FINAL REPORT

On

QUATERNARY GEOLOGICAL MAPPING OF DHAKA, CHITTAGONG AND SYLHET CITIES

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CHAPTER - ONE

1. THE QUATERNARY

1.1. Concept of the Quaternary

The report has been aimed to prepare a detail Quaternary stratigraphy of the deposits exposed in the three major cities Dhaka, Chittagong and Sylhet. Before going through the stratigraphic aspects, the understanding of the Quaternary needs to be discussed. Quaternary is the topmost Period of the Geological Times Scale. The forth Cenozoic Era includes Quaternary (top) and Tertiary (below). The Quaternary Period includes Pleistocene and Holocene Epochs. The whole Quaternary covers a small span of geological time, only 2.5 million years (my). The Holocene Epoch covers only the last 10,000 years. The present landscape and contemporary surroundings are the result of Quaternary evidences and neotectonics.

Quaternary has been ignored for long time. Unfortunately, most of the authors of last century considered the Quaternary as an integral part of the Tertiary. Some of them state that Quaternary does not exist. Quaternary is continuation of the Tertiary. They argue that traditional Periods are subdivided based on either unequivocal major tectonic movement all over the world or the guide fossils those demarcate the Period boundaries. In addition, the duration of earlier Period covers a long geological time. Considering the geological time, duration of Quaternary is so small that the time span of a single unconformity can more or less accommodate the whole duration of Quaternary. On the other hand, Quaternary has not been separated in a traditional way. There was not such important universal orogenic movement that could make a sharp tectonic or stratigraphic boundary with the underlying Tertiary System. The subdivision of Quaternary mainly based on the climatic changes what contradict to the principles and practices of conventional ways of Geochronologic or chronostratigraphic classification.

The next debate concerns with the subdivision of the Quaternary into Pleistocene and Holocene Epochs. In 1846, Sir Edward Forbes equated the Pleistocene with the glacial Epoch. During the Pleistocene Epoch, cold phases (glacials) were alternated with the warm phases (Interglacials). Present day warm phase or Interglacial, started at about 10,000 years ago, and is called Holocene. The last glacial phase (Weischel Glaciation in Europe) of Pleistocene was alternated with the interglacial phase of the present day in the similar way as the cold and warm phases were alternated during the whole Pleistocene Epoch. In this sense, Holocene can be considered as the part or continuation of Pleistocene. Hence, giving the status ‘Epoch’ (Holocene) for the last warm phase is questionable.

Despite of the fact that Quaternary has its own special characteristics those separate the Period from the earlier System. Present day environments, however, are treated largely from an historical viewpoint, but contemporary process and spatial distribution studies are used as a basis for inference about the past. The Quaternary (which includes present day) processes and sediments are well preserved and quite fresh. The data obtained from Quaternary sediments are relatively fresh, accurate and informative. Present is the key to the past. Quaternary environments and processes may precept and unravel the geological ambiguities of the long past.

1.2. General characteristics of the Quaternary

The main characteristics of the Quaternary are; 1) Dramatic climatic changes, resulted accumulation of ice sheets around the poles; their advancement towards the equator and their retreats, 2) Sea level changes, 3) Development of present landscape, 4) Changes of vegetational zones, 5) Changes of mammalian faunas and 6) Appearance of modern man.

1.3. GEOLOGY OF BANGLADESH

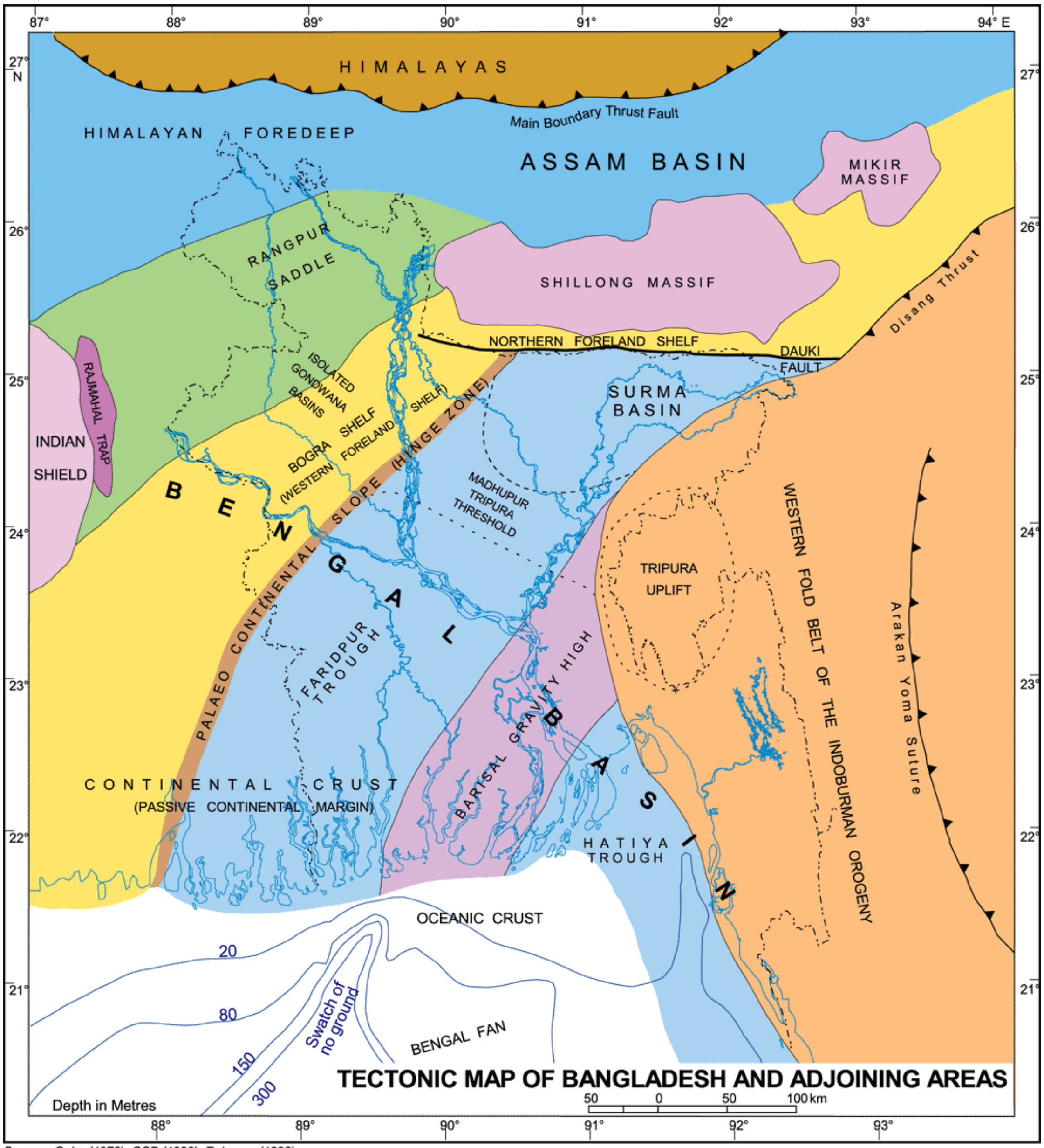
1.3.1. Introduction

Bangladesh is situated in the northeastern corner of the Indian subcontinent. It has an area of 144,000 sq.km and has the population of about 140 millions. Geologically Bangladesh is situated inside the Bengal basin. The Bengal basin is bordered to the west by the Precambrian Indian shield, to the north by the Shillong shield and to the east by the frontal fold belt of the Indoburman Hill Range. It is open to the south for more than 200 hundred kilometers to the Bay of Bengal. Hence, the Bengal basin includes, in addition to Bangladesh, part of the Indian state of West Bengal in the west and Tripura in the east.

Geological evolution of Bengal basin (includes whole of Bangladesh) is related to the Himalayan orogenic movements and outbuilding of large deltaic landmass by the major river system originated from the uplift of the Himalayas. As the mega delta prograded south accompanied by rapid subsidence of the basin, a huge thickness of deltaic to fluvio-deltaic sediments was deposited. The delta building process is still continuing into the present Bay of Bengal and broad fluvial front of the Ganges-Brahmaputra-Meghna river system gradually follows it from behind. The eastern part of Bangladesh has been uplifted into hilly landform incorporating itself into the frontal belt of Indoburman Range lying to the east

1.3.2. Tectonic setup of the Bengal basin

Tectonically, Bangladesh has been subdivided into three major structural units: (1) Western platform area, (2) Central foredeep and (3) Eastern folded belt (Fig.1.1). The western platform covers the gap between the Indian shield (Rajmahal trap) and Shillong Massif. Here, the basement complexes (represented by metamorphosed gneiss, schists, diarite, granodiarite etc.) are very close to the surface. Dome shaped structural feature of basement complex which is called Rangpur Saddle, northern flank plunges northward into the Himalayan foredeep. The central part of the basin is the Foredeep area where the Tertiary sediments have the thickness of more than 20 km has some highs and lows (Fig.1.1). The Folded belt covers the Jointiapur and Chittagong hilly areas.



Source: Guha (1978), GSB (1990), Reimann (1993)

Fig.1.1 . Tectonic map of Bangladesh and adjoining areas（Source, Banglapedia）.

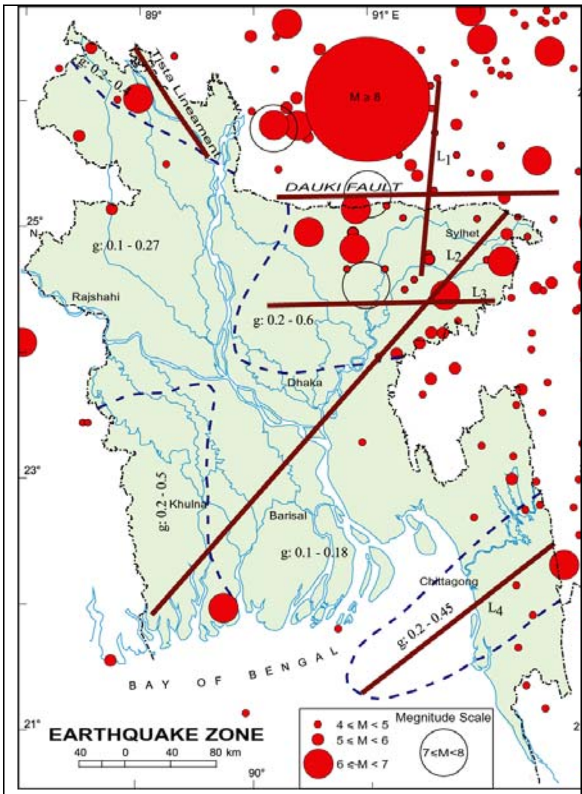


Fig.1.2. Earthquake zone map, showing the epicenters of some major and minor earthquakes in the historical past（Source, Banglapedia）.

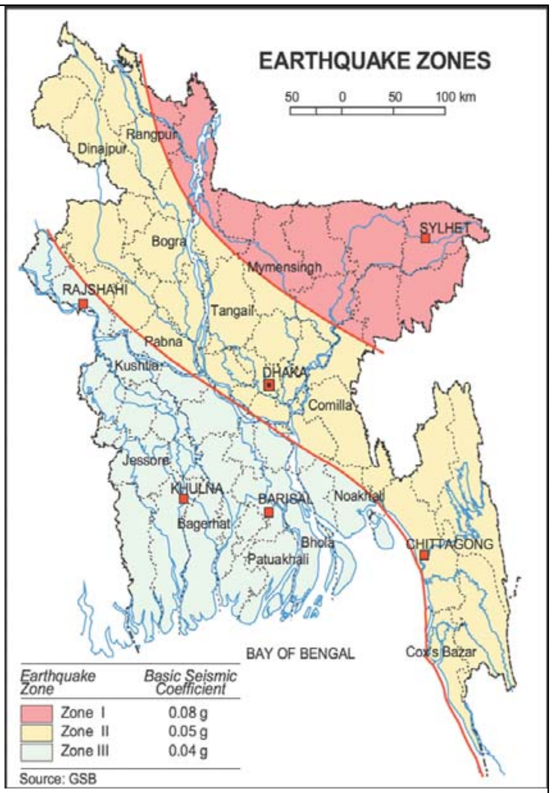


Fig.1.3. Shows the earthquake zones of Bangladesh（Source, Banglapedia）.

It is well known that the sediment characteristic of a particular site is the most important factor for earthquake ground motion. The earthquake ground motion is amplified by local geologic condition. Therefore, the effect of near surface geology is most critical rather than other two factors: path and source. Quaternary sediments amplify the seismic energy and the amplification factor depends upon the thickness and softness of Quaternary sedimentary layers. Hence, the near surface or subsurface geological mapping is important prior to other consideration of disaster management programme. Bangladesh is an earthquake prone area. There were several shakes of earhquakes in high Richter scales during the geological past. Minor shocks are very frequent in the recent years. Fig.1.2 shows the epicenters with magnitudes of several earthquakes, recorded in the geological past and Fig.1.3 shows the earth zones of Bangladesh.

1.3.3. A brief stratigraphic succession of the Bengal basin

Geological evolution of Bangladesh is related to the uplift of Himalayan mountain and outbuilding of large deltaic landmass by major river system originated from the rising Himalayas. The Ganges, Brahmaputra, Meghna, Tista, Surma etc. are the major rivers. These rivers carry billions of tons of sediemts each year and discharge into the Bay of Bengal towards the south. Figures 4, 5 and 6, show the major rock type, soil and physiographic features of Bangladesh.

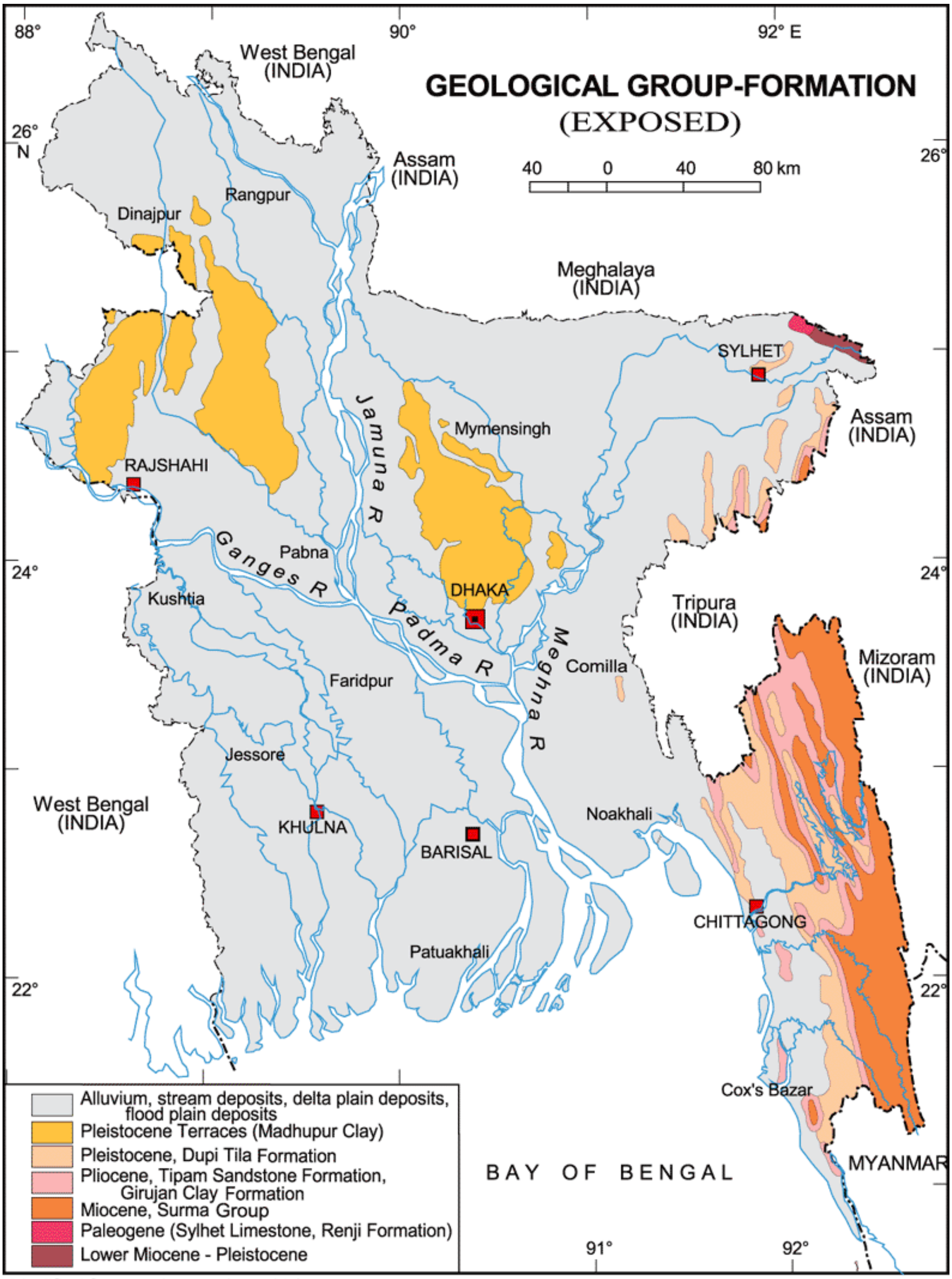
Almost whole of Bangladesh, except the folded belt in the eastern and north-eastern parts, is covered with Quaternary deposits. In the northwestern areas, in the district of Panchagarh, some parts of Dinajpur and greater Rangpur districts, piedmont deposits are exposed. Piedmont deposits are called Panchagarh Gravels, represented by well rounded gravels with high sphericity and roundness, exposed in the Panchagarh area, the northern extremity of Bangladesh. These Quaternary gravels are well exposed at Boalmary, Vojanpur, Tetulia, Dahagram and Angarpota, Patgram, Dalia, Uttar and Dakhin Kharibari, Jaldhaka and Kaliganj. Pleistocene gavels are also exposed in the Jointiapur area. The weathered and well rounded gravels caps the hill tops Jointiapur hillocks. These gravels are called Sona Tila Gravels. In the Madhupur and Barind tracts, highy oxidized reddish-brown deposits, called Madhupur Formation form north-south elongated terrace systems, slightly elevated from the adjacent flood plain. The rest of Bengal territory is covered by fluvial and brackish water alluvium. The Holocene fluvial and brackish water sediments are fine grained moderately consolidated or in the coastal region the Holocene Series are unconsolidated deposits, containing several intercalated or inter fingering peat layers.

Gondwana sediments (Permian and Jurassic) are underlain by the Precambrian basement complexes and are overlain by the Cretaceous sediments, called Shibgonj Trapwash Formation.

Tertiary sediments are exposed in the eastern and north-eastern folded belt of Bangladesh. Tertiary (Mio-Pliocene) sediments are represented by sandstone, silty and sandy shales. They form some north-south elongated hill ranges parallel to line of subsidence (Arakan Yoma Suture) where Bengal basin is subsiding under the Burmese plate.

Precambrian basement complexes are not exposed in the territory of Bangladesh. The Rangpur Saddle represents the shallowest part of the basement. The basement is the subsurface continuation of Indian shield to the west and Shillong shield to the east. The Precambrian rocks are mainly granite, granodiorite and gneiss with occasional mafic to ultramafic intrusions.

In the deeper part of the basin, the tertiary sediments attain maximum thickness. To understand the general concept of sedimentary sequences, the lithostratigraphic successions of the stable platform area and geosynclinal areas of the Bengal basin are given in the Table-1.1 and Table-1.2.



Modified from *Reimann, Klaus-Ulrich*, 1993

Fig.1.4. A generalized geological map of Bangladesh (Source, Banglapedia).

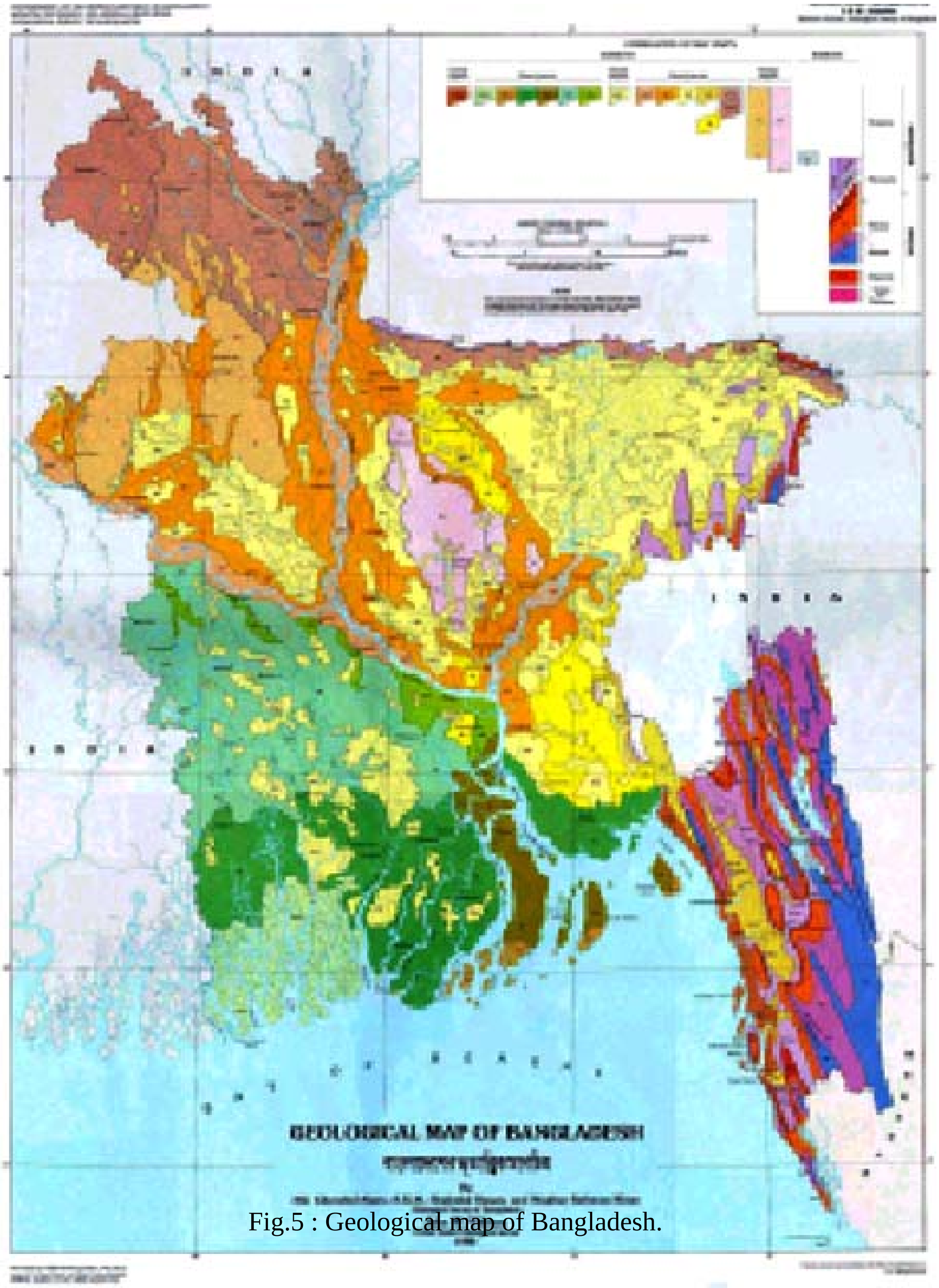


Fig.1.5. Geological map of Bangladesh.

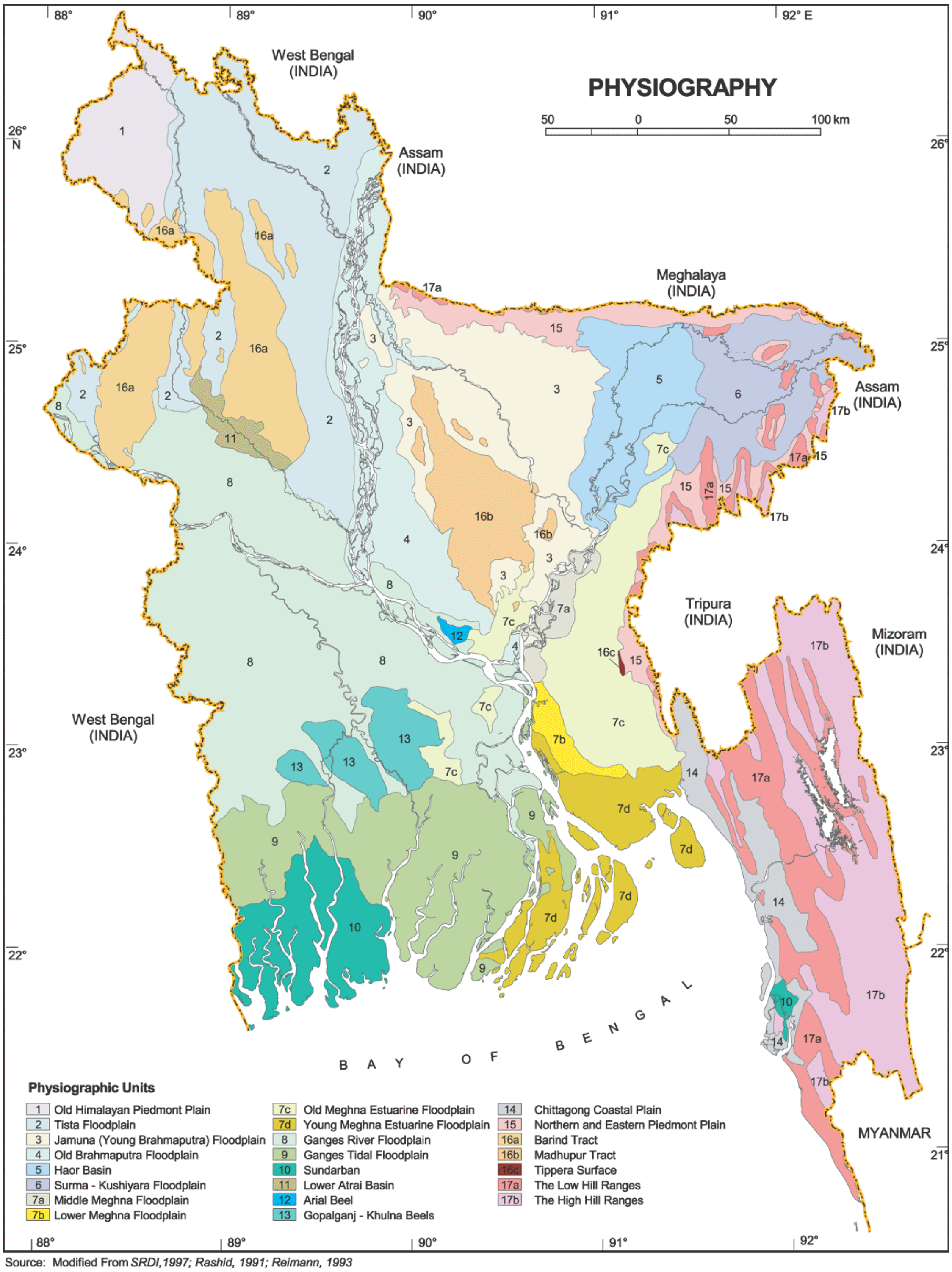


Fig.1.6. Physiographic map of Bangladesh (Source, Banglapedia).

Table 1.1. Stratigraphic succession of stable platform in Bangladesh.

Age	Group	Formation	Thickness (meter)	Rock types
Holocene		Rohonpur/Boalmari	5	Alluvium, silty-sand and clay
Pleistocene		Barind Clay	15	Reddish-brown highly weathered clay in the upper part and micaceous sand in lower part.
Pliocene		Dupi Tila	270	Loosely compact sandstone with intercalated shale layers.
Miocene		Jamalganj	400	Alternation of sandstone and shale
Oligocene		Bogra	160	Sandstone and shale
Eocene	Jaintia	Kopili Shale	170	Mostly shale
		Sylhet Limestone	240	Numulitic limestone
		Tura Sandstone	370	Mostly sandstone
Cretaceous		Shibganj Trapwash	130	
Jurassic	Upper Gondwana Lower	Rajmahal Trap	540	Basaltic volcanic rock in layer
Permian		Paharpur Kuchma	1000	Mostly hard sandstone with some coal layers, few shale and conglomerates
Precambrian Crystalline Basement				Igneous and metamorphic rocks.

Table 1.2. Stratigraphic succession of geosynclinart area of Bangladesh

Age	Group	Formation	Thickness (meter)	Rock types
Holocene		Basabo Formation	1-5	Alluvium, Silty-clay or sticky clay. Fluvial and coastal plain.
Pleistocene		Madhupur Clay	10-12	Highly weathered reddish-brown clay in the upper part and micaceous sand in the lower part.
Plio-Pleistocene	**Tipam**	Dupi Tila	2500	Sandstone with minor shale and clay beds, having colour bands.
Pliocene		Girujan Clay	1000	Shale of clayey shale
		Tipam Sandstone	2500	Predominantly cross bedded sandstone with minor shale and clay beds.
Mio-Pliocene	**Surma**	Bokabil	3500	Alternating shale and sandstone with minor siltstone. Sand dominated
Miocene		Bhuban	700	Alternating sandstone and shale with minor siltstone. Shale dominated
	Borail	Renji	700	Sandstone with minor shale

Oligocene		Jenam	240	Predominantly shale with minor siltstone and sandstone

1.3.4. Late Quaternary erosional and depositional environment of the Bengal plain

The capital city Dhaka is situated in the southern margin of Madhupur tract, a north-south elongated Pleistocene terrace having undulated surfaces slightly elevated from the recent floodplain. Before going through the details of the Quaternary stratigraphy it is necessary to discuss about the Late Pleistocene climatic episode and is erosional and depositional history of the Bengal plain.

Late Quaternary monsoon climatic episodes played the vital role in creating the present morphology of the Madhupur surfaces. The peak of the last glaciation was evidenced by dry climatic condition over the Bengal plain. From 22,000 to 15,000 yars BP, north-east monsoon was prominent. Since it was flowing from the continental surface, contained less vapour and caused scanty rain fall. By that time, the Himalayas were considerably high and were glaciated. The Bengal basin was acting like an outwash plain. Melt water was flowing through a number of palaeoriver system over the Bengal plain. During the last glacial maximum (i.e. at about 18,000 years ago), sea level was about 100 to 140m below the present sea level. Hence, the rivers were narrow and deeply incised. The monsoon climate started changing from 18,000 to 15,000 years BP. At about 12,000 years ago, south-west monsoon became prominent and caused heavy rainfall. Therefore, at the end of last glaciation (at about 10,000 years ago) amplified monsoon water plus deglaciated melt water from the Himalayas enormously flowed over the Bengal plain, i.e. over the Madhupur surfaces. Due to the strong hydrodynamic condition, the initial Madhupur surfaces were deeply dissected, created some local pools and depressions, left over a number of north-south elongated reddish-brown islands or terraces. At the beginning of Holocene (12,000 years BP), sea level started rising very rapidly. At about 5,500 years BP, sea level attains its maximum height, about 1 to 2m above the present MSL. Hydrodynamic condition of the river system changed. Erosional activities ended and the erosional surfaces were filled up by Holocene sediments. During the Mid Holocene sea level rise (marine transgression), brackish water sediments deposited over the eroded Madhupur surfaces. Dhaka city is surrounded and drained by three major rivers the Buringanga, the Turag, the Balu and their tributaries and distributaries. These rivers were tidal rivers during the during the Mid-Holocene sea level rise. Brackish water sedimens can be found near the banks of these rivers and erosional depressions of the Madhupur surfaces.

1.3.5. APPLIED METHODOLOGY

The report includes the geological mapping of Quaternary sediments and preparation of Quaternary stratigraphy of the three major cities: Dhaka, Chittagong and Sylhet. The following methods were applied:

1. Direct observation has been made to prepare the geomorphological maps of Dhaka, Chittagong and Sylhet cities using aerial photographs and landsat imagery. The maps have been prepared by the CDMP team of the Geolgical Survey of Bangladesh.
2. Borehole data have been collected from different organizations.
3. Field works were performed in Dhaka, Chitagong and Sylhet cities for the confirmation of the boundaries of lithostratigraphic units.
4. Rigorous field works were performed in Dhaka city. Careful observations were made during the excavation for the building construction at different sites. Photographs were taken and the deposits were subdivided into lithostratigraphic units.
5. Sections were delineated and lithostratigraphic units were subdivided during the drilling activities of the Geological Survey of Bangladesh.
6. Using the available data, geological cross sections and contour maps of engineering bed rocks of 3 cities (Dhaka, Chittagong and Sylhet) have been prepared.
7. At the end Final Report has been prepared using the obtained data and field investigations.

CHAPTER – TWO

2. THE CAPITAL CITY DHAKA

2.1. Introduction

Dhaka, the capital city of Bangladesh is situated in the southern margin of Madhupur tract. The urbanization in ancient Dhaka city (Pre-Mughul) started long before the arrival of the Mughul had been started to develop on the left bank of the river Buriganga (Fig.2.1). At the beginning of the seventeenth century, Mughul emperor built up a fort at Lalbagh and Dhaka became the capital of the Bengal (Fig.2.2). Dhaka started to expand along the river Buriganga. No significant expansion of the city had been noticed during the British time. Dhaka was slowly expanded during Pakistan Period. After the independence the capital city Dhaka started to expand very rapidly and took the resent shape of a megacity (Fig.2.3) with an area of 360 sq.km, (city corporation area) having the population of more than 14 millions.

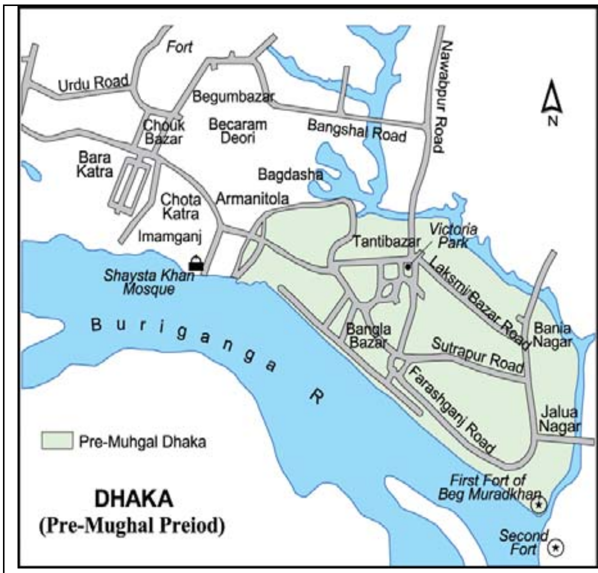


Fig.2.1. Ancient Dhaka city during Pre-Mughal time (Source: Banglapedia).

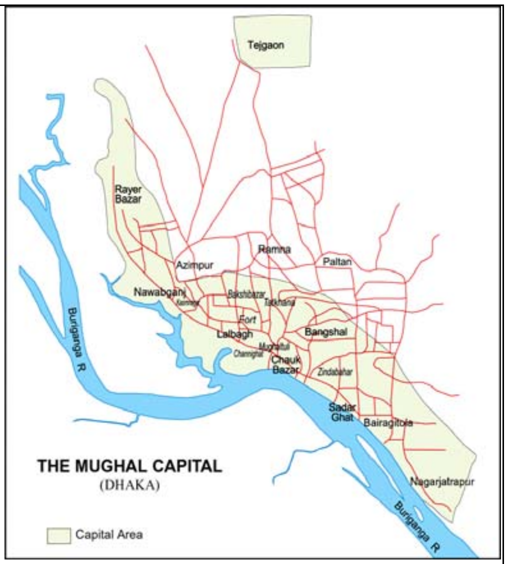
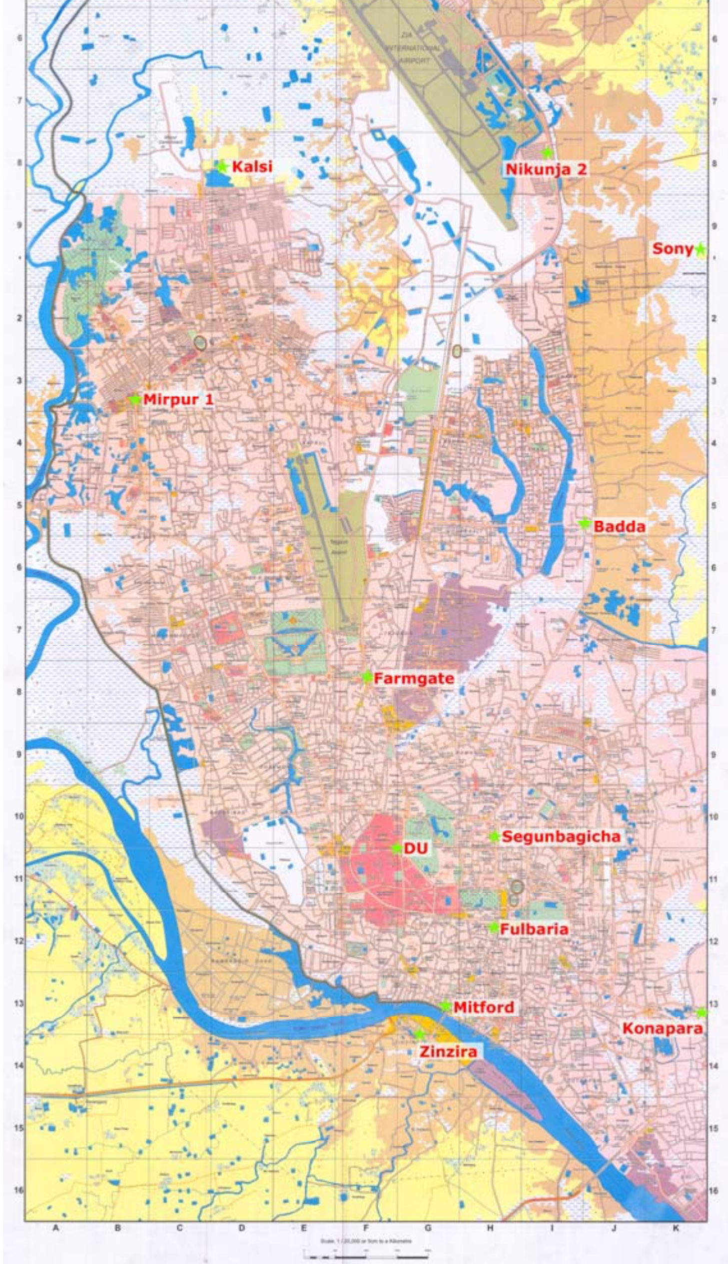


Fig.2.2. Dhaka the capital of Bengal during the Mughal Period (Source: Banglapedia).

Elevated red soil on left bank of the river Buriganga favoured rapid development of Dhaka city. River was the main transport for trade and communication.



DHAKA GUIDE MAP
Northern Part
Kalsi
Nikunja 2
Sony
Mirpur 1
Badda
Farmgate
Segunbagicha
DU
Fulbaria
Mitford
Konapara
Zinzira

Fig. 2.3. Present megacity Dhaka, the capital of Bangladesh

2.2. GEOMORPHOLOGICAL SUBDIVISION OF DHAKA CITY

Late Pleistocene climatic episodes produced a number of north-south elongated terrace systems in the Bengal plain. Dhaka Terrace (Alam, 1988) is one of the north-south elongated terrace in the southern extremity of the Madhupur tract where megacity Dhaka is situated. Atmospheric precipitation resulted undulated topography, hanging valley and palaeodrainage system. The elevation of the greater Dhaka city varies from 2m to 13m above the Mean sea Level (MSL). The erosional margin slopes under the Holocene sediements towards the west, south and south-east.

Karim and Haider (1994), Karim (2003) and Karim et al. (2003), Rahman and Karim (2005), identified three distinct geomorphic units of the greater Dhaka City (Fig.2.4) which are as follows:

a) Central High Area: This unit represents an elevated and north-south elongated table surface above the flood plain level. The elevation more than 7m from the Mean Sea Level (MSL).
b) Complex of High and low areas: This unit consists of narrow strips of benches or foot slopes, rounded to elongated domes of central unit, narrow and shallow erosional gullies and incised valleys or abandoned channels. The elevation of this unit varies from 2m to 5m above MSL.
c) Complex of Low Areas: These areas represent the present flood plain of r. Burhiganga, Balu and Sitalakhay. These areas annually inundate during the monsoon time. This geomorphic unit is flat and the average elevation is 2m above MSL.

Rahman and Karim (2005) have described the details of the above geomorphological units from the following geological-geotechnical point of view:

Zone 1: The Central High area,
Zone2: Complex of High and Low Areas and
Zone 3: Complex Low areas.

Zone 1: The Central High Area forms the axial zone and extends northward upto Gazipur and beyond. The Madhupur Clay Formation is well exposed throughout the zones. This zone has been rated as Class 1 type ground condition, which is composed of very stiff to hard reddish brown clay to silt and sand (complete Madhupur Formation), having better engineering properties of the materials and considered to produce less ground motion than the other two zones.

Zone 2: The Complex of High and Low areas consists of small domes of nodes of the Madhupur Clay Formation which is exposed at lower elevation or buried under thin cover of young alluvium or fill materials. The zone is rated as Class 2 type. The elevation of this zone is below the central zone. The materials are moist and have lower shear strength than the elevated materials. The inter-depressions of this zone are sometimes filled up with very soft clay, organic clay and peat deposits (sometimes

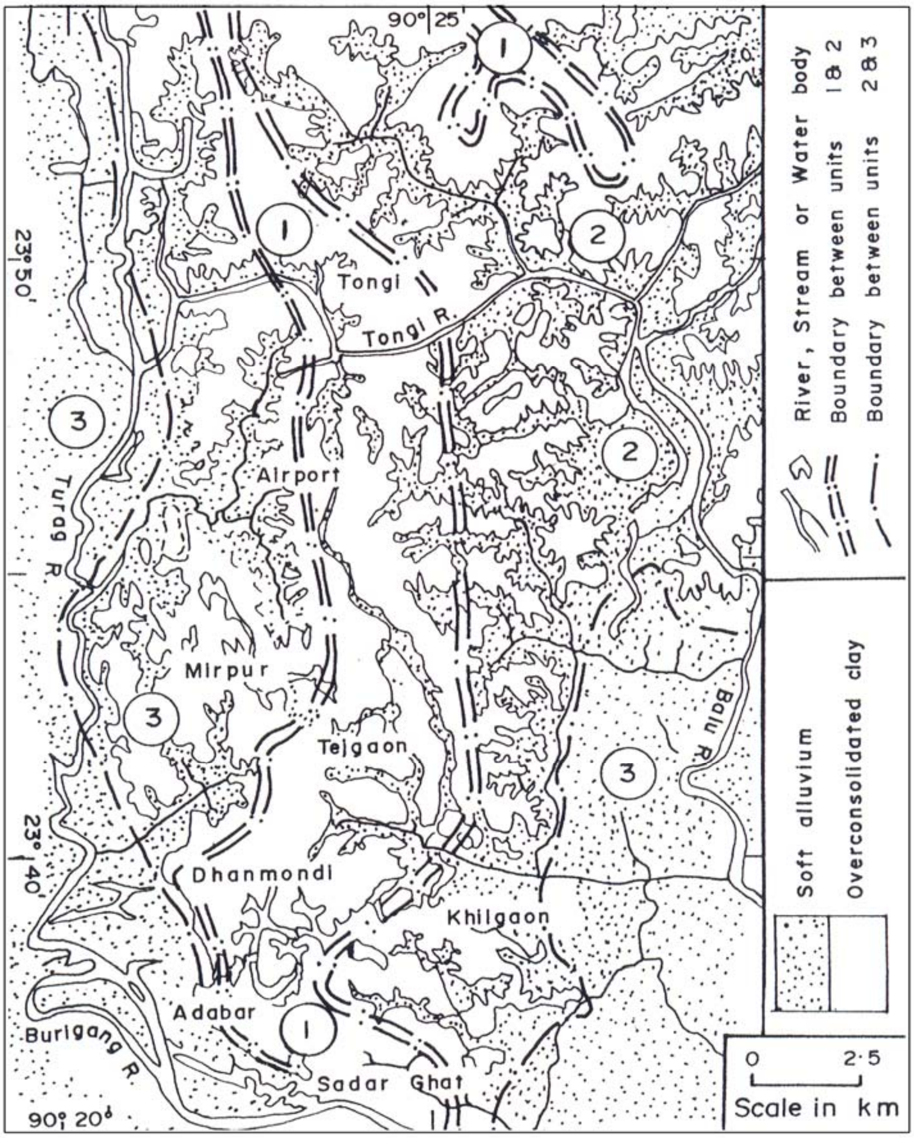


Fig. 2.4. Geomorphic units of Dhaka City (Karim and Haider, 1994).

Mangrovs). The materials are often compressible and suffer strong ground motion to severe destruction.

Zone 3: The complex of Low Area is located in the eastern and western periphery of Dhaka City. This zone is formed of very soft clay-silt in the east and flood plain of silt-sand in the west. This zone has been rated as Class 3 type. The general elevation of this zone is below the Complex of High and Low areas. The materials are very soft and susceptible to compression and liquefaction.

There are more geomorphological maps introduce by ASM Maksud Kamal (personal communication) and Atlas of urban geology, vol. 11 (Fig.2.5 and Fig.2.6). Those are the pioneer works and have detail environmental subdivisions of Quaternary sediments.

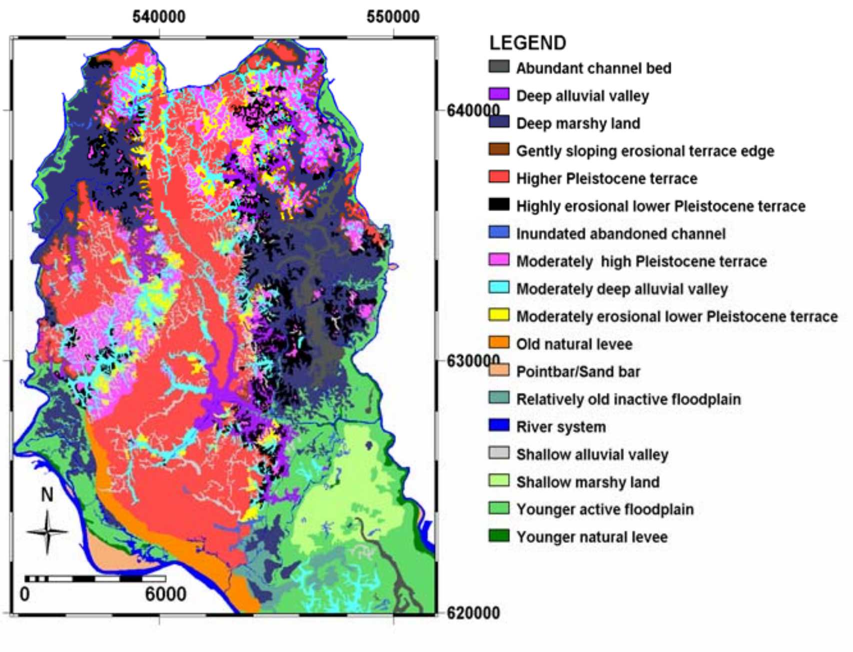


Fig.2.5. Geomorphological map of Dhaka city (after ASM Maksud Kamal, personal communication)

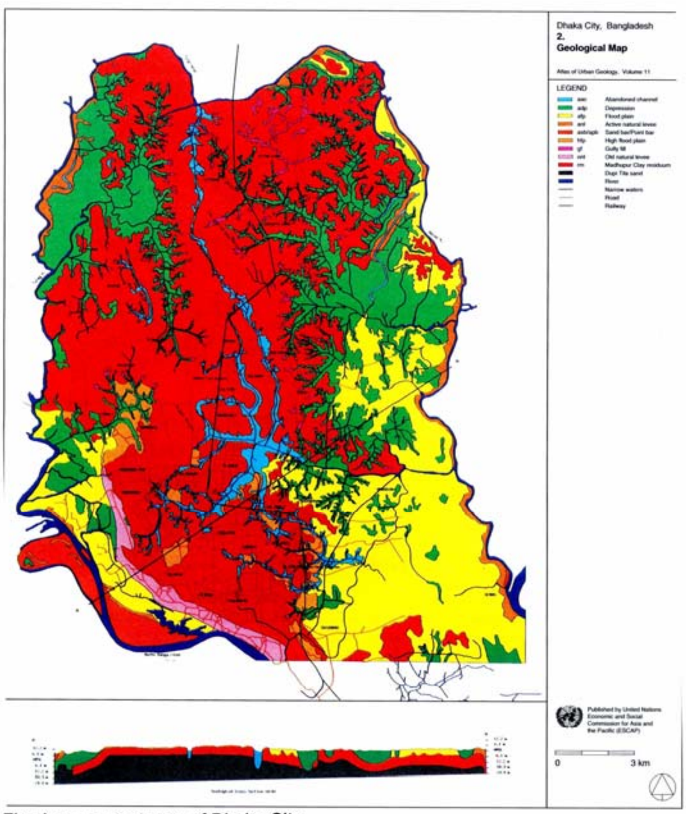


Fig: 4. Geological map of Dhaka City.
Source: Atlus of Urban Geology Vol-11

Fig.2.6. Geomorphological map of Dhaka city (Atlas of urban geology, vol. 11)

2.3. QUATERNARY STRATIGRAPHY OF THE DHAKA CITY

The Quaternary deposits exposed in Dhaka city (include surface exposures and borehole drilling at shallow depth up to 30m) have been organized and subdivided into three Formations, namely, 1) Basabo Formation (Holocene age), Madhupur Formation (Pleistocene age) and 3) Dupitila Formation (Pleistocene age?). In naming the lithostratigraphic units the traditional names have been restored as per Hedberg (1976) suggestions. Detailed descriptions of the lithostratigraphic units, their geomorphic subdivisions and areas of extensions are discussed in the following text.

2.3.1. Holocene Series

2.3.1.1. Basabo Clay Formation

The Holocene Series exposed in and around Dhaka city have grouped together and are called Basabo Formation. The Formation is unconformably underlain by the Madhupur Formation. The boundary stratotype is represented by an erosional surface which had been created by Late Pleistocene climatic episodes. The Formation is exposed in the eastern, southern and western margins of the Dhaka city, as well as exposed in flood plains, natural levees, point bars, Lateral bars, marshy or swampy wetlands, depressions, abandoned channels, erosional gullies and incised valleys of Madhupur surfaces. Geomorphological subdivisions with lithologic characteristics are well described in Fig.2.7. Eighteen boreholes were dug in Dhaka city at a depth of 30m to describe the lithology and to subdivide the deposits into lithostratigraphic units. Some additional borehole data have been collected from engineering farms to have clear idea of subsurface geology. Locations of boreholes and stratigraphic cross sections are shown in the fig.2.8 and Fig.2.9. Lithologic columns of 18 boreholes with sediments characteristics are given in Fig.2.10, Fig.2.11 and Fig.2.12 (It should be noted that all the 18 boreholes were dug by the team of the Geological Survey of Bangladesh and the author regularly visited the drilling sites and had direct observation). A general subdivision of the Quaternary deposits exposed in the Dhaka city and its surrounding areas is given in the lithostratigraphic table 2.1. Systematic descriptions of different facies of the Basabo Formation are given in the following text.

a) Active Channel deposits

The greater Dhaka city is drained by four major perennial rivers: the Buriganga, the Shitalakhay, the Turag and the Balu. These perennial rivers carry a huge quatity of suspended and bed load sediments, like sand, silt and clay. Sometimes, the river bed sediments are used for filling materials of lowland areas.

b) Abandoned Channel deposits

Late Quaternary climatic episodes (at about 10,000 to 5,000 years BP) had created numerous deeply incised channels on the madhupur reddish-brown surfaces. These are now the abandoned channels. Gulshan, Bonani and Dhanmandi Lakes were such kind of palaeochannels. The palaeochannels had north-south flow in the central zone of Dhaka city and discharged its water into the Buriganga. The channels had a lot of tributaries and distributaries. Mid Holocene sea level rise changed the hydrodynamic condition of the river systems. As a result these incised palaeochannels were filled up with Holocene sediments. The Fig.2.13 and Fig.2.14 represent the grain size distributions of Basabo and Madhupur Formations respectively. Fig.2.15, Fig.2.16 and Fig.2.17 are the cross sections of the palaeochannel deposits exposed during digging in the Gulshan lake at Kamal Ataturk Avenue in 1987 (Monsur, 1990). Four samples of wood fragments found in Gulshan lake were dated by radiocarbon dating and the obtained dates were 4040$\pm$70, 4910$\pm$75, 5730$\pm$60 and 8940$\pm$105 years BP. Similar sediments were found in Kalibari pond and Dakhingaon (during digging in 1987) at Basabo. The obtained dates of wood fragments were 12780$\pm$140 and 4830$\pm$75 years BP. The sediments are mostly cross bedded sand and clay with some involutions of post depositional sedimentary structures, containing humic materials and concretions. Those concretions were the reworked materials, can be found in the Madhupur Formation.

c) Alluvial Gullies

The surface and subsurface water flow of Early Holocene amplified monsoon had created innumerous gullies in the margin of the central zone (north-south elongated) of Dhaka city. These gullies were deeply incised (when sea level was low compared to the present MSL) whereby middle and lower part of Madhupur Formation were exposed. These gullies are now filled up with Holocene sediments. Gully fill Holocene deposits are shown in the Fig.2.7. The deposits are represented by dark or yellowish brown silty-clay with plenty of humic matters.

d) Lateral and point bars

These are the Holocene deposits exposed at the left (north) bank of the river Buriganga at Kamrangi char area and Mitford locality. It covers a small area along the river side of the Balu. The sediments are represented by grayish to yellowish brown silty sand with humic contents.

e) Swamps

There are swamps or marshy land in Dhaka city (Fig.2.7). Swamp of Khilgaon, Ashulia, DND area and the areas inside the western barrage (Beribadh) represent such marshy land. These are the man made water logged areas where recent unconsolidated alluvium sediments are depositing.

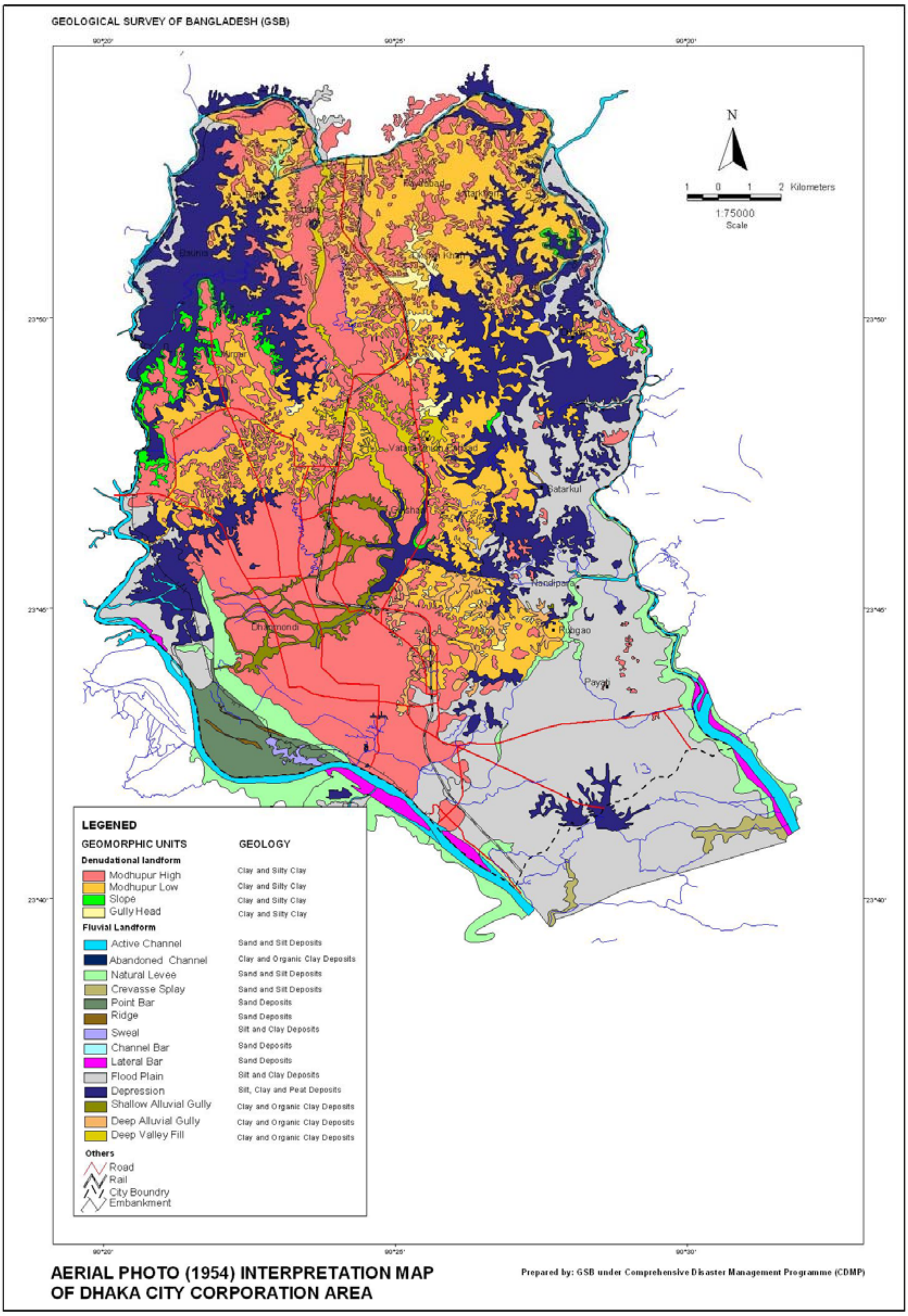


Fig.2.7. Geomorphological map of Dhaka city (Reshad et. al.,, 2008, GSB).

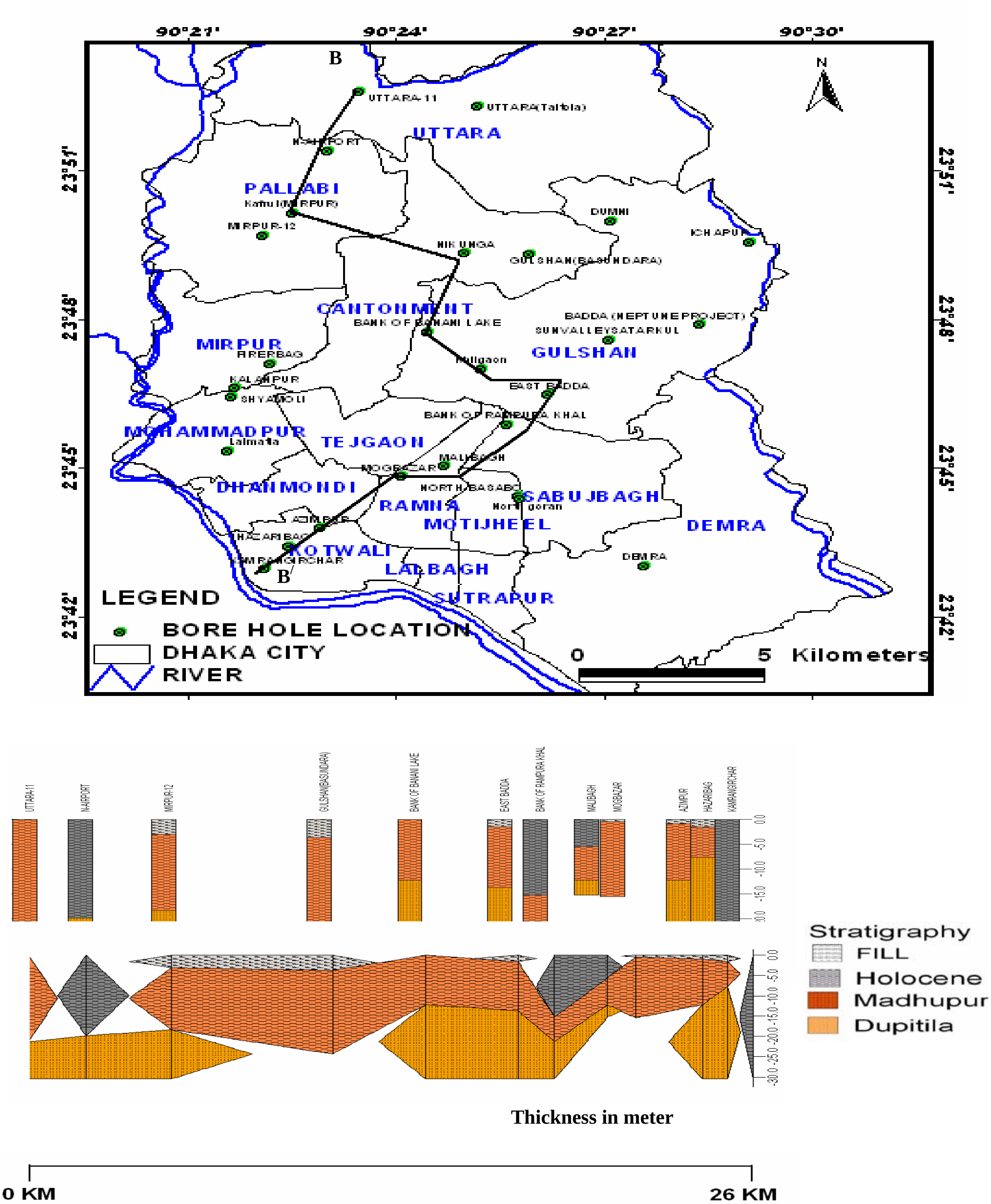


Fig.2.8. Location of boreholes and stratigraphic cross section of Quaternary deposits in the Dhaka city.

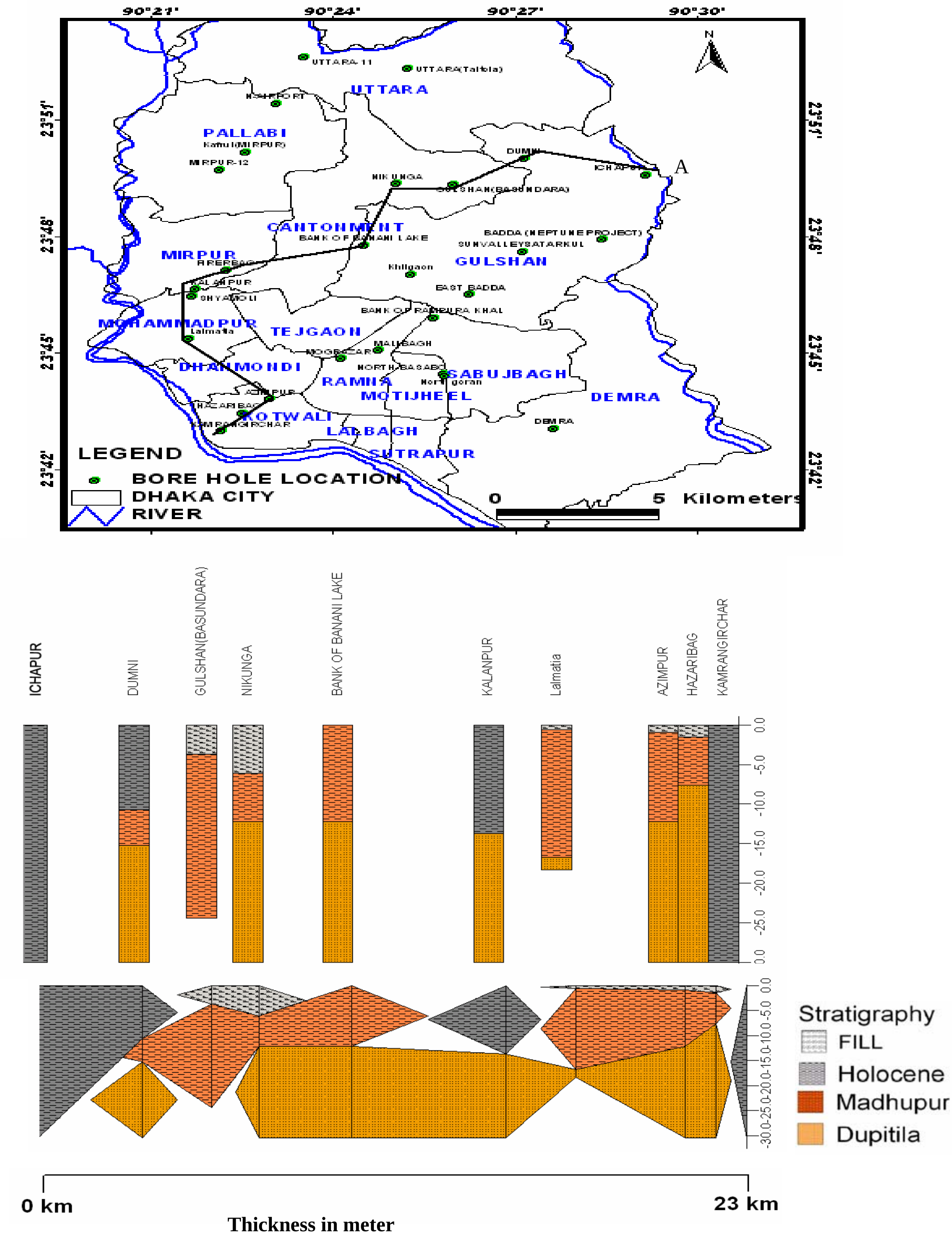


Fig.2.9. Location of boreholes and stratigraphic cross section of Quaternary deposits exposed in the Dhaka city.

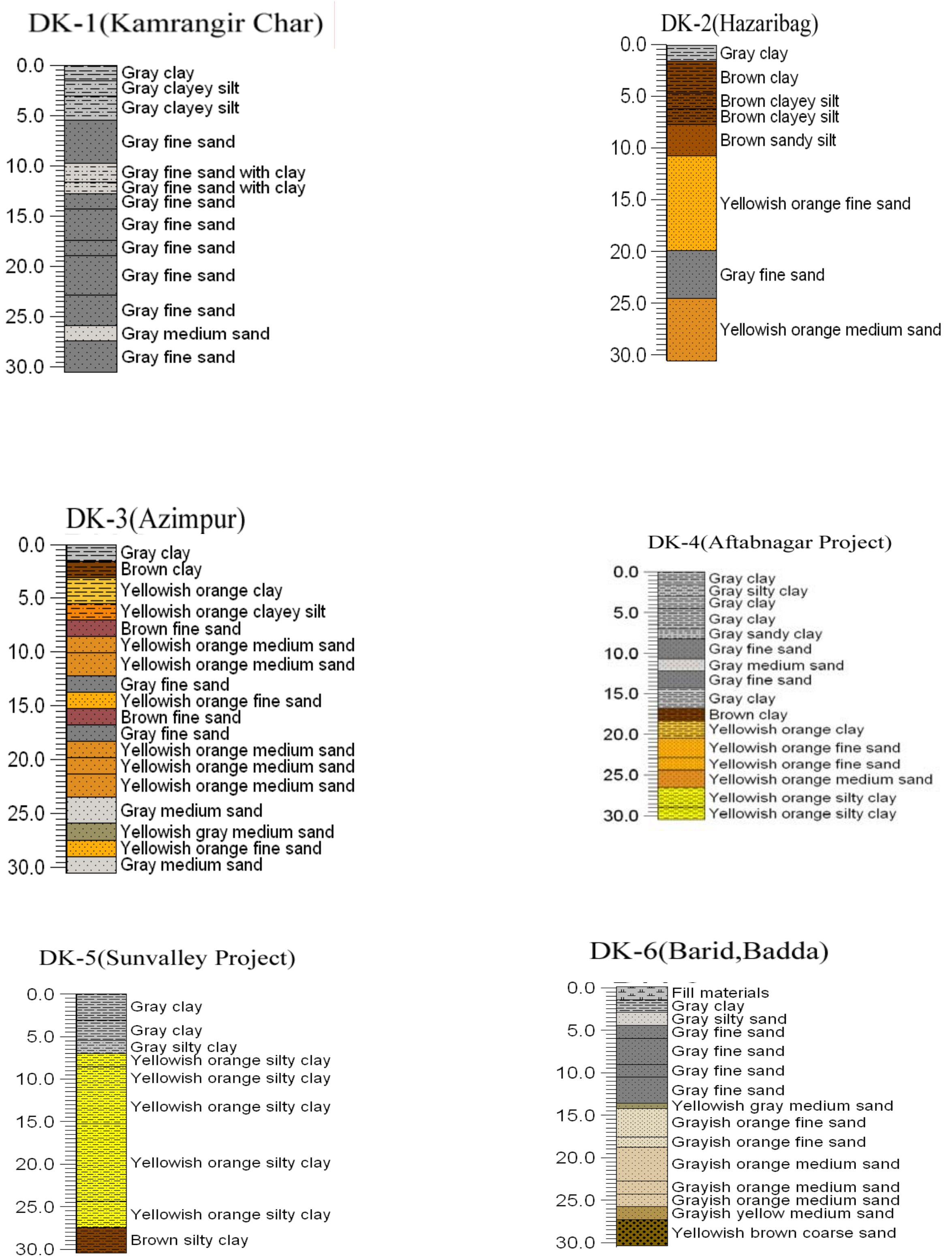


Fig.2.10. Lithologic colums of selected boreholes with lithologic descriptions.

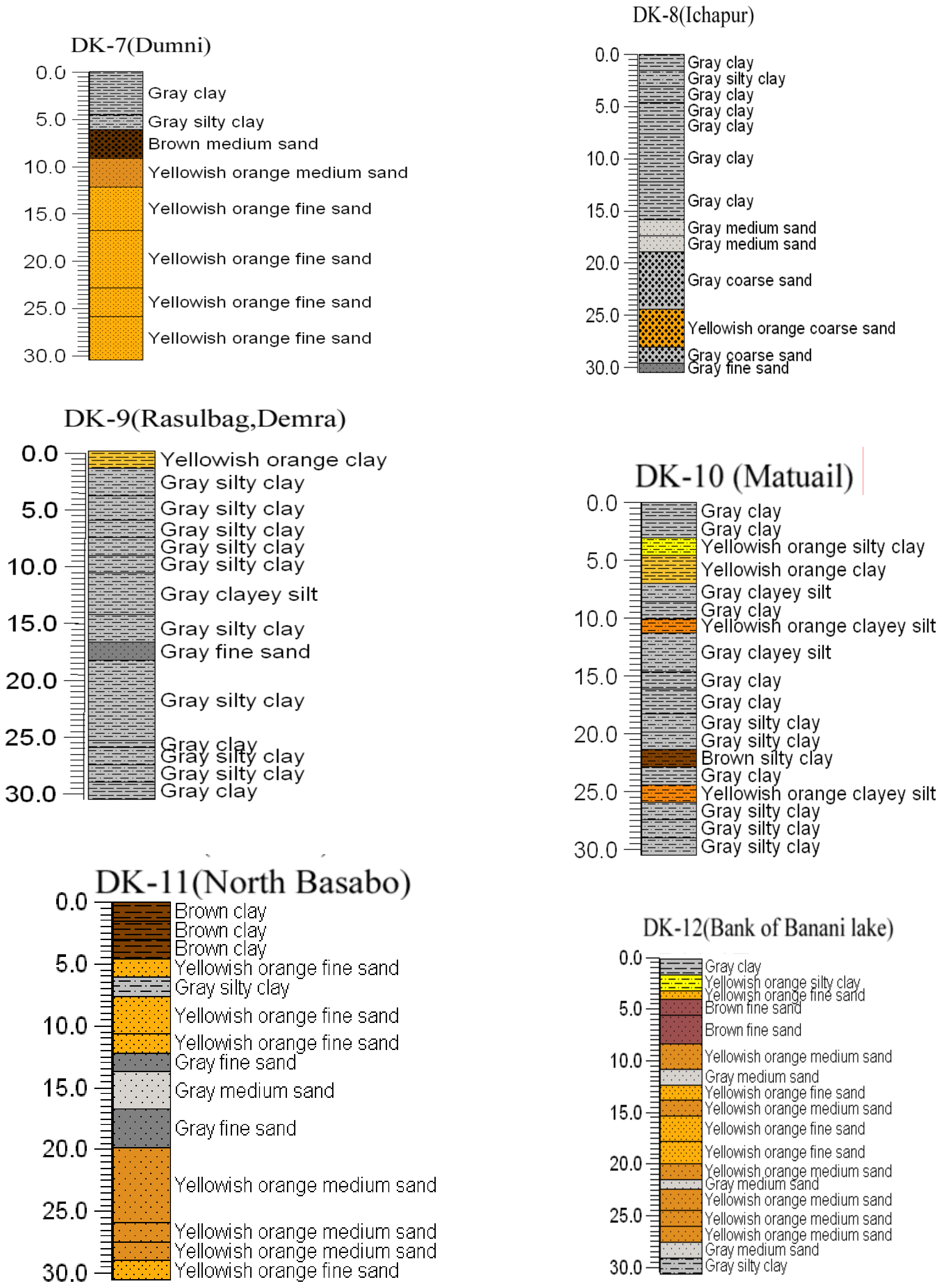


Fig.2.11. Lithologic colums of selected boreholes with lithologic descriptions.

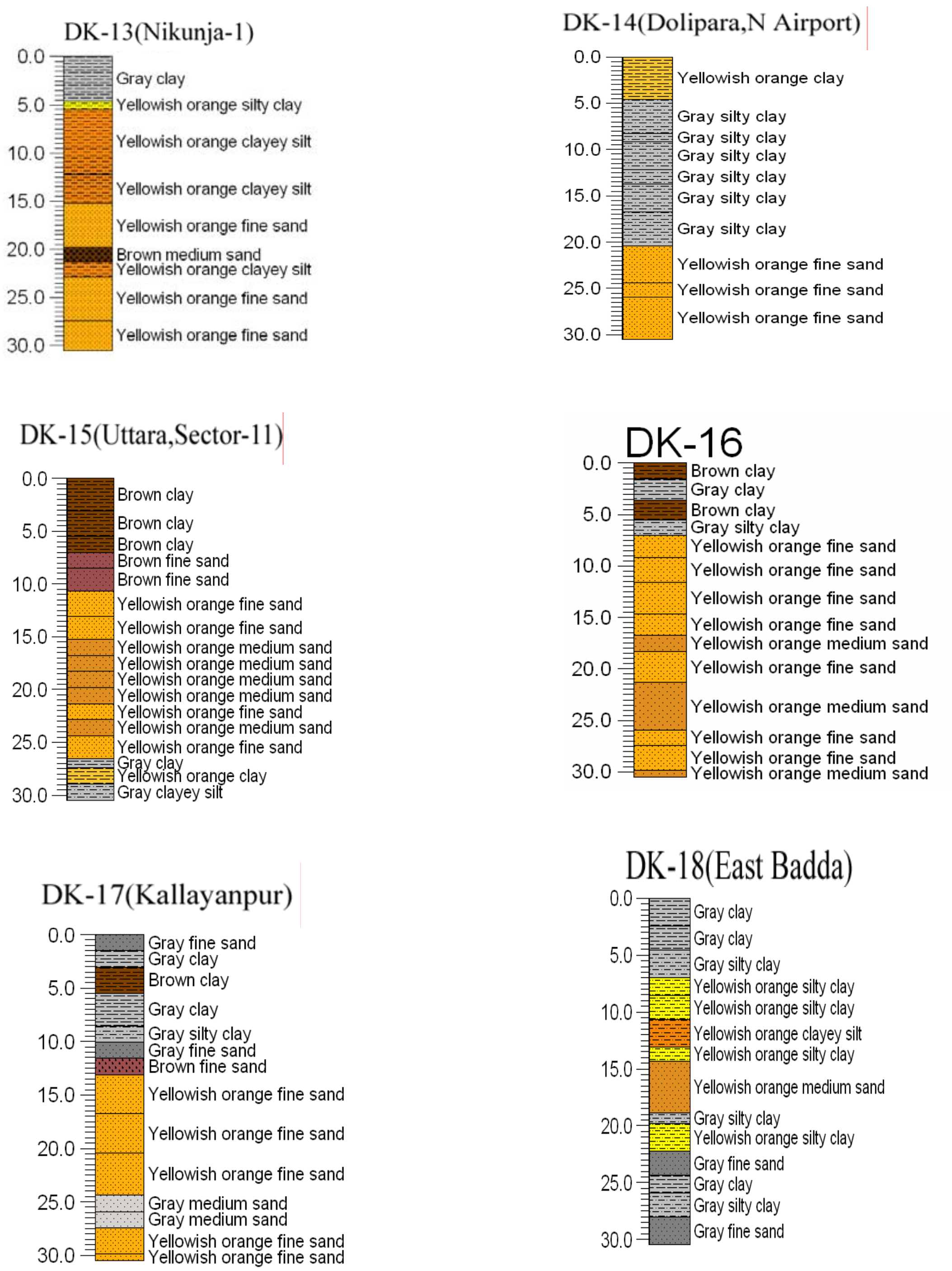


Fig.2.12. Lithologic colums of selected boreholes with lithologic descriptions.

Table 2.1. Quaternary stratigraphic succession of Dhaka city and surrounding areas.

Chronostratigraphy		Formation	Member	Bed	Lithologic description	Thickness (m)
Series	Sub-Series					
HOLOCENE	Sub-Atlantic	Basabo Silty-clay	Matuail Clay	Silty-Clay	Pale olive very sticky silty clay with modern soil on top	2 to 5
	Sub-Boreal			Clayey Silt	Light yellowish brown very sticky clayey silt, containing plenty of plant roots and iron concretions.	
	Atlantic		Gulshan Sand	Silty Clay	Yellow red silty-clay.	
	Boreal			Clayey Silt	Pale yellow clayey silt, containing wood fragments, plants' roots and iron concretions.	
	Pre-Boreal			Sand	Light bluish grey sand-silt-clay to sand. It contains roots, wood fragments and iron concretions.	
PLIOSTOCENE	Middle	Madhupur Clay and Sand	Kalsi Bed	1	Pale yellowish brown with light brown spotted sandy clay	12 to 15
				2	Yellowish brown very sticky silty-clay, containing iron concretions.	
			Dhaka Clay	Upper	Red with reddish yellow reduction spots. It is highly weathered and powdery. It contains iron concretions, pipe stems, calcareous nodules, plants' roots and manganese spots.	
	Lower		Mirpur Siltyclay	Middle	Light brown sandy clay to clayey sand with moderate reddish brown spots, containing iron concretions, pipe-stems, plants' roots and manganese spots.	
			Bhaluka Sand	Lower	Pale yellowish brown silty-sand to sand. It is highly micaceous and cross bedded, contains Mn-spots. Micas are biotitic and highly oxidized. It has intraformation or intercalated silty-clay layers.	
L.Pleistocene (Pliocene?)		**Dupi Tila**			Oxidized reddish brown fine grained to coarse asnd. It contains silicified wood fragment and peaty wood fragments. It has primary sedimentary structures, such as cross bedding, ripple marks etc. There are some intraformational yellwish brown and bluish silty clay layers having hickness of about 1 to m. The sediments are highly oxidized. The main characteristic is that the sediments have colour bands. The boundary between Madhupur and Dupi Tila Formation is represented by smooth quartz-chalcedony gravel beds.	2500

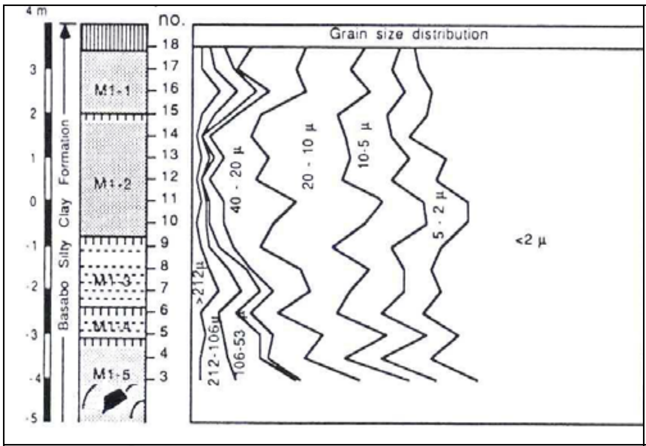


Fig.2.13. Grain size distribution of the Basabo Formation. M1-1 and m1-2 are the topmost subunits of floodpain deposits. The subunits are called Matuail Clay Member These are the silty clay subunits. Grain size increases downward. The lower 3 subunits, M1-3, M1-4 and M1-5 are called Gulshan Sand Member.

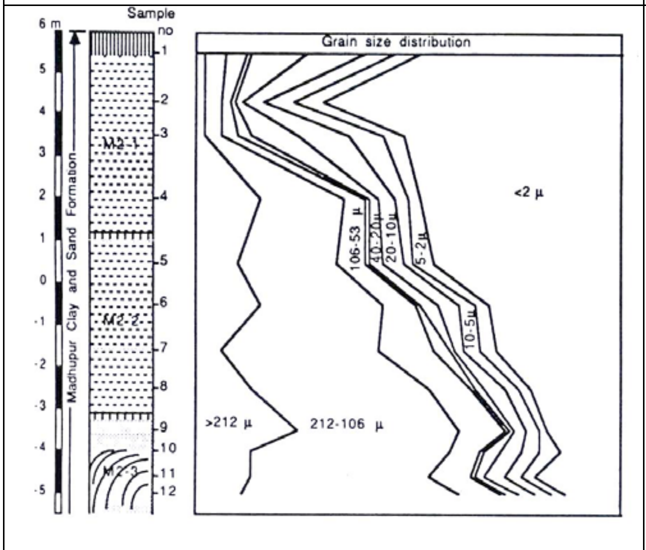


Fig. 2.14. Grain size distribution of Madhupur Formation. Finning upward sequence. Grain size increase downward. Three Members of Madhupur Formation: Subunit M2-1 is called Dhaka Clay Member, M2-2 is called Mirpur Silt Memebr and M2-1 is called Bhaluka Sand Member. Upper Member is highly weathered and the Lower Member is quite fresh, having primary sedimentary structures.

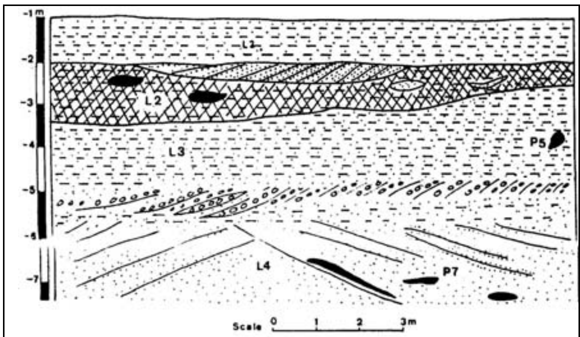


Fig.2.15. Stratigraphic cross-section in Gulshan Lake at Kamal Ataturk Avenue. L4 is the lower most layer dated at about 8940±105 years BP. L3 (dated 5730±60 yrs BP) unconformably underlain by concretional bed (Ferruginous) and overlain by humic layer (dated 4910±75 yrs BP). Lower part represents the deposits of high flow regime (when sea level was low compared to the present MSL) and upper part represents the deposits of low flow regime (when sea level was high. Rise of sea level changed the hydrodynamic condition of river systems).

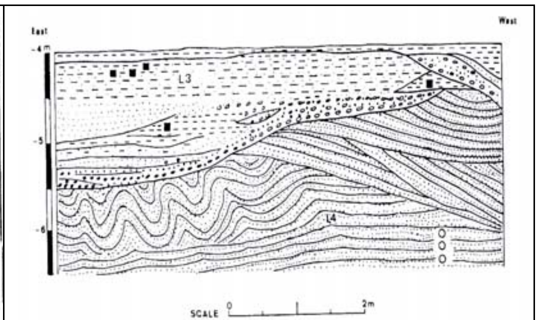


Fig.2.16. Startigraphic cross section in Gulshan lake at Kamal Ataturk Avenue. Typical channel deposits. Bed load deposits (Ferruginous concretions) eroded away the cross bedded sand layers. Post depositional involutions are remarkable. Palaeomagnetic results showed normal Brunhes polarity of these deposits.

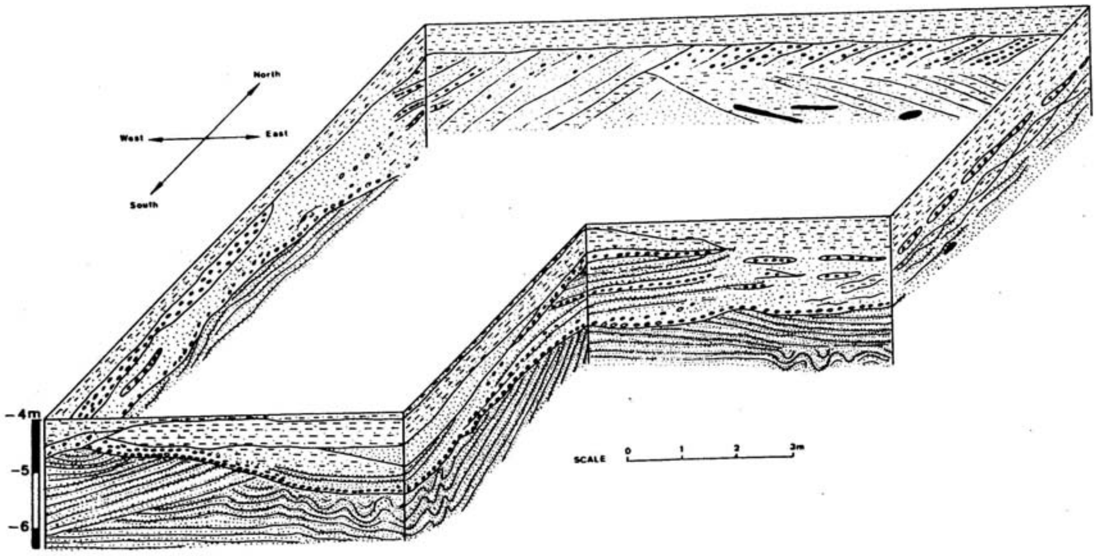


Fig.2.17. Panel diagram of the Quaternary deposits exposed at Gulshan Lake. Coarse grained sediments represent channel deposits of Holocene age. Cross bedded sand have some post depositional sedimentary structures (convolutions and involutions).

Photo-2.1. Section at Aftabnagar. Holocene tidal flat deposits are exposed in the Banashree and Aftabnagar housing areas. Mangroves vegetational fragment can be found in the deposits. Plenty of mangrove pollens are available. There are some reddish-brown islands which are surrounded by these Holocene deposits.

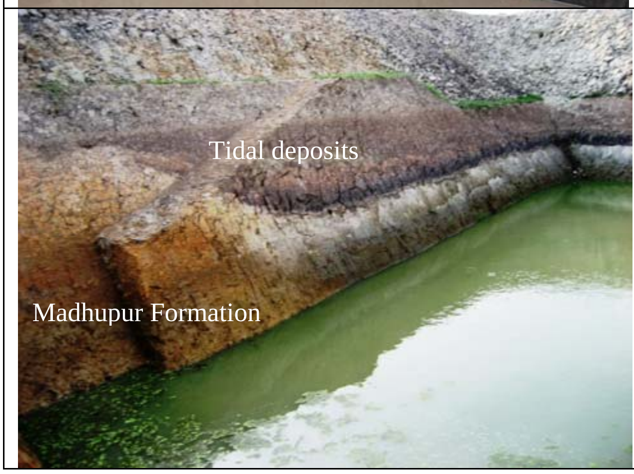


Photo-2.2**.** Section at Simulia rail crossing. Holocene tidal deposits underlain by the Madhupur Formation with an erosional contact. These Holocene deposits contain plenty of mangrove pollens.

f) Flood plains

The Dhaka city is surrounded by recent floodplain (except a small portion of northern side). These are the flood plains of the rivers Buriganga, Balu, Turag and Shitalakhay. The floodplains are annually flooded having some increments of alluvial sediments. Initial Madhupur surface was eroded away during the Late Pleistocene and Early Holocene time and had created some erosional depressions. During Mid-Holocene, these erosional depressions were filled up with brackish water sediments as sea level was high compared to present sea level. Sea level started to drop after mid Holocene and the tidal or brackish water sediments aerially exposed. During the present time, these tidal flood deposits are overlying by annual increments of flood plain deposits.

g) Tidal flat deposits

In the paragraph 2.4, it has been discussed about that the Mid Holocene sea level rise changed the hydrodynamic condition of the river system. Incised valleys were filled up with Holocene sediments. The Buriganga, Turag, Balu and Shitalakhay rivers were acting just like the tidal rivers. Low land areas, in particular areas near the banks of these tidal rivers were inundated with brackish water and tidal sediments were deposited (Photo.2.1 and Photo.2.2). Rasulbag, a locality on the right bank of the river Shitalakhay was the area of a tidal flat. Thickness of tidal deposits more than 30 meters. The lithologic descriptions of the bore has been given in the Fig.2.11.

2.3.1.2. Mid-Holocene Marine transgression and brackish water inundation in and around Dhaka city.

It is quite unfortunate that geologists of Bangladesh can not come out from their traditional old concept introduced by Morgan and McIntire about more than half a century ago (1959). It makes a big hindrance in putting forward a new concept with full of data and logical arguments. Late Quaternary climatic episodes had created erosional valleys and a lot of marginal gullies. The erosional valleys were filled up with Holocene sediments (fluvial and brackish water). North-south elongated terraces and the isolated reddish-brown islands are the results of amplified monsoon water erosion. That’s why Madhupur surface is slightly elevated from the adjacent (erosional) flood plain.

There is lot of evidences that the erosional valleys of Madhupur surfaces in and around Dhaka city had been inundated with brackish water. Brackish water sediments are exposed at the village Sony on the left bank of the Balu river, at Majukhan (Fig.2.18), Nayanipara (Photo-2.15A), Baghabon (Photo-2.15B), Batpara (Photo-2.15C), Pubail, Simulia rail crossing section (Photo-2.2) and Aftabnagar (Photo-2.1) in Dhaka city. Tree trunks, woods and roots of mangroves are available in all sections. Peat samples were dated and collected pollens were identified. Field investigation and laboratory analyses of mangrove pollens confirm the Mid-Holocene marine transgression and brackish water inundation in and around Dhaka city. Detail research works have been performed and are discussed in the following texts.

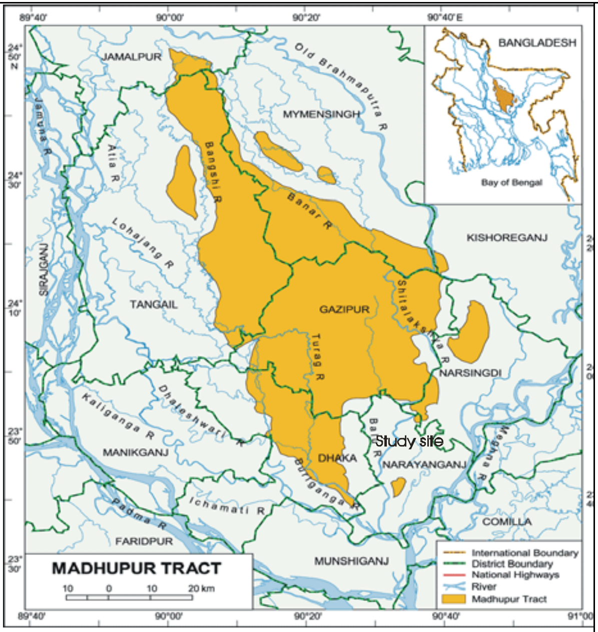


Fig.2.18. Drainage map, showing location of the village named Sony.

Photo-2.3. Quarry at Sony, Isapur.

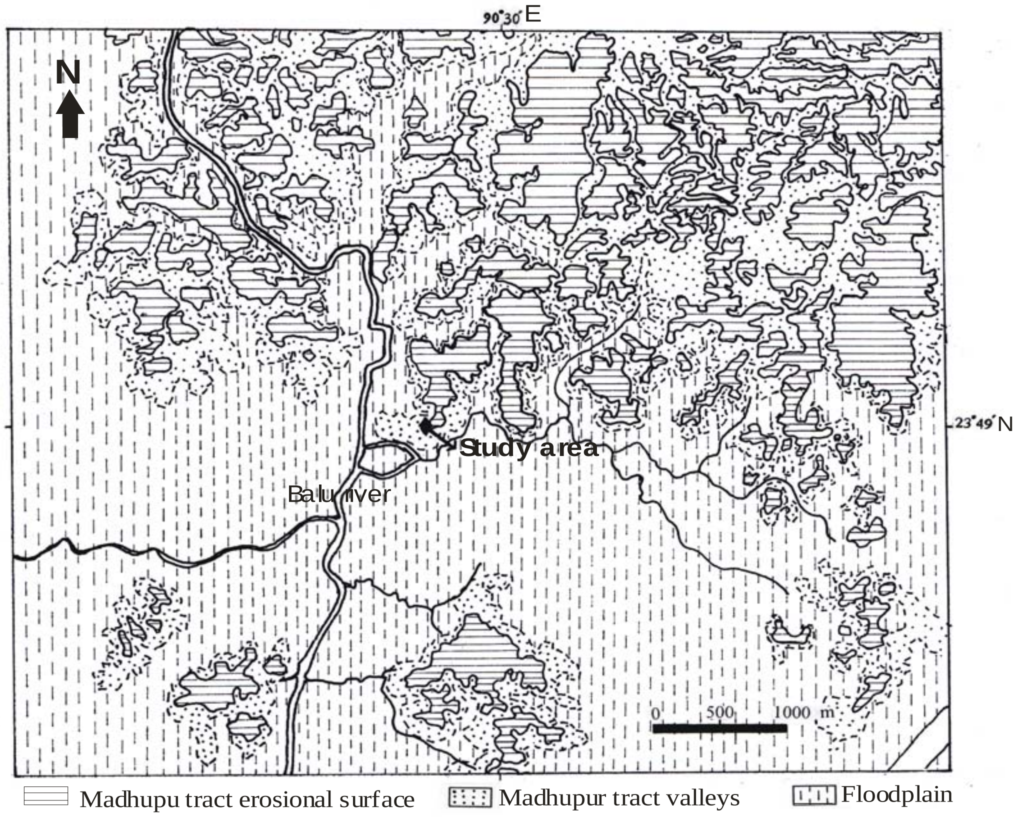


Fig 2.19. Location map. Map shows the geomorphologic units near the exposure at Sony.

Photo-2.4. Course of the r. Balu.

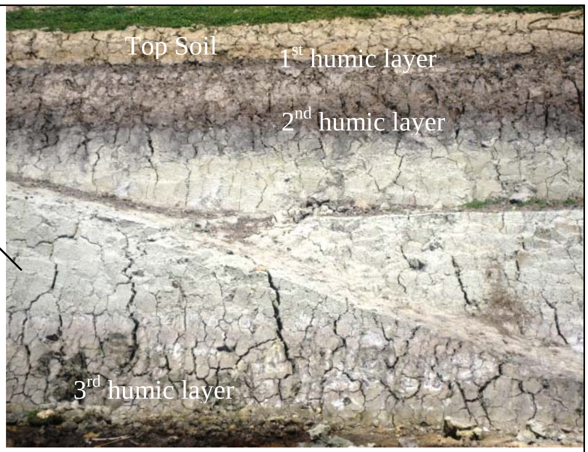


Photo-2.5. Geological cross section at Sony.

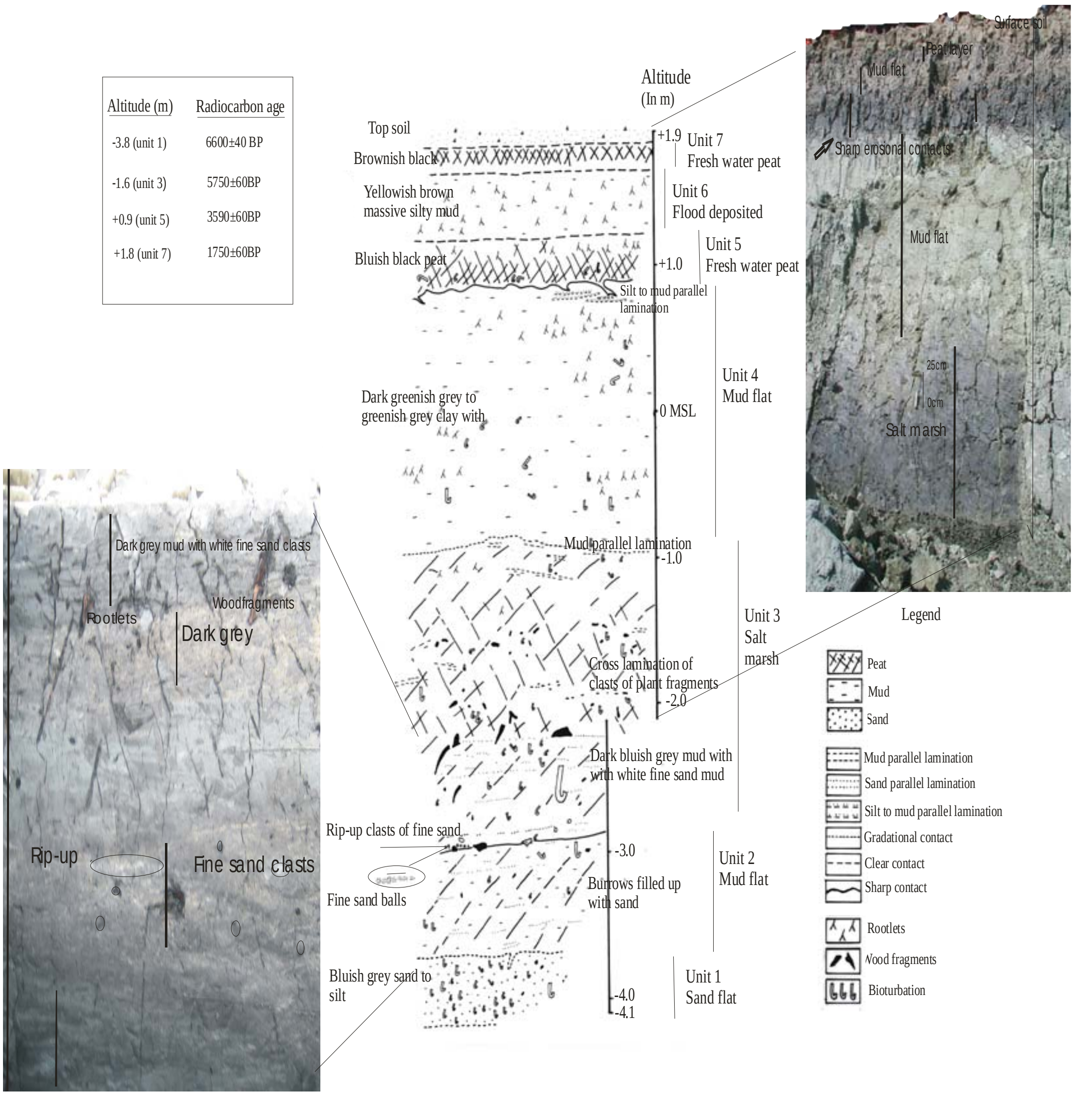


Fig.2.20. A detail cross section with photographs of the quarry at Sony showing lithologic characteristic and sedimentary facies (Towhida, R., Monsur, M.H. and S. Suzuki 2008).

The River Balu and Flood Plain

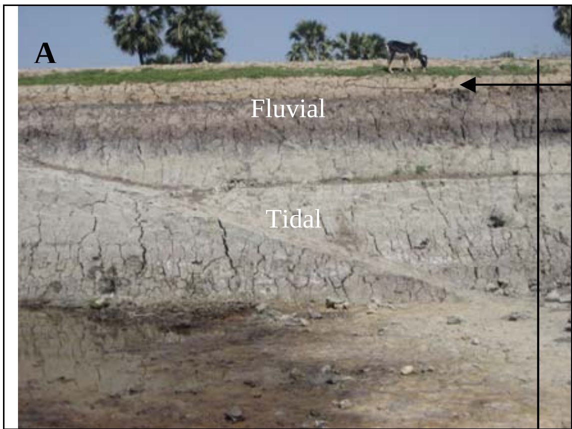
Isapur, Left bank of the r. Balu

Photo-2.6. Flood plain of the r. Balu (left bank, viewed northward from Isapur Bridge. Vegetated area: Madhupur terrace. Planted area: Flood plain of r. Balu.

Photo-2.7. Course of the r. Balu. Viewed southward from Isapur bridge.

Section at Sony

Depth: 6m



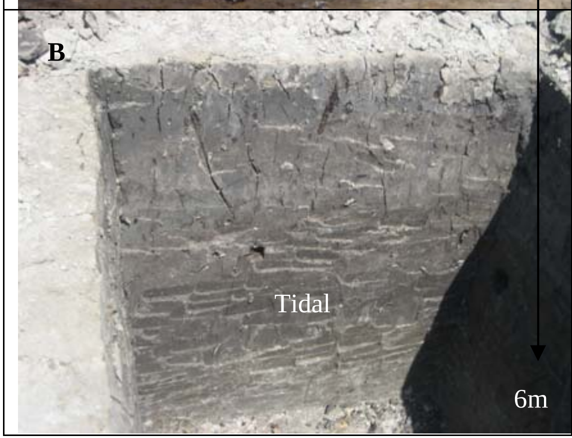


Photo-2.8. At right hand side, Madhupur Clay forms an elevated terrace. Madhupur Clay slope westward under the Holocene bracksh water and flood plain sediements, represented by silty clay (top) and fine sand (Bottom). There are humic layers contain fragments of mangroves. Radiocarbon dates back 1760 to 6600 yrs BP. Mangrove trees: Rhizophoraceae, Myrtaceae, Leguminosae, Sonneratia etc. Brackish water sediments are overlain by fluvial (flood plain) deposits.

2.3.1.3. Basabo Formation at the Locality Sony

A detail sedimentological, diatoms (Photo-2.9), palynological (paragraph-6.1.3, Photo-2.10, Table 2.4), and radiocarbon dating (Table 2.3) were performed with the samples from a section at Sony (Isapur, Rupganj Upazila) on the left bank of the r. Balu (Photos-2.4, 2.6 & 2.7) at the eastern margin of Basundhara housing (Photos-2.3, 2.5 and 2.8). The latitude and longitude of the central point of the section are 23 degree 49 minutes north and 90 degree 29 minutes east, respectively (Figs. 2.19). Erosional gully of the Pleistocene surface, called Madhupur Formation slopes westward (toward the r. Balu) and merges under the Holocene deposits (Photos.2.3, 2.5 and 2.8). Three humic horizons have been noticed in the cross section (Photo-2.5). Fig.2.20 provides lithological descriptions with sedimentary facies. Lithologic descriptions of the section are given in the Table 2.2. It is clear from the Photographs 2.3 and 2.8 that the Holocene Tidal flat deposits (units- 1, 2, 3 and 4) are underlain by basement soil, called Lower Madhupur Formation and then overlain by floodplain deposits (units: 5, 6, 7 and 8). Table 2.3 provides the radiocarbon dates. Marine influences started at about 6600 years BP and ended at about 3590 years BP. After the marine influences, sea retreated when fluvial floodplain sediments over lied the brackish water sediments.

Table 2.2. Environments and Lithofacies descriptions of the section at Sony, Isapur (Towhida et. al., 2008).

name of unit	stratigraphic and lithofacies description	Environment	range of the units (in m)
Unit -1	Bluish grey (5BG 5/1) sand with silty mud, abundant burrows, bioturbated sand	Sand flat intertidal flat, tide dominated estuary (transgression)	-4.10 to -3.70
Unit -2	Light bluish grey (5BG 7/1) to dark bluish grey (5BG 4/1) mud, less organic matter, low angle cross lamination, burrows filled with white fine sand, plenty of wood fragments	Mud flat intertidal flat, tide dominated estuary (transgression)	-3.70 to -2.85
Unit -3	Dark bluish grey (5BG 3/1) mud with high content of organic matter; organic material decreases upwards, parallel lamination in the upper part, wood fragments are common in lower portion, rip-up clasts of fine sand are observed at bottom, cross lamination of clasts of plant fragments	Salt marsh or supra tidal flat, tide dominated estuary (regression)	-2.85 to -0.92
Unit -4	Dark greenish grey (10G 4/1) to greenish grey (10G 6/1) clay, many burrows in the lower part and rootlets in the upper part, mud to silt parallel lamination remains in the upper part	Sud flat coastalplain, intertidal flat (transgression?)	-0.92 to +0.82
Unit -5	Bluish black (5BG 2/1) clay with decomposed organic matter, upper boundary is clear but the lower one is sharp with some cracks which lies with the next mud layer, burrows in the lower part.	Fresh water marshy land (regression)	+0.8 to +1.20
Unit -6	Yellowish brown (2.5Y 5/3) silty clay, plenty of rootlets	Flood deposited mud	+1.20 to +1.64
Unit -7	Brownish black (2.5Y 3/1) organic matter	Very recent fresh water marshy land	+1.64 to +1.81
Unit-8	Top soil	Top soil	+1.81 to +1.9

2.3.1.4. Lithologic escription of the subunits of the section at sony

The general stratigraphy of the Madhupur area has been given in Table 2.1. The Holocene Series in the type locality at Bashabo is very near to the section at the locality Sony. Hence, he Holocene Series at the locality Sony can be called as **Bashabo Formation**. The section at Sony has been considered to an ideal section for Holocene stratigraphy, as the exposed deposits have two depositional environments: Brackish water (Tidal, Marine) and Fresh water (Fluvial, continental) deposits. Detail descriptions of the units are given below (Fig.2.20; Photo.2.3):

Unit 1 (-4.1 to -3.70m from MSL): This is the lowermost unit of the exposed deposits. The unit is bluish grey to dark grey ((5BG 5/1) silty-clay to silty-sand. The unit contains plenty of wood fragment, roots and humic materials. The thickly bedded unit has a burrowing contact with the upper sequence. The unit has been dated by radiocarbon dating and the obtained date is 6600 ± 40 years BP (Towhida et. al., 2008)

Unit 2 (-3.70 to -2.85m from MSL): The unit is light bluish grey (5BG 7/1) to dark bluish grey (5BG 4/1) mud, containing less organic matter. It has low angle cross lamination, burrows filled with white fine sand and plenty of wood fragments.

Unit 3 (-2.85 to -.92m from MSL): The unit is dark bluish grey (5BG 3/1) mud with high content of organic matters; organic materials decrease upward, parallel lamination in the upper part, wood fragments are common in lower portion, rip-up clasts of fine sand are observed at bottom. The unit has gradation boundary with the upper unit. Radiocarbon date indicates that the unit has the age of 5750 ± 60 years BP.

Unit 4 (-0.92 to +0.82m from MSL): This unit represents dark greenish grey to light grey (10G 4/1) very thickly bedded mud. Thickness of his unit is about 1.8 meters. It contains thin parallel mud to silt lamination near the upper sharp boundary. The upper part contains roots and rootlets. Burrows are available in the mid to lower part.

Unit 5 (+0.8 to +1.20m from MSL): The unit is bluish black (5BG 2/1) clay medium bedded peaty clay with plenty of humic materials. This layer is rich in decomposed organic materials. The upper boundary of this unit is not very sharp. The age of this unit is about 3590±60 years BP.

Unit 6 (+1.20 to +1.64m from MSL) : The unit is yellowish brown (2.5Y 5/3) silty clay with plenty of roots and root lets.

Unit 7 (+1.64 to +1.81 m from MSL): This unit is black to dark grey medium bedded peaty clay and is very close to the surface.

Unit 8 (+1.81 to +1.9m from MSL): This is top soil. It is classified as inceptisoil.

Table 2.3. Radiocarbon dates of peat samples of the section at Sony.

Unit (range in m)	Altitude (in m)	Material	^{14}C Age	Calibrated ^{14}C (BP)
Unit -7 (+1.64 to +1.81)	+1.8	Peat	1760±60	1750±60
Unit -5 (+0.8 to +1.20)	+1.2	Peat	3560±60	3590±60
Unit -3 (-2.85 to -0.92)	-1.6	Peat	5819±60	5750±60
Unit -1 (-4.1 to -3.70)	-3.75	Wood	6690±40	6600±40

2.3.1.5. Palynological studies

Palynological studies were performed in the Geology department of Dhaka University as well as in Okayma University Japan (Table 2.4; Towhida et. al., 2008). The followings are the mangrove tree pollen indicating the environment of deposition.

Unit -1 (6600±40 BP)

The unit is dominated by Mangrove trees, such as *Rhizophoraceae* (28.9%), *Myrtaceae* (17.2%), *Leguminosae* (7.0%), *Sonneratia* (3.5%). The zone is also characterized by tropical rainforest trees such as *Elaeocarpaceae* (2.6%), *Barringtona*, *Combeataceae*, *Bytteneria*. In addition, some mangrove pollen like *Arecaceae*, *Avicennia*, are also found and *Myrica*, *Rhamnaceae* (2.3%); *Anacardiaceae*, *Melastomataceae*, *Castanopsis/Lithocarpus*, *Cetis/Aphananthe* (0.6%) are recognized. These mangroves indicate that the depositional environment was a Supratidal flat.

Unit -3 (5750±60 BP)

This unit is characterized by mangroves, tree pollen like, *Rhizophoraceae* (16.9%), *Leguminosae* (11.8%), *Sonneratia* (7.9%), *Myrtaceae* (4.7%). In addition, it includes grass pollen like *Gramineae* (7.5%), *Rhamnaceae* (5.8%), *Apocynaceae*, *Quercus subgen*, Cyclobalanopsis, *Trema*. A few other mangrove trees such as *Myrsinaceae*, *Grewia*, *Nypa* are also found in this zone. It was a salt marsh area of a coastal plain.

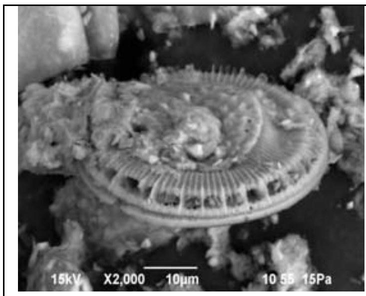
Unit -5 (3590±60 BP): This unit is dominated by grass pollen, such as, *Gramineae* (32.3%), *Cyperaceae* (7.3%), *Phyllantus* (4.6%), *Euonymus* (2.0%) and so on. These pollens indicate an open grassland. It is thought that freshwater environment was prevailing during that time.

Unit -7 (1750±60)

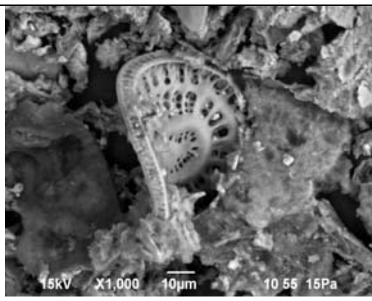
This uppermost unit is characterized by large type of *Gramineae* (41.9%) with *Cyperaceae* (9.5%), *Umbelliferae*, *Lygodium* and *Utricularia*, probably originated from cultivated plants. These pollens indicate that the area is a floodplain.

2.3.1.6. Diatom analysis

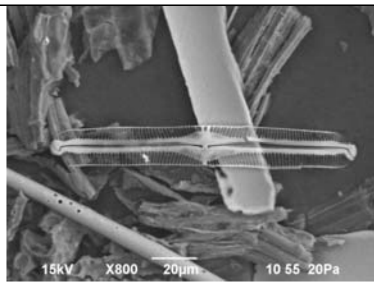
Two marine diatoms have been observed and these are *Cyclotella striata and Campylodiscus sp.*



Cyclotella striata

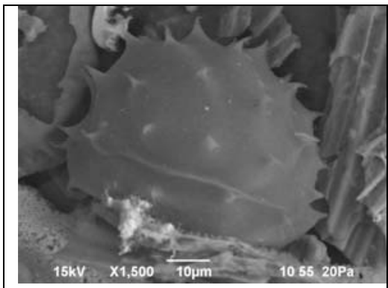


Campylodiscus sp.

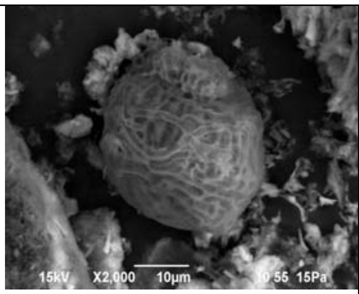


Diatom filamen

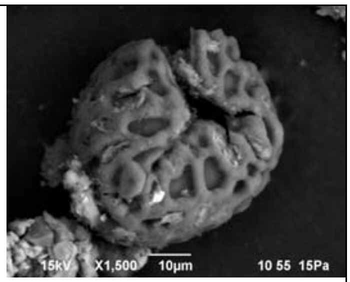
Photo-2.9. Photographs of Diatoms with the aid of Scanning Electron Microscope (SEM), Section at Sony, Isapur, Purbachal, Rupgonj, Greater Dhaka City.



Couperipollis brevispinous



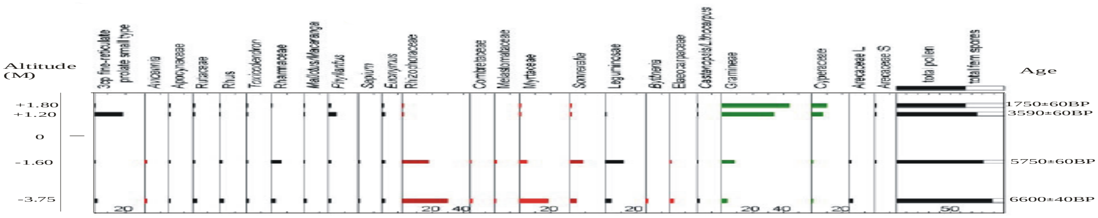
Exoecaria sp.



Corrugatisporites formosus

Photo-2.10. Photographs of Pollens of mangroves with the aid of Scanning Electron Microscope (SEM), Section at Sony, Isapur, Purbachal, Rupgonj, Greater Dhaka city

Table 2.4. Pollen Frequency diagram



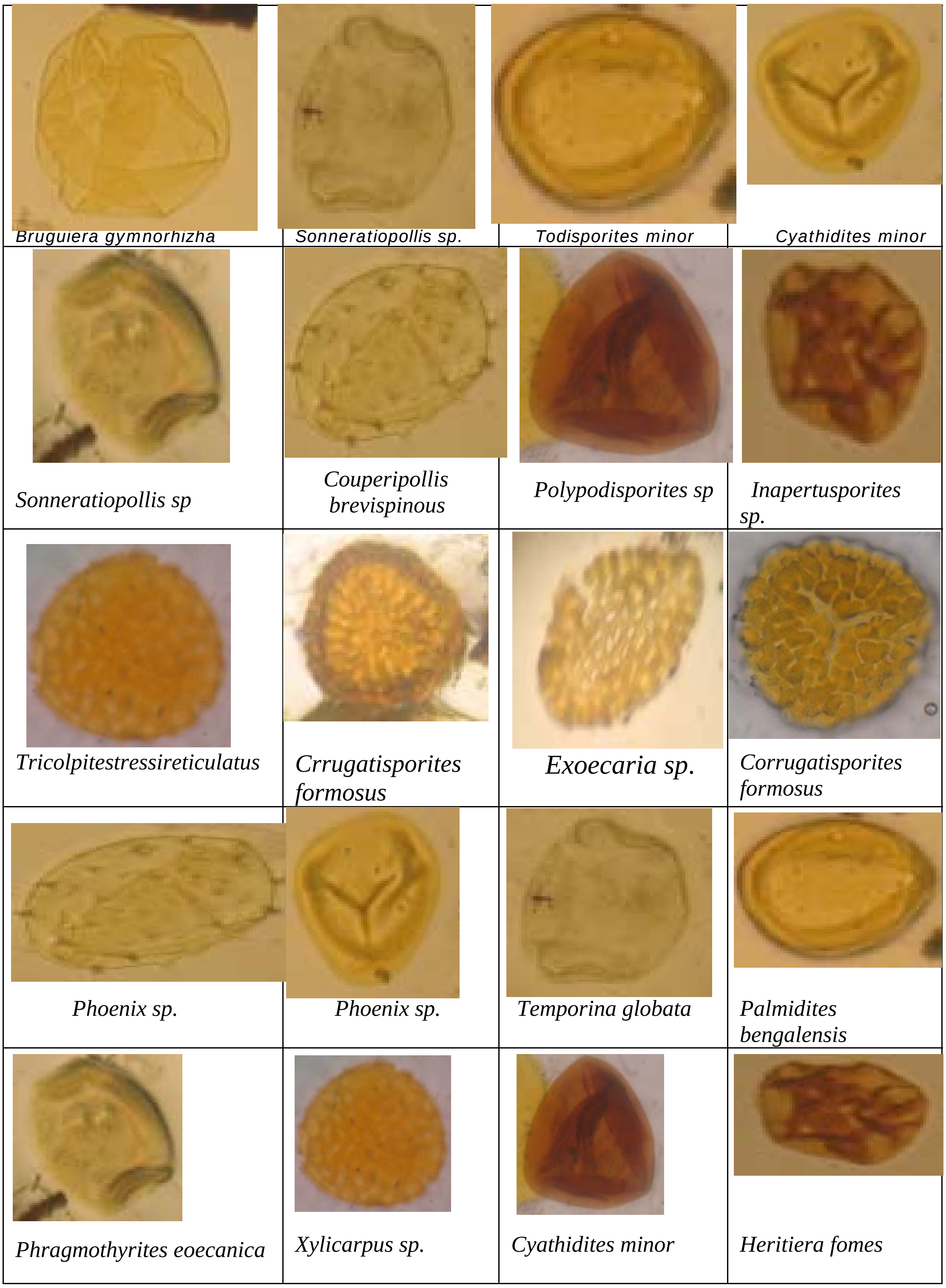


Photo-2.11. Photographs of pollens, mostly mangroves, identified with the aid of binocular microscope. Section at Sony.

 *Nyssapollenites sp.*	 *Palmaepollenites longicolpus*	 *Sonneratiopollis bellus*

Photo-2.12. Photographs of pollens, mostly mangroves, identified with the aid of binocular microscope. Section at Baghabon, Polash, Norsingdi. Pollens are found at 1.2m above sea level.

Pollens discovered at Batpara

Norsingdi

(3m above the MSL

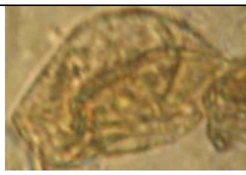
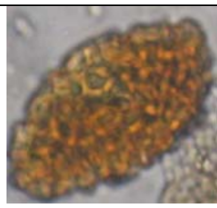
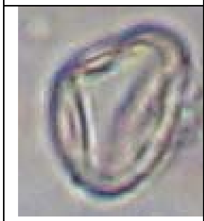
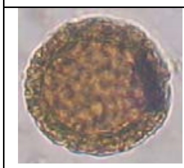
 *Xylicarpus sp.*	 *Aegicerus sp*	 *Rhizophora sp.*	 *Heritiera sp.*	 *Exoecaria sp.*
 *Bruguiera sp*	 *Melliapollis sp*	 *Striatriletes indicus*	 *Aegicerus comiculatum*	 *Xylicarpus sp*
 *Melliapollis sp*	 *Avicennia sp.*	 *Xylicarpus sp*	 *Phoenix paludosa*	 *Xylicarpus sp.*

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Photo-2.13. Photographs of pollens, mostly mangroves, identified with the aid of binocular microscope. Section at Batpara, Norsingdi.

Section at Majukhan, Pubail, Greater Dhaka city

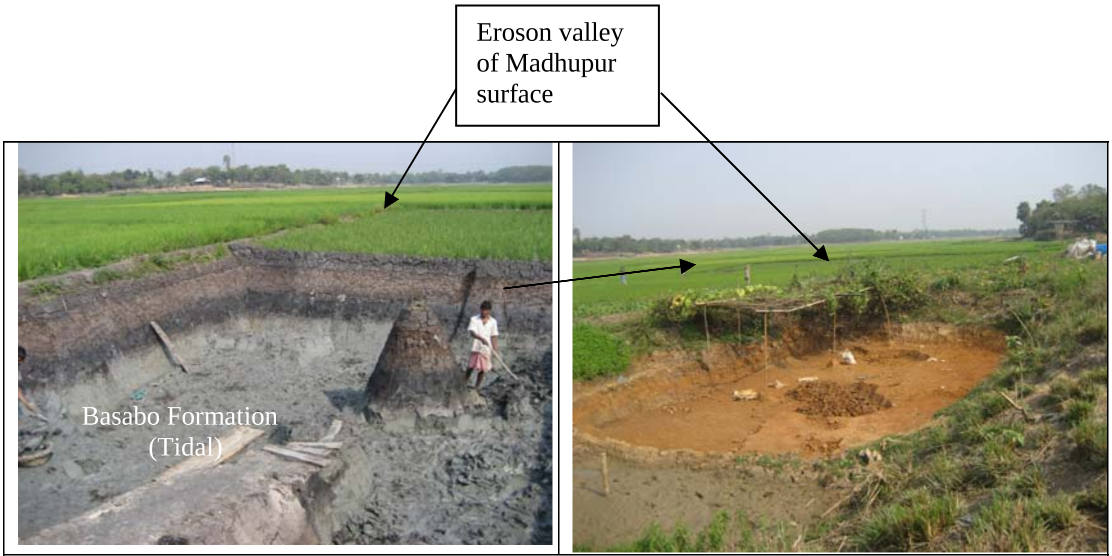


Photo-2.14. Right hand side: Erosion margin of Madhupur Formation (red coloured deposits) slopes westward (left) under Holocene dark colour humic clay (Left photo). There are two humic horizons. The lower horizon has been dated by radiocarbon dating. Palynological results indicate that those are the peat of mangroves. It mean that the erosional surface of Madhupur Formation was inundated with brackish water at about 6600 years BP.

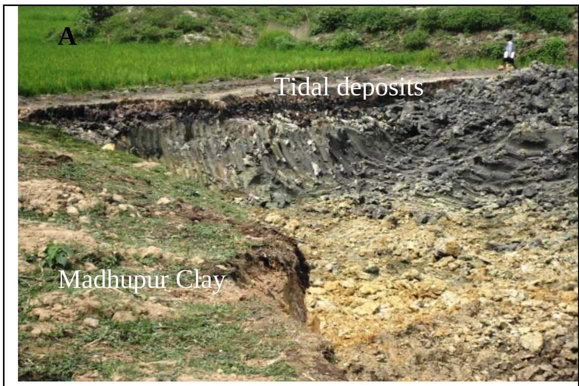
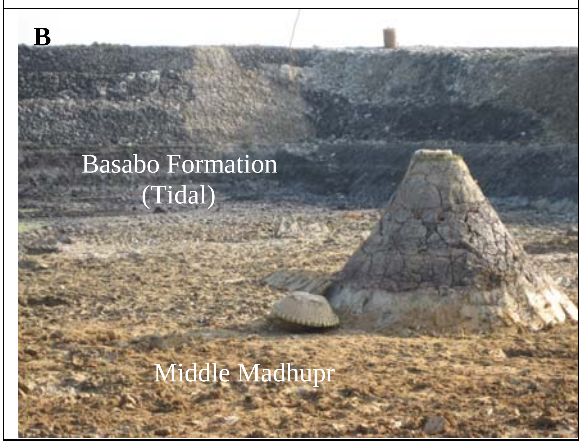


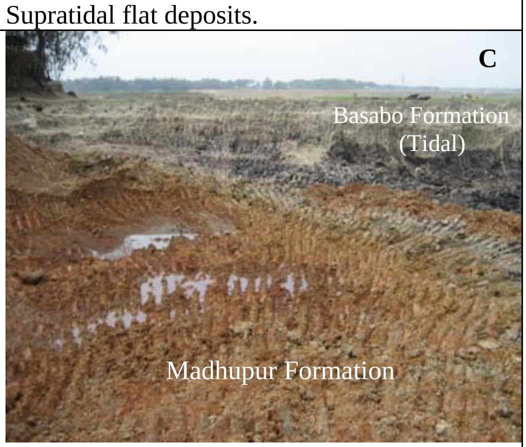
Photo-2.15.

A - Section at Nayanipara, Pubail. Middle Madhupur is overlain by Tidal Holocene Series.

B - Section at Baghabone, Polash, Norshindi. Middle Madhupur is overlain by Basabo Formation. Presence of mangroves indicate that the deposits are Supra tidal.

C – Section at Batpara, Norsingdi. Erosional margin of the Madhupur slopes under the Holocene deposits. Palynological studies indicate that the Holocene sediments are Supratidal flat deposits.





2.3.1.7. Summary

Hence, Holocene sediments are deposited on the erosional Pleisotocene surface of the Madhupur Formation. Geomorphologically those are the erosional valley fill and gully fill, abandoned channel fill, point bars, river bars, floodplain, tidal and supratidal flood deposits. Late Pleistocene fluvial channel deposits (Fluvial) were overlain by brackish water (Tidal and Estuarine) deposits at the Middle Holocene (around 6000 years BP). After Mid-Holocene sea level rise, tidal influence culminated in and around Dhaka city. The 'Null Point' of the tidal rivers moved southwards and fresh water dominated the river valleys. The tidal deposits were aerially exposed and seasonally flooded with suspended fluvial sediments. Thus the tidal or brackish water sediments were again covered by fluvial or flood plain sediments. These tidal and fluvial sediments are more or less compacted due to the aerial exposition compared to the tidal deposits of Chittagong city where Holocene tidal unconsolidated sediments are soft having very low STP.

2.3.2. Madhupur Clay Formation

2.3.2.1. General characteristics and subdivision of Madhupur Formation

The deep reddish-brown deposits exposed in the Madhupur tracts are called **Madhupur Clay Formation**, represented by highly weathered micaceous sand and clay. Madhupur Formation has been subdivided into three Members (bottom) and two beds (top). The uper Member of the Madhupur Formation so intensively weathered that the deposits became almost red in colour and powdery materials (Photos-2.16 and 2.17). The upper member is highly weathered yellowish-brown micaceous sticky clay, in some places, it has deep reddish-brown colour, mottled structure, containing ferruginous concretions and pipe stems. Micromorphologically, the upper member of the Formation has amorphous pedofeature. The upper member is called **Dhaka Clay Member**. The middle member of the Madhupur Formation is called **Mirpur Silty-clay Member** and is represented by micaceous silty-sand and clay. It has mottled structure and has distinct oxidation and reduction spots. Micromorphologically, this kind of texture is called depletion pedofeather. The lower member of the Formation is called **Bhaluka Sand Member,** represented by highly micaceous fine sand having primary sedimentary structure. It has bridged grain pedofeature. The lower Member is less weathered and has greater thickness. On the top of the upper Member there lie two beds which are called Kalsi Beds. The Beds were first observed at Kalsi brickyards and had already been dug out. The upper Kalsi Bed is light coloured sand dominated clay and the lower Kalsi Bed is yellowish brown very sticky clay. These two beds are the palaeo-valley fill deposits, occurs discontinuously on the upper Member of the Madhupur. These erosional valleys were formed on the surface of the upper Member of the Madhupur long before. This sticky clay bed can be found at Shaheengarh (Photo-2.21, Photo-2.22 and Photo-23), Uttarkhan and Matuail (Photo-24). It is very similar to the middle member of Madhupur Formation.

Top part of the Madhupur Formation, sometimes, is called Madhupur Residuum (GSB) because of its level of chemical weathering. Mica and feldspars were easily weathered to clay minerals. On the other hand, decomposition of organic materials enhanced the Fe^{+2} and Fe^{+3} ions in the deposits. In contact with air and water ferrous and ferric ions chemically formed ferrous and ferric oxides and hydroxides. Hematite, limonite, goethite, maghemite etc. are the prominent minerals. That's why the colour of the Formation is brown and the process is called brownification.

Madhupur Formation is unconformably underlain by Dupi Tila Sand Formation. The boundary between the Madhupur and Dupi Tila Formation is represented by a quartz-chalcedony gravel bed, called Comilla Gravel Bed. Quartz-chalcedony gravels are smooth, seems to be fluvial or channel deposits. These gravel bed represents a marker horizon and can be found all over the country. This is not a continuous bed, as gravels are the bed load sediments and deposited only on the river beds. The gravel bed is exposed in Ranirbanglow section of Lalmai Hills. This gravel bed represents an unconformity. The Formation belongs to the Pleistocene Epochs of the Quaternary Period.

CENTRAL HIGH LAND OF DHAKA CITY
Secton at Fargate, South of Ananda Cinema Hall, Dhaka City.

Photo-2.16. Total depth:7 m.

Madhupur Clay Formation
Upper: Highly weathered and oxidized reddish-brown clay.
Middle: Yellowish brown silty clay.
Lower: Highly micaceous yellowish fine sand.

Photo-2.17. Shows the intense weathering of the Upper Member of Madhupur Formation. Section at Mirpur-1, Beside Muktijadhay Supper Market, Dhaka City.

Dupi Tila Formation is represented by sandstone and intercalated shale beds. Coarse to fine grained sandstones have well defined colour bands. These sandstones sometimes contain silicified wood fragments. The formation is fluvial origin, having primary sedimentary structures: ripple marks, cross bedding etc. Initially, the Dupi Tila Formation was thought to be Pliocene in age. Recent publications indicate that the Formation has the age of Pleistocene.

2.3.*2.2. Extension of Madhupur Formation in and around Dhaka City.*

The complete or whole sequence of Madhupur Clay Formation is exposed in the central zone of Dhaka city and it extends considerably toward the north (Fig.). Early Holocene climatic episodes created the undulated topography. Sometimes, upper part or sometimes up to the middle part of the Formation eroded away and the erosional surfaces were covered by Holocene deposits. In most areas of Dhaka city (except some deeply incised river valley) middle or lower Member of Madhupur Formation can be found beneath the Holocene deposits. Gulistan, Dhaka University Campus, Azimpur, Mohammadpur, Dhanmadi (except lakes and valley fill areas), Mirpur, Farmgate, Tejgaon, Uttara, Tongi, Joydevpur are the areas where complete section of the Madhupur is exposed. There are some gullies and incised valleys or erosional depressions where middle or lower Member of the Madhupur is overlain by Holocene Series.

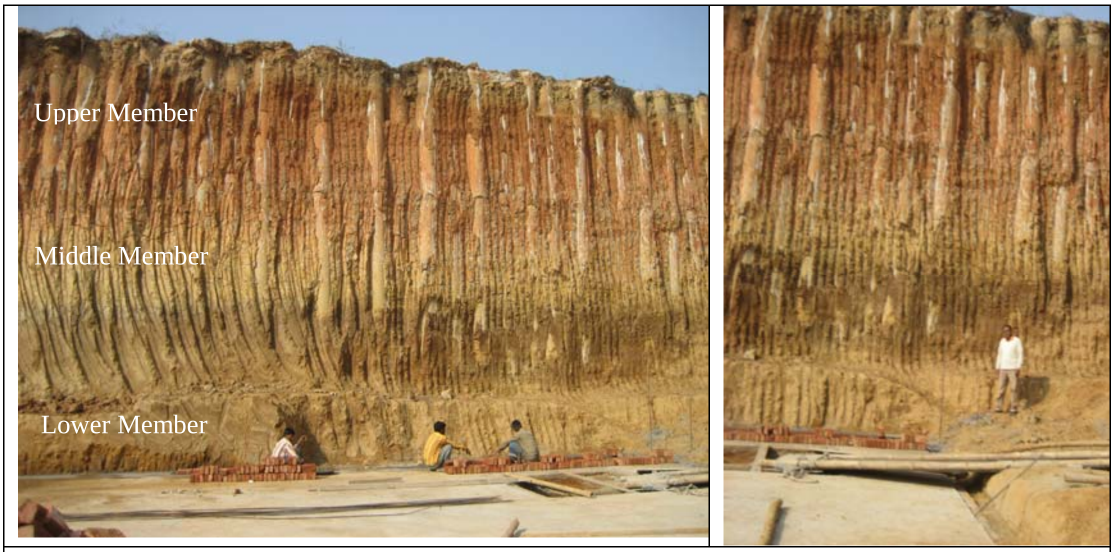


Photo-2.18. Section at Nikunja-2, Joarsahara. Dhaka city. An ideal section for Madhupur Formation up to the depth: 10m. Basement contruction of Pran Company's Building.
(left, west wall; right, north wall): **Madhupur Clay Formation.** Upper Member: Highly weathered and oxidized reddish-brown mottled clay, containing ferruginous nodules, pipe stems and manganese spots. Middle Member: Yellowish brown miaceous silty-sand, containing ferruginous nodules. Lower Member: Highly micaceous light yellowish brown fine sand. The Lower Member contains primary sedimentary structures, ripple marks, cross bedding, herringbone cross bedding etc. The Lower Sand Member have intraformational silty-shale or clay layers.

Kalsi Brickfield

Mirpur-12 (Fig. 9)

(Type Section of Madhupur Formation), Total depth: 14m

Photo-2.19a. Upper Member of Madhupur Formation. Highly weathered and oxidized reddish brown mottled clay. Highly micaceous containing iron concretions, pipe stems and manganese spots.

Photo-2.19b. Middle Member of Madhupur Clay Formation. Yellowish brown micaceous silty-clay, containing plants' roots, pipestem and manganese spots.

Kalsi Brickfield

Mirpur-12

(Type Section of Madhupur Formation)

Photo-2.20a. Middle Member of Madhupur Formation. Sometimes, process of kaolinitization is very active.

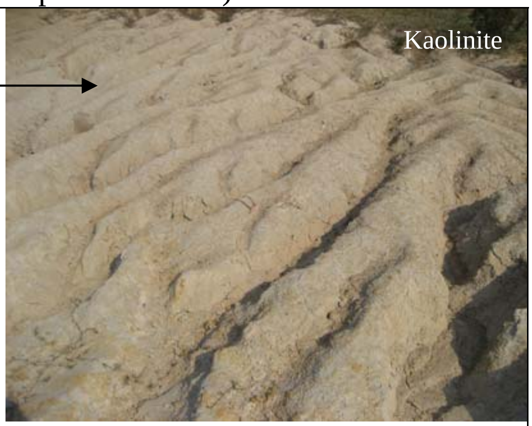


Photo-2.20b. White clay (Kaolinite), Middle Member of Madhupur Formation.

On the top of the Upper Member of the Madhupur Formation overlies the Lower Kalsi Bed. The Kalsi Bed is represented by yellowish-brown, very sticky sand-silt-clay or swelling soft clay. Kalsi Bed is very similar to Madhupur Clay but is much younger and is less weathered. It has sporadic extension and can be found only on the depressions and erosional valleys of Madhupur surfaces. The lower Kalsi Bed shows reversed polarity indicating Matuyama Epoch (within 0.90 million years to 73 million years BP). On the other hand upper Kalsi Bed is light coloured silty clay, only found in the Kalsi brickyard. The deposits are already been dig out.

Photo-2.21. Section at Shaheengarh, Pubail. Kalsi Beds of Madhupur Formation is exposed.

Photo-2.22. Section at Shaheengarh, Pubail, Lower Kalsi Bed. Thick deposit of yellowish-brown swelling clay

Photo-2.23. Section at Shaheenbug, Pubail. Kalsi Beds. Top: Upper Kalsi Bed. Bottom: Lower Kalsi Bed.

Photo-2.24. Section at Konapara (DND) bus stand. Section shows soft clay of Lower Kalsi Bed.

2.3.2.3. Summary

In short, highly weathered reddish brown, sometimes, deep-brown compacted clay exposed in the Central Zone of Dhaka city is called Madhupur Formation. The Formation has been subdivided into three Members and two Beds. The Member are called, i) Dhaka Clay Member (upper). It is strongly weathered, swelling clay, ii) Mirpur silty-clay Member (middle), reddish-brow sand, having mottled structure and Bhaluka Sand Member (lower), Less weathered micaceous fine sand containing primary sedimentary structure. On the top of the upper Member of Madhupur Formation lie two beds, are called Kalsi Beds (upper and lower). Kalsi Beds were deposisted on the erosional valleys of the Madhupur surface.

CHAPTER – THREE

3. QUATERNARY STRATIGRAPHY OF CHITTAGONG CITY

3.1. The port City "Chittagong"

Chittagong City (Fig.3.1) is not only the principal city of the district of Chittagong but also the second largest city of Bangladesh. It is situated within 22°-14´ and 22°-24´-30´´ N Latitudes and between 91°-46´ and 91°-53´ E Longitudes and on the Right Bank of the river Karnafuli. Historians have given various explanations as to the origin of the name Chittagong. Bernoli in his Description Historique et Geographic de L'Inde (1786) explains that the name Chittagong came from the Arabic word Shat (delta) prefixed to Ganga (Ganges), indicating the city at the mouth of the Ganges (Banglapedia).

Chittagong is the major port city of Bangladesh. Being a port city from early times, Chittagong attracted people from various regions of the world. These international contacts left a lasting impact on the language, religion and culture of the city. The early history of Chittagong is not very clear. Burmese chronicles speak of a long line of kings over the region of Arakan, which included Chittagong in the sixth and seventh century AD. The names of these kings invariably ended with the title Chandra. Historian Lama Taranath mentions a Buddhist king Gopichandra who had his capital at Chittagong in the tenth century. According to Tibetan traditions Chittagong was the birthplace of the Buddhist Tantric Tilayogi, who lived and worked in the tenth century. Al Idrisi, writing in 1154 AD, states that Arab merchants from Baghdad and Basrah frequently visited an area near the mouth of the Meghna, which is now generally believed to be Chittagong. Other travellers and historians have recorded Arab contacts with Chittagong as far back as the ninth century AD. Apart from the merchants, many *sufis* and saints also visited and settled in Chittagong. The conquest of Bengal by BAKHTIYAR KHALJI in 1204 led to large-scale Muslim settlement in Chittagong. The frequent intercourse with people of different races, religions and cultures which trade and settlement entailed left a permanent mark on the physical features, dialect and religion of the people of Chittagong.

3.2. Growth and Development:

In 1947 the area of the town of Chittagong was only four and half square miles and was centered around the low and small hillocks which were found scattered all over the city. Dampara, Nasirabad, Katalganj, Kapashgola and Solokbahar bound the town on the north, the Karnafuli on the south, Chaktai nullah on the east and Madarbari, Pathantuli and Dewanhat on the west. Originally the town was confined within this limit. With rapid industrialisation and development the town soon grew into a city outstripping the old Municipality area. The city extended southwest up to Patenga where the Chittagong international airport is now located. Its expansion to the west incorporated the villages of Halishahar, Askarabad and Agrabad. The government acquired the land of these villages to construct offices and commercial firms. To the north it extended up to Faujdarhat and the Chittagong Cantonment area and in the northeast up to Kalurghat.

By 1961 the CDA drew up a "Regional Plan" covering an area of 212 square miles and a "Master Plan" covering an area of 100 square miles. From the funds provided by the UNDP and UNCHS the following Master Plan was drawn up for Chittagong City during the years 1992 to 1996: (a) A structure plan for 1154 square kilometres of Chittagong city and the adjoining area, (b) Urban area Master Plan for Chittagong City, (c) Multi-Sectoral Investment Plan for the development of Chittagong City on a priority basis in a planned and balanced way, (d) Master Plan for drainage and flood-protection of Chittagong City, (e) Master Plan for easing the traffic congestion in Chittagong and for improvement of the traffic handling capacity of the city system, (f) Proposals for updating the laws and rules relating to City Development and plans for restructuring the administrative system of CDA, and (g) Manpower development for better functioning of CDA and transfer of technology for future city planning and development.

3.3. Topography

Chittagong is very different in terms of topography, with the exception of Sylhet and northern Dinajpur, from the rest of Bangladesh, being a part of the hilly regions that branch off from the Himalayas. This eastern offshoot of the Himalayas, turning south and southeast, passes through Assam and Tripura State and enters Chittagong across the river Feni. The range loses height as it approaches Chittagong town and breaks up into small hillocks scattered all over the town. This range appears again on the southern bank of the Karnafuli river and extends from one end of the district to the other. Chandranath or Sitakunda is the highest peak in the district, with an altitude of 1152 feet above mean sea level. Nangarkhana to the north of Chittagong town is 289 feet high. In the town itself, there is a peak known as **Batali Hill,** which used to be 280 feet high and was the highest point in Chittagong City. There was a light post at the top of Batali Hill for the guidance of vessels far away in the sea. This famous hill, like other beautiful hills and hillocks in the city of Chittagong, is being gradually leveled up and reduced in height for the construction of houses.

3.4. Artificial lakes

Chittagong district possesses no natural lakes. As a result several artificial lakes and ponds or *dighis,* as they are popularly known, are found all over the district. A large number of dighis, big and small, were dug during the Muslim period. The most popular reason given for the presence of such a large number of ponds is that during the Muslim period it was felt necessary to provide ponds for the use of the womenfolk of the town. Therefore almost every well-to-do house had a pond or a dighi. Among the big ponds in Chittagong city mention may be made of *Laldighi*, *Kamal Daha's dighi*, *Askar Khan's dighi* and *Belowa dighi*. Many of these dighis have been filled up. Laldighi is still an important place. A boundary wall has protected the entire dighi. Most of the large public meetings in Chittagong are held in the field next to Laldighi. This field is known as the *Laldighi Maidan*. The Assam Bengal Railway dug two artificial lakes (in 1920 and 1924) near the Pahartali Railway Station. These lakes are called “Jora Dighi” served as reservoirs to supply water to the Railway. Foy's Lake was dug in 1924 and was named after the Railway engineer Foy. Both the lakes are places of attraction because of their beautiful location**.** The city of Chittagong is well communicated by air, water and rail ways.

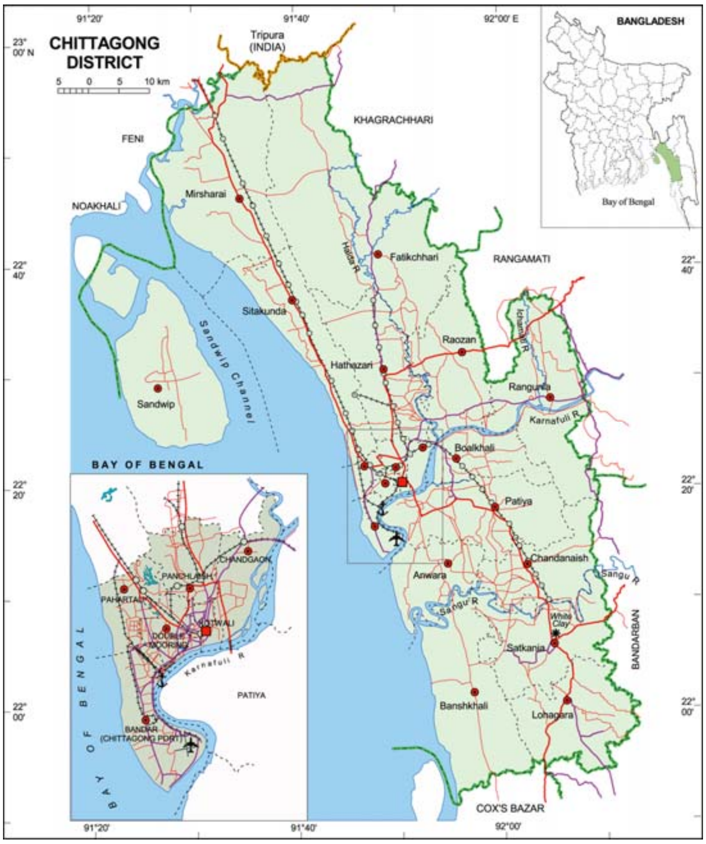


Fig.3.1. Map of Chittagong district and the port city.

3.5. General stratigraphy – A literature Review

Chittagong city offers limited scope of geological studies because of lack of rock exposures due to urbanization and dense vegetation. The rock exposures are found along the streams and hill slpoes. Road-cutting and quaries also offer opportunist for the study of rock at places. All the rock units as such may be named after the Tertiary succession of Assam. A general geological succession of Chittagong City is given in the following table 3.1.

Table 3.1. Geological succession of Chittagong City (after Muminullah, 1978)

Epoch	Group	Formation	Lithology description	Thick-ness (m)
Recen		Alluvium	Dark clay, silt and sand	
Pleistocene		Dihing	Sandstone, ill sorted, pebbly and mottled clay	
Plio/ Pleistocene		Dupi Tila	Yellowish brown medium grained sandstone with subordinate slty shale or clay layer.	200
Miocene	Tipam	Girujan Clay	Shale and silty-shale with calcareous bands.	200
		Tipam	Yellowish brown medium to fine grained sandstone with subordinate silty shale layers. Cross bedded.	800
	Surma	Bokabil	Sandstone, siltstone and shale. Sandy shale with subordinate massive sandstone. Cross bedded, ripple marks and thickly bedded.	500
		Bhuban	Fine gained sandstone with subordinate sandy shale and siltstone (upper). Greyish coloured sandy shale with subordinate buish grey laminated silty shale.	450

A general lithostratigraphic succession in the Chitagong district has been described in the following text. Not all the units, those are described in the following texts, have not been exposed in the metropolitan areas of Chittagong City. However, some highlights of the lithostratigraphic units are described in the following text for clear understanding of regional stratigraphy.

A. Surma Group

Surma Group is consists of two Formations: i) Bhuban Formation and ii) Bokabil Formations. It is very difficult to make a sharp boundary between these two Formations, as both the Formations are coastline deposits depositional environments were very sensitive to the sea level changes; environments changed from shallow marine to coastal plain environments and vice-versa. In general, fine grain sediments dominate in Bhuban Formation where as coarse grain sediments dominate in Bokabil Formation. Because of the absence of some distinct boundary stratotype, further detailed subdivisions of the individual Formation have avoided in this discussion.

i) Bhuban Formation

Bhuban is the oldest Formation occupies both the flanks around axial region. Bhuban Formation consists of shale, sandy shale, siltstone and sandstone. Middle Bhuban is the oldest exposed rock of the area and occupies the core of the axis of the Sitakund anticline. The unit is characterized by dark grey thin bedded, well cleaved sandy shale. Hard and compact irregular calcareous sandstone lenses are found in this Formation. Thinly laminated to thinly bedded shale with flaser or lenticular beddings, Sometimes, herringbone cross beddings are very common sedimentary structures. The Formation is well exposed in Baraiyadhala, Sitakund and Barabkund areas.

ii) Bokabil Formation

Bokabil Formation occupies the eastern flank as well as both north and south plunge areas of the Sitakund anticline. The Formation is characterized by sandy shale, siltstone, massive sandstone and alternations of sand and silt. The lower part of this Formation is constituted of sandy shale, siltstone and massive sandstone. Sandy shales are grey coloured laminated and well cleaved. Siltstones are grey, laminated and occasionally ripple marked. Sandstones are grey, fine to medium grained, moderately consolidated and massive. Litholgical variations of the lower and upper parts of this Formation are not so much distinct. Medium to large sizes calcareous concretions are very common in this Formation.

B. Tipam Group

Tipam Group consists of two Formations: i) Tipam Sandstone Formation and ii) Girujan Clay Formation. Tipam Formation is well exposed in the Chittagong Hill range areas.

i) Tipam Sandstone Formation

Geological Survey of Bangladsh (Muminullah, 1978) has subdivided the Tipam Sandstone Formation into three subunits: lower, middle and upper. The lower Tipam Sandstone is greenish grey and weathered to reddish brown, highly ferruginous, medium grained, friable and cross bedded. It is characterized by the presence of grey siltstone intercalated with hard calcareous concretions with soft chocolate brown ferruginous concentric coatings. Middle Tipam is dominated by shale and clay. The shale is bluish grey, soft, laminated and sandy at the upper part while the clay is dark grey. Hard calcareous sandstone lenses are found in association with this middle shale unit. The upper Tipam sandstone consists of massive brown sandstone with subordinate bedded grey sandstone and siltstone.

ii) Girujan Clay Formation

The Girujan Clay Formation is well exposed in the Hari river-cut section in Jaitiapur area of Sylhet district. Some geologists claim that the Girujan Clay is exposed in the Chittagong area. The author of this report has not found in exposure of Girujan Clay in Chittagong area. Degradation of shales of Surma or Dupitila seem to be very similar to Girujan Clay. But those are the weathering product of Surma Group or Dupitila Formation.

Dupitila Sand Formation

Dupitila Formation is constituted of massive sandstone with subordinate sandy clay and siltstone. The upper part of the sequence is characterized by pink and brown coloured bands, cross bedding, the presence of quartz pebbles and grey sandy clay beds. The lower and middle parts of the Formation are massive and have yellow to yellwish brown coloured bands. The massive sandstone is brown to yellowish brown, medim to coarse grained with subangular grains and friable. Silicified woods are found in the middle part of this Formation.

Dihing Formation

Dihing Formation in Assam represented by coarse grained sediments, such as, pebbles, cobbles, boulders and coarse sands.

Alluvium

There is a vast stretch of land on either side of the Sitakund Anticline with recent alluvial deposits. The old channels of the Karnafuli river and the river Halda are also filled up with recent sediments. Dark grey sticky clay, silt , fine to medium sand and organic matters are the main ingredients of alluvial sediments.

3.6. An outline of the sea level changes during the Quaternary Period

Before going through the details of stratigraphic subdivision and Quaternary mapping of the exposed deposits in Chittagong metropolitan area, it is quite relevant to discuss about the scenario of the sea level during the Quaternary as the City of Chittagong is situated on the coast of the Bay of Bengal and on the right bank of the tidal river Karnafuli.

Sea level changes are directly related to the climatic changes. Due to the variation of solar radiation global climate changes periodically in some long term, intermediate term and short term cycles. One hypothesis that has attracted much critical attention is the **‘Astronomical Theory’**, developed by Croll over 100 years ago. This theory subsequently elaborated by the Yugoslavian geophysicist Milankovitch in the early years of the twentieth century. The theory was based on the assumption that the surface temperature of the earth would vary in response to periodic changes in the earth’s orbit and axis. Orbital and axial variations affect the receipt of solar radiation at the earth's surface. According to Milankovitch the cycles of climatic changes are: i) Over approximately 96,000 years, the shape of earth's orbit is known to change from circular to elliptical and back. This called the **Eccentricity of the orbit**; ii) the axis of the earth tilts from about 21.5^o to 24.5^o and back over a period of around 42,000 years. This phenomeno is called **Axial tilt**; iii) the third variable is the precession of the equinoxes' resulting from the 'wobble' of the earth's axis. This means that the time of year at which the earth is nearest to the sun **(perihelion)** varies. At present, the northern hemisphere winter occurs in perihelion, while the summer occurs at the furthest point on the orbit **(aphelion)**. The cycle complete in 21,000 years time. These variables in combination will affect the amount of radiation received at the earth's surface. However, Milankovitch climatic curves (Fig.3.2) shows the variations of solar radiation and very much resembles sea level changes curves (Figs.3.3 and 3.4).

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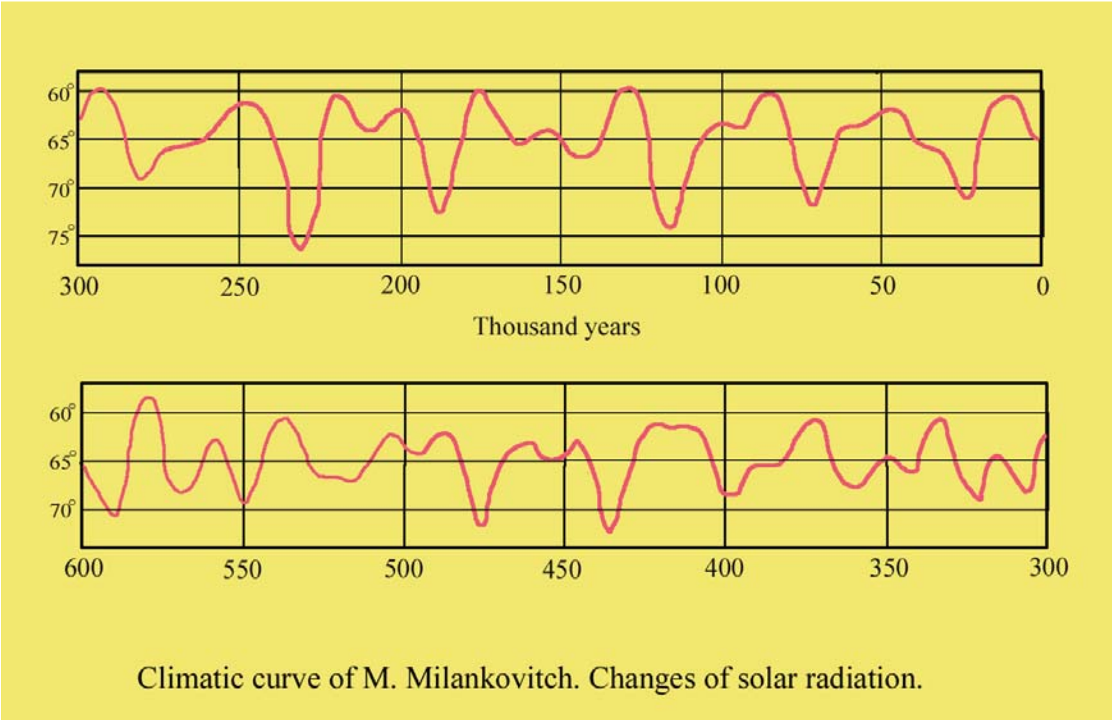

Fig.3.2. Milankovitch climatic curve (1924) showing the variation of solar radiation.

In addition to the climatic change, there are other causes of sea level changes: long term tectonic changes, glacial isostassy, hydro-isostassy and geoidal change. There are two kinds of sea level changes, namely, i) eustatic sea level changes and ii) relative sea level changes. Eustatic sea level change is the real sea level change when water volume in the ocean basin changes. It is the change of distances from the centre of the earth up to the Mean Sea Level (MSL). Relative sea level changes are confined to a particular coast. A coast may rise up or fall down due to tectonic movement, apparently seems to rise or fall of the sea level. Climatic change causes rapid movement of eustatic sea level.

There are several sea level curves (Figs.3.3 and 3.4) showing the sea level changes during the Quaternary. In the Middle Pleistocene sea level was about 16m above the present Mean Sea Level. During the last interglacial, eustatic sea level was about 8m higher than the present MSL. Since, there is no outcrop of Pleistocene Series, Holocene sea level changes are most important for the Chittagong coast.

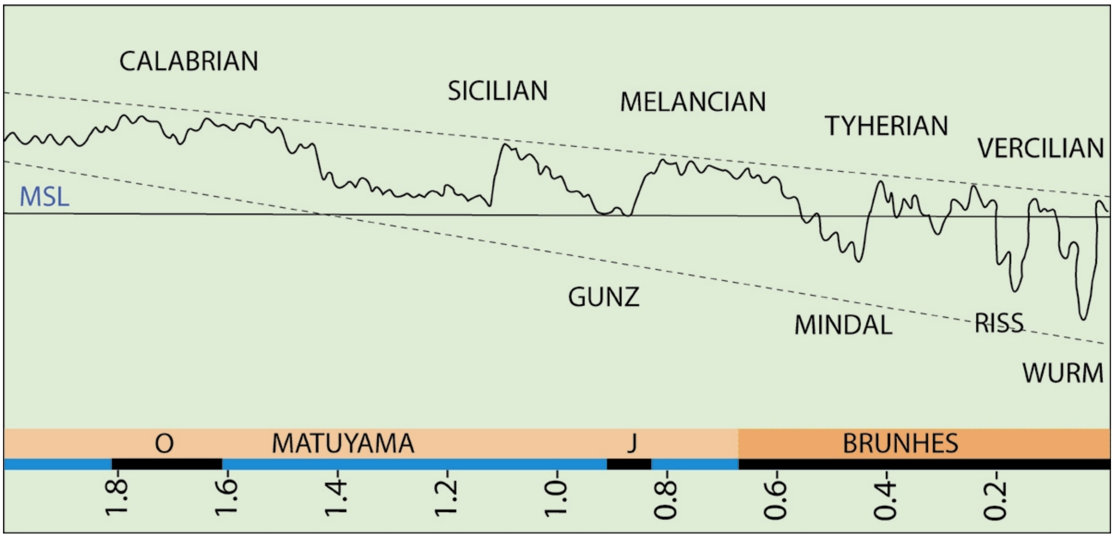

Fig.3.3. Sea level curve of the Mediterranean sea, covering the whole time span of the Quaternary.

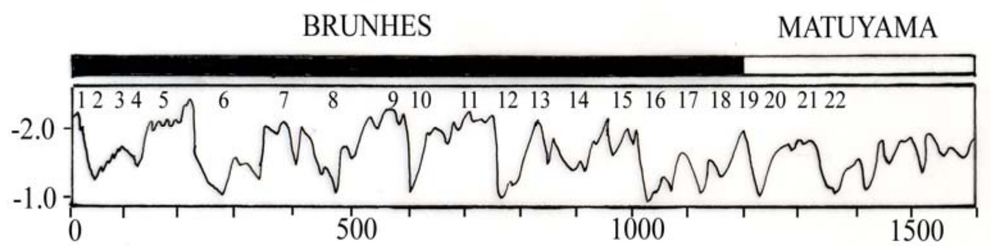

Fig.3.4. Oxygen isotope curve (Opdyke and Shackleton, 1973). Oxygen isotope curve has 22 stages. Odd numbers represent Interglacial or warm phases and even number represent Glacial or cold phases. Warm phase indicate higher sea level and cold phase indicate lower sea level. Hence, the curve represent the curve of the sea level changes for 1.5 my.

During the last glacial maximum, i.e. at about 18,000 years ago, eustatic sea level was about 100m to 140m below the present MSL. The coast line of the Bay of Bengal was some hundreds of kilometers southward from the present coast. Fig.3.5, shows the continental shelf and continental slope of the Bay of Bengal. The rivers were discharging water into the Bay of Bengal southward, far away from the present coastline through the swatch of no ground. River gradient obviously was quite high and the rivers were deeply incised. The Bengal plain was acting just like an outwash plain. After the glacial maximum, global climate started to warm up. Ice sheet on the continent started melting and the melt water started to return to the ocean basin. As a result, sea level started to rise. However, the rise of sea level was not always upward trend. Minor climatic change caused a small drop of sea level. These minor drops resulted aerial expositions of the submerged islands or subtidal zones where mangroves were developed. Next sea level rise and next cycle of sedimentation overlapped the mangrove layers. In stratigraphic section, these are called intercalated or inter-fingering peat layers. But in general, sea level had upward trend and reached its maximum height at about 5,500 years BP. At about 5,500 years BP, sea level was about 1 to 1.5 m above the present MSL. Holocene sea level curve Fig.3.6, shows the upward trend of sea level. As has been discussed minor drops of sea level favoured the growth of mangroves on the exposed surfaces. The surface with the mangroves was again overlapped by next cycle of sedimentation as the sea level rose up. Thus within the Holocene coastline sediments, more precisely costal plain sediments of Chittagong city, intercalated or inter fingering peat layers can be found.

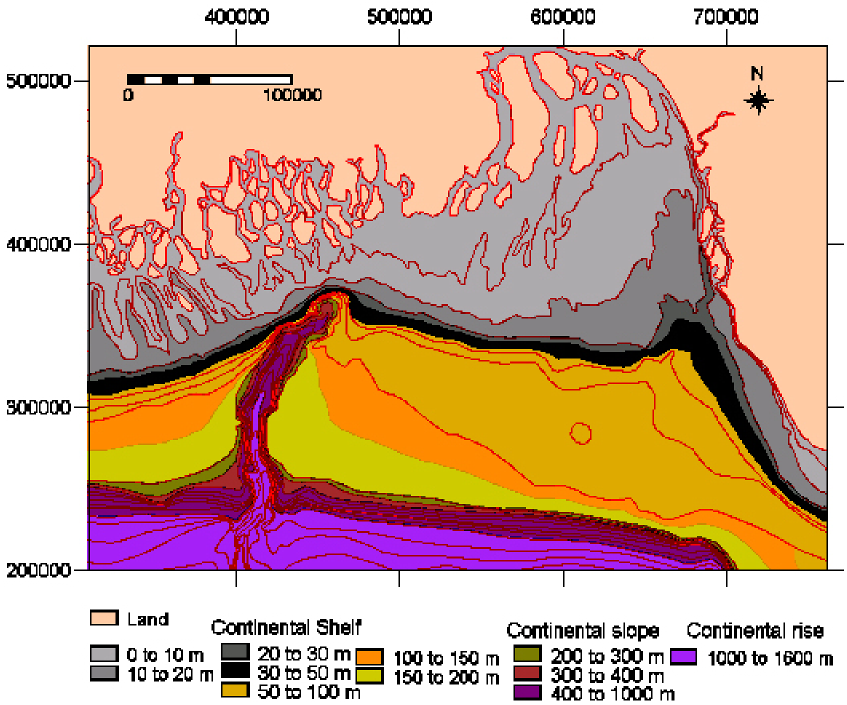

Fig.3.5. Continental margin features with Bathemetry (Kamal, A.S.M)

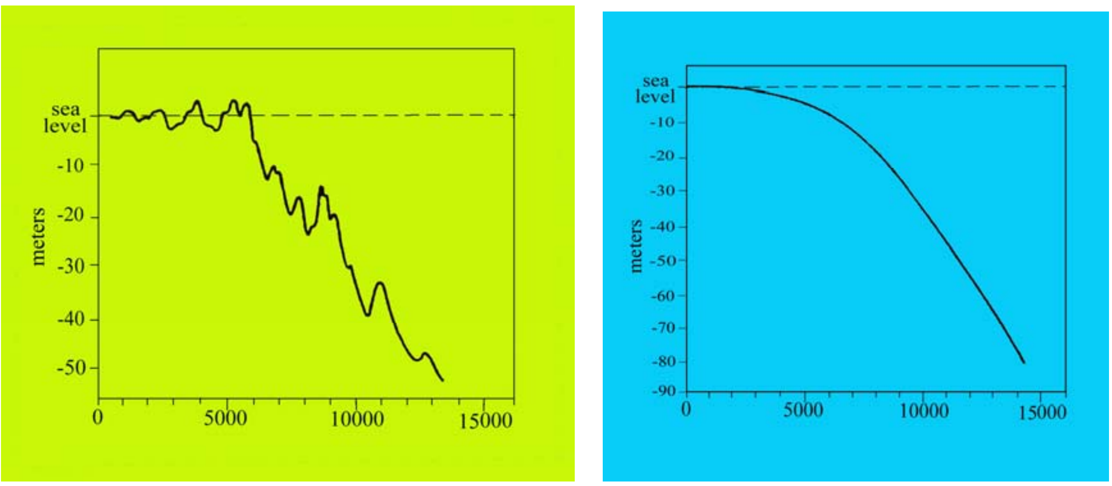

Fig.3.6. Holocene Sea Level Curves. Rapidly fluctuating sea level curve (left), Smoothly rising sea level curve (right)

3.7. Coastal plain environment

For better understanding of the complex geology of the Chittagong City, it is necessary to highlight some aspects of coastal plain environment. Normally, coastal plain develops in an area free from wave action. In deltaic environment, suspended sediments come from the continent, whereas in coastal plain environment suspended sediments come from the sea. Coastal plain is subdivided into three sub-environments:

1. Subtidal
2. Intratidal
3. Supratidal

Subtidal is the part of a coastal plain, always below the high tide level. Since, sediments come from the sea, coarser sediments (sands) settle down there. Above the subtidal zone toward the land, there is a flat surface inundates twice in a day during the high tide. During low tide, the flat is exposed. This zone is called intratidal flat or tidal flat (Photo. 3.1). Tidal flat can be subdivided into 3 sub-zones: i) sand flat (seaward), sand dominated area of tidal flat; ii) mixed flat (middle portion), sand and clay dominated area and mud flat (landward), mud dominated area of tidal flat. Supratidal zone is the area which normally does not inundate with saline or brackish water. The supratidal zone inundates only during the spring tide, tidal surges, tsunami or during the storm periods. Mangroves grow in the supratidal zone. All these zones move landward if sea level rises (during marine transgression) and move seaward during the fall of the sea level (during marine regression). Hence, the vertical succession of tidal flat has alternation of sand, sand-silt-clay or muddy sequences. Rise and fall of sea level change the litho-facies in vertical sequence of coastal plain stratigraphic sections. Holocene tidal sequences do not have time to aerially expose. Hence, the sediments are unconsolidated.

Photo.3.1. A tidal flat, near middle Halishahar, outside the city protected barriage in Chittagong.

3.8. QUATERNARY STRATIGRAPHY OF THE CHITTAGONG CITY

Quaternary stratigraphy of Chittagonh City is little bit complex. The major part of the city has been developed on the right bank of the tidal river Karnafuli and is extended to the shoreline of the Bay of Bengal. Hence, Chittagong city is the place of interaction of saline and freshwater environments. The city has been fall in the zone of wave dominated coast. The river Karnafuli carries less suspended sediments compared to rivers of the middle coastal zone (Meghna estuary). In Chittagong city, variety of depositional environments can be found. Moreover, human intervention has changed the scenario of natural environments. However, intensive fieldworks were done for mapping the geomorphic units and boreholes were dug at shallow depth (5 m to 30 meters) to subdivide the lithostratigraphic units. The exposed rock units of Chittagong city are broadly subdivided into: Tertiaty System and Quaternary System.

A) Tertiary System includes: Bokabil and Tipam Formations
B) Quaternary System includes: Dupitila Formation, Dihing Formation
and Holocene Series.

It is to be noted that in subdividing the Tertiary and Quaternary systems, Dupitila Formation has been considered as the Lower Pleistocene deposits, based on palaeomagnetic data. All the Members of the Madhupur Formation showed Normal Polarity, points to the Jaramillo event (from 0.97 m.y. to 90 m.y BP) of Matuyama Magnetozone (Monsur, 1990). Dupitila Formation showed reversed polarity of Matuyama Magnetozone (older than 0.97 m.y. BP). Lower boundary of the Quaternary Period is 2.50 m.y. BP. Hence, Dupitila Formation fairly can be called as the Lower Pleistocene deposits.

A) Tertiary System

Tertiary rocks are exposed in the central part of the city as some isolated low hills and hilly terrains (Fig.3.7). Most of the hills have been cut off and leveled for urban settlements. The natural valleys are filled up with hill-cut sediments. Hill cut surfaces are quite flat and naturally elevated. In the natural valleys, slope wash or valley fill post Tertiary sediments are overlapped by artificial hill-cut sediments.

i) Bokabil Formation

Bokabil Formation is exposed in the middle part of Chittagong at wireless station, Bhatiary area. The Formation is characterized by sandy shale, siltstone, massive sandstone and alternation of sand and silt. The lower part of this Formation is constituted of sandy shale, siltstone and massive sandstone. Sandy shales are grey coloured laminated and well cleaved. Siltstones are grey, laminated and occasionally ripple marked. Sandstones are grey, fine to medium grained, moderately consolidated and massive. Lithological variations of the lower and upper parts of this Formation are not so much distinct. Medium to large sizes calcareous concretions are very common in this Formation. Exposed shale of Bokabil Formation is highly weathered.

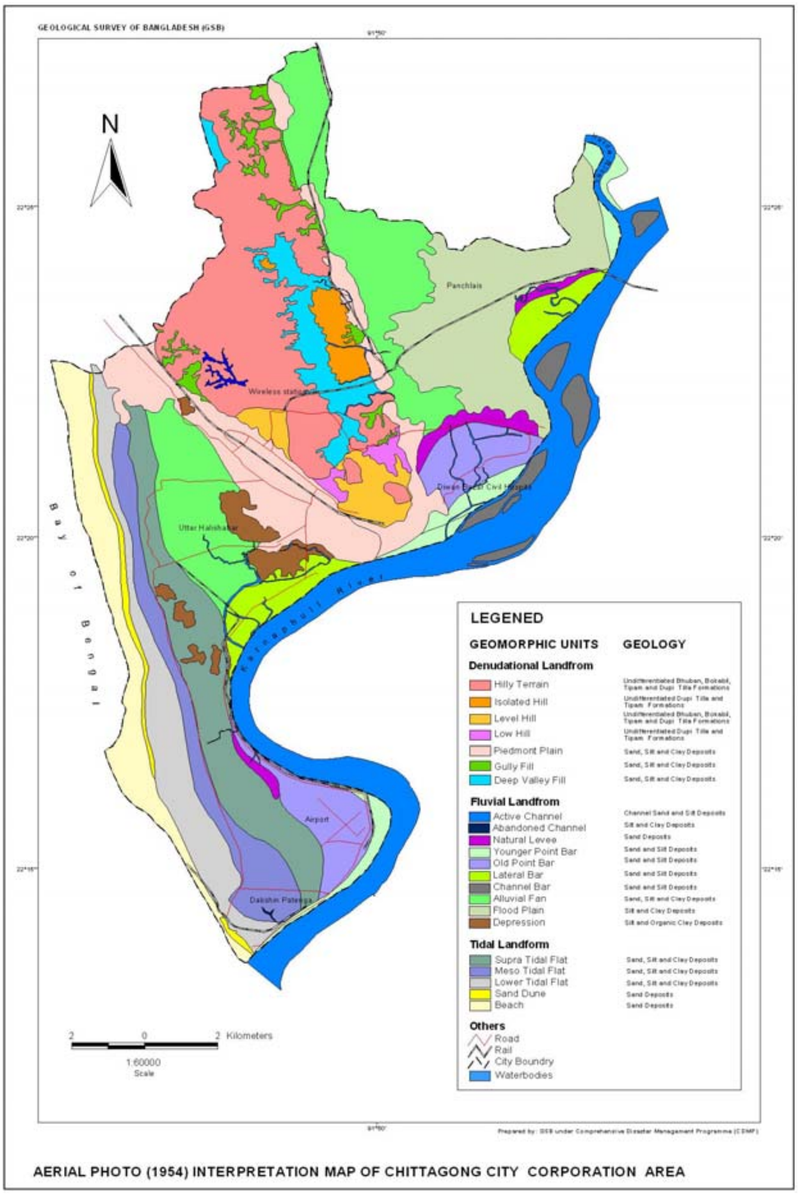

Fig.3.7. Geomorphological map of the Chittagong city (Source, GSB).

Photo.3.2.Batali Hill. Massive sandstone of Tipam Formation.

Photo.3.3. Shale subordinate of Tipam Formation.

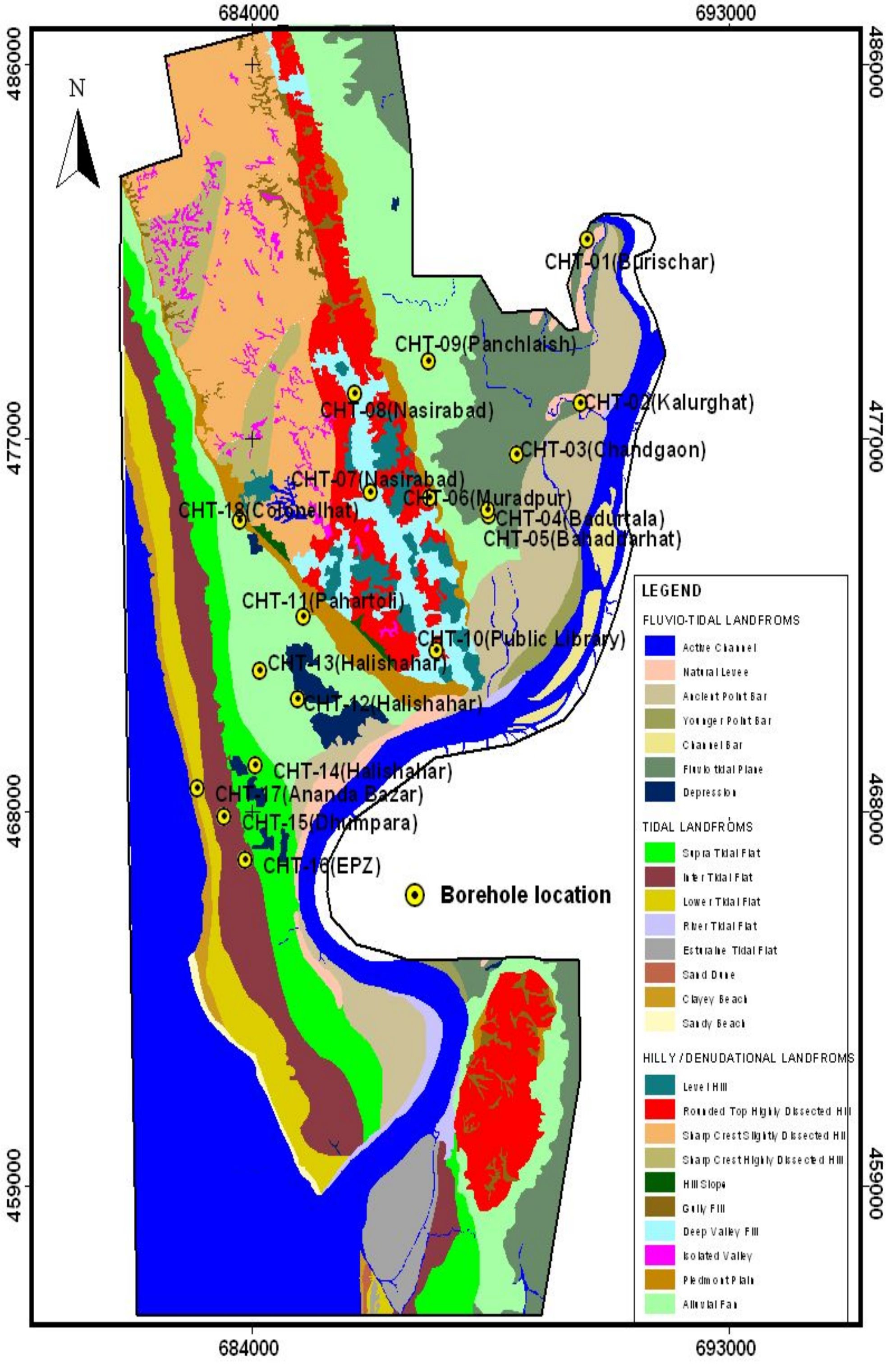

Fig. 3.8. Locations of bore holes in the geomorphological map of Chittagong City.

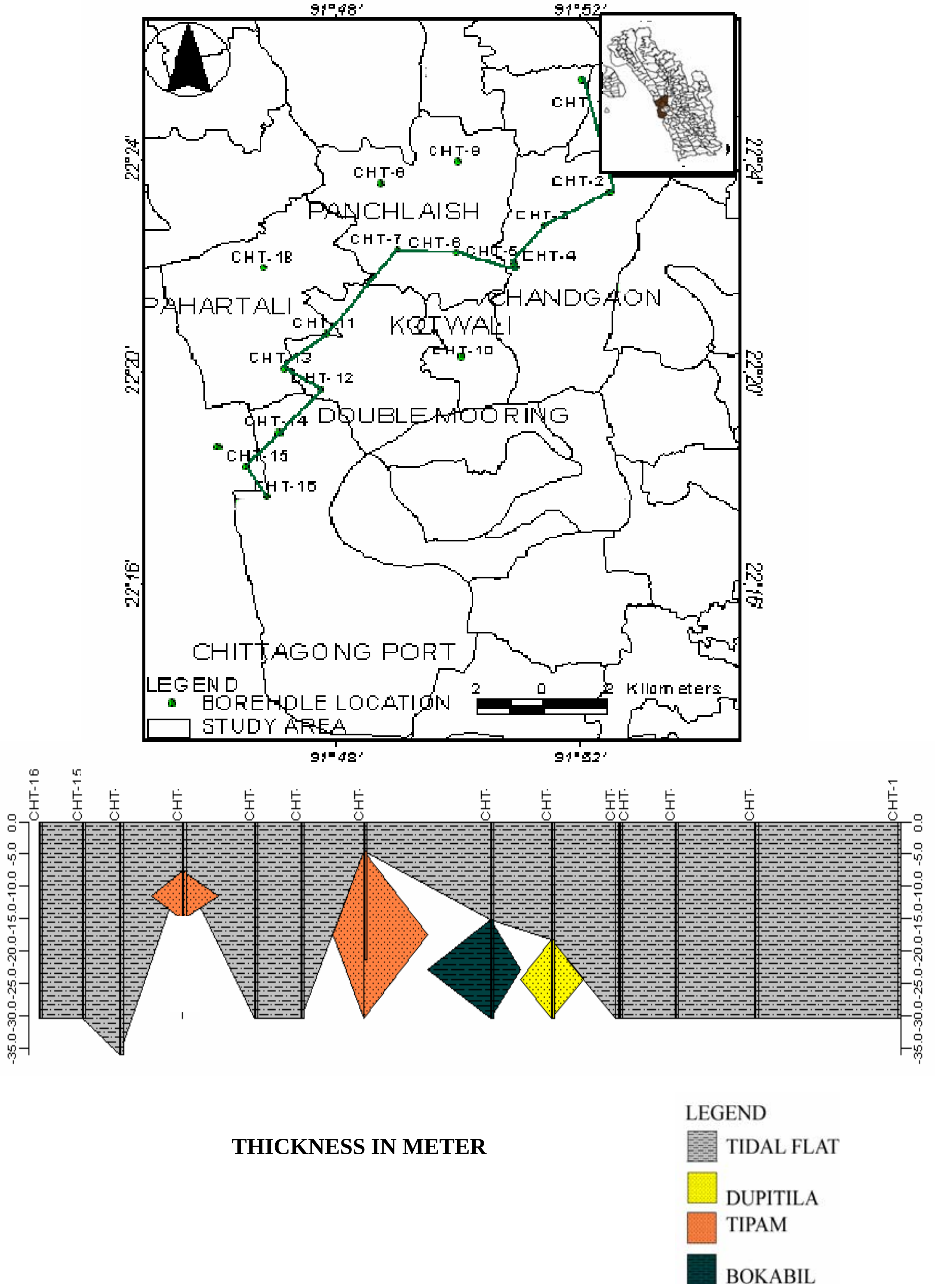

Fig.3.9. Locations of boreholes (Top) and geological cross section (Bottom) along the western margin of the Chittagong city.

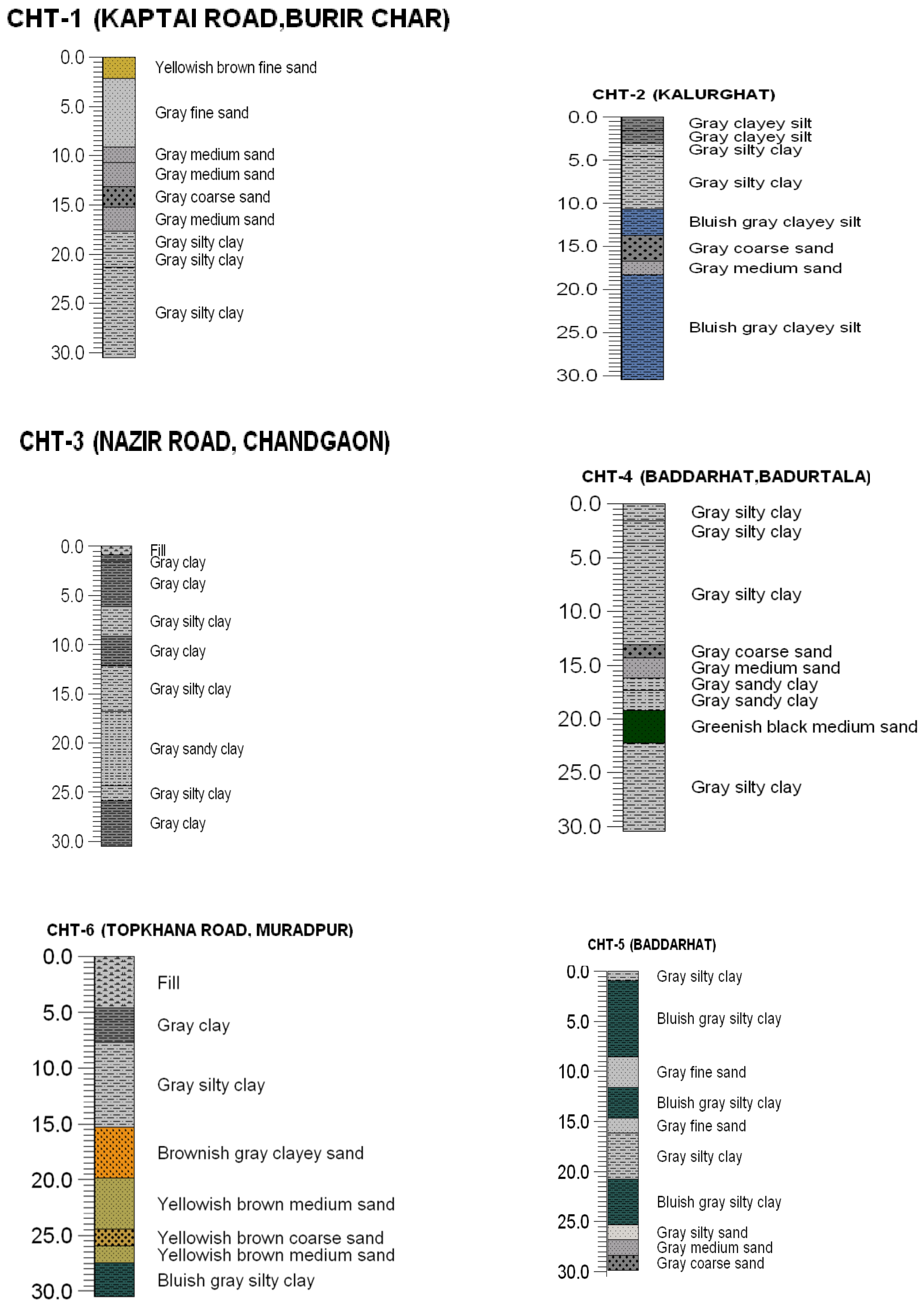

Fig.3.10. Showing the lithologic column of the borehole nos.1 to 6.

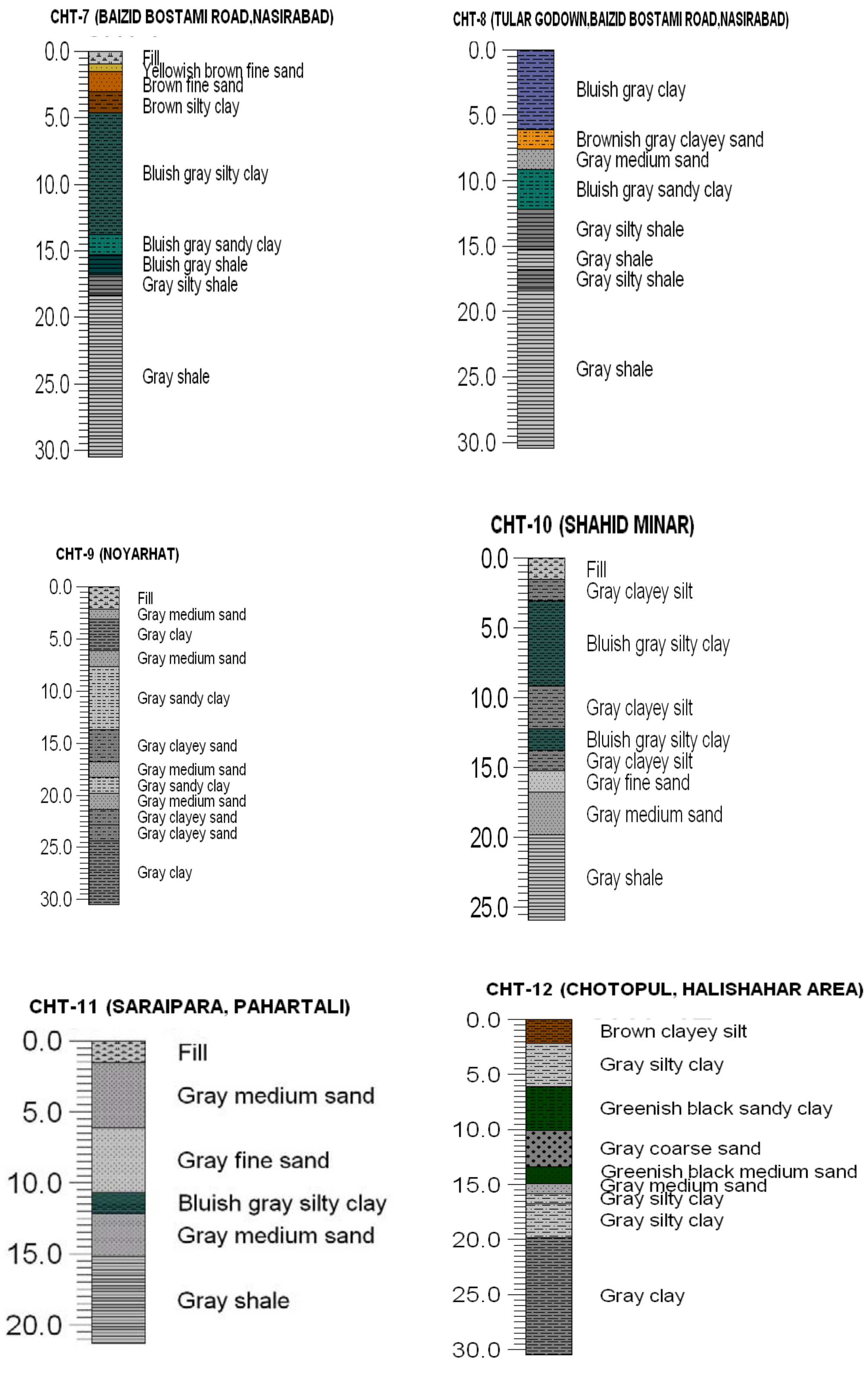

Fig.3.11. Showing the lithologic column of the borehole nos.7 to 12.

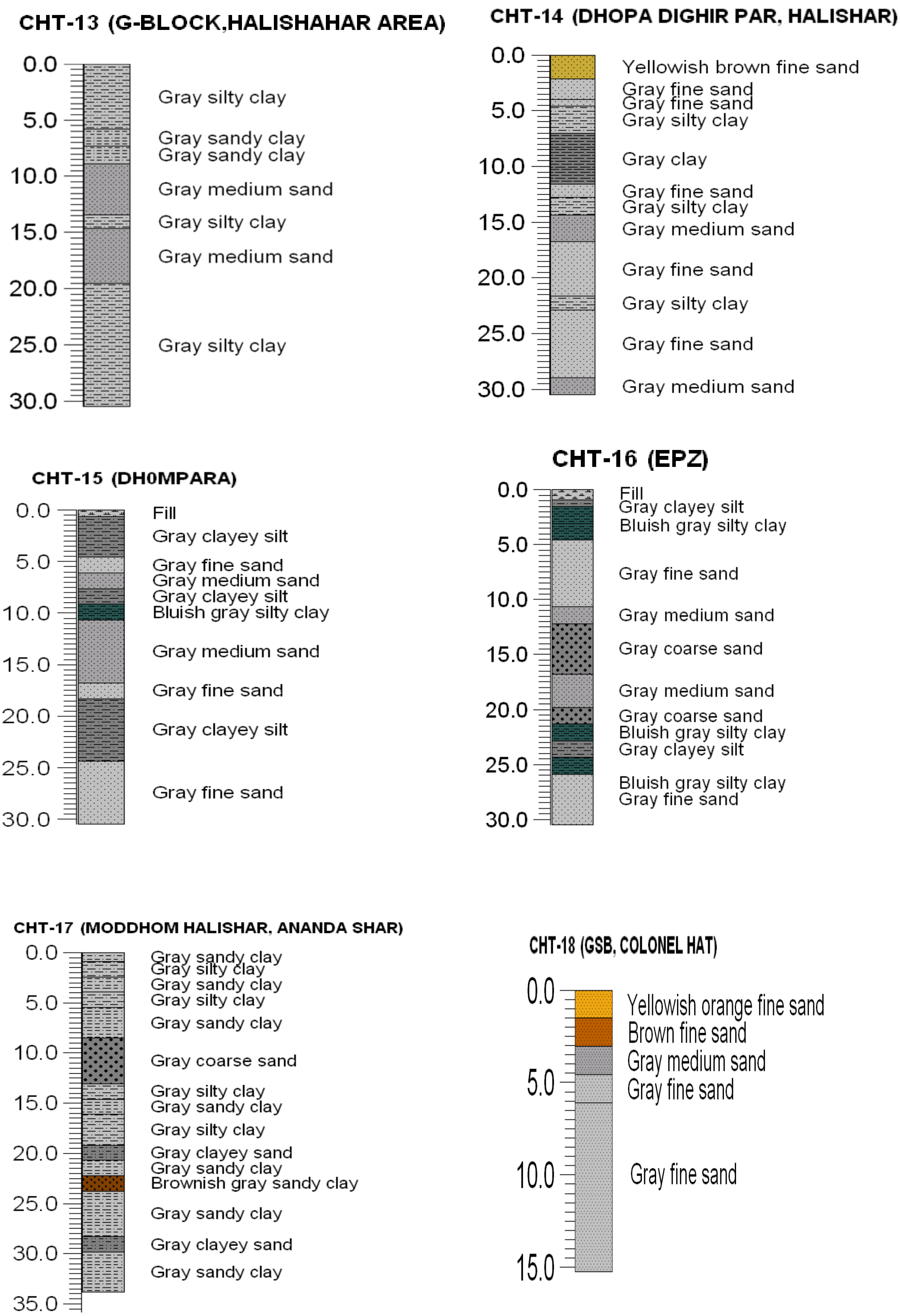

Fig.3.12. Showing the lithologic column of the borehole nos.13 to 18.

ii) Tipam Formation

Tipam Formation is well exposed at Batali hill and Cantonment area. The Formation is represented highly consolidated yellowish or reddish brown massive sand with the subordinate of thinly bedded to laminated shale. The Formation is highly ferruginous, medium grained, friable and cross bedded.

B) Quaternary System

Quaternary deposits are extensively exposed in Chittagong City. The deposits formed some hillocks or low mounds in the central part of the city. On the other hand, Quaternary deposits are exposed in the shoreline and river bank as coastal plain or estuarine deposits. Dupitila Formation, Dihing Formation and Holocene Series are the Quaternary deposits.

i) Dupitila Formation

Dupitila Formation is well exposed in the central part of the city. The Formation forms some hillocks or low mounds. Most of the hillocks have been cut off and has made some leveled ground. Dupitila Formation is constituted of massive sandstone with subordinate sandy clay and siltstone. The upper part of the sequence is characterized by pink and brown coloured bands with cross bedding and ripple marks. The Formation contains quartz pebbles and grey sandy clay beds. The lower and middle parts of the Formation are massive sands and have yellow to yellwish brown coloured bands. The massive sandstone is brown to yellowish brown, medium to coarse grained with subangular grains and friable. Dupitila Formation is fluvial deposits and has the age of Lower Pleistocene.

ii) Dihing Formation

Dihing Formation in Assam represented by coarse grained sediments, such as, pebbles, cobbles, boulders and coarse sands. The types of gravels depend on the source rocks. In Jaintiapur areas, the gravels of Dihing Formation is called Sonatila gravels. Those gravels are represented by quartz and quartzite, feldspars rocks and shally gravels. But in the Chittagong city gravels are shally gravels. These gravels are well exposed in Aftabnagar area of the city. Dihing Formation fluvial deposits, deposited as bed load sediments (channel beds)

iii) Holocene Series

Holocene Series have variety of depositional environments. The deposits cover the major part of the city. Specially, the Holocene deposits are exposed along the river Karnafuli and in the coast line. The Holocene Series have mix environments. The estuarine deposits are overlain by coastal plain (Tidal) deposits which are again overlapped by fluvial deposits (fresh water). The following geomorphological features have been observed during the field investigations: a) Piedmont plain, b) Gulley fill, c)

Valley fill, d) Active channel, e) Channel bar, f) Alluvial fan, and g) Tidal flat (Fig.3.7). The lithologic descriptions with their depositional environments are given in the following texts.

a) Piedmont plain

A narrow zone around the hillocks has been mapped as the piedmont plain (Fig.3.7). There were two boreholes: one at Topkhana road, Muradpur (22º22'13"N, 91º49'58"E) (Fig.3.11, Borehole CHT-18) and the other at Dulhan Community Center, Saraipara, Pahartali (22º20'43"N, 91º47'52"E) (Fig.3.10, Borehole CHT-11). Piedmont area has been considered as the present piedmont area. The deposits of soft rock sediments attain the thickness of about 15 meters. It means that the depth of the Pleistocene surface is about 15m. From the Sea Level Curve, it can be seen that at about 8,000 yrs BP MSL was at the height of 15m below the present MSL. Since the exact spot height of the locality is unknown, approximate time can not be calculated from the standard sea level curve. However, it is clear that the deposits of the piedmont areas are the combination of the hill wash and brackish water sediments. Hill slope deposits (about 2-3m) represented by coarse to fine grained olive brown to brownish sand are underlain by brackish water sediments (Fig.3.10 and 3.11). Brackish water sediments (Tidal) are represented by olive brown to bluish brown, bluish grey to dark grey sticky silty clay with black organic matters. The sediments are thinly laminated. Thise tidal flat sequences are underlain by dark grey laminated very compacted shale (SPT-45), seems to the shale of Dupitila Formation.

b) Gully fill

The Gullies in the hill slopes are filled up with coarse to fine grain sediments with organic matter. The gully fill sediments are not thick and cover a small area in the central zone. The gullies are sometimes filled up with hill cut sediment.

c) Valley fill

North-south elongated valley fill zone covers the eastern side of the Hilly Terrain. There were two bores, one at Cotton Mill, Baezid Bostami Road, Nasirabad (22º23′32″N, 91º48'45"E) (Borehole CHT-08, Fig. 3.10) and the other at Baezid Bostami Road, Nasirabad (22º23′32″N, 91º49'00"E) (Borehole CHT-07, Fig.3.10). About 18m thick valley fill deposits are the combination of fresh water slope deposits and brackish water tidal deposits. About 2.5m thick slope wash valley fill sand deposits cover the upper part. After the sand deposits tidal sequences started. The tidal deposits are represented by the alternation of sand, grayish silty sand and sticky clay, containing humic materials. The deposits are carbonaceous, sometimes contain iron concretions. These are soft sediments and SPT does not exceed 8. These tidal sediments are underlain by fine medium grained yellowish-brown silty sand and sands of Dupitila Formation.

d) Channel and Lateal Channel bars

These are the point bar, lateral bar and channel bars of the tidal river Karnafuli. In fact, these are the areas of present tidal flat. Some of the areas inundate with saline water during the spring tides. Thirty meters thick deposits are the unconsolidated tidal deposits. One borehole was dug at CJM High School, Mohna Kalurghat (22º23ʹ23ʺN, 91º52ʹ29ʺE). Upper soft sediments (SPT< 7), thickness about 13m, are represented by alternation of yellowish grey clayey silt, bluish sand, greenish grey or dark greenish grey sticky silty clay. Sediments become compacted with the alternation of sand and silty sand (SPT rises upto 36). Lower sediments have the estuarine characteristics. All the sediments are carbonaceous.

Coastal plain

In this text all the geomorphological units (Fig.3.7), demarcated as old point Bar, Supratidal flat, Meso-tidal flat (Intertidal), Lower tidal flat (Intertidal), Sand dune, Beach, Alluvial fan, Flood plain, Depression have been group together and have been considered as Coastal plain on the basis of the lithofacies and sediment characteristics. Eleven boreholes were dug at Dampara (22º18ʹ12ʺN, 91º46ʹ32ʺE). Dhopa dighirpar, Halishahor (22º18ʹ50ʺN, 91º47ʹ03ʺE). EPZ (22º17ʹ38ʺN, 91º46ʹ52ʺE). Chotopul, Halishahor area (22º19ʹ40ʺN, 91º47ʹ46ʺE). Badurtala, Boddarhat (22º21ʹ58ʺN, 91º50ʹ57ʺE). Yar Ali Hat Govt. Primary School, Bazar Panchlais Noyarhat (22º23ʹ57ʺN, 91º49ʹ59ʺE). Central Mosque Complex, G Block , Rd-1, Halshahar (22º20ʹ03ʺN, 91º47ʹ09ʺE). Nuruzzaman Nazim Road, Chandgaon (22º22ʹ44ʺN, 91º51ʹ25ʺE). Maddham Halishahar, Anandabazar (22º18ʹ34ʺN, 91º46ʹ05ʺE). Baddarhat (22º22ʹ02ʺN, 91º50ʹ56ʺE) and Kaptai Road, Burirchar (22º25ʹ28ʺN, 91º52ʹ02ʺE) (Fig.3.9, 3.10 and 3.11). The above bore covered all the geomorphological units of Fig.3.7.

All the deposits of these localities have brackish water soft rock sediments, having very low SPT values. Sometimes, intercalated sand layers show high SPT, around 25 or 15, but at greater depths SPT values drop down to 4 or 5. There are some buried peaks of Tertiary sediments. The isolated buried hard rock peak has been observed at Dhopa Dighir part, Halishahar, where very compacted sand of Tertiary formation was found. In the rest of localities, tidal sequences were observed up to the depth of 30 meters. The tidal sequences are represented by the alternation of greenish grey fine sand mixed with clay, dark grey silty clay with very fine silt or very fine sand layers, olive grey silty clay, sometimes contain organic matters. The sediments contain considerable micas. Clayey or silty sediments are unconsolidated, soft and very sticky.

It is to be mentioned that at about 10,000 years BP, the eustatic sea level was about 30 meters below the present MSL. After 10,000 years BP, sea level continued rising and at about 5,500 years BP the sea level attained the maximum height of 1m above the present MSL. Hence, it can be said that the sediments of these areas deposited within 10,000 years BP. One meter drop of sea level caused the aerial exposition of most of these areas. Excepting the central part of the city where Dihing, Dupitila, Tipam and Bokabil Formations are exposed, most of the areas represent coastal plain areas, either supratidal or tidal flat.

3.9. Summary

Hence, in short, Tertiary (Mio-Pliocene) and Quaternary deposits are exposed in Chittagong city. In the central part of the city, Bokabil, Tipam, Dupitila and Dihing Formations are exposed. These are highly compacted and consolidated sediments. In the surrounding areas of the central part of the city, near the Bay and close to the tidal river Karnafuli, coastal plain and estuarine sediments are exposed. These estuarine and coastal plain sediments are unconsolidated and represented by sand, silty sand, silt, silty clay, clay with micas and organic matters.

CHAPTER-FOUR

4. Quaternary Stratigraphy Of Sylhet City

4.1. Introduction

The city of Sylhet is situated on the banks of the river Surma in the north-eastern part of Bangladesh (Fig. 4.1). The city consists of 27 wards and 210 mahallas. The area of main town is 10.49 sq. km. It has a population of 285308 and the density of population is 27198 per sq km (Banglapedia). Exact time of ancient settlement in Sylhet is unknown, but the city has a long archaeological history and tradition. Sylhet has its own heritage and culture. Shah Jalal's (a major sufi saint of Bengal). name is associated with the Muslim conquest of Sylhet, around 12 to 13^{th} century A.D. His full name was Shaikh Jalaluddin. Shah Jalal (R) was buried at Sylhet. Before the Muslim conquest, the Sylhet area was ruled by a Hindu king named Gaur Govinda.

4.2. Tectonic set up of Sylhet-Jaintiapur areas

Sylhet Sadar is very close to the Jaintiapur structure. Jaintiapur structure lies in between two contrasting structural set ups, the uplifting Shillong massif in the north and the subsiding Surma Basin in the south. It is bounded by the Khasi-Jaintia hills and Shillong massif in the north, Goyain trough in the south, Atgram anticlinal structure in the east and Goyain Trough and foothills of Khasi-Jaintia range in the west. The area forms a narrow east-west elongated strip and is characterised by intermittent swamps between the hills. Tectonically, the whole area has been subdivided into three zones: zone-i - the area between Dauki river in the west and Naljuri bazar in the east, zone-ii - the area between Naljuri and Assampara in the east, and zone-iii - the area between Jaintiapur in the west and Hari river in the east including Dupigaon. Further to the south-west, lies the Sylhet anticlinal structure, where the Tipam Formation is exposed in the crestal zone.

The tectonic structure of sylhet is quite complex and yet to be explored. Initially, it was thought that no rock older than Dupitila is exposed in the Metropolitan area of Sylhet city. The present investigation has totally changed the older concept based on the following facts:

1. Tipam Formation is exposed in the Kalagul Tea Garden area, closed to the metropolitan city.
2. Wide extension of lateritic beds in the Galimpur area (south bank of the Surma river) of Sylhet city. This laterite bed represents the boundary stratotype between Barail and Surma Group.
3. In Galimpur area the Laterite Bed is overlain by the Surma Group and underlain by the Barail Group of sediments.

Further investigation may unravel the tectonic history of Sylhet area.

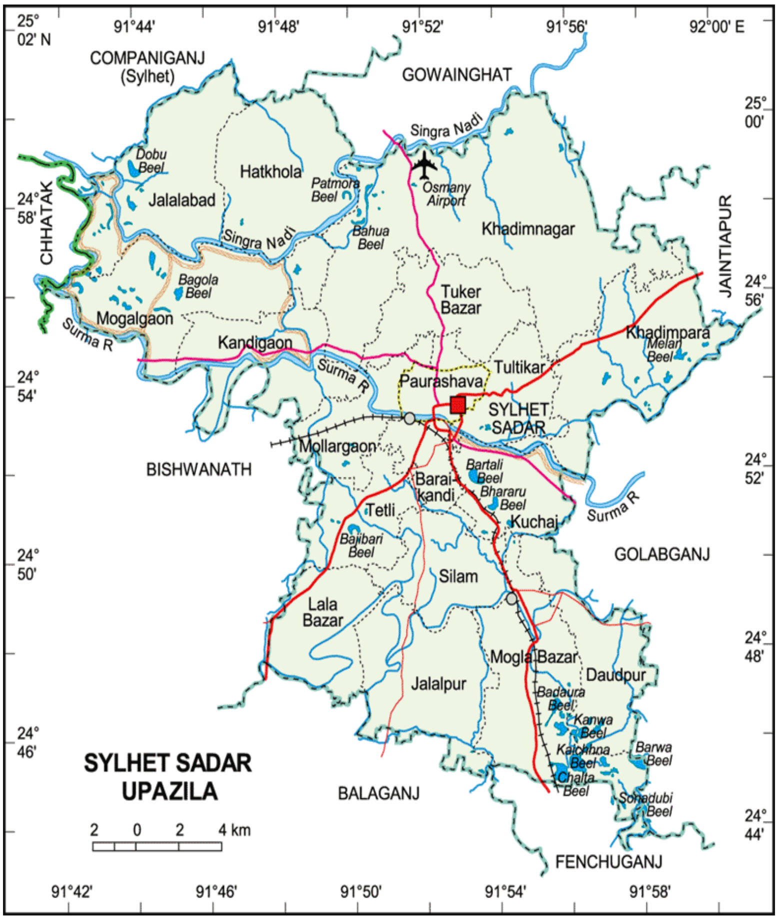

Fig.4.1. Map of Sylhet Sadar Upazila.

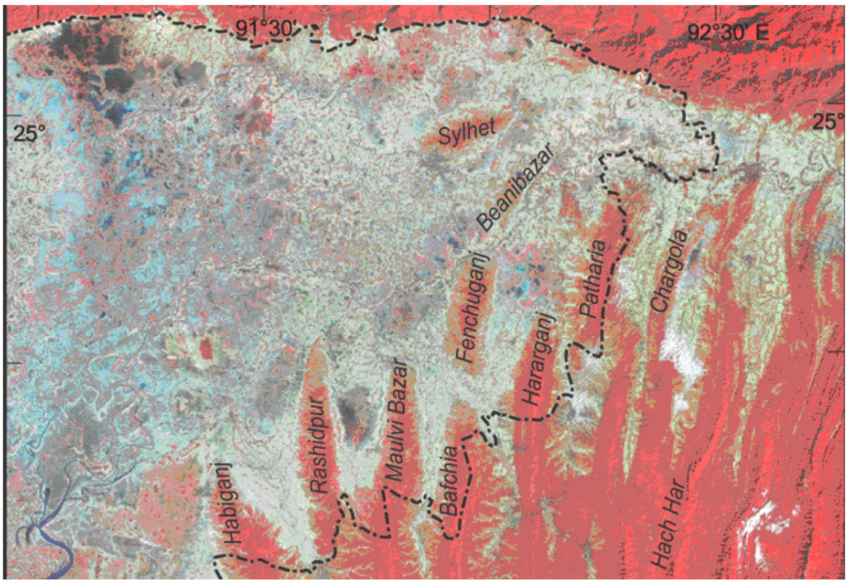

Fig. 4.2. Shows the anticlinal structures of the folded belt around Sylhet-Jaintiapur area.

4.3. General stratigraphy of Sylhet area

The exposed rocks of Jaintiapur area can be classified from older to younger as Sylhet Limestone, Kopili, Barail, Bhuban, Boka Bil, Tipam Sandstone, Girujan Clay, Dupi Tila and Dihing formations. All the above Formations are not exposed in the Sylhet area. The exposed rocks in the Sylhet area are (older to younger): Barail Group, Surma Group, Tipam Formation, Dupitila Formation and Holocene Series.

Table 4.1. Stratigraphic table for the Sylhet area.

Age	Group	Formation	Rock types
Holocene			Very coarse sand, silt, clay, alluvium
Pleistocene		Dupitila	Sandstone with minor shale and clay beds, having colour bands.
Pliocene	**Tipam**	Tipam Sandstone	Predominantly cross bedded sandstone with minor shale and clay beds.
Mio-Pliocene	**Surma**	Bokabil	Alternating shale and sandstone with minor siltstone. Sand dominated
Miocene		Bhuban	Alternating sandstone and shale with minor siltstone. Shale dominated
Oligocene	**Borail**	Renji	Sandstone with minor shale
		Jenam	Predominantly shale with minor siltstone and sandstone

The lithological characteristics of exposed rocks in the Sylhet area are the same as have been described in the Chapter-one: General geology of Bangladesh. Some highlights of the lithology have been gien in the Table 4.1. The Girujan Clay Formation has not been exposed in Sylhet Metropolitan area. The Dupitila Formation forms some rolling isolated symmetrical hills, in the Sylhet City. The Tipam Formation forms some steep hills in the crestal zone of Sylhet anticline. The Dihing Formation represented by gravels (Sonatila Gravel Beds) is not exposed in the Sylhet area.

It is interesting to note that te Barail Group of sediments are exposed in areas of the southern bank of the river Surma. The lateritic bed which represents the boundary (Boundary Stratotype) between the Surma Group (top) and Barail Group (bottom) is widely exposed in Galimpur area of Sylhet Metropolitan City (Photo. 4.1 and 4.2). Below the laterite Bed typical pink colour sandstone of Barail Group is exposed in the Galimpur area (Photo. 4.3 and 4.4). Surma Group (shale) overlies the Lateritic Bed and is exposed in the Galimpur area.

Photo.4.1 Gigantic laterite block makes boundary between Surma and Barail Groups.

Photo.4.2. Laterite bed makes boundary between Surma and Barail Groups.

Photo.4.3. Barail Group of sediments, showing typical pinkish colour.

Photo.4.4. Barail Group of sediments, showing typical pinkish colour.

Photo.4.5. Symmetrical rolling hills of Dupitita Formation. S.J. University area.

Photo.4.6. Exposure of Surma Group above Lateritic Beds at Galimpur area.

Photo.4.7. Lateral bar deposits on the right bank of the r. Surma

Photo.4.8. Piedmont deposits near S.J. University area.

4.4. Quaternary stratigraphy of Sylhet City and its surrounding areas

Quaternary stratigraphy of Sylhet City is little bit complex. Initial hilly terrains, specially deep valleys are filled up with soft rock sediment. As a result, thickness of soft rock sediments or valley-fill sediments varies a lot within a short distance. In addition, depressed areas initially formed some marshy land filled up with recent sediments. The sediments are not dated by any method. Based on their compactness or consolidation, the soft rock sediments have been considered as the Quaternary deposits.

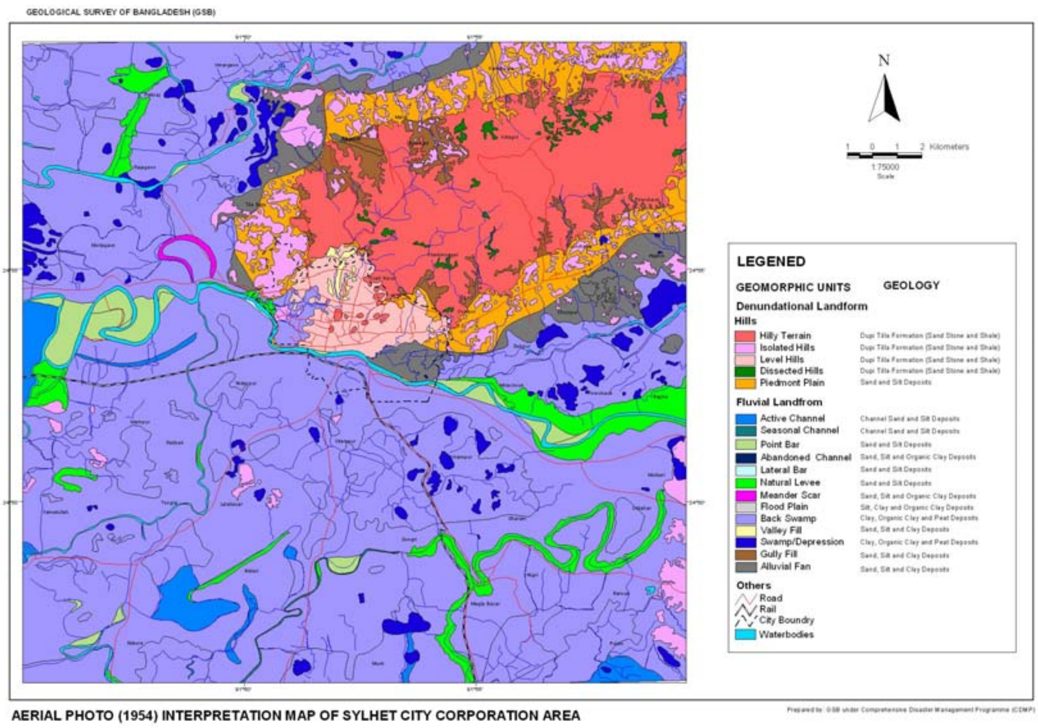

Fig.4.3. Geomorphological map of the Sylhet City (Source, GSB)

A team of Geological Survey of Bangladesh along with the present author prepared a geomorphological map of Sylhet city from the aerial photograph of 1954 (Fig.4.3). The author had some field investigation along with the GSB to confirm the above geomorphic units by hand auger. In addition, 18 boreholes were dug to describe the lithology and to understand the sedimentary sequences Fig.3

The following geomorphic units were delineated for the Sylhet City and its surrounding areas:

A) Denudational Landform: i) Hills, ii) Isolated hills, iii) level hills, iv) Dissected hills and v) Piedmont palin.
B) Fluvial Landform: i) Active channel, ii) Seasonal channel, iii) Point bar, iv) Lateral bar, v) Natural levee, vi) Meander scar, vii) Flood plain, viii) Back swamp, ix) Valley fill, x) Depression, xi) Gully fill and xii) Alluvial fan.

Fig.4.4: Borehole locations in the geomorphological map of the Sylhet City.

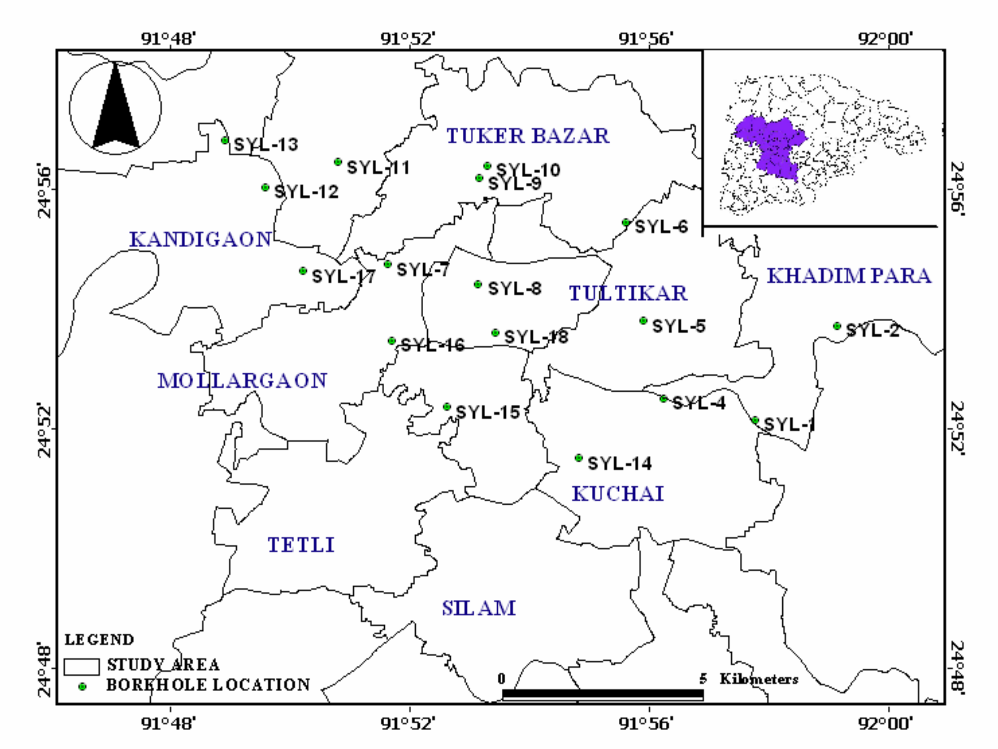

Fig.4.5. Location of boreholes in the Sylhet Corporation area.

A) Hilly terrain (Denudational landform)

Dupitila Formation is exposed in the northeastern part of Sylhet City on the northern bank of the river Surma (Fig.4.3). Geomorphologically the area represents hilly terrains, likely, symmetrical hills, isolated hills, level hills and dissected hills. The old town had been developed on these consolidated sediments.

i) Dupitila hills

Four boreholes were dug. SYL-6 at Natun Bazar, Uttar Balur char (24º 54′ 48″ N, 91º 54′ 02″ E) was dug through the Dupitila Formation (Fig. 4.4). Dupitila Formation was overlain by a thin cover of filling materials of thickness about 2m (Fig.4.6). The Formation is represented by dusky yellow medium to coarse grained sands. Sometimes contains small quartz pebbles. The Formation is inter bedded with silty-clay or clayey silt layers. Sediments are well consolidated (SPT is more than 50). The same sequence has been observed in SYL-8 (Fig.4.7) at Alia Madrasa (24º 53.976′ N, 91º 52.069′ E). In SYL-9 (Fig.4.7), at West Pir Mohallah, Jalalabad Residential area (24º 55′ 23″ N, 91º 52′ 05″ E), Dupitila Formation is overlain by valley fill sediments of thickness about 5m. Valley fill sediments are represented by medium to fine grained yellowish brown sands with some clayey layers containing humic materials. The valley fill sediments also have been observed at Shah Jalal University Campus (24º 55′ 36″ N, 91º 50′ 11″ E), SYL-11 (Fig.4.7). Valley fill sediments having the thickness of about 8m are underlain by Dupitila Formation. In the University Campus peat layer has been observed at a depth from 3m to 8m.

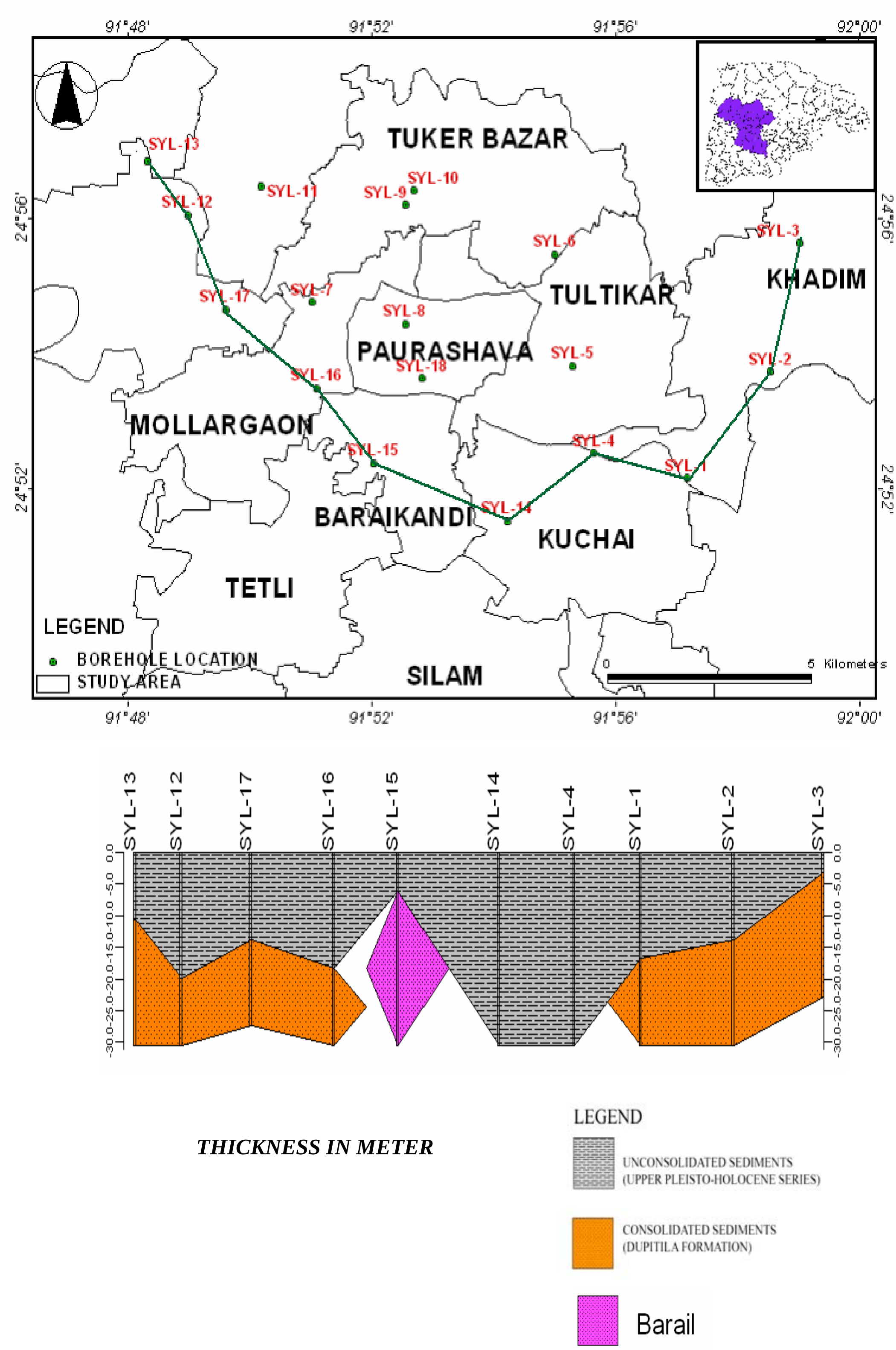

Fig.4.6. Geological cross section along the green line

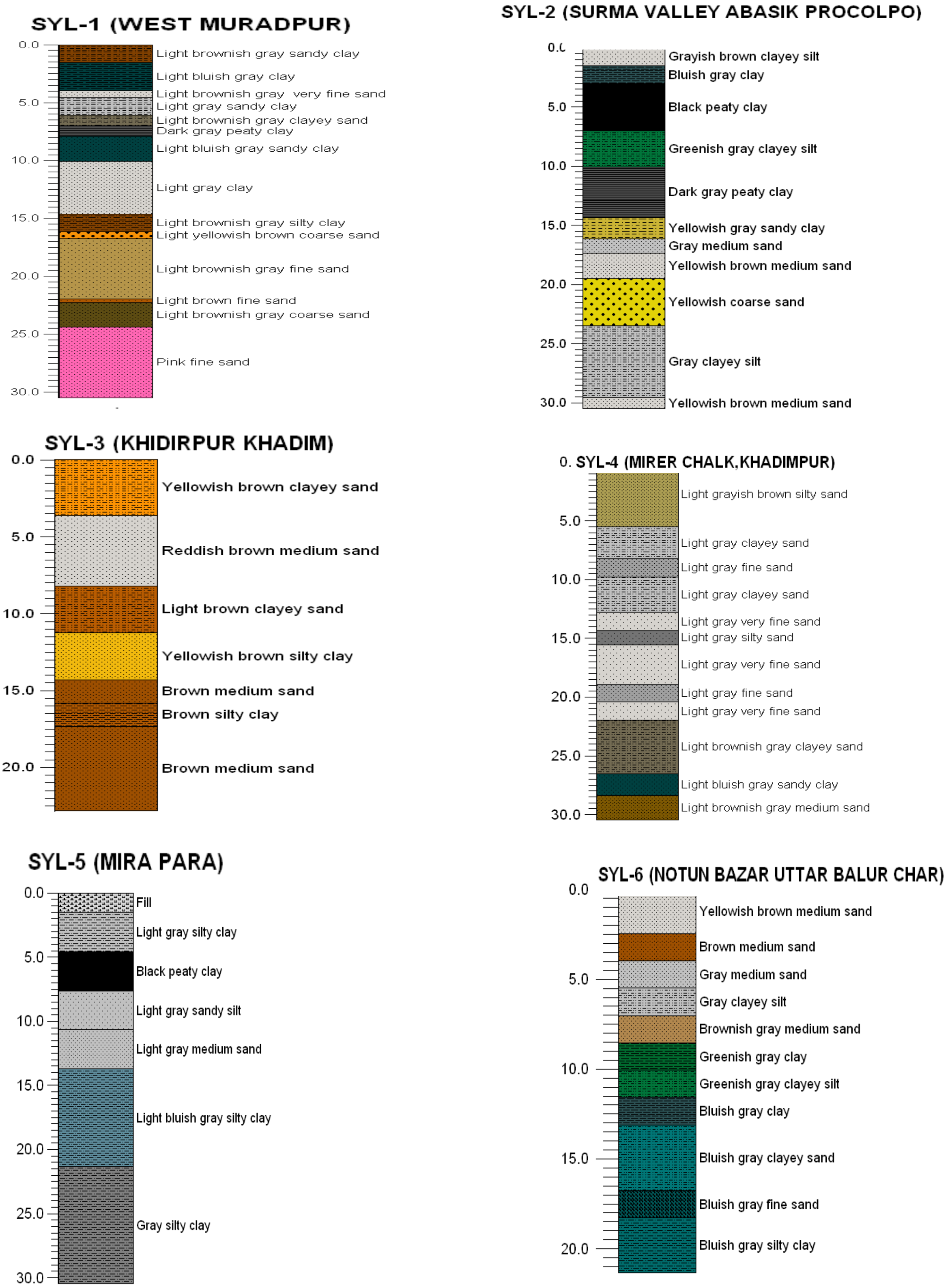

Fig.4.7. Lithological descriptions of Boreholes SYL-1 to SYL-6.

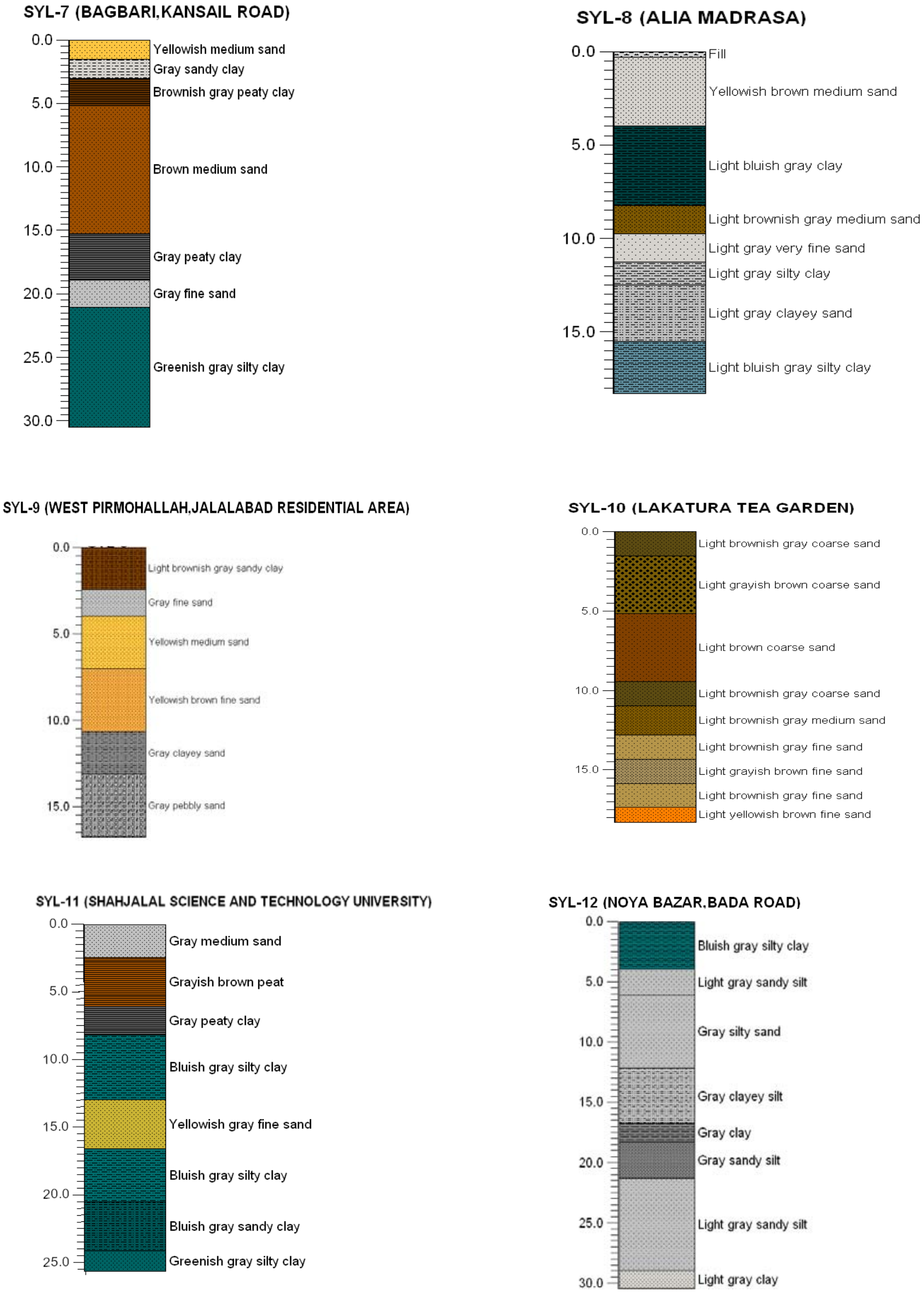

Fig.4.8. Lithological descriptions of Boreholes SYL-7 to SYL-12.

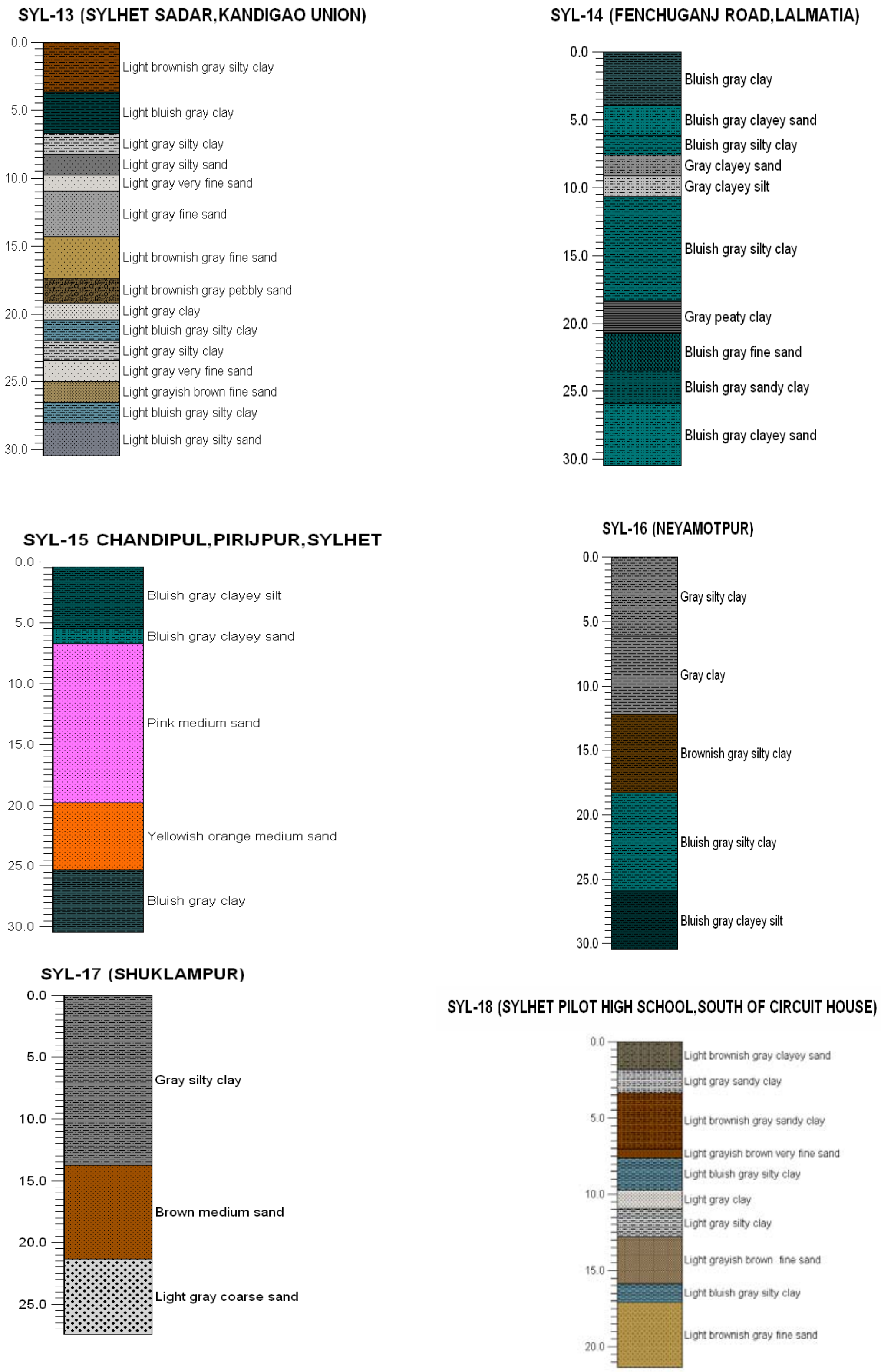

Fig.4.9. Lithological descriptions of Boreholes SYL-13 to SYL-18.

ii) Isolated hills

There are some isolated hills near the Shahjalal University campus (Photo.4.5). The isolated hills formed by Dupitila Formation. Iron crusted layers and colour banded sands with intercalated silty clay layers are typical sequences of Duptila Formation. These rolling hills are symmetrical. Initially, the hills were separated by deep valleys. The deep valleys among the hills are filled up with valley fill sediments. These valley fill sediments form some flat surfaces within the hills. As a result, it seems that the hillocks are isolated.

iii) Level hills

Level hills means the hill cut areas. Undulated hills of Dupitila Formation were cut off to make some flat surfaces. Hence, the level hill areas are the surfaces where deeper part of Dupitila Formation is exposed. The sediments of these areas are comparatively consolidated.

iv) Dissected hills

Dissected hilly region are the areas where valley fill sediments attain their great thickness. A borehole was dug at Lakatura Tea Garden, borehole SYL-10 (Fig.4.7). The valley fill sediments at Lakatura Tea Garden are represented by yellowish brown coarse grained sands with small gravels. The sediments are unconsolidated, but show very high values of SPT because of textures.

v) Piedmont plain

Hill terrains are surrounded by piedmont plains. Sediments of these areas are slope wash sediments of the standing hillocks. Dupitila Formation is overlain by piedmont deposits. The deposits are represented by yellowish brown sand, silt and silty-clay. The sediments are very much similar to sediments of the alluvial fan.

Hence, it can be said that the main city has been developed on the Dupitila Formation of Pleistocene age. In some places, Dupitila Formation is overlain by filling materials or unconsolidated valley fill sediments. All the valley fill sediments on top of the Dupitia Formation have been considered as the Late Pleistocene or Holocene Series.

B) Fluvial deposits (Fluvial landform)

Sylhet area is far from the marine influences. The Holocene deposits of this area are continental fluvial deposits. Therefore, fluvial landforms have the deposits having more or less same characteristics and textures.

i-ii) Active and seasonal channel

Most of the rivers of Sylhet area are braided rivers, carry huge amount of suspended and bed load sediments.

iii-v) Point bars, lateral bars and natural levees

These geomorphological features have deposits of Late Quaternary unconsolidated sediments. These deposits unconformably overlie the erosional surface of Dupitila Formation (Early Quaternary). Two boreholes were dug through these sediments.

Point bar

The other borehole no. SYL-4 (Fig.4.6), representing mapping unit: Poit Bar was dug at Mirer Chalk (24º 52.448ʹ N, 91º 54.548ʹ E), Khadimpur. The sediments are little bit coarser than the previous natural levee unit. The sediments are light brown fine grained sand, silty-sand to clayey-silt. The hole deposits are the alternation sand and fine grained sand and silty sand layers. It seems to be unconsolidated deposits of Pleisto-Holocene Series. Presence of sand and silty sand layers raise their SPT value (maximum to 32).

Natural levee

One borehole no. SYL-1 (Fig.4.6) was dug on the mapping unit: Natural Levee at Muradpur (24º 52.155ʹ N, 91º 55.768ʹ E), near Shah Paran Bridge. The sediments of natural levee are represented by light brownish grey sand, silty-sand, clayey silt and clay. It contains plants' roots, rootlets and organic matters. The thickness of the sediments is about 17m at Muradpur. The deposits overlie the Dupitila sand Formation.

vi) Meander scar or abundant channel

This geomorphic feature form some ox-bow-lake. Change of river coarse left this type of ox-bow-lake. Such a typical ox-bow-lake has been found at Naya Bazar (24º 55ʹ 16ʺ N, 91º 49ʹ 13ʺ E), SYL-12 (Meander scar) on northern bank of the river Surma. The ox-bow-lake is filled up with unconsolidated Holocene sediments. The Holocene deposits have the thickness of about 20m and unconformably overlie the Dupitila sand Formation. The Holocene channel deposits are represented by grye or light grey sand or silty sand, containing organic matters.

vii) Flood pain

Other than the northeastern part of the central town, the south and western sides of the metropolitan city have been demarcated as the flood plain areas. Very occasionally the areas are flooded during the time of flash flood. Six bore holes were dug in the flood plain area. The locations of the boreholes are:

At Bagbari (24º 54ʹ 14ʺ N, 91º 50ʹ 51ʺ E), Kansail Road, Shamimabad Residential Area (SYL-7, Fig.4.7). The thickess of unconsolidated sediments is about 20m. The sediments are represented by dusky yellow, brownish black or olive brown sand, silty sand, clayey silt or dark clay. The sequence contains organic materials. The unconsolidated sediments are underlain by the Dupitila Formation.

At Sanatola Primary School ((24º 55.90′ N, 91º 48.687′ E), Kandigaon union, Syhet Sadar (SYL-13, Fig.4.8). About 10m thick unconsolidated sediments are underlain by Dupitila Formation. The sediments are represented by brownish or bluish grey silty clay or silty sand. It contains plants' roots and organic matters (Fig.4.8).

At Lalmatia, SYL-14 (24º 51′ 39″ N, 91º 53′ 25″ E), bluish grey or dark grey unconsolidated sediments attain the thickness of about 30m. The sediments of this section are represented by brownish or bluish grey silty clay or clayey silt. It contains plants' roots and organic matters. Up to the depth of 20m, sediments are silty clay dominated. At greater depth, the sediments are sand dominated (Fig.4.8)

But at Chandipul, SYL-15 (24º 52′ 20″ N, 91º 51′ 39″ E), South Surma Degree College, Pirojpur, Sylhet, Holocene cover is only 5m. The Holocene sediments are representd by bluish grey clayey silt or silty clay. The same sequence has been observed at Niamatpur (BH-16) and Shuklampur, SYL-17 (24º 54′ 09″ N, 91º 49′ 43″ E), having the thickness of unconsolidated sediments about 15m. It is to be noted that the Barail Group of sedimens have been observed at Chandipul at a depth of 6m (Fig.4.8).

viii) Swamp

There are some swamps or marshy lands within the Sylhet Metropolitan area. These swamps are either tectonic depressions or erosional valleys. These swamps may had been created due to eddies of some braided river system. Still these are the low land areas compared to the surrounding upland surfaces. One borehole was dug (SYL-2) at Surma Valley Residential Project (24º 53′ 25″ N, 91º 56′ 52″ E), a newly developing area. The thickness of unconsolidated sediments is about 15m. The unconsolidated Late Quaternary (Late Pleistocene-Holocene) sediments are represented by greenish brown or bluish grey, sometimes dark peaty clay to clayey-silt or silty-sand. Almost the whole sequence contains decomposed or undecomposed organic materials. This unconsolidated sequence is underlain by pale yellowish brown, yellowish grey (colour banded) consolidated coarse to medium sands of Dupitila Formation (Fig.4.6).

ix) Valley fill

In SYL-9, at West Pir Mohallah, Jalalabad Residential area (24º 55′ 23″ N, 91º 52′ 05″ E), Dupitila Formation is overlain by valley fill sediments of thickness about 5m. Valley fill sediments are represented by medium to fine grained yellowish brown sands with some clayey layers containing humic materials. The valley fill sediments at Lakatura Tea Garden (SYL-10) are represented by yellowish brown coarse grained sands with small gravels. The sediments are unconsolidated, but show very high values of SPT because of textures (Fig.4.7).

x) Gulley fill

SYL-6 represents Gulley fill deposits at Natun Bazar, Uttar Balur char (24º 54′ 48″ N, 91º 54′ 02″ E). The borehole was dug through the Dupitila Formation. Dupitila Formation was overlain by a thin cover of Gulley fill materials of thickness about 2m.

xi) Alluvial fan

The valley fill sediments also have been observed at Shah Jalal University Campus (24º 55′ 36″ N, 91º 50′ 11″ E), SYL-11 (Fig.4.7). Valley fill sediments having the thickness of about 8m are underlain by Dupitila Formation. Alluvial fan and valley fill sediments have the same lithologic characteristics. These sediments are represented by dark grey sand, silty-sand decomposed organic matters (Fig.4.7). In the University Campus peat layer has been observed at a depth from 3m to 8m. At Khidirpur borehole no. SYL-3 (24º 54′ 56″ N, 91º 57′ 15″ E), alluvial fan deposits have the thickness of about 3m. The sediments are unconsolidated yellowish brown fine to medium sands and clayey sand. The same sequences have been observed at Borhanuddin road, Mirerpara (SYL-5), having the thickness 8m of dark clayey-silt or silty sand, containing organic matters (Fig.4.6). At Sylhet Pilot High School (south of circuit house), SYL-18 (24º 53.330′ N, 91º 52.296″ E), fan deposits are represented by light grey to grey or brownish yellow clayey silt and sand (Fig.4.8). The thickness of these deposits is about 7m. All the fan deposits are underlain by yellowish-brown or pinkish-brown colour banded Dupitila Formation of high SPT values.

Summary

In short, unlike other two cities, namely, Dhaka and Chittagong, Quaternary stratigraphy of the City of Sylhet is little bit different. Because of its geographical position, the city has not any marine influences like Chittagong city. Both the two cities Chittagong and Sylhet developed on the hilly terrains. Chittagong city has coastal plain sediments, but Sylhet has not. Chittagong is developed on the bank of the tidal river Karnafuli, Dhaka on the meandering river Buriganga and Sylhet is on the braided river Surma.

Depths of soft rock sediments vary a lot. Deep incised valleys were filled up with soft rock sediment. The exact time when these soft rock sediments started to accumulate, has not been fixed as the sediments are not dated. But on the basis of degree of compaction or consolidation it has been assumed that the sediments were started accumulation at the end of Pleistocene. Almost in all places, these unconsolidated sediments are underlain by Dupitila Formation of Early Quaternary Period.

CHAPTER FIVE

5. General Summary

Rigorous field works have performed in the three major cities: Dhaka, Chittagong and Sylhet. To understand the subsurface geology, hand auger and bore holes were dug upto the depth of 30m. In view of establishing the detail Quaternary stratigraphy, 18 boreholes were dug in each city. The Quaternary stratigraphy of the three major cities are given in the following paragraphs.

5.1. Quaternary stratigraphy of the Dhaka City

Dhaka is situated in the Madhupur area where Pleistocene reddish-brown deposits are esposed. Dhaka is drained by four major rivers Buriganga, Turag, Balu and Shitalakhaya and their tributaries and distributaries. At present, the rivers do not have tidal effects. The river Buriganga may have negligible effect. However, these rivers had tidal effect during the Mid-Holocene time (at about 6000 years BP), deposited some brackish water sediments on the Pleistocene erosional surfaces or incised valleys and gullies. In short, highly weathered reddish brown, sometimes, deep-brown compacted clay exposed in the Central Zone of Dhaka city is called Madhupur Formation.

The deep reddish-brown deposits exposed in the Madhupur tracts are called **Madhupur Clay Formation**, represented by highly weathered micaceous sand and clay. Madhupur Formation has been subdivided into three Members (bottom) and two beds (top). The uper Member of the Madhupur Formation so intensively weathered that the deposits became almost red in colour and powdery materials (Photo- 16 and 17). The upper member is highly weathered yellowish-brown micaceous sticky clay, in some places, it has deep reddish-brown colour, mottled structure, containing ferruginous concretions and pipe stems. Micromorphologically, the upper member of the Formation has amorphous pedofeature. The upper member is called **Dhaka Clay Member**. The middle member of the Madhupur Formation is called **Mirpur Silty-clay Member** and is represented by micaceous silty-sand and clay. It has mottled structure and has distinct oxidation and reduction spots. Micromorphologically, this kind of texture is called depletion pedofeather. The lower member of the Formation is called **Bhaluka Sand Member,** represented by highly micaceous fine sand having primary sedimentary structure. It has bridged grain pedofeature. The lower Member is less weathered and has greater thickness. On the top of the upper Member there lie two beds which are called Kalsi Beds. The Beds were first observed at Kalsi brickyards and had already been dug out. The upper Kalsi Bed is light coloured sand dominated clay and the lower Kalsi Bed is yellowish brown very sticky clay. These two beds are the palaeo-valley fill deposits, occurs discontinuously on the upper Member of the Madhupur. These erosional valleys were formed on the surface of the upper Member of the Madhupur long before.

Late Quaternary monsoon climatic episodes played the vital role in creating the present morphology of the Madhupur surfaces. The peak of the last glaciation was evidenced by dry climatic condition over the Bengal plain. From 22,000 to 15,000 yars BP, north-east monsoon was prominent. Since it was flowing from the continental surface, contained less vapour and caused scanty rain fall. By that time, the Himalayas were considerably high and were glaciated. The Bengal basin was acting like an outwash plain. Melt water was flowing through a number of palaeoriver system over the Bengal plain. During the last glacial maximum (i.e. at about 18,000 years ago), sea level was about 100 to 140m below the present sea level. Hence, the rivers were narrow and deeply incised. The monsoon climate started changing from 18,000 to 15,000 years BP. At about 12,000 years ago, south-west monsoon became prominent and caused heavy rainfall. Therefore, at the end of last glaciation (at about 10,000 years ago) amplified monsoon water plus deglaciated melt water from the Himalayas enormously flowed over the Bengal plain, i.e. over the Madhupur surfaces. Due to the strong hydrodynamic condition, the initial Madhupur surfaces were deeply dissected, created some local pools and depressions, left over a number of north-south elongated reddish-brown islands or terraces. At the beginning of Holocene (12,000 years BP), sea level started rising very rapidly. At about 5,500 years BP, sea level attains its maximum height, about 1 to 2m above the present MSL. Hydrodynamic condition of the river system changed. Erosional activities ended and the erosional surfaces were filled up by Holocene sediments. During the Mid Holocene sea level rise (marine transgression), brackish water sediments deposited over the eroded Madhupur surfaces.

The Holocene Series exposed in and around Dhaka city have grouped together and are called Basabo Formation. The Formation is unconformably underlain by the Madhupur Formation. The boundary stratotype is represented by an erosional surface which had been created by Late Pleistocene climatic episodes. The Formation is exposed in the eastern, southern and western margins of the Dhaka city, as well as exposed in flood plains, natural levees, point bars, Lateral bars, marshy or swampy wetlands, depressions, abandoned channels, erosional gullies and incised valleys of Madhupur surfaces. Geomorphological subdivisions with lithologic characteristics are well described in Fig. 13.

Holocene sediments are deposited on the erosional Pleisotocene surface of the Madhupur Formation. Geomorphologically those are the erosional valley fill and gully fill, abandoned channel fill, point bars, river bars, floodplain, tidal and supratidal flood deposits. Late Pleistocene fluvial channel deposits (Fluvial) were overlain by brackish water (Tidal and Estuarine) deposits at the Middle Holocene (around 6000 years BP). After Mid-Holocene sea level rise, tidal influence culminated in and around Dhaka city. The ‘Null Point’ of the tidal rivers moved southwards and fresh water dominated the river valleys. The tidal deposits were aerially exposed and seasonally flooded with suspended fluvial sediments. Thus the tidal or brackish water sediments were again covered by fluvial or flood plain sediments. These tidal and fluvial sediments are more or less compacted due to the aerial exposition compared to the tidal deposits of Chittagong city where Holocene tidal unconsolidated sediments are soft having very low STP.

5.1.1. Comments

Hence, it can be said in Dhaka City, the sand member of Madhupur Formation or sands of Dupitila Formation of high SPT can be found at shallow depth (in most case not exceeding the depth of 30m) after a thin cover of Basabo Formation of Holocene age.

5.2. Quaternary Chittagong city

Quaternary stratigraphy of Chittagonh City is little bit complex. The major part of the city has been developed on the right bank of the tidal river Karnafuli and is extended to the shoreline of the Bay of Bengal. Hence, Chittagong city is the place of interaction of saline and freshwater environments. The city has been fall in the zone of wave dominated coast. The river Karnafuli carries less suspended sediments compared to rivers of the middle coastal zone (Meghna estuary). In Chittagong city, variety of depositional environments can be found. Moreover, human intervention has changed the scenario of natural environments. However, intensive fieldworks were done for mapping the geomorphic units and boreholes were dug at shallow depth (5 m to 30 meters) to subdivide the lithostratigraphic units. The exposed rock units of Chittagong city are broadly subdivided into: Tertiaty System and Quaternary System.

A) Tertiary System includes: Bokabil and Tipam Formations
B) Quaternary System includes: Dupitila Formation, Dihing Formation
and Holocene Series.

It is to be noted that in subdividing the Tertiary and Quaternary systems, Dupitila Formation has been considered as the Lower Pleistocene deposits, based on palaeomagnetic data. All the Members of the Madhupur Formation showed Normal Polarity, points to the Jaramillo event (from 0.97 m.y. to 90 m.y BP) of Matuyama Magnetozone (Monsur, 1990). Dupitila Formation showed reversed polarity of Matuyama Magnetozone (older than 0.97 m.y. BP). Lower boundary of the Quaternary Period is 2.50 m.y. BP. Hence, Dupitila Formation fairly can be called as the Lower Pleistocene deposits.

Holocene Series have variety of depositional environments. The deposits cover the major part of the city. Specially, the Holocene deposits are exposed along the river Karnafuli and in the coast line. The Holocene Series have mix environments. The estuarine deposits are overlain by coastal plain (Tidal) deposits which are again overlapped by fluvial deposits (fresh water). The following geomorphological features have been observed during the field investigations: a) Piedmont plain, b) Gulley fill, c) Valley fill, d) Active channel, e) Channel bar, f) Alluvial fan, and g) Tidal flat (Fig.3.7).

In short, Tertiary (Mio-Pliocene) and Quaternary deposits are exposed in Chittagong city. In the central part of the city, Bokabil, Tipam, Dupitila and Dihing Formations are exposed. These are highly compacted and consolidated sediments. In the surrounding areas of the central part of the city, near the Bay and close to the tidal river

Karnafuli, coastal plain and estuarine sediments are exposed. These estuarine and coastal plain sediments are unconsolidated and represented by sand, silty sand, silt, silty clay, clay with micas and organic matters.

5.2.1. Comments

Geology of Chittagong City is more complex. Most part of the city is covered with coastal plain deposits having low SPT. In addition, valleys are filled up with hill slope wash and tidal flat deposits having very low SPT values.

5.3. Quaternary stratigraphy of Sylhet City

The exposed rocks of Jaintiapur area can be classified from older to younger as Sylhet Limestone, Kopili, Barail, Bhuban, Boka Bil, Tipam Sandstone, Girujan Clay, Dupi Tila and Dihing formations. All the above Formations are not exposed in the Sylhet area. The exposed rocks in the Sylhet area are (older to younger): Barail Group, Surma Group, Tipam Formation, Dupitila Formation and Holocene Series.

The lithological characteristics of exposed rocks in the Sylhet area are the same as have been described in the Chapter-one: General geology of Bangladesh. Some highlights of the lithology have been gien in the Table 4.1. The Girujan Clay Formation has not been exposed in Sylhet Metropolitan area. The Dupitila Formation forms some rolling isolated symmetrical hills, in the Sylhet City. The Tipam Formation forms some steep hills in the crestal zone of Sylhet anticline. The Dihing Formation represented by gravels (Sonatila Gravel Beds) is not exposed in the Sylhet area.

Quaternary stratigraphy of Sylhet City is little bit complex. Initial hilly terrains, specially deep valleys are filled up with soft rock sediment. As a result, thickness of soft rock sediments or valley-fill sediments varies a lot within a short distance. In addition, depressed areas initially formed some marshy land filled up with recent sediments. The sediments are not dated by any method. Based on their compactness or consolidation, the soft rock sediments have been considered as the Quaternary deposits.

It is interesting to note that te Barail Group of sediments are exposed in areas of the southern bank of the river Surma. The lateritic bed which represents the boundary (Boundary Stratotype) between the Surma Group (top) and Barail Group (bottom) is widely exposed in Galimpur area of Sylhet Metropolitan City (Photo. 4.1 and 4.2). Below the laterite Bed typical pink colour sandstone of Barail Group is exposed in the Galimpur area (Photo. 4.3 and 4.4). Surma Group (shale) overlies the Lateritic Bed and is exposed in the Galimpur area.

The following geomorphic units were delineated for the Sylhet City and its surrounding areas:

A) Denudational Landform: i) Hills, ii) Isolated hills, iii) level hills, iv) Dissected hills and v) Piedmont palin.

B) Fluvial Landform: i) Active channel, ii) Seasonal channel, iii) Point bar,
iv) Lateral bar, v) Natural levee, vi) Meander scar,
vii) Flood plain, viii) Back swamp, ix) Valley fill, x) Depression,
xi) Gully fill and xii) Alluvial fan

However, unlike other two cities, namely, Dhaka and Chittagong, Quaternary stratigraphy of the City of Sylhet is little bit different. Because of its geographical position, the city has not any marine influences like Chittagong city. Both the two cities Chittagong and Sylhet developed on the hilly terrains. Chittagong city has coastal plain sediments, but the City of Sylhet has not. Chittagong is developed on the bank of the tidal river Karnafuli, Dhaka on the meandering river Buriganga and Sylhet is on the braided river Surma.

Depths of soft rock sediments vary a lot. Deep incised valleys were filled up with soft rock sediment. The exact time when these soft rock sediments started to accumulate, has not been fixed as the sediments are not dated. But on the basis of degree of compaction or consolidation it has been assumed that the sediments were started accumulation at the end of Pleistocene. Almost in all places, these unconsolidated sediments are underlain by Dupitila Formation of Early Quaternary Period.

5.3.1. Comments

Quaternary stratigrahy of Sylhet City is more complex. Thickness of Quaternary deposits varies a lot within a very short distance. Quaternaries are mainly valley fill slope wash deposits. Sometimes, the valleys are filled up with hilcut sediments, having vary low SPT. In some areas, new settlement has started to develop on thick swampy or marshy land deposits.

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