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GEOLOGY OF THE KHULNA CITY CORPORATION

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Abstract

The Khulna City Corporation (KCC) consists of late Holocene to Recent Alluvium of the Ganges deltaic plain in north and tidal plain in south. The area is composed of sand, silt and clay in various proportions with small amount of coarse sand, which is classified into seven litho-stratigraphic units from base to top. Stratigraphic cross-sections and pannel diagram through the KCC area indicate presence of seven sedimentary cycles, each cycle resembling fining upward sequence. Complexes of channels of fluvial/tidal origin, natural levees, bars, swamps and plains like floodplain, deltaic plains, estuarine plains or coastal plain constitute the KCC area. Channels (tidal as well as fluvial), natural levee, flood plain, flood basin, ox-bow lake, abandoned channels, bars, swamps/ flood basins and estuarine plain have been recognized as geomorphological units within the KCC area. Of these the area occupied by the natural levee, flood plain and bars are ranked high for future urban development.

***Key words*:** Khulna, Stratigraphy, Geomorphology, Sedimentary cycle

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Introduction

The study area of Khulna City Corporation (KCC) is located in the southwest Bangladesh. The city along with its surrounding is bounded by the longitude 89°28′ to 89°37′ East and latitude 22°46′ to 22°58′ North. The Bhairab on northern side, Rupsa River in the middle part and Pasur on the southern side flows along eastern margin of the city and Mayur on the northern side and Hatia River on the southern side flow along the western side of the city (Fig.1).

The investigated area falls within the western part of Faridpur Trough of Bengal Foredeep (Alam 1990). The trough is filled with Tertiary and Quaternary sand and clay rich sediments with few coarse sand beds. The present investigation of the KCC area is made to prepare a geological report that could provide information for future urban planning and development of the KCC area.

Materials and Methods

The methods used in the study area include collection of topographic map, KCC and Khulna Development Authority (KDA) map, spot imagery; available deep tube well and engineering bore hole logs and geological field data. A detailed investigation over the whole study area was carried out during November, 2002 to April, 2003 on the

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basis of which geomorphological units were delineated and a geological map was prepared. Bore holes data were collected, borehole logs were studied and some shallow borehole logs were done by hand auger. Lithologies were noted down in the field notebook. Borehole litho-logs and surface as well subsurface geomorphologic and geologic information were later analyzed in the laboratory to prepare surface and subsurface geological map, stratigraphic cross section and pannel diagram. Stratigraphic succession of the study area is prepared on the basis of data collected from field and other published/unpublished scientific papers (Alam, 1990; BWDB, 1983-2000; Umitsu, 1985, 1993; Molla, 1995; Rahman *et al*. 2000)

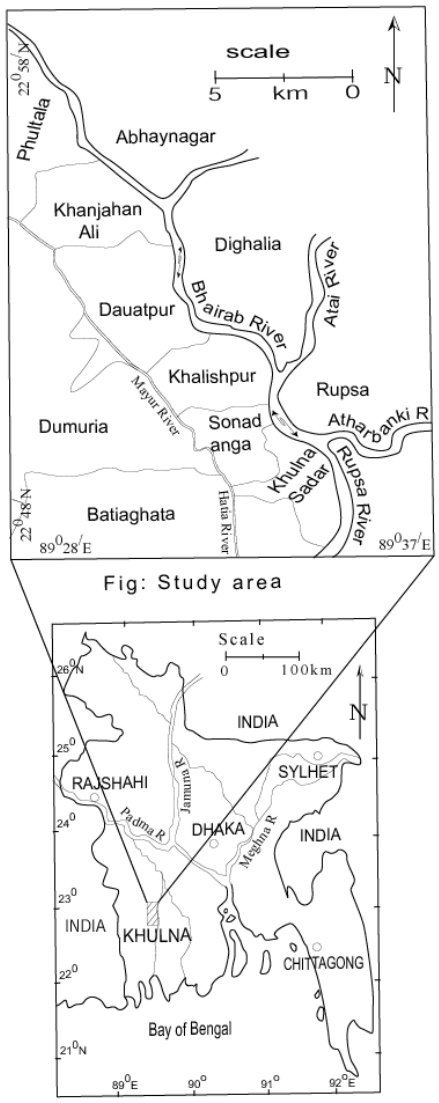


Fig. 1. Location map of the study area

Results and Discussion

Stratigraphy: The investigated area is in transition of the inactive Ganges deltaic plain in north and estuarine plain in south of Recent or Sub-Recent alluvium. The vertical geological sections as revealed from the bore holes drilled in connection with foundation engineering works and ground water exploration consist of clay, silty clay, fine to coarse sandy materials with peaty soils. The location of boreholes is shown in Fig. 2.

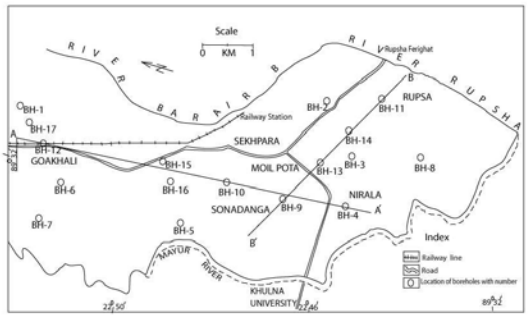
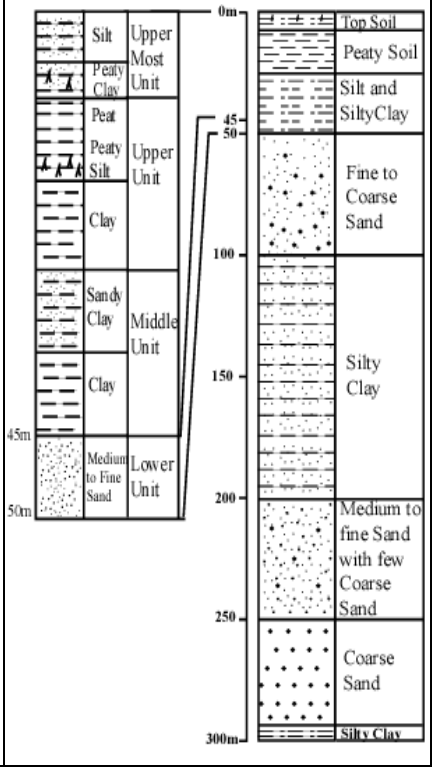


Fig. 2. The location of the boreholes in Khulna City Area.

The Unit 1 is composed of gray silty clay, the lower contact of which is not encountered in any drill hole and the upper one is erosive. It is about 10 feet thick. The Unit 2 unconformably overlies the unit1 and is composed of gray colour coarse sand at the lower part and light yellow to gray colour medium sand at the upper horizon. The Unit is 90 feet thick. The Unit 3 overlies the Unit 2 with sharp contact and is basically a gray colour sitly clay unit. The overlying Unit 4 consisting of light yellow to grayish yellow colour fine to coarse sand has lower erosive and unconformable contact. Bluish gray colour silty clay and clay rich Unit 5 with sharp lower contact overlie the Unit 4. The Unit 6 composing of deep gray to grayish black sand, silt and clay with peat overlies the Unit 5 with gradational contact. The uppermost Unit 7 is gray colour sand, silt and clay with soil peds, root traces and locally peaty soil having lower gradational contact.

A generalized stratigraphic succession of the area is prepared on the basis o of the bore hole litho-logs, fieldwork and works of Umistu (1985, 1987, 1993) is given in Table 1.

Table 1. Stratigraphic succession of the Khulna City Corporation.

Age (yr BP)		Lithology		Land forms and inferred sedimentary environment and events.	Unit	Probable age in yr BP
GaK	NUTA	Khulna Coastal Region (Umitsu, 1993)	Study Area, 2003			
3230 4180 6860 10190 12320	6490 7060 7640 8890 8910		NL, FB, ML and AC form peatlands in some parts of the inactive area of the Ganges delta and coastal plain.	7	Present to 1100±90
				Flood plain, channels and peat lands within the Ganges delta in progradational phase with intermittent deposition of fine silt of transgressive sea.	6	3000
				Shallow marine shelf, estuarine and tidal flat under transgressive sea	5	5000 to 12000
				Deposits of rivers flowing in the Ganges delta during Late Pleistocene to Holocene epoch. The lower is erosive and unconformable.	4	12000 to 18000
				Tidal creeks, tidal channel and estuarine plain deposition in the coastal area in the Bengal Basin during early Quaternary epoch, which may be equivalent to upper part of the Dupi Tila Formation. The lower contact is sharp to gradational	3	1 to 3 my
				Deposition of sand in large channels in the KCC area of the southern part of the present inactive Ganges delta which may be equivalent to the Lower Dupi Tila Formation and or Upper part of the Tipam Formation. The lower contact is erosive and unconformable.	2	5 to 9 my
				Marshy area and small channels in flood plain.	1	10my

Note: NL= Natural Levee, FB= Flood Basin, ML= Marshy Land and AC = Abandoned Channel

Depositional history: The depositional history of the Bengal Basin began with the breakdown of the Gondwanaland during the Late Mesozoic age (Reimann, 1993). The Bengal Basin was filled with sediments of Tertiary and Quaternary age (Morgan and McIntire, 1959; Umitsu, 1985, 1987, 1993). The plains of Bangladesh are affected by settlement due to consolidation of sediments and by the tectonic movements.

Mainly the Ganges deltaic deposits of late Holocene to Recent age cover the study area. The surface lithology of the area is of deltaic deposits which are composed of tidal deltaic deposits, deltaic silt deposits and mangrove swamp deposits (Alam, 1990). The sub-surface lithologies are characterized by a heterogeneous mixture of sand, silt and clay (Figs.3, 4 and 5).

The lowest unit of the study area consists of silty clay. This Unit 1 was probably deposited in marsh and small-channeled sedimentary environment, may be back swamp and flood plain of the larger channels. During the Pliocene epoch, large channels flowed in this area which is now occupied by the inactive Ganges deltaic plain in the north and estuarine plain in the south and those channels deposited coarse sand at the bottom of the Unit 2 that ended in fine sand through medium sand having characteristic fining upward sequence of fluvial deposit. The thickness of this unit is about 90m suggesting longer time period of deposition. These rock sequences are correlated with the Dupi Tila

Formation as these have the close similarity with the Dupi Tila Formation in its type section at the Dupi Tila Hill Ranges, NE Sylhet (Roy *et al*., 2004). Similar rocks have been also assigned to Dupi Tila

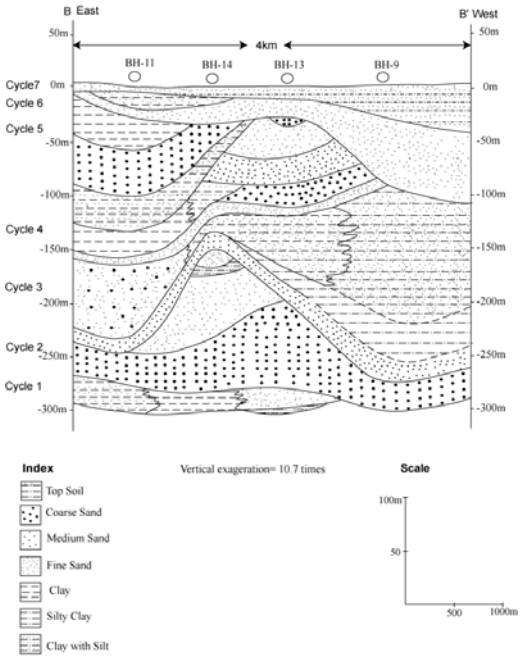


Fig. 3. Lithostratigraphic cross section along east-west direction in the study area

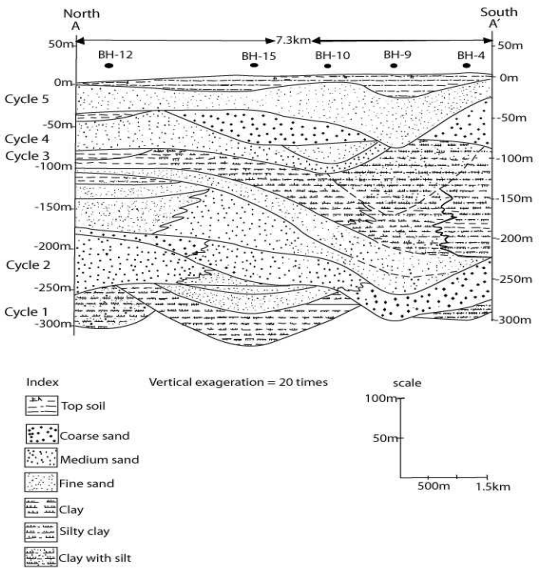


Fig. 4. Lithostratigraphic corss section along north-south direction in the study area.

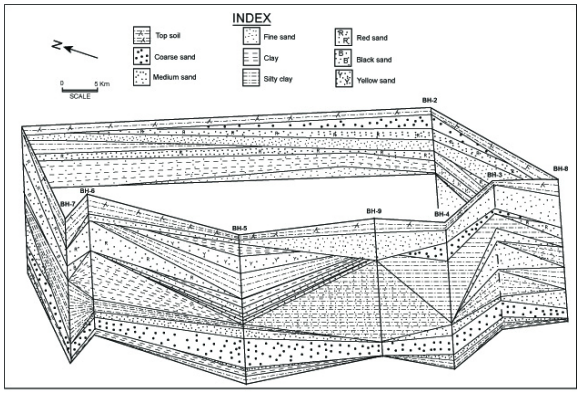


Fig. 5. Panel diagram of the study area

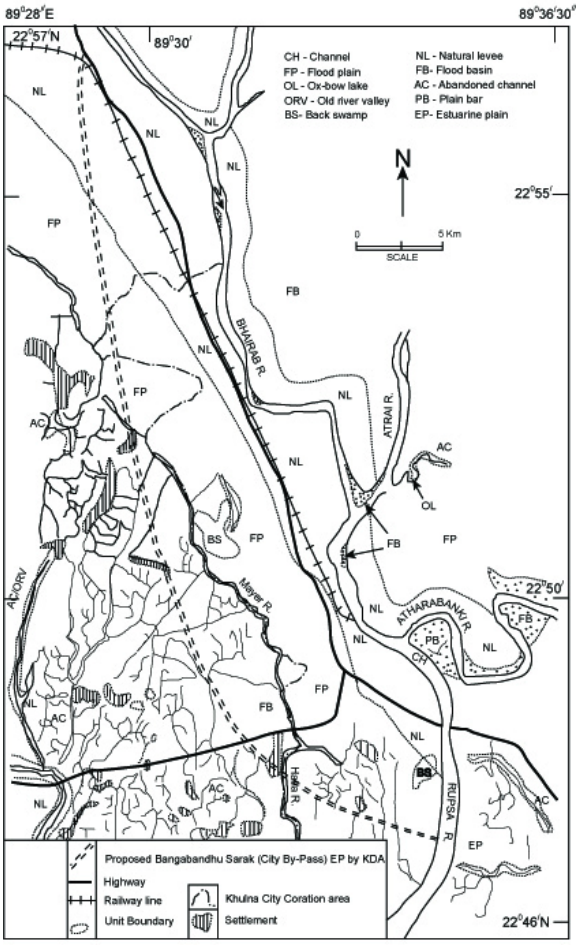


Fig. 6. Geological map of Khulna City and its adjoining area

Formation mainly based on gross lithology in the NW Bangladesh (UNDP, 1982). After the deposition of the Unit 2, during a period in between Pliocene to Pleistocene, silty clay of Unit 3 was probably deposited in tidal creeks, estuarine -tidal channels and tidal flat environment. The Unit 4 of the Late Pleistocene to Holocene epoch consisting of coarse to fine sand was deposited during last glacial maximum (18 kyr) to 12000 yr BP under deltaic condition having a thickness of about 50m when Ganges delta prograded much to south (Umitsu, 1985, 1987 and 1993). During 7000 to 5000 yr. BP, the Unit 5 was deposited after the deposition of Unit 4. This unit (Unit 5) consists of silt and silty clay, which is similar to middle unit of Umitsu's (1993) succession in the Khulna coastal region (Table-1). This unit was deposited under shallow transgressive sea and estuarine set up (Roy *et al*., 2003). The Unit 6 was deposited during 3000 to 1100 ± 90 yr.BP when sea retreated from the Bengal Basin to the south to its present limit with small intermittent transgressive phases (Monsur and Kamal, 1995). The lower part of the Unit 6 consists of black organic soils or peaty soils, which were deposited in flood basin and marshy land within the Ganges delta of the study area. The light colored silt and silty clay of Unit 6 might had deposited under local marine tongue within the Ganges delta on its southern periphery or estuarine condition. The uppermost unit (Unit 7) of litho- succession consists of noncalcareous and calcareous gray and dark gray soils. This unit has been deposited in natural levee, floodplain, marshy land, abandoned channels of the inactive Ganges delta and estuarine channels to estuarine plains of the coastal area during the time interval from 1100±90 yr. BP to present time (Umitsu, 1997).

Morphostratigraphy: Stratigraphic cross section along east south-east west north-west direction (section B′-B) in the study area covering the boreholes BH-11, BH-14, BH-13 and BH-9 (Fig.3) exhibits the vertical distribution of lithologies up to 300m depth. Seven cycles of sedimentation have been recognized within the litho-column. Every cycle of sedimentation begins with coarse sand at the bottom and ends to clay through fine to medium sand and silty clay in the middle having characteristic of fining up sequence. From the cross section it is evident that the depositional site is characterized by undulations as identified by the concave up large channel like morphologies and convex up bar ones. The width and depth of the channels vary in between 1.4 km to 2.6 km and 1.2 to 15m respectively; and width and height of bars range from 1.33 to 2.67 km and 2.5 to 15m respectively. Along the margins of the channels the elevated area are natural levees, which are also quite broad. Some small concave shaped areas lying below the bars in Fig.3 and 4 are swamps that persisted there before the development of the bars in the area. As these bars were well above the bank lines of the channels, these might have vegetated. The more or less flat lying areas adjacent to natural levees composing of fine sand, silty clay and clay with silt may be flood plain/estuarine plain. The positions of deep thalweg part of the channels and the upper part of the bars more or less remained stationary through out the lifetime of deposition that started probably from Mio-Pliocene boundary at base and ended in late Holocene- Recent time. Moreover, the rivers probably flowed towards southeast direction from the northwest, as paleocurrent azimuth could not be properly determined from borehole data.

The litho-stratigraphic cross section 2 was drawn the through bore holes BH-12, BH-15, BH-10, BH-9 and BH-4 (Fig.4) along nearly north-south (section A-A′) direction in the study area and it shows a change of morphometry with sediment infills from north to south direction. In this section, the widths of the rivers are seen to be comparatively larger from that of the east-west section (Fig.3). Here the rivers are more prominent and the bars may be present in the northwestern side in the section.

From the two reconstructed stratigraphic sections, it is evident that channels, bars, natural levees, flood plains and swamps occupied the area through out the depositional period and these produced subsurface lithologies. A part of silty clay and peaty soil represents the product of peat lands and flood basins formed in the swampy area. Apart of these sub- environments, a portion of finer sediments may be the deposits of estuaries, tidal creeks, estuarine plains and tidal flats which interfinger with the fluvial sub-environments that prevailed on the northern part of the area.

Three or more geologic sections showing the relationship of boreholes to subsurface formations is fence/ pannel diagram. These are more advantageous over the stratigraphic cross sections in exhitibiting three-dimensional view of the disposition of the

subsurface lithologies (Weller, 1960). The pannel diagram is much essential for delineation of porous and permeable aquifer that is needed for groundwater/ petroleum reservoir. It is also useful to delineate non-cohesive and high bearing capacity subsurface layers for foundation engineering of medium to heavy constructions. As for example sand dominated morphologic elements like natural levee and sand dominated layer in flood plain will yield much more ground water than a clay dominated element like flood basin and these sand dominated elements are more favorable for any type of constructions, light or heavy. Careful observation reveals that the morphogeologic elements of channels, natural levees, bars, flood plain/ estuarine plain and flood basin/ swamp can also be identified from the pannel diagram (Fig.5).

Local geology: The study area covers the natural levee, floodplain-estuarine plain, oxbow lake etc of the Rupsa-Bhairab-Pasur rivers on the east and flood plain, flood basin, swamp, abandoned channel etc of the Mayur- Hatia rivers on the west and is characterized by tidal and flood inundation with low relief. The elevation of the area varies from 3.90 m in north to 2.70 m towards southwest direction. The area is completely underlain by alluvium composed of sand, silt and clay in varied proportion as shown in Figs.3, 4 and 5. Based on topographic map, fieldwork and local information a geological map of the area is made (Fig.6). On the basis of geomorphology, relief and drainage, sediment characteristics, vegetation cover, water logging and flooding, the study area has been divided into nine geomorphological units, characteristics of which are described below.

a) Channel: Khulna City area is bounded by the river of Bhairab on the northeast, Rupsa on the southeast and Pasur in further down south. The Atharobanki river meets with Rupsa and Atai river meets with the Bhairab River on the central east and the Mayur River-Hatia Rivers lie on the west. These rivers are virtually the distributaries of Ganges River, which carry sediments from upstream. The rivers also experience semidiurnal flood tides from the Bay of Bengal. The Rupsa-Bhairab-Pasur are the active tidal rivers with strong current which carries coarser sediments from upstream and finer sediments mainly clay from downstream by flood tide. Sand grains are gray in colour and very fine to coarse grained and moderately sorted.

b) Natural levee: Natural levee is long broad low ridge of sand and coarse silt, built by the River Rupsa and Bhairab bordering the flood plain and along both banks of them (Fig. 6). The sediments are gray in colour and moderately sorted.

c) Flood Plain: Flood plain is a broad flat area gently sloping towards flood basins in the west as well as east from the natural levees of the combined Bhairab - Rupsa river system. Flood plains are occasionally inundated by high flood but the depth of such flooding does not exceeding one meter except in few low-lying areas. Aerially flood plain covers about 50% of the study area (Fig. 6). Deposits consist of clay, silty clay and very fine sand.

d) Flood Basin: This geomorphological unit is the lowest lying part of the area. The flood basins remain water logged during most of the year. Some of the flood basins start drying at the end of November. These are mostly concentrated in the southwestern part of the study area. Deposits consist of gray clay and grayish black carbonaceous clay/peaty clay with some silt.

e) Ox-bow Lake: Ox-bow lake is crescent shaped body of standing water situated by the side of a stream in the abandoned channel of meandering river when the stream formed a neck cutoff and the ends of the original bend were silted up. Ox-bow lake is mainly seen in the eastern part of the Atai River. It consists of fine to medium sand with gray clay on top horizon. It is a part of abandoned channel.

f) Abandoned Channel or Old River Valley: These are narrow depressed areas having channel like morphologies. These are once the tributaries/ distributaries of the main trunk channels of the Bairab- Rupsa, Atharabanki and Mayur River. Abandoned channels are mainly found in the western as well as eastern side of the study area. Deposits consist of dark gray clay and silt.

g) Point Bar: Point bar is a lateral ridge of sand and / gravel developed on the inside of a meander by the slow addition of individual accretions accompanying migration of the channel toward the outer bank of a meandering river. The point bars are present at places in the Atharabanki meandering channels in the eastern part of the study area. Deposits consist of light colored fine to medium sand.

h) Back Swamp: A depressed area occupied by swamp or marsh is developed on a flood plain of the river with poor drainage. Back swamps occur in the southwestern part of the area.

i) Estuarine plain: The estuarine plains are low laying narrow areas adjacent to tidal rivers which are inundated every day by tides coming from Bay of Bengal in the south. These plains consist of clay with silty materials.

Conclusions

The Khulna City Corporation (KCC) in southwest Bangladesh lies on young Holocene-Recent Alluvium of the Ganges deltaic plain in north and Ganges tidal plain in south. The area is composed of coarse to very fine sand, silt and silty clay up to a depth of 300m with peaty soil and calcareous as well as non-calcareous soil at the top. This litho-succession is divided into seven units, where Unit 1 represents back swamps and floodplains with small channels. The Unit 2 is coarsest of all units consisting of coarse to fine sand deposited by large channels and may be equivalent to a part of either Dupi Tila or Tipam Formation of Late Miocene to Pliocene age. The Unit 3 being composing of silty clay is a depositional unit of tidal channels, tidal creeks and estuarine plain. The Unit 4 is a sandy one deposited during Late Pleistocene to Holocene time (18 ka to 12000 years BP) under deltaic condition. Being consisting of silt and silty clay the Unit 5 was deposited under the marine transgression during the period of 7000-5000 years BP. The unit 6 is composed of sand, silt and clay with peaty soil and was deposited under the regressive stage with intermittent small transgressions when the Ganges delta prograded much to its present limit during the time period of 3000 yr BP to 1100±90 yr BP. The Unit 7 represents topsoil, which is a complex of natural levee, flood basin, marsh and abandoned channel in some part of the inactive area of the Ganges delta locating in the north and tide dominated coastal plain of Recent age (present time to 1100 ± 90 year BP) lying in the south of the study area.

Morpho-stratigraphically the study area up to 300m depth represents various undulations formed by seven cycles of sedimentation, where each cycle starts with coarse sand that ends with finer silty clay and clay rich deposit. The concave up undulations are formed by complexes of channels (fluvial/tidal), convex up ones by bars and horizontal ones by plains (floodplain, deltaic plains or estuarine plains). Geomorphologically the area is characterized by channels (tidal as well as fluvial), natural levee, flood plain, flood basin, ox-bow lake, abandoned channels, point bar, back swamp and estuarine plain.

References

Alam M. 1990. Bangaldesh in world regional geology. Columbia University Press, New York.

BWDB 1983-2000. Bore log data of the Khulna City Area, Bangladesh Water Development Board, Khulna.

Molla MA 1993. Geotectnical Conditions of the deltaic alluvium plains of Bangladesh and associated problems. Engin. Geology, Amsterdem 36, 125-140.

Monsur MH, Kamal M. 1995. Holocene sea level changes along the Mohesshkhali and Cox's Bazar-Teknaf coast of the Bay of Bengal. J. NOAMI 11, 15-21.

Morgan JP, McIntire WG. 1959. Quaternary Geology of the Bengal Basin, East Pakistan and India. Bull. Geol. Soc. Am 70, 319-342.

Rahman MM, Hasan MQ, Islam MS. 2000. Environmental impact assessment on water quality deterioration caused by the decreased Ganges outflow and saline water intrusion in in southwestern Bangladesh.

Reimann KU. 1993. Geology of Bangladesh: Gebruder Borntreger, Berlin-Stuttgar.

Roy MK, Karmakar BC, Saha S, Chaudhuri S. 2004. Facies and depositional environment of the Dupitila Formation, Dupitile Hill Range, Jaintiapur, Sylhet, Bangladesh. J Geol Soc Ind 63: 139-157.

Roy MK, Saha S, Ahmed SS, Mazumder QH. 2005. Tide, morphology, lithofacies, zonation and evolution of a middle Holocene to Present estuary-Meghna in south central Bangladesh. J Geol Soc Ind 66: 354- 364

Umitsu M. 1985. Natural levees and landform evolutions in the Bengal Lowland, Geogr Rev Japan 58: 149-164.

Umitsu M. 1987. Late Quaternary Sedimentary environment and landform evolution in the Bengal Lowland. Geogr Rev Japan 60: 164-178.

Umitsu M. 1993. Late Quaternary sedimentary environments and landforms in the Ganges Delta. Sed Geol Amsterdam 83: 177-186.

Umitsu M. 1997. Landforms and Floods in the Ganges Delta and Coastal Lowland of Bangladesh. Marine Geodesy 20: 77-87.

UNDP, 1982. The hydrological condition of Bangaldesh. Ground Water Survey. Technical Report DP/UN/BGD 74- 0091, New York, p.1-88.

Weller JM. 1960. Glossary of Geology and related sciences with supplement. American Geological Institute