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International Journal of Paleobiology & Paleontology
ISSN: 2642-1283

Mid Holocene Sea-Level Changes in and around Dhaka City, Bangladesh

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Research Article

Volume 3 Issue 1

Received Date: October 29, 2020

Published Date: November 26, 2020

Abstract

Bengal basin, the largest fluvio-deltaic sedimentary system on Earth, is located in Bangladesh and three eastern states of India. Sediment accumulates in the basin from the Ganges, Brahmaputra, and Meghna (GBM) river systems and is dispersed into the Bay of Bengal, forming the largest submarine fan in the world. The present-day geomorphology is dominated by the extensive Holocene GBM floodplain and delta. The initiation of the modern GBM delta at the onset of the Pleistocene glacial maximum and its evolution to the present configuration are intricately related to Holocene fluvio-dynamic processes, eustatic sea-level changes, and tectonic movements. Quaternary System in Bengal basin has varieties of depositional environment. Sediment characteristics of different geomorphic units are different. Late Quaternary monsoon climatic episodes played the vital role in creating the present morphology of the Madhupur surfaces. During the Holocene, the central part of the basin experienced cyclic transgression and regression phase in several times. This was the evidence by mangrove pollens. The presence of mangrove pollen specially *Phoenix paludosa, Avicennia* sp, *Phoenix sylvestris*, *Prosopis grandis, Sonneratiopollis* sp found in *Chatbari*, *Dubadia* and Mirertek area of Dhaka city along with radiocarbon dating indicated that marine influence occurred during Mid Holocene time. Two phases of transgression and regression have been recorded during mid Holocene time. First transgression was noticed around 6500 cal BP and then a subsequent regression of the bay had been observed around 5500-3500 cal BP. This was again followed by another transgression episode around 3500-1500 cal BP. and then a regression during between 1500 cal BP onwards.

Keywords: Sea-Level; Dhaka; Paleocoasts

Introduction

Environmental changes associated with Quaternary sea-level fluctuations have had a profound impact on the distribution of mangrove habitat at both local and regional scales. During the Holocene, regionally synchronous phases of changes have been attributed to fluctuations in the availability of suitable substrates, controlled by the interplay between deposition and sea-level behavior [1,2]. The Bengal Lowland is greatly threatened by sea level rise as its land subsidence rate is 2.5 cm per year, among the highest in the world [3]. Bangladesh lies less than 5 m above sea level and thus flooding is a common occurrence.

Paleocoasts are relatively easy to identify using fossils evidences because not only may contain a brackish water flora but they also coincide with vertical and/or lateral changes from strata with dominantly marine flora to strata with fresh water or no fauna. Hence landward migrations of the shoreline (transgressions) and seaward migrations of the shoreline (regressions) are comparatively easy to pin-point in both space and time as the rise of relative sea-level decreases the influence of terrestrial processes and increases the influence of marine processes [4]. As a result of transgression along with the rise of relative sea-level, fresh-water vegetation would be replaced by brackish-water mangrove species [4]. Mangrove pollen is thus a very useful indicator of relative movements of sea-level in tropical environments [5,6], as well as the principal technique for reconstructing the Quaternary environment [7]. The mangrove ecosystem is considered as highly susceptible to sea level changes [8], and the sediments deposited beneath mangrove vegetation can provide useful indications of former sea levels [9,10].

Sediments deposited beneath mangrove or salt marsh vegetation provide useful indications of present and past sea levels. Where depths of such sediments exceed the tidal range, or where they exceed the range of elevation within which these halophytes may presently be found, this indicates that the area has undergone relative submergence as a result of changes in the level of the land or of the sea, or movements of both.

Palynology is another powerful and useful tool to reconstruct the Quaternary environment [7]. Litho-bio-chrono-stratigraphic techniques to reconstruct the Holocene sea-level changes are well established and have been applied successfully in many coastal areas of the world including in Bangladesh [4,11-13].

The Indian Summer Monsoon (ISM) during early to middle Holocene was generally stronger than today, with peaks identified at 8.5, 6.4, and 2.7 k.y. B.P. detected in numerous ISM records [14-17], but weaker than today between 5000-1200 yrs BP [18]. The shoreline of Bay of Bengal has been observed not to be static in relation to previous geological events during the mid-Holocene and the sea level of the bay was slightly higher, the climate was warmer, and rivers of this region discharged up to two and half times more than in present times. It has generally been accepted that around 6000 yrs BP, eustatic sea-level was higher than the present sea level [4,19-22]. During the peak of the last glaciations (18 kyr BP) the Bengal Lowland experienced dry climatic conditions and sea-level was 100 meters or more lower than the present sea level [19]. At about 12 kyr BP, south-west monsoon became prominent, and caused heavy rainfall and very rapid sea-level rising [23]. This amplified monsoon water plus deglaciated melt water from the Himalayas flowed over the Bengal Lowland and the initial Madhupur and Barind surfaces were highly dissected, creating some local pools and depressions [23]. It seems that the coastal processes and climate had a significant control on topography of this region during Late Pleistocene time.

As a coastal region, it was thought that there should be some evidences of Mid-Holocene marine transgression in and around Dhaka city. A limited number of detailed studies have been made in the last few decades to reconstruct the Holocene sea-level change of the Bengal Lowland, including those of [4,19,20,24-26]. These past attempts to reconstruct the Holocene sea-level history have been based on borehole samples. The past studies did not determine the paleo-MSL and timing, magnitude of mid-Holocene high stand, either. The RSL curves constructed by the authors did not show any specific regression phase during Holocene and showed continuously rising RSL through the Holocene. The present study also attempts to show the mid Holocene marine to brackish water invasion in and around Dhaka city on the basis of lithofacies and biofacies (including pollen analysis).

Geology of the Study Area

Physiographically, Dhaka city is situated in the southern half of the Madhupur Tract and Floodplain area with southern river system. Regional elevation of the area gradually declines towards Buriganga River on the south and the elevation ranges from 10m to 17m but is generally around 14m above mean sea level. The surface geology of the study area follows the geomorphic expression of the area. At the land surface, Pleistocene alluvium occupies the dissected uplands, and alluvium of recent river-borne deposits covers the low lying flood plains (Figure 1). The area is well linked with the surrounding big rivers by the interconnecting streams, streamlets, retention lakes ponds and canals. Among the major rivers Turag comes from the north and joins the Buriganga River near Mirpur, Balu comes from north-east and joins Sitalakhya River near Demra, and Tongi Khal takes water from Turag River and discharges it into Balu River. The rivers commonly show Dendritic Pattern and only the western part of river system shows Trellis Pattern. Geologically Dhaka city belongs to Bengal Foredeep and is situated in the Pleistocene uplifted block (Madhupur Tract) within the passive margin surrounded by subsiding floodplains bounded on the west by a series of NW-SE trending en-echelon faults including the Dhamrai, Maijail and Kaliakoir ones. Land surface is covered by gray floodplain and non-Cretaceous floodplain soils. Late Pleistocene climatic episodes produced a number of north-south elongated terrace systems in the Bengal plain. Dhaka Terrace is one of the north-south elongated terrace in the southern extremity of the Madhupur tract where megacity Dhaka is situated [27]. Stratigraphically, Old Dhaka is characterized by hundreds of meters thick unconsolidated sequence of fluvio-deltaic deposits many composed of gravels, sands, silts and clays of Plio-Pleistocene age.

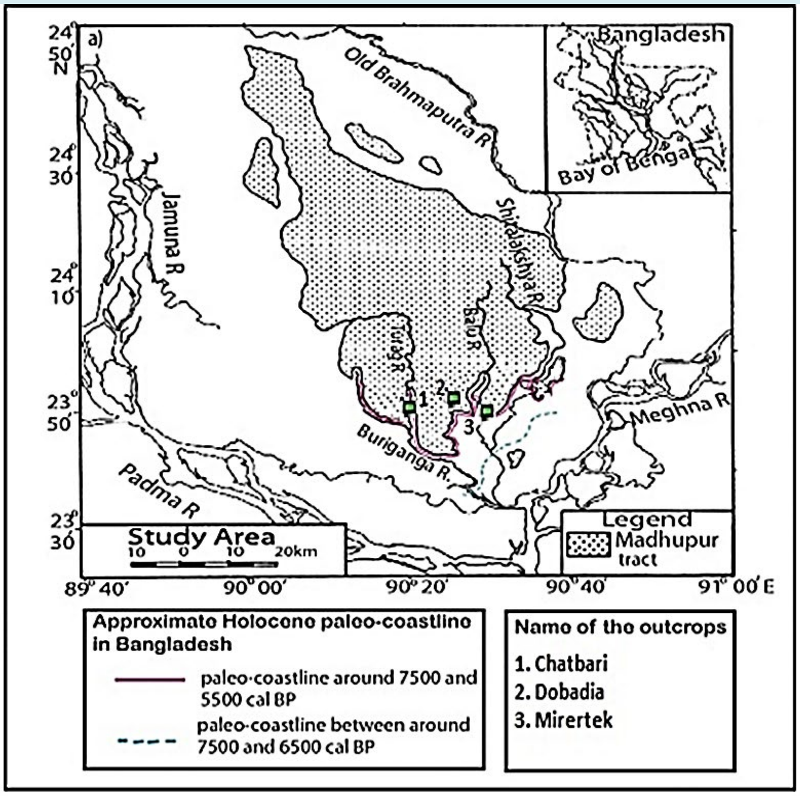

Figure 1: Location map and approximate paleo-coast line during Holocene of the study area.

The study area is divided into two major lithostratigraphic units in the following ascending order: the Madhupur Clay Formation [28] of Pleistocene age and the Bashabo Silty-clay Formation of Holocene (Recent) age [28].The present study area Dhaka is located in the central part of Bangladesh, a large upland area called the Madhupur tract. The study area was named Chatbari (23˚50'42" N, 90˚20'33" E on north side of Mirpur along Dhaka Asulia road. The climate of Bangladesh is influenced by summer and winter winds and partly by pre-monsoon and post-monsoon circulation (ISM). The mean annual rainfall varies widely by geographical location in the country, ranging from 1,200 mm in the extreme west to 5.800 mm in the east and north-east. Bangladesh in general possesses luxuriant vegetation, with villages appearing to be buried in groves of mango, jackfruit, bamboo, betel nut, coconut, and date palm. However, only a small portion of the country's land surface is covered with forests.

The outcrops are named Chatbari, Dobadia and Mirartek and belong respectively to Dhaka and Narayangonj cities.

The Quaternary deposits exposed in Dhaka city (include surface exposures and borehole drilling at shallow depth upto 100 feet) have been organized and subdivided into three Formations, namely, Basabo Formation (Holocene age), Madhupur Formation (Pleistocene age) and Dupitila Formation (Pleistocene age?).

Chatbari (23˚50'42" N, 90˚20'33" E)) is located on north side of Mirpur along Dhaka Asulia road were observed in south-western fringes of the Madhupur tract, and are situated on the left bank of the Turag river. On the basis of lithological character nine facies have been examined minutely to describe the paleoenvironment of the area. These are stated from bottom to top (Figure 1).

Unit-1: Alternation of bluish grey silty mud and fine sand. Thickness 20cm.

Unit-2: Grey colored silty mud containing rootlet. Fine sand lamination is observed. Thickness 27 cm.

Unit-3: Bluish grey to dark grey /black organic silty mud containing abundant rootles. This unit is not uniform, it contains few sand lamination. This sand lamination is an indication of tidal environment or a tide influence environment.

Unit-4: It shows alternation of grey-colored silty mud and black grey to brown-colored organic mud bed (30 cm). Very fine sands are observed. Dark brown organic leaf fragments are common in middle to upper part. Upper boundary is gradational and lower one is clear. A thin bed of dark brown organic mud is seen in the upper part of this unit.

Unit-5: Light grey to light brown color massive mudstone having fine sand and silt. This unit is oxidized occasionally dark grey color. This is due to presence of organic matter in mud. Thickness of this unit is 45 cm. Unit five is overlain by black massive peat layer and underlain gradationally by bluish grey mud.

Unit-6: Dark grey to black massive fragmental peat. This unit is overlain by black/organic mud and underlain by massive silty/ fine sandy mud.

Unit-7: Black clay/mud containing organic matter.

Unit-8: Grey clay containing fine sand or silt having rootlet.

Dobadia is located on 23°51'45" N, 90°26'42" E. This outcrop belongs to Dhakhin Khan area of Uttara Thana. Turag River is on the northern side and Banor River is situated few kilometer east of the Dobadia section. Dobadia area is divided into three stratigraphic unit such as unit-1 (Mud facies), unit-2 (Peat) and unit-3 (Sandy mud) (Figure 1). Individual description are stated below:

Unit-1: Mud Facies: The unit consists of blue-grey colored mud. It contains huge quantity of leaf fragments in the lower part and fine sand laminations (1-2mm) near the upper clear boundary. The upper boundary has some dark-brown organic clay. The lower part contains mud fragments and mud balls of iron concretion, as well as some large to small woods which are filled with burrows. It has some rootlets coated by lignite. Few stem pipe burrows filled by yellowish mud is observed at the border of the Madhupur red clay basement. The border between Madhupur basement and this mud unit is very clear. In the southern wall cream and reddish fragments of Madhupur clay, mud with clay fragments and balls of iron concretion, plant fragments are observed.

Unit-2: Peat Layer: Black massive peat contains small rootlets, sometimes very dense. The upper part is muddy but the lower portion has huge quantity of loose, undecomposed organic materials. Its upper boundary is gradational.

Unit-3: Sandy Mud: It consists of grey sandy-mud and containing rootlets. On top of this unit agricultural soil is present. The thickness of this unit is 80cm (8m).

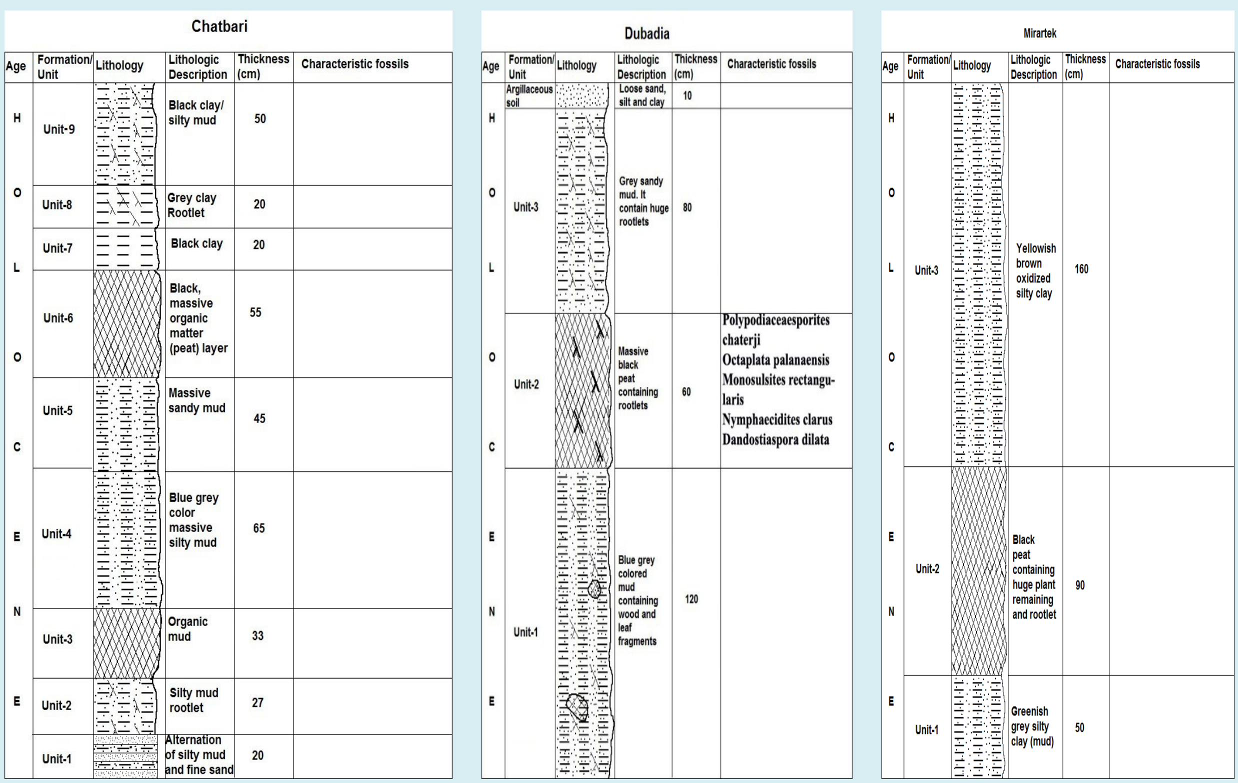

Figure 2: Columnar section of the Chatbari, Dobadia and Mirertek areas of the study area.

Mirertek area belongs to Sonargaon Upazila of Narayangonj district. It is located 10 kilometer east from Dhaka Chittagong highway and 12 kilometer south west of Dhaka-Sylhet highway. Brahmaputra River is the main drainage of the area. The study side is just few km northwest of river Meghna. Sediments are mainly Holocene sediments. Artifacts are found in unit topmost unit. Sediments are fine grained sand, silt and clay. Peat layer found in Mirartek section is blocky fragmental. Three sedimentary litho-unit are observed in this section.

These are stated below.

Unit-1: Silty Mud: The lower most unit is sandy to silty mud unit. This is a light bluish-grey to dark Greenish-grey, massive blocky silty mud and fine sand layer. Very thin layers of cream-colored fine-grained sand (2-5mm) and light green-grey silt are also present. Thickness of this litho-unit is variable. Its thickness ranges from 30-60cm. A sharp contact is observed with the overlying peat deposits. Parallel lamination is observed in mud layer near the base. Rootlets and burrows are present.

Unit-2: Peat Layer: The dark grey to black massive fragmental peat containing plant rootlet, wood fragment, vegetal remaining, leaf. Organic rich mud also present within the peat layer. Peat layer is over lain by yellowish brown oxidized silty clay layer (unit-3) and underlain by greenish grey silty mud (unit-1). Thickness of the peat layer ranges from 0.6m to 1.1m.

Unit-3: Silty Clay Layer: The top most layer is yellowish brown silty clay layer. This unit is highly oxidized and unconsolidated. Yellowish brown color is due to oxidization. Numerous plant rootlet borrows have been also observed in this unit. Artifacts are found in the top most unit. Thickness ranges from 1.5 to 1.7 m (Figure 1).

Materials and Methods

Facies identifications and interpretation have been based on detailed examination of composition, sedimentary structure, bedding characteristics, sediment grain-size, and colour [29,30]. Interpretation was also based on an examination of vertical facies associations [31]. Two sections were cleaned off in the northern and southern walls to examine the lithofacies and biofacies.

For pollen analysis, the samples were collected in a way to represent the major lithologic variations. To extract the palynofossils, 10gm samples were treated with 5% Hydrochloric acid (HCl) and kept 1 hour to dissolve calcareous materials. Thereafter, added Conc. Nitric acid (HNO_3) and kept the residue for 2 days to dissolve organic matter and carbonates, if any. Then it was sieved to separate the large particles. Finally, added Sodium hydroxide (NaOH) to clean the dark coating from the pollen body [32]. Double-mount slides were made after maceration and ready for microscopic studies. The remainder of the original samples and treated and single-mount specimens are preserved in the laboratory of Department of Geology, University of Dhaka. The pollen assemblages were done by the Dept. of Geology, University of Dhaka, Bangladesh. To determine the chronology for the sea-level changes radiocarbon dating were performed of four samples: three samples were peat and the other was wood sample. The samples were measured by Beta Analytic Radiocarbon Dating Laboratory, Miami, Florida. With the help of the nearest reference datum, Mean Sea Level (MSL) of the outcrop was calculated by "differential leveling" method.

Result and Discussion

Pollen Record, Age and Biozonation of Chatbari Section

The Pollen sample was collected as C-1 (+ 2.85 - +3.2), C-2 (+2 - + 2.3m), C-3 (+ .8 - +1.2m) represent the depositional sequences of the section. Twenty five slide of sample were studied and 90 pollen were identified of different species. Of them *Palmidites plicatus, Palmidites maximus, Lygodiumsporites eocaenicus, Spore type-1, Palmidites* sp, *Polypodiisporites* sp, *Monosulsites rectangularis, Monosulsites* sp, *Palmidites assamicus*, *Monosulsites rectangularis*, *Palmidites assamicus, Palmipollenites subtilis, Octaplata palanaensis, Notothyrites padappakarensis, Palmidites maximus, Polypodiisporites haardi*, *Phoenix sylvestris, Callimothalus* sp, *Prosopis grandis, Avicennia* sp, *Palmipollenites* sp, *Phoenix paludosa*, *Octaplata palanaensis* are specially remarkable.

Sampling Point	Representative Pollen	Bio-zone	Vegetal Nature	Age (C^{14})	Paleo-Environment
C-1	*Palmidites plicatus, Palmidites maximus, Octaplata palanaensis, Monosulsites* sp	*Palmidites plicatus*	Palm	1750 ±60	Near Shore
C-2	*Avicennia* sp, *Phoenix sylvestris, Phoenix paludosa.*	*Phoenix paludosa*	Mangrove	3590 ±60	Tidal-Marine (Transgression)
C-3	*Palmipollenites eocaenicus Araucariacites australis*	*Palmipollenites sp*	Palm	5750 ±60	Near shore

Table 1: Showing biozonation and associated paleoenvironment of Chatbari area.

Pollen collected from C-1 (+2.85-+3.2 m) section (*Palmidites plicatus, Palmidites maximus, Octaplata palanaensis*) represents palm type vegetation and shows intertidal zone of paleoenvironment. *Polypodiisporites* sp represents marshy land. Moreover, this zone is represented by abundant algae, fungi and pteridophytic spores which reflected the area was not permanently submerged.

C-2 (Depth +2 - +2.3 m) was dominated by mangrove pollen such as *Avicennia* sp, *Phoenix sylvestris, Phoenix paludosa.* In C-2 *Avicennia* sp *is 25%* and *Phoenix paludosa is 35 %.* It is interpreted that the environment is suitable for mangrove vegetation and a shift of coast line towards landwards during the transgression phase.

Again in C-3 (+1.2m) is characterized by palm pollens such as *Palmipollenites eocaenicus, Araucariacites australis*. This type of pollen plant grows in near to the coastal margin.

Sampling Point	Representative Pollen	Bio-zone	Vegetal nature	Age (C^{14})	Paleo-environment
D-1	*Octaplata palanaensis, Monosulsites rectangularis, Nymphaecidites clarus, Fungal tube, Palmidites assamicus*	*Monosulsites rectangularis*	Palm	1750 ±60	Near Shore
Unconformity					
D-2	*Dandostiaspora dilata*, *Prosopis grandis,* *Couperipolles brevispinous*	*Dandostiaspora dilata*	Rain forest	5750 ±60	Moist
D-3	*Sonneratiopollis* sp, *Prosopis grandis*	*Sonneratiopollis sp*	mangrove	6600±60	Tidal-Marine
D-4	*Cordosphaeridium* sp, *Notothyrites padappakarensis, Bisacate pollen, Pollen sac,*	*Cordosphaeridium sp*	Marine plankton	6600±60	Marine

Table 2: Showing biozonation and associated paleoenvironment of Dobadia area.

Pollen Record, Age and Biozonation of Dobadia Section

Pollen assemblage was studied for Dobadia as D-1 (+4.6 - +5.0), D-2 (+.5 - +5.5), D-3 (+5.5 - +6.0), D-4 (+6.0 - +6.2) and belongs to Unit-2. Dobadia contained both fresh water pollen and brackish mangrove pollen. The identified pollens are *Octaplata palanaensis, Corrugatisporites formosus, Polysphaeridium sutilis, Sonneratiopollis* sp, *Monosulsites rectangularis*, *Prosopis grandis*, *Areoligera* sp, *Fungal tube*, *Palmidites assamicus*, *Dandostiaspora dilata*, *Monoporopollenites* sp, *Areoligera* sp, *Polypodiaceaesporites chaterji, Bruguiera gymnorhizha, Callimothalus* sp, *Melliapollis* sp, *Nymphaecidites clarus*, *Sonneratiopollis* sp.

Sampling Point	Representative Pollen	Bio-zone	Vegetal nature	Age (C^{14})	Paleo-environment
M-1	*Phoenix sylvestris, Corrugatisporites formosus, Phoenix sylvestris, Polysphaeridium sutilis, Monosulsites* sp, *Phoenix paludosa, Bissacate* pollen, *Polysphaeridium sutilis, Sonneratiopollis* sp	*Phoenix paludosa*	Mangrove	3590±60	Tidal environment (Transgression)
M-2	*Corrugatisporites formosus, Octaplata palanaensis Polypodiaceaesporites chaterji Palmidites maximus*	*Corrugatisporites formosus*	Rain forest	5750±60	Moist-Shady
M-3	*Octaplata palanaensis, Corrugatisporites formosus, Octaplata* sp *Monosulcites rectangularis, Palmidites* sp	*Octaplata palanaensis*	Rain forest	5750±60	Moist-Shady

Table 3: Showing biozonation and associated paleoenvironment of Mirertek area.

D-1 is dominated by palm pollen. Remarkable pollens are *Nymphaecidites clarus*, *Octaplata palanaensis, Monosulsites rectangularis, Palmidites assamicus*.
D-2 is dominated by Pteridophyte palm pollen such as *Couperipolles brevispinous, Dandostiaspora dilata* and represents swampy environment.
D-3 is dominated by mangrove pollen such as *Prosopis grandis, Sonneratiopollis* sp. of herbaceous vegetation which is the signature of paleoenvironment of transgressive phase.
D-4 contains both fresh water and marine pollen. *Cordosphaeridium* sp is the dominant species of mangrove. *Notothyrites padappakarensis, Bisacate pollen*, *Pollen sac*, *Corrugatisporites formosus* are habitat of fresh water shady environment species.

Pollen Record, Age and Biozonation of Mirertek Section

The pollen assemblage has performed for Unit 2 as M-1(2.5m), M-2 (-3.0m), M-3 (-3.5m). Most of the representative pollen is fresh water tropical nature. Pollen species that are available in this area are *Palmidites major, Palmidites minor, Palmidites plicatus, Polypodiaceaesporites chaterji*, *Corrugatisporites formosus, Monosulcites rectangularis, Corrugatisporites* sp, *Palmidites* sp, *Palmidites* sp. A few mangrove species was identified and they are *Prosopis grandis, Sonneratiopollis* sp, *Palmidites maximus.*

Conclusion

Qualitative and quantitative analyses of the palynological assemblages recorded from the various formations of the Quaternary sediments of Dhaka and its surroundings comprise 49 species belonging 35 form genera. Out of these, 11 species belonging to 9 genera are pteridophyta, 22 species under 14 genera belong to angiosperms, while 1 genus with 1 species have an affinity with gymnosperms. Algae are represented by 9 species of 7 genera and 6 species of 4 genera belong to fungi.

Environmental changes associated with Quaternary sea level fluctuations have had a profound impact on the distribution of mangrove habitats at both local and regional scale. Mangrove pollen may have the greatest potential for accurately and precisely reconstructing sea level from mangrove environment. Mangroves provide the coastal tropical and sub-tropical tidal areas, and as such have a high degree of salinity. Areas where mangals occur include estuaries and marine shorelines. Pollen study as well as radiocarbon age dating [26] of all the three section shows that the studied section undergone marine influence. The Quaternary succession of in and around Dhaka has been differentiated into a number of biostratigraphic units viz., assemblage zone based on FAD line or LAD line, acme and ranges of various marker palynotaxa in the different formations.

With regards to ancient topography of Bangladesh, particularly the origin and evolution of the Pleistocene tracts (Lalmai, Madhupur and Barind tracts), two trends of thoughts are common. Most of the authors including Fergusson, Hirst, Morgan and McIntire, Rizvi, Alam and Alam [33-38] believed that the Madhupur, Barind and Lalmai tracts represent recent tectonically uplifted surface and refereed to the earthquake of 1762. Some researchers including Monsur [23] opined that the Lalmai hills and the small portion of Madhupur (locality) represent tectonically uplifted blocks but the entire Barind tract and the major portion of the Madhupur tracts are originated by erosional processes rather than structural. 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.

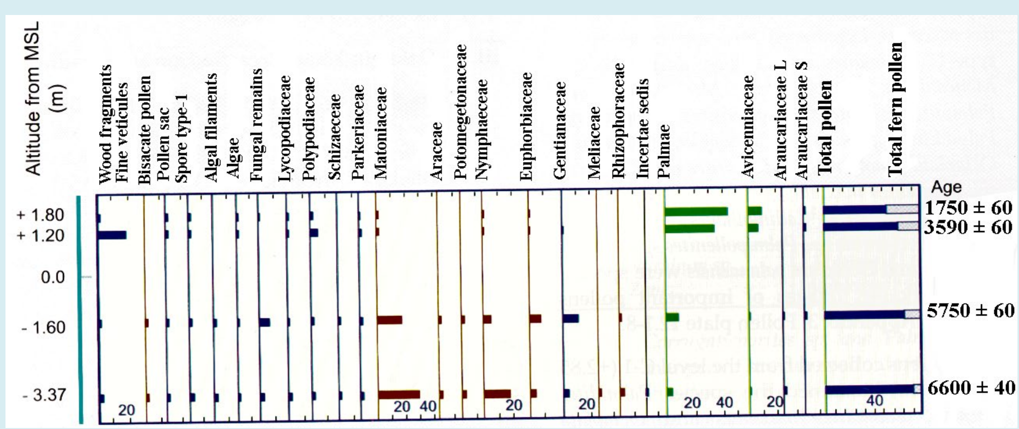

Figure 3: Pollen frequency diagram along with Altitude from MSL and C^{14} dating.

Sedimentological, palynological and radiocarbon data indicate that mangrove community developed under transgressive condition in and around Dhaka city during Mid Holocene time (7000 to 5500 years BP) leading to the locally wide spread deposition of organic-rich sediments. During Holocene time, Global rise and fall of Eustatic Sea Level play an important role not only in the depositional environment but in creating geomorphic feature in the central part of the basin. Recurrent occurrence of freshwater and mangrove pollen in Chatbari, Dobadia and Mirartek area indicate that these area undergone cyclic marine and non-marine influence. In Mirartek area, the presence of rain forest pollen in the lower part of unit 2 (M-1 and M-2) indicate that environment was shady and coast line was further towards north but in the upper part of unit 2 (M-3) mangrove pollens indicating tidal to marine environment and this is due to transgression. In Chatbari area unit-4 (C-3) shows palm type vegetation and indicating near shore environment. Above unit-4 the lower part of unit-6 shows mangrove pollen due to transgression and then the upper part is concealed with near shore palm vegetation. So it is observed that there is a cyclic occurrence of marine and non-marine pollen. Dobadia also shows cyclic pattern of mangrove and fresh water pollen. By pollen analysis and radiocarbon age dating, two transgressive and regressive phases were identified. First transgression was noticed around 6500 cal BP and then a subsequent regression of the bay had been observed around 5500-3500 cal BP. This was again followed by another transgression episode around 3500-1500 cal BP and then a regression during between 1500 cal BP onwards. The palynomorph assemblage from the late Pleistocene sediment sample indicated that Dhaka and its surrounding area was an intertidal environment occupied by mangrove community. These suggest a period of inter stadial marine transgression prior to the subsequent drop in the level during last glacial maxima. The inland vegetation close to the site was tropical swamp and lowland forest.

References

1. Woodroffe CD, Grindrod J (1991) Mangrove biogeography: the role of Quaternary environmental and sea-level change. Journal of Biogeography 18(5): 479-492.
2. Grindrod John, Moss P, van der Kaars Sander (1999) Late Quaternary cycles of mangrove development and decline on the North Australian continental shelf. Journal of Quaternary Science 14(5): 465-470.
3. Maslin M (2004) Global Warming: A Very Short Introduction. Oxford University Press, New York.
4. Islam MS (2001) Sea-level changes in Bangladesh: The last ten thousand years. Asiatic society of Bangladesh.
5. Belperio AP (1979) Negative evidence for a mid-Holocene high sea level along the coastal plain of the Great Barrier Reef Province. Marine Geology 32(1-2): M1-M9.
6. Ellison JC (1989) Pollen analysis of mangrove sediments as a sea level indicator: Assessment from Tongatapu, Tonga. Palaeogeography, Palaeoecology, Palaeoclimatology 74(3-4): 327-341.
7. Birks HJB, Birks HH (1980) Quaternary Palaeoecology. Edward Arnold Ltd, London, UK.
8. Gornitz V (1991) Global Coastal Hazards from Future Sea Level Rise. Palaeogeography Palaeoclimatology Palaeoecology 89(4): 379-398.
9. Scholl DW (1964) Recent sedimentary record in mangrove swamps and rise in sea level over the southwestern coast of Florida: Part 2. Marine Geology 2(4): 343-364.
10. Woodroffe CD (1981) Mangrove swamp stratigraphy and Holocene transgression, Grand Cayman Island, West Indies. Marine Geology 41(3-4): 271-294.
11. Tooley MJ (1978) The history of Hartlepool Bay. Intl Journal of Nautical Archaeology and Underwater Exploration 7(1): 71-87.
12. Shennan I (1982) Interpretation of Flandrian sea-level data from the Fenland, England. Proc Geol Asso 93(1): 53-63.
13. Ireland S (1987) The Holocene sedimentary history of the coastal lagoon of Rio de Janiero state, Brazil. In: Tooley MJ, Shennan I, (Eds.), Sea-level changes, Blackwell Oxford.
14. Fleitmann D, Burns SJ, Mudelsee M, Neff U, Kramers J, et al. (2003) Holocene forcing of the Indian monsoon recorded in a stalagmite from Southern Oman. Science 300(5626): 1737-1739.
15. Gasse F, Fontes JC, VanCampo E, Wei K (1996) Holocene environmental changes in Bangong Co basin (western Tibet). Part4. Discussion and Conclusions. Palaeogeography Palaeoclimatology Palaeoecology 120(1-2): 79-92.
16. Van Campo E, Cour P, Sixuan H (1996) Holocene environmental changes in Bangong Cobasin (western Tibet). part 2: The pollen record. Palaeogeography Palaeoclimatology Palaeoecology 120(1-2): 49-63.
17. Wang YJ, Cheng H, Edwards RL, He YQ, Kong XG, et al. (2005) The Holocene Asian Monsoon: Links to solar

changes and North Altantic climate. Science 308(5723): 854-857.

18. Naidu CV, Durgalakshmi K, Munikrishna K, Ramalingeswararao S, Satyanarayana GC, et al. (2009) Is summer monsoon rainfall decreasing over India in the global warming era? Journal of Geophysical Research: Atmosphere 114: D24108.

19. Umitsu M (1987) Late Quaternary sedimentary environment and landform evolution in the Bengal Lowland. Geographical Review of Japan 60(2): 164-178.

20. Umitsu M (1993) Late Quaternary sedimentary environments and landforms in the Ganges Delta. Sedimentary Geology 83(3-4): 177-186.

21. Kudrass HR, Spiess V, Michels M, Kottke B, Khan SR (1999) Transport processes, accumulation rates and a sediment budget for the submarine delta of the Ganges-Brahmaputra, and the Swatch of No Ground, Bangladesh. In International Seminar of the Quaternary Development and Coastal Hydrodynamics of the Ganges Delta in Bangladesh, Geological Society of Bangladesh, Dhaka.

22. Goodbred Steven, Kuehl Steven (2000) The significance of large sediment supply, active tectonism, and eustasy on margin sequence development: Late Quaternary stratigraphy and evolution of the Ganges-Brahmaputra delta. Sedimentary Geology 133(3-4): 227-248.

23. Monsur MH (1995) An Introduction to the Quaternary Geology of Bangladesh. City press and publications, pp: 70.

24. Banerjee M, Sen PK (1987) Palaeobiology in understanding the changes of sea-level and coastline in Bengal Basin during Holocene Period. Indian Journal Earth Science 14(43528): 307-320.

25. Islam MS (2003) Holocene sea-level changes and coastal geomorphic evolution in Bangladesh: Example from Matuail near Dhaka city. Final Conference, pp: 139-140.

26. Rashid T, Suzuki S, Sato H, Monsur MH, Saha SK (2013) Relative sea-level changes during the Holocene in Bangladesh, Journal Asian Earth Science 64: 136-150.

27. Alam AKMK, Huq MA (1988) Evidence of neotectonic activity on the Bengal delta. Geological Society of America, Bangladesh, pp: 54-55.

28. Monsur MH, Paepe R (1994) Holocene stratigraphy and palaeoclimatological interpretation of the deposits of the Madhupur, Barind and Chalanbil areas of the Bengal Basin, Bangladesh. Bangladesh Journal of Science Research 12: 255-264.

29. Miall AD (1990) Principles of Sedimentary Basin Analysis. Springer, New York.

30. Bridge JS (1993) Description and interpretation of fluvial deposits: a critical perspective. Sedimentology 40: 801-810.

31. Walker RG (1984) Facies Models: General Introduction. Geoscience, Canada, Reprint Series 1: 1–10.

32. Faegri K, Iversen J (1989) Text book of pollen analysis. John Wiley and Sons, Chichester, UK.

33. Fergusson J (1863) On Recent Changes in the Delta of the Ganges. Journal of the Geological Society 19: 321-354.

34. Hirst Major FC (1916) Report on the Nadia Rivers 1915: Calcutta. The Bengal Secretariate Book Depot.

35. Morgan JP, McIntire WG (1959) Quaternary geology of the Bengal Basin, East Pakistan and India. Bulltin of the Geological Society of America 70(3): 319-342.

36. Rizvi SNH (1975) Dacca [Bangladesh District Gazetteers]. Bangladesh Government Press.

37. Alam M (1972) Tectonic classification of the Bengal Basin. Geological Society of America Bulletin 83(2): 519-522.

38. Alam AKMK (1995) Neotectonic evidences along the eastern margin of the Barind Tract, Bangladesh. Bangladesh Journal of Geology 7: 51-62.