. They told about en-echelon faults but unfortunately, neither field work nor examination of aerial photographs yielded evidence as to the type of movement along these faults.

According to the second thought, during glacial and interglacial periods the combined effects of seaward subsidence and landward uplift have caused a warping of the alluvial terraces, which are called the Pleistocene terraces. Afterwards the dissected valleys were filled up with alluvial sediments, generating a recent floodplain surface at lower position than the initial Pleistocene Terraces.

A further research, therefore, is needed to bring

forward the history of the formation, deformation of these tracts by using modern equipments which may help to resolve the problems associated with origin and evolution of the tracts.

II. Topography of Bangladesh

Bangladesh, a south-east Asian country, is located at the lowermost reaches of the Bengal Basin. The Quaternary (began about 2 million years ago and extends to the present) sediments; deposited mainly by the three mighty rivers, the Ganges, Brahmaputra and Meghna; covered about three-quarters of Bangladesh (Fig.1). About half of its surface is below the 10 meter contour line.

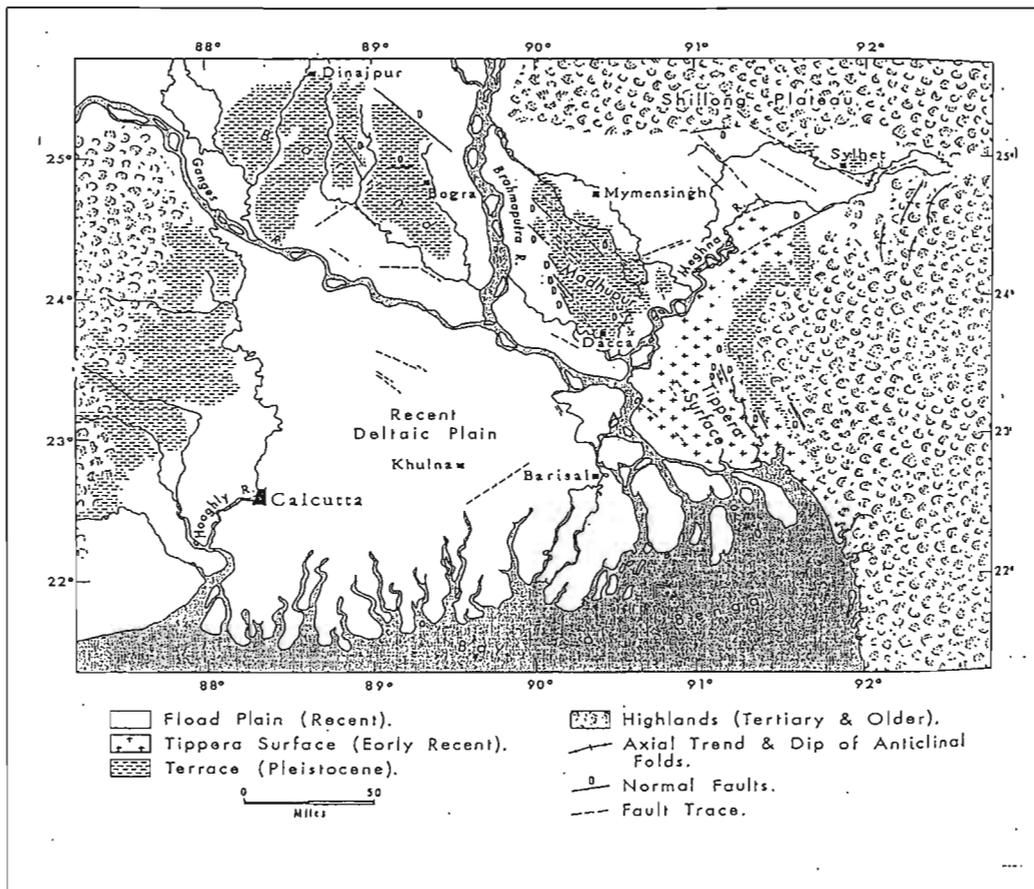


Fig. 1 Quaternary geological map of the Bengal Basin (Morgan & McIntire, 1959)

And about 10% of the land consists of Pleistocene sediments with an average elevation of more than 15m above sea level (Banglapedia, 2000). Pleistocene upland, in Bangladesh, is divided into three blocks: a) the Lalmai hills, b) the Madhupur tract and c) the Barind tract. Five kinds of relief pattern, namely, level, poorly-drained areas (occupies most of the Barind Tract and a few small areas of the Madhupur Tract), high uplifted areas (15m high western edge of the Barind Tract), broadly dissected areas (mostly on the Madhupur Tract), minor areas in the Barind terrace, closely dissected areas (on the Madhupur Tract only) and broadly dissected valleys (on the Madhupur Tract).

The Lalmai hills represent a north-south elongated low hill range of about 16 km long and about 2-3 km wide. The total area is 33 sq.km. Some of the hill tops represent table surfaces and these table surfaces

are separated from each other by deeply incised valleys and the drainage pattern is almost dendritic. The Madhupur tract is a large upland area in the central part of Bangladesh. Geologically, it is a terrace from one to ten meters above (Banglapedia, 2000). Geologically, it is a terrace from one to ten meters above the adjacent floodplains (Fig. 2). The total extent of this tract is 4,244 sq.km. It is largely in one piece, with five small outliers. All of them seem to have been separated, at least superficially, by faults (Banglapedia, 2000). This tract is extensively dissected, with narrow or broad valleys extending deep into the level landscape and the drainage pattern is clearly dendritic. The block is eastward tilted. The Barind area falls in the central part of north Bengal and covers an area of about 7680 sq.km. The area comprises about six north-south elongated isolated exposures reddish brown deposits. The drainage pattern is almost trellis.

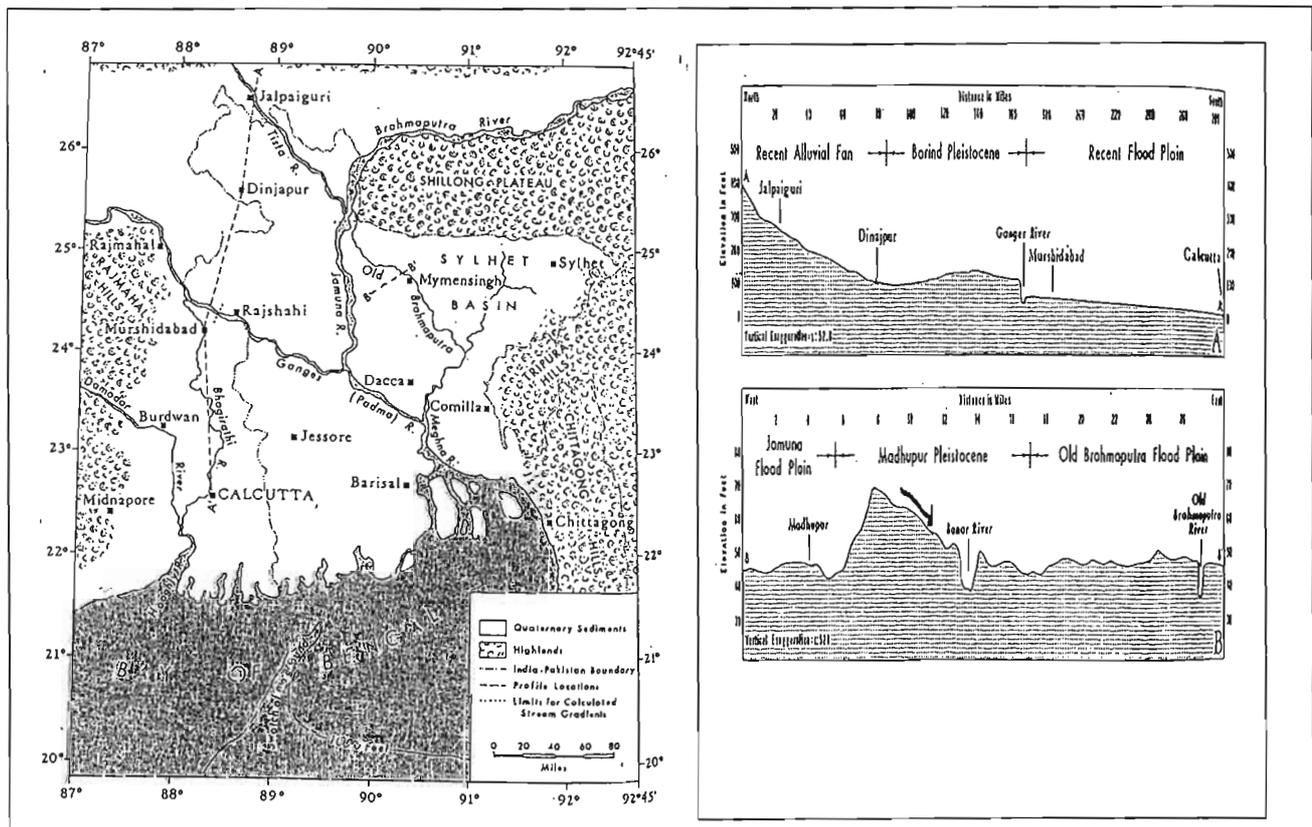


Fig. 2 Profile across the Pleistocene and Recent floodplain surfaces (Morgan & McIntire, 1959)

III. Lithostratigraphic units of the Pleistocene tracts

In Bangladesh, the north south elongated reddish brown islands of the Lalmai, Madhupur and Barind tracts are considered as the Pleistocene Terraces (Morgan & McIntire, 1959). These are characterized by plateau like hillocks and the height varying from 9 to 18.5m but some peaks of Lalmai hills rise up to 40 meters or more. The sediments of the tracts are deeply weathered and strongly oxidized and it is called Madhupur Clay (Morgan & McIntire, 1959).

Madhupur tract

Before Morgan and McIntire (1959), the Madhupur Clay was referred to as the 'older alluvium' on the assumption that they are floodplain deposits of the earlier rivers (Monsur, 1994). Eusufzi (1973) expressed the view that new Dhaka has a cap capping of 'red clay' of glacial origin. Bakr (1977) and Islam (1974) called these reddish-brown deposits as the

Madhupur Clay without giving a proper lithostratigraphic ranking. First lithostratigraphic ranking of this Madhupur Clay was given by Alam and Khan (1980). The authors ranked this Madhupur Clay up to the level of Formation. Much more detailed stratigraphical and sedimentological research was done by Hassan (1986) for his doctoral dissertation, but nowhere he mentioned the lithostratigraphical ranking of this formation. In accordance with the suggestion of Hedberg (1976), Monsur and Paepe (1994) revised the name of the Madhupur Clay and proposed new names for lithostratigraphic units and subunits. According to the authors the Quaternary deposits exposed of the Madhupur area can be subdivided into two Formations: 1) Madhupur Clay and Sand Formation (lower unit) represented by reddish-brown sand, sandy-clay and clay; and 2) Bashabo Silty-clay Formation (upper unit) represented by yellowish brown to bluish grey sand to clay.

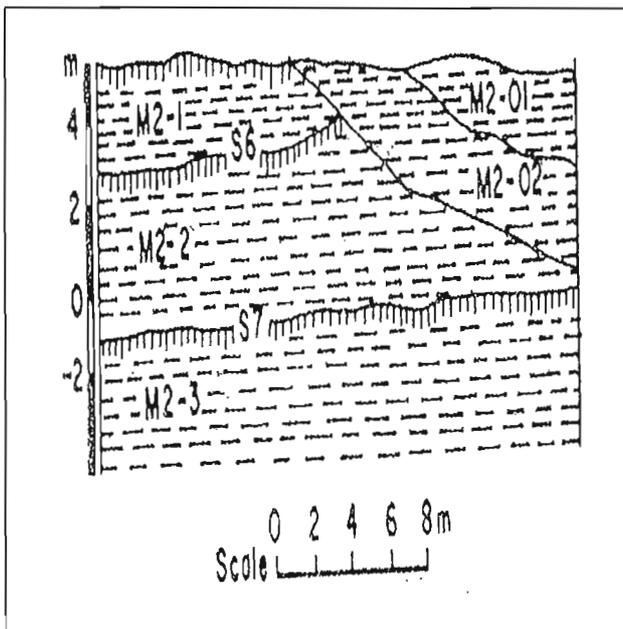


Fig. 3a Stratigraphic cross section of Madhupur Clay and Sand Formation (Monsur and Paepe, 1994). The section is at Mirpur, Dhaka city. M2-3, M2-2, M2-1 represent respectively, Bhaluka Sand, Mirpur Silty-clay and Dhaka Clay Members of the Madhupur Formation. M2-02 and M2-01 are, respectively, the lower and upper Kalsi Beds. S6 and S7 are palaeosols.

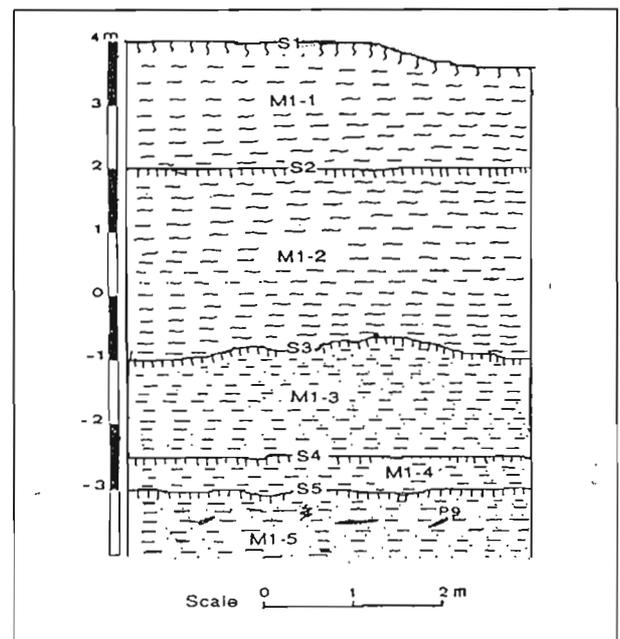


Fig. 3b Stratigraphic cross section Bashabo Silty-clay Formation (Monsur and Paepe, 1992). This cross section of the Bashabo Formation at Kalibari pond, Bashabo, Dhaka city. M1-5 to M1-3 are Gulshan Sand Members. M1-2 & M1-1 are Matuail Clay Members. S1 to S5 are palaeosols.

The Madhupur Clay and Sand Formation has been further subdivided into three Members (lower subunits) and two Beds (upper subunits) based on the presence of two palaeosol horizons: S6 and S7 (Fig. 3a). The Members are called Bhaluka Sand Member (lower Member, M2-3), Mirpur Silty-clay Member (middle Member, M2-2) and Dhaka Clay Member (upper Member, M2-1). The lower (M2-02) and upper (M2-01) Beds of this Formation are called Kalsi Beds. Similarly, the Bashabo Formation has been subdivided into two Members: Gulshan Sand Member (lower subunit, M1-5, M1-4 and M1-3) and Matuail Clay Member (upper subunit, M1-2, M1-1) (Fig 3b). The presence of buried horizons represent the Boundary of Stratotype.

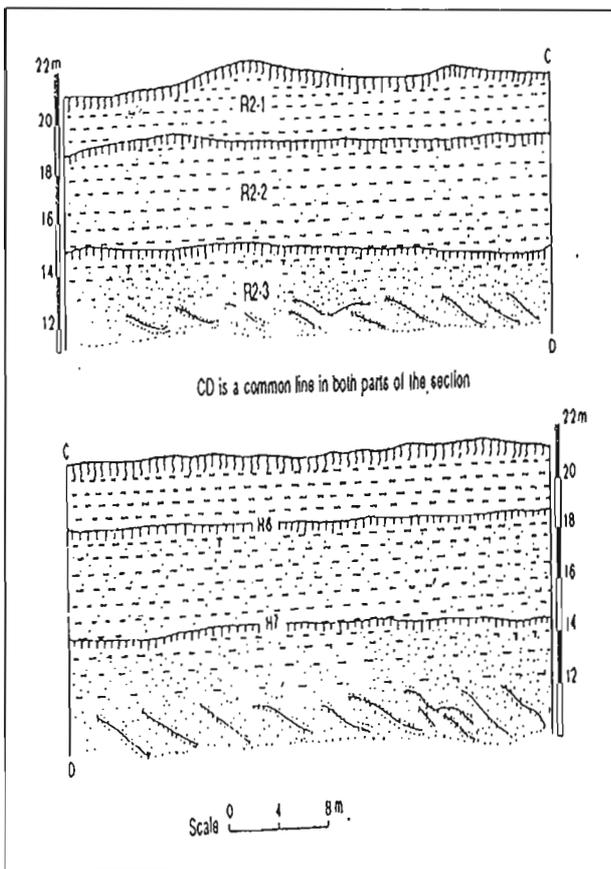


Fig. 4a Stratigraphic cross section of Barind Clay and Sand Formation (Monsur and Paepe, 1992). R2-3: Gujorghat Sand Member; R2-2: Nachole Silty-clay Member and R2-1: Sherpur Clay Member. H6 and H7 are palaeosol horizons.

Barind tract

Previously, the reddish brown deposit exposed in the Barind area was called Madhupur Clay (Morgan & McIntire, 1959; Alam & Khan, 1980). Monsur and Paepe (1994) first identified that the Barind and Madhupur area are quite apart from each other and there is no lithologic continuity. And the author subdivided the deposit exposed in Barind area into two Formations: 1) Barind Clay and Sand Formation represented by deep reddish brown highly oxidized and weathered clay, silty-clay and sand with ferruginous concretions, calcareous nodules, plant roots, pipe stems and manganese spots (Fig. 4a). and 2) Rohonpur Silty-clay Formation, represented by yellowish grey, silty-clay to clay with organic matter and plant roots (Fig. 4b).

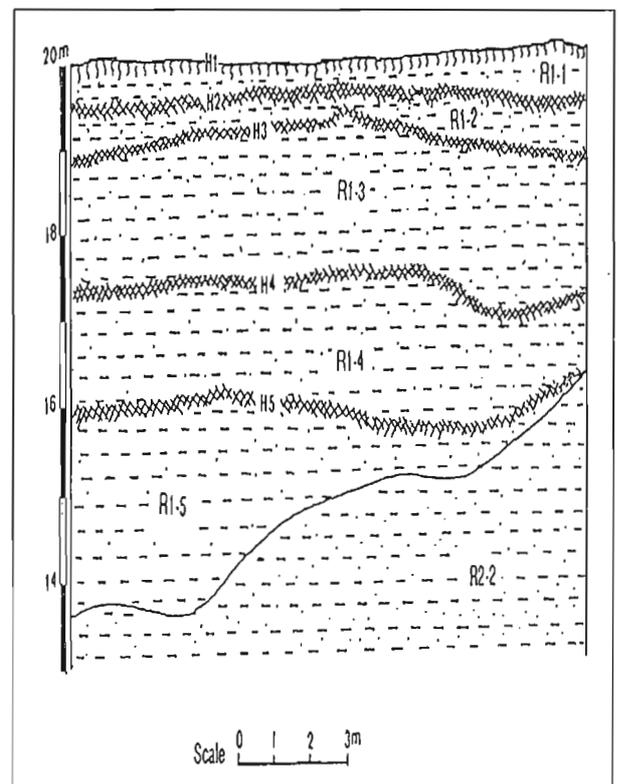


Fig. 4b Stratigraphic cross section of the Rohonpur Silty-clay Formation (Monsur and Paepe, 1992). R1-R5 are the subunits. H2 to H5 represent buried soils.

The Barind Clay and Sand Formation has further been subdivided into three Members (lower subunits) and one Bed (upper subunit) based on the presence of two palaeosol horizons. The Members are called Gujorghat Sand Member (lower Member), Nachole Silty-clay Member (middle Member) and Sherpur Clay Member (upper Member). The upper Bed of this Formation is called Gouripur Sand-silt-clay Bed. Similarly, the Rohonpur Silty-clay Formation has also been subdivided into five subunits (R1-5 to R1-1) based on the presence of buried soil horizons represents the Boundary Stratotype.

Lalmai hills

The deep reddish brown to yellowish brown color with reduction spots combine to form typical textures, which are the striking characteristics of the Lalmai hill tops. The Madhupur Clay and Sand Formation were being extended to the Lalmai hill area and for this area Madhupur Clay and Sand Formation

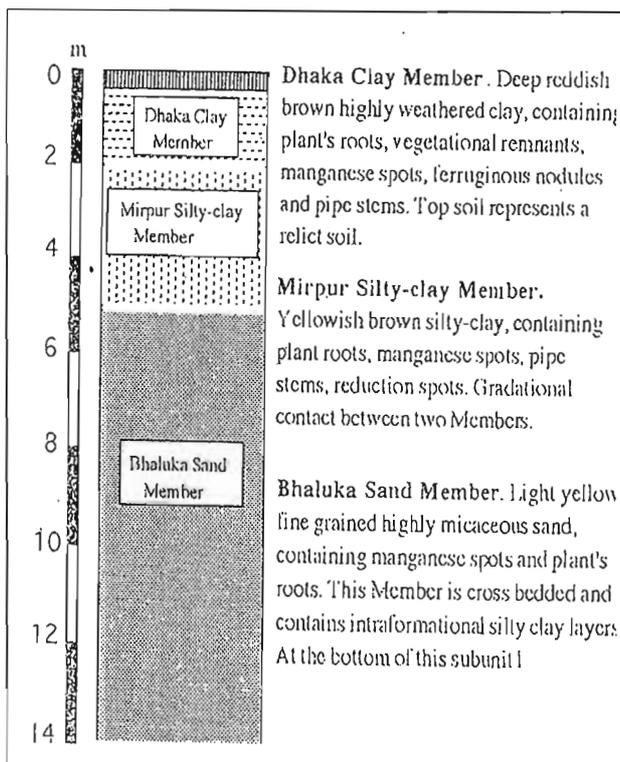


Fig. 5 Stratigraphic cross section of the Lalmai hills area (Monsur, 1995).

can be subdivided into three subunits. The upper clay unit is quite identical to the upper Member of the Madhupur Clay and Sand Formation which is called Dhaka Clay Member (Monsur, 1995). The clayey sand subunit is equivalent or similar to the middle Member of the Madhupur Clay and Sand Formation. In the case of Lalmai hill area, palaeosol has not been recognized (Monsur, 1995). The lower sand subunit is called Bhaluka Sand Member which is cross bedded. This Member overlies the Dupi Tila Formation of Pliocene Series. The boundary between the Madhupur and Dupi Tila Formation represented by the first quartz-chalcedony gravel layer at the base of this Member which is called Comilla Quartz-chalcedony Gravel Bed (Monsur, 1995).

IV. Origin and evolution of the Pleistocene tracts

It was strongly believed that Madhupur and Barind tracts evolved as uplifted tectonic landforms of the Pleistocene period. Structural implications of the area were recognized by a number of authors such as, Fergusson (1863), Hirst (1916), Morgan & McIntire (1959), Khondoker (1987, 1989), Huq et al. (1991), Rizvi (1975), Coates et al. (1988, 1990), Alam (1988 & 1995) and Kamal (1998 & 2005).

According to Morgan and McIntire (1959), the Lalmai hill area is an uplifted block of highly oxidized, red Pleistocene sediments. The area is bounded on both east and west by faults. They considered this area as a horst. Hassan (1986), Monsur (1995) and Islam et al. (2001) ascertained that the Lalmai hills are the result of tectonic uplift. Islam et al. (2001) indicated ample of neotectonic evidences of Lalmai hills and he believed that the sifting of the Gumti river valley might have been related to the block uplift in the south and tilting of the Lalmai hills. He mentioned about the occurrence of the devastating earthquake in 1762 which might be

the source of the last major tectonic activities.

Regarding the Madhupur tract, Fergusson (1863) believed that this region has been uplifted in very recent times and he referred to the earthquake of 1762 which was accompanied by elevation and subsidence of large tracts of land. Fergusson (1863) suggested that the

Madhupur jangal (forest region) occurs along the 'axis of the belt of Volcano action' which extends in a north-western direction through Chittagong and Dhaka from the Sunda Island arc. He also believed that the cause of Brahmaputra River diversion was responsible for the uplifting of the Madhupur Tract (Fig.6).

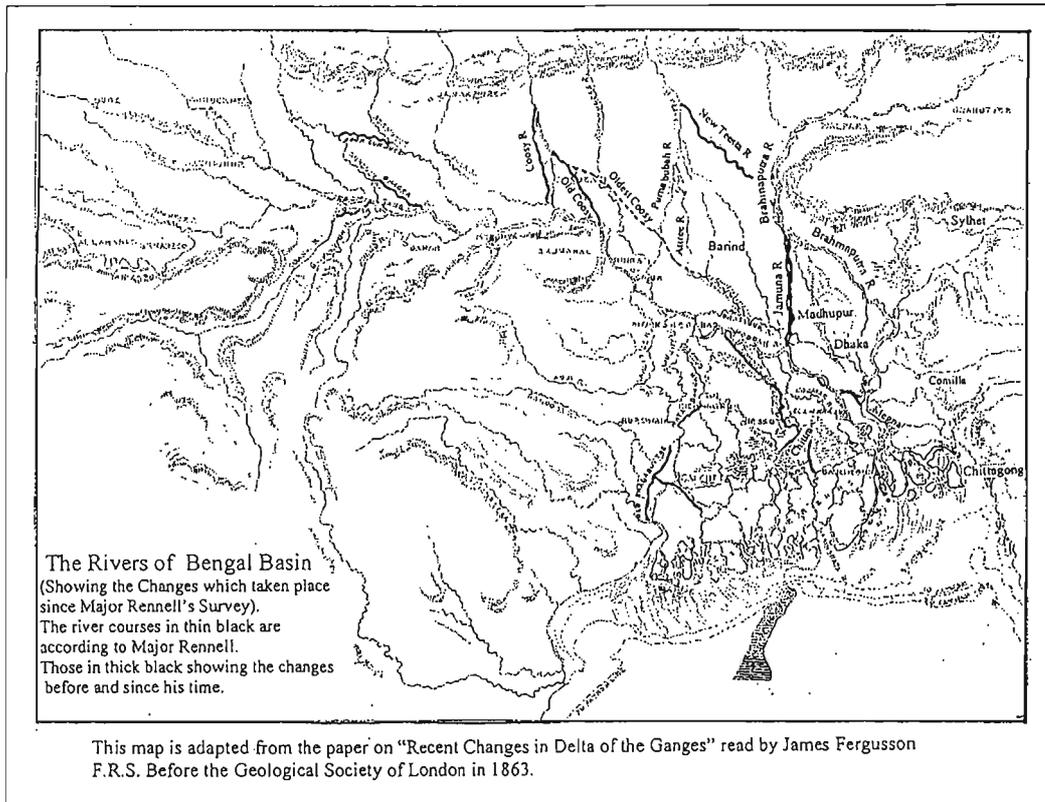


Fig.6 The rivers of Bengal Basin since Major Rennell's survey (1764-1777) (Mojumdar, 1942)

Hirst (1916) agreed and advanced the concept of a zone of sinking and compensatory uplift of the Barind and Madhupur. LaTouch (1910) believed that the Brahmaputra diversion resulted directly from a major increase in water volume of the river. He stated that the old Brahmaputra flowed east of the Madhupur Jungle, which was a "relic of the delta face of the Ganges". In other words, he considered that the entire Bengal basin (excluding the Sylhet basin) as the sole regime of the Ganges prior to the sudden increase in Brahmaputra

water volume. He suggested that the diversion of the additional water volume of the Tista river from the Ganges to the Brahmaputra in 1787 was the final action that triggered the diversion of the Brahmaputra river down the old Jenai channel west (100km) of the Madhupur jangal. In this connection, Morgan and McIntire (1959) opined that the diversion of the Brahmaputra, probably, was gradual and was caused in part by gradual tilting of the Madhupur block. According to Morgan & McIntire (1959), the Barind and

Madhupur tracts were uplifted through a 'zone of weakness', which was caused by either a subsiding trough or a major fault at depth. They noted a series of en-echelon faults (six in number) along the west face of the Madhupur and the Korotoa River fault flanking the northeast edge of the Barind tract (40 miles long). They believed that surface en-echelon faulting of the Madhupur jungal resulted either from torsion of the region or from the effect of shear along a postulated buried fault, or possibly a combination of both (see Fig.1).

Rizvi (1975) mentioned that the severe earthquake of 1775 in this area might be responsible for reactivation of the 'zone of weakness' in the Barind – Madhupur Tract forming a subsiding graben, which represents the present-day Jamuna floodplain.

Khandoker (1987) postulated that the Barind and Madhupur Tracts were uplifted as a horst block along the pre-existing line of crustal weakness with compensatory subsidence of the bordering areas, which was thought to be a part of isostatic adjustments that occurred in the plain of northern India after retreat of the glaciers into the higher Himalayan region at the end of the Pleistocene. He also added that Banar is a structurally controlled valley, which is the continuation of Korotoya fault, and he named the system as a whole Korotoya-Banar fault.

Monsur (1994, 1995) mentioned that the locality of Madhupur resulted due to the block uplift during the middle Pleistocene time. But the rest of the area of Madhupur and Barind tracts represent an erosional feature. Monsur (1994) stated that in stratigraphic sections of the central part of the Madhupur and Barind all the three members can be seen but in the marginal areas, the middle or lower Member is overlain by the Holocene deposits. It happened as the upper or middle Member of these Formations is eroded away and on the erosional surface, the Holocene series had been deposited. Monsur

and Paepe (1994) dated the lithostratigraphic subunits M1-1, M1-3, M1-4 and M1-5 of the Bashabo Formation and according to them these are equivalent to the subunits R1-1, R1-2, R1-3, R1-4 and R1-5 of the Rohonpur Formation of the Barind area. The obtained radiocarbon dates provided to correlate these subunits with the five substages of the Holocene series. They believed that climatic fluctuation during Holocene epoch placed the changes in the Monsoon regime and resulted the deposition of different subunits of the aforesaid Formations. In this connection, they added that during the Late Pleistocene time, amplified monsoonic rainfall and deglaciated melt water enormously flowed over the Bengal plain. As a result the both surfaces were eroded away leaving these reddish brown islands, created some pools and depressions. The Holocene sea-level (about 5,500 yrs BP) rise changed the hydrodynamic condition of the palaeoriver system and these dissected surfaces were filled up with the alluvial sediments.

V. Radiocarbon dating of the Pleistocene tracts

Monsur and Paepe (1994) collected several samples to obtain date of Madhupur Clay and Sand Formation. The obtained radiocarbon dates for the subunits M1-2 to M1-5 respectively are 4040 ± 70 , 5730 ± 60 , 8940 ± 105 and 12780 ± 140 year BP (Fig.7). Through these dating they established the erosional-depositional history of the Madhupur and Barind area. They believed that the Holocene sequence overlying on the erosional surface of the Madhupur Clay and Sand Formation and the wood fragment obtained from the lower part of the Formation showed the age 12780 ± 140 which represents the deposits of the Early Holocene erosional activities. The wood fragments found in the upper layers (from the base upwards) gave the following dates: 8940 ± 105 YBP, 5730 ± 60 YBP, 4910 ± 75 YBP, 4830 ± 75 YBP. Kamal et.al (2005) collected a wood fragment which was obtained from the base of the palaeosol layer at a depth

of 36 m, across a major en-echelon fault scarp of western part of the Madhupur tract. Radiocarbon dating ($3,050 \pm 200$ BP) implied that the neotectonic activities in the region mainly occurred during the late Holocene.

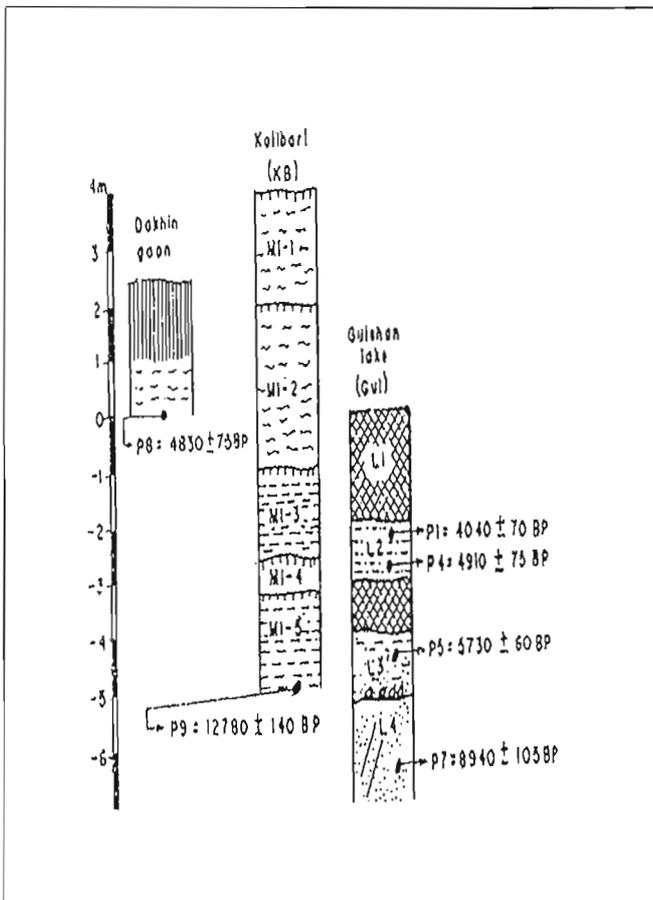


Fig. 7 Radiocarbon dating (Monsur & Paepe, 1994)

VI. Mineralogical studies of the Pleistocene tracts

Heavy mineral studies of Madhupur and Barind Clay and Sand Formations were carried out by Hassan (1986), Monsur and Paepe (1990). The study found abundance of garnet and hornblende in Bashabo Formation (Holocene series), and biotitic mica and opaque minerals in upper Members of both Madhupur and Barind Clay and Sand Formations (Pleistocene series). These minerals revealed that the sediments were

derived from gneissic and schistose rock sources which were naturally derived from Himalayas. From the geomorphological configuration, it can be seen that the Bengal Basin has been receiving sediments, washed out from the Assam Himalayas up to the Kumaon Himalayas for a long geological time. The shifting of river system produced an admixture of sediments derived from different parts of the Himalayas (Monsur, 1990).

A detail clay mineralogical study was performed by Hassan (1986). From his study it has been found that the Madhupur and Barind Clay and Sand Formations have two components and the first component includes the halloysite and illite and the second one is a minor component includes mainly the mixed layers of smectite-illite. The Madhupur and Barind Clay and Sand Formations are very much swelling and the presence of smectite and illite-smectite mixed layers are responsible for swelling. It is to be mentioned here that the weathering of ferromagnesian and silicate minerals resulted in the development of clay inter-grown which ultimately formed the clay minerals.

VII. Sedimentological studies of the Pleistocene tracts

Detail sedimentological research of the Madhupur and Barind Clay and Sand Formations were carried out by Hassan (1986) and Monsur (1990, 1995). From the grain-size distribution it has been found that the grain size increased downward with the decrease of the clay size material and occupy the sand fractions, only the upper part is dominated by clay materials (Monsur, 1995). Sedimentological studies indicated that the Madhupur and Barind formations are fluvial deposits. According to the authors, the cross bedding and ripple marks are quite prominent in the lower Members of these Formations. Moreover, these deposits contain wood fragments and plants roots which are quite

indicative for a fluvial environment. It is more likely that the Madhupur and Barind Formations represent cumulative palaeosols formed progressively with the increment of a few millimeter or a centimeter of sediment per year by numerous floods in depositional basin (Monsur et al. (1992). The lower Members of these formations represent channel pattern and the middle and upper Members probably represent flood plain deposits. Morgan and McIntire (1959) also considered the Madhupur Clay as fluvial deposits.

VIII. Microstructural studies of the Pleistocene tracts

Microstructural studies of the Madhupur and Barind Clay and Sand Formations of the Bengal Basin were performed by Hossain (1986) and Monsur (1992) showed similar pedological characteristics, such as color, rootlets and root traces, peds, voids, coatings, infillings ect. All the Formations have the similar pedofeatures. Among them depletion, textural, cryptocrystalline and amorphous pedofeatures are important. All the pedological characteristics indicated that the deposits had undergone strong pedogenic processes. The pedofeatures indicate that the palaeoclimate was wet-humid. Absence of large trees and the presence of grass type vegetation, and also the formation of the cumulative palaeosols indicate that the depositional basin was a floodplain. The reddish brown color of the Madhupur and Barind Formations is clearly related to the iron compounds. Monsur (1990) said that the most distinctive aspects of some palaeosol are color mottling reflecting localized changes in oxidation and reduction. This color mottling is a common feature of the Barind and Madhupur Formations

IX. Paleomagnetic studies of the Pleistocene tracts

Monsur (1990, 1995) did the paleomagnetic study of Madhupur, Barind, Lalmai hills and Chalanbil areas. His study indicates that the Rohonpur (unit-R1) of

Barind area and Bashabo Silty-clay Formation of Madhupur area have normal polarity. The Bashabo Silty-clay Formation has five subunits which were dated by C-14 dating method. From the radiocarbon dating, it was found that the maximum possible age of the lower part of the Bashabo Silty-clay Formation is about 12780 yrs BP. The Bashabo and Rohonpur Formations were correlated and they belong to the Brunhes Magnetozone (Holocene Series). The upper Kalsi Bed (M2-01) has normal polarity., probably, belongs to the Brunhes Magnetozone (Middle Pleistocene). The lower Kalsi Bed (M2-02) and the Gouripur Bed of the Barind Formation have the reversed polarity (Fig. 8).

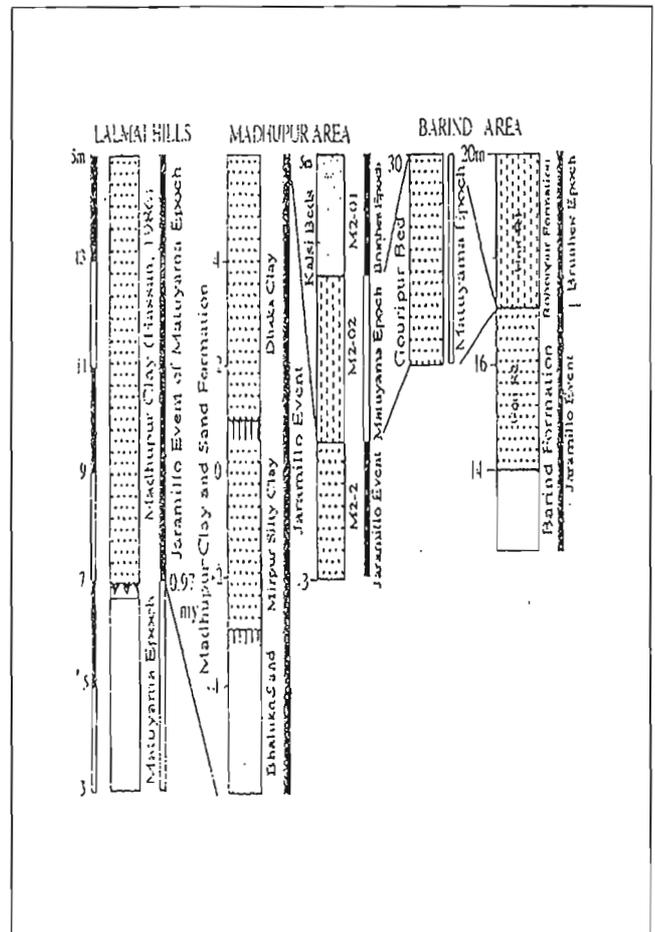


Fig. 8 Palaeomagnetic results of the Quaternary deposits in the Madhupur, Barind and Lalmai hills area (Monsur, 1995).

These two Beds belong to the Matuyama Magnetozone (within the time limit of 0.90 to 0.73 my BP). The boundary between the upper and lower Kalsi Beds represent the Brunhes-Matuyama boundary (0.73 my BP). Gouripur Bed and the lower Kalsi Bed can be correlated with the lower Pleistocene series.

All the Members of the Barind and Madhupur Clay and Sand Formation have normal polarity which probably belong to the Jaramillo event (0.90-0.97 my BP). He found that the sediments below the Quartz-chelcedony gravel Bed seems to be the age of 0.97 my BP. From the palaeomagnetic investigation, the author stated that the beds which gave reversed polarity were isolated and occurred as fluvial terraces. And he assumed that the red beds in the Bengal basin are, probably, a combination of several fluvial terraces which are yet to be recognized. These isolated terraces were formed during the geological time, probably, with a long time gap. Monsur (1990, 1995) also mentioned about the existence of Kalsi Beds in the Mirpur brickyard indicates the erosional processes by fluvial current which was also active even in the lower Pleistocene time.

X. Conclusion

After reviewed of the different literatures related to the Pleistocene tracts, it is clear that there are two different trends of thoughts. To resolve the problems associated to the origin and evolution of the tracts, borehole data across the old Brahmaputra river Basin and the new Brahmaputra river basin (Jamuna Valley) can be collected to explore the history of the river shifting and their impacts on the formation as well as of deformation these tracts. And the impact of climatic changes, sea level changes, neotectonic activities on the river shifting from the last glaciation to the Holocene maximum (interglacial) can be examined. Different terraces may be recognized by using aerial photographs

and satellite images. Fusion images may be prepared to detect neotectonic imprints and geomorphological signatures of the areas. Elaborate laboratory analysis of sediments including radiocarbon dating shall indicate a new dimension about their origin and evolution.

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