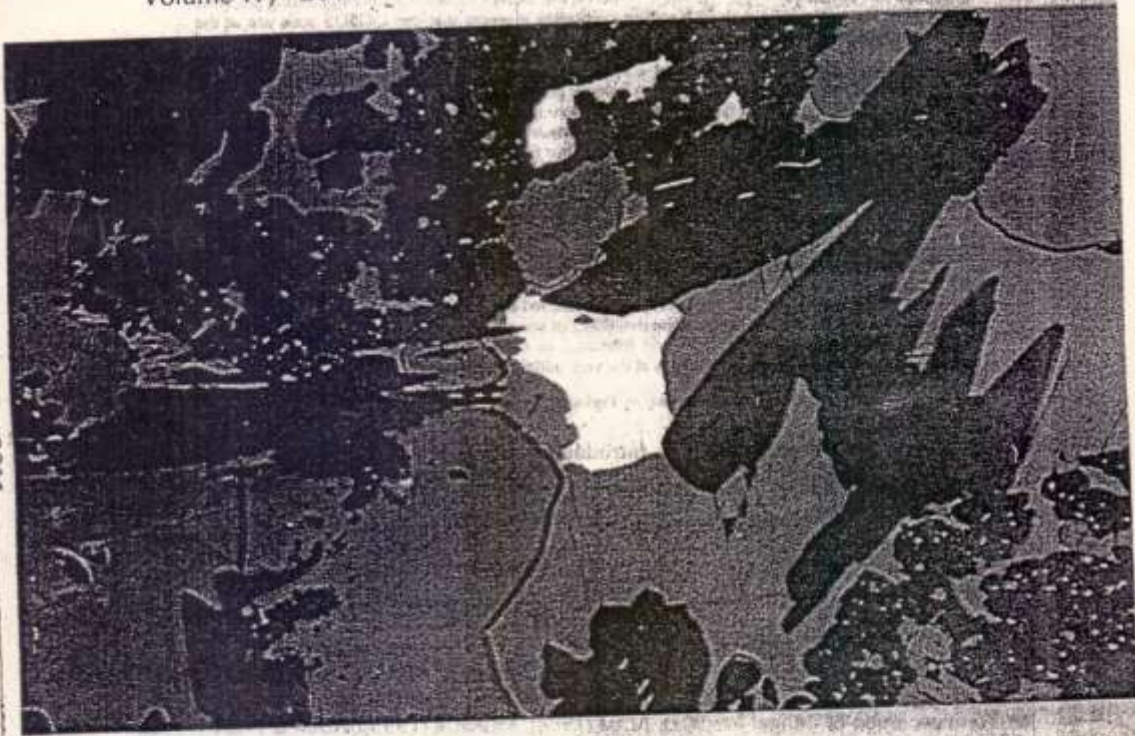


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Soil Geomorphic Evolution of Shitalakhya-Dhaleswari Interfluve

MD. SHARIF HOSSAIN KHAN, RAJIB KUMAR SAHA & SHIREEN AKHTER

Abstract

Soil-geomorphic studies of the Shitalakhya-Dhaleswari Interfluve have helped in identifying five soil-geomorphic units. Based on pedogenic developments and available records of dates from the study area, five member soil-chronoassociation was inferred and tentative ages assigned are: QGSD1 to QGSD5 are <500 yr., 0.5-2 ka, 4-7 ka, 10-12 ka and >18 ka respectively. The youngest structureless to very weakly developed and weakly developed soils of Member QGSD1 & QGSD2 respectively show features related to hydromorphism. Weak to moderate developed soils (QGSD3) and moderately developed soils (QGSD4) & strongly developed soils (QGSD5), show forestallitisation stage of weathering. But considering the intense surface weathering, strong pedality, strong clay illuviation and their ferruginous coloration it seems that the QGSD5 soils are at the initial phase of ferrugination stage and suggest their 'relict' nature of soil formation.

Neotectonics seem to have played a significant role in the evolution of the geomorphology and soils of the study area. Alluvial morphology, position of composite profiles and pedogenic characteristics from different soil-chronoassociation members five transverse lineaments/faults namely Tongi-Ghorashal, Dhamrai-Ruggani, Vakurta-Murapara, Ruhitpur-Paglia and Sirajdikhan-Bandar lineament are identified which delineate four tectonic blocks from the area and they are: Madhupur, Dhaka-Tongi, Ruggani-Keraniganj and Narayanganj-Munshiganj Blocks. These control the configuration of local catena that is soil-chronoassociation member QGSD5 at the top position, QGSD4 & QGSD3 soils are at the middle position and QGSD2 & QGSD1 are at the bottom.

The final phase of the terrace formation on the Madhupur Tract with QGSD5 soil-chronoassociation member was accomplished during 20-18ka (LGM) under subhumid-semiarid climate when sea level regression entrenched the rivers of Bengal low land. During a period between 10 to 12ka, onset of humid monsoon climate led the deposition of parent material of older floodplain soils (QGSD4); later transgressive effect of sea at 7ka initiated the deposition regime of QGSD3 soils. Around 1500 yrs B.P. soil formation of QGSD2 member took place. In QGSD1, active sedimentation is going on and it is at the very initial phase of pedogenic processes.

Keywords: Interfluve, Soil-chronoassociation, Pedogenesis, Composite profiles, Lineament, Catena.

Introduction

Bangladesh is a lower riparian country. About 85% of the land area of Bangladesh is covered by Quaternary deposits. The Quaternary landforms of Bangladesh include Pleistocene Terraces such as Madhupur, Barind and some outliers of Lalmai and Chhatak (MORGAN & MCINTIRE 1959) and Holocene floodplain deposits. Interfluves are upland areas and occur at the highest level with respect to river floodplain levels in the adjoining areas and are overlain by moderately to strongly developed soils (KUMAR *et al.* 1996). Shitalakhya-Dhaleswari Interfluve receives sediments from the Himalayan orogen through the major rivers in the region. Many researchers studied landform evolution of Bengal lowland. UMITSU (1985, 1987 & 1993) and GOODBRED & KUEHL (2000) described the landform evolution of Bengal lowland. ALAM (1988), MONSUR (1995), ALAM & PAEPE (1996), HOSSAIN (1994), RASHID *et al.* (2009) and SAHA (2011) described the stratigraphy, neotectonic and climatic fluctuation in the area during the late Pleistocene. The investigated area includes a greater part of the Pleistocene Madhupur Tract and Holocene floodplain deposits.

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A pedogenic approach has been adopted in the present study to evaluate the landform evolution of Shitalakhya-Dhaleswari interfluvium. The history of landform evolution is closely related with the history of soil development at a site and across ranges of landforms (MCFADDEN & KNIEPFER 1990). Study of soils is important in deciphering the history of landform evolution and climatic changes because the soils represent episodes of land surface stability with little or no deposition and thus record Quaternary environments in areas where there is no depositional and erosional evidence of subaerial Quaternary history (CATT 1992). Keeping these points in view the present study is aimed at the following objectives.

- I. Identifications and mapping of different soil-geomorphic units.
- II. To prepare a soil-chronoassociation.
- III. To decipher the roles of paleoclimate, sea level changes and neotectonics on the evolution of soils (Pedogenesis) in the area and in turn the landforms of the study area.

General Features

The study areas namely Savar, Tongi, Gazipur Sadar, Rugganj, Ghorashal and Kaliganj Thana fall into Terrace area which are the deposits of Pleistocene Madhupur Tract. On the other hand, Narayanganj Sadar, Bandar, Keraniganj, Sirajdikhan and Demra fall into floodplain area. On a smaller scale the area has a distinctive dendritic drainage pattern and shows a complex landform pattern characterized mainly by terrace area in upper portion and recent floodplain deposits in lower reaches. The area lies between latitudes 23° 30' N to 24° 15' N and longitude from 90° 15' E to 90° 35' E. Strongly developed yellowish brown to reddish brown, friable, soils occupy on Terrace areas and younger floodplain deposits comprises recent sediments. The study area is bounded by two major rivers, namely Shitalakhya and Dhaleswari; Buriganga, Turag, Balu, Bangshi and Tongi Khal are other important rivers in the area.

Geomorphic features like broadly dissected Terrace, level deeply weathered Terrace and level shallow weathered Terrace are the features found in the terrace areas. Broad valleys appear to be paleochannels as recognized from satellite imagery and field checks. Plains associated with Shitalakhya and Dhaleswari rivers are the site of active sedimentation.

The investigated area include four seasons i.e. Pre-monsoon (summer), monsoon (rainy), post monsoon and dry (winter). Annual average temperature of the study area ranges from maximum 36°C and minimum 12.7°C; annual rainfall 2376mm (BANGLAPEDIA 2007). The rainy season from the middle of June to late September accounts for over 90% of total annual rainfall in the area. The depth of groundwater in Terrace area is approximately 50-55m and in recent floodplain area is 25-30m.

Investigation procedure

Prior to field investigation, a soil-geomorphic map (Fig. 1) was constructed based on Topographic map (Topo sheet no.: 79 I/2, 79 I/5, 79 I/6, 79 I/9 & 79 I/10), Satellite image of the study area Landsat TM image (false colour composite with bands 4, 3 and 2, path-8221, row-7201, acquisition date: 10.3.2008), SROI (Soil Resources Development Institute) soil resource maps of corresponding Upazilla. During field investigation, the constructed soil-geomorphic map was checked and found consistent with field data. As the soils on these geomorphic units were fairly uniform and their properties varied within a narrow range, these have been called soil geomorphic units. A total number of 20 pedons were studied in the field and pedogenic characteristics of different horizons were recorded. Several other

places were also checked to find out the continuity of the units. Different soil horizons are marked along the profiles, the horizon depth/thickness; different pedologic characters (color, structure, pedality, cutan, and boundary) were recorded following SOIL SURVEY STUFF (1966). Bulk samples were collected from different horizons for analyses of the grain size distribution and pH of soils. The grain size distribution and pH were evaluated by the standard hydrometer method as described in ASTM 1974 (D422) and by Hanna HI 91 ON ATC pH meter respectively. Clay fraction ($<2\mu\text{m}$) of soil samples were used for the identification and estimation of clay minerals by X-ray diffraction analysis. Clay minerals were identified following the procedure described by WILSON (1987) and their semi-quantitative estimation was done following the method of SCHULTZ (1964).

Major Landforms and Soil-Geomorphic Units

Using remote sensing techniques followed by direct observation in the field, three major landform units were recognized and mapped in the study area. Soil geomorphology is basically an assessment of the genetic relationship of soils and landforms. In the studied area, five soil-geomorphic units with fourteen subunits were identified. Different soil-geomorphic units have developed with soils of different pedogenic characteristics. The variation in local relief and drainage conditions of the studied area and the climate of the area control the formation of different soils in different soil-geomorphic units. The Soil-geomorphic units (Fig. 1) along with sub units are listed below in Table 1.

Unit-A: Urban area (Northern part of Dhaka Metropolitan city)

This area includes northernmost part of Dhaka Metropolitan City which is mainly exposed Pleistocene Madhupur clay formation and in places covered by thin alluvium of Holocene age. Investigation and examination of typical soil profile of this area was not possible due to excessive urbanization. But according to reconnaissance survey of SROJ (1973) these soils comprise shallow red-brown Terrace soil, deep red-brown Terrace soil, brown mottled Terrace soil, shallow grey Terrace soil, deep grey Terrace soil and grey valley soils.

Unit-B: Urban area (Rest of the Dhaka Metropolitan city)

This area comprises the rest of Dhaka Metropolitan City which is entirely exposed Madhupur clay formation. Soil-geomorphic unit B soils fall in level, deeply weathered terrace area which is well drained, very pale brown silty clay to clay top soils graded into yellowish brown clay sub soils and diffusely mottled soils indicating hydromorphic condition.

Unit-C: Madhupur Tract

The Significant portion of the study area comprises Madhupur Tract. It is almost level surface represents the outcrop of the horizontal bed of Madhupur clay which underlies the area (BRAMMER 1996). This unit has been subdivided into four subunits C1, C2, C3 and C4. Soil-geomorphic subunit C1 soils fall in level, deeply weathered terrace area. C1 Soils showing a strong degree of ped development. Soil-geomorphic subunit C2 soils fall in level, shallowly weathered terrace area, showing moderate to strong degree of ped development. Soil-geomorphic subunit C3 soils fall in closely dissected, deeply weathered terrace area showing strong degree of ped development. Soil-geomorphic subunit C4 soils fall in closely-dissected, shallowly weathered terrace area showing moderate to strong degree of ped development.

Table 1: Soil-geomorphic units identified in the area.

Landform Units	Soil-Geomorphic Units	Soil-Geomorphic Sub-Units
Terrace	Unit A: Urban area (Northern part of Dhaka Metropolitan city)	
	Unit B: Urban area (Rest of the Dhaka Metropolitan city)(Madhupur Tract)	
	Unit C: Madhupur Tract	Sub unit C1: (Northern part of Rugganj, Tongi, Uttara & Mirpur Area: Area between Shitalakhya & Turag River and Adjacent to Tongi khal)
		Sub unit C2: (Savar Upazilla)
Sub unit C3: (Garipur Sadar Upazilla)		
	Sub unit C4: (South eastern part of Rugganj, deposits of Madhupur Tract)	
Old Flood plain	Unit D: Young Brahmaputra and Jamuna Flood plain, and Unexposed Madhupur Tract	Sub unit D1: (North Western part of Karaniganj Upazilla, area between Buriganga & Dhaleswari River; deposits of Old Brahmaputra Flood plain)
		Sub unit D2: (South Eastern part of Karaniganj Upazilla, area between Buriganga & Dhaleswari River; deposits of Old Brahmaputra Flood plain)
		Sub unit D3: (Demra, deposits of Old Brahmaputra Flood plain, Madhupur tract)
Young Flood plain	Unit E: Mixed floodplains of Brahmaputra, Jamuna and Meghna rivers	Sub unit E1: (Old Brahmaputra Flood plain & Madhupur Tract, Ghorashal area; adjacent to Shitalakhya River)
		Sub unit E2: (Old Brahmaputra Flood plain; Kalliganj area; adjacent to Shitalakhya River)
		Sub unit E3: (Old Brahmaputra Flood plain & Madhupur Tract; Kanchan, Bhulta, Murapara, Rugganj area; Deposits of Shitalakhya & sparse deposits Meghna River)
		Sub unit E4: (Middle Meghna River Flood plain; Purbaganj, Rugganj, Confluence or Bar deposits of Balu & Shitalakhya River)
		Sub unit E5: (Old Meghna Estuarine Flood plain; Narayanganj, deposits of Shitalakhya River)
		Sub unit E6: (Old Brahmaputra Flood plain; Bandar, Confluence deposits of Dhaleswari & old Brahmaputra River deposits)
		Sub unit E7: (Young Brahmaputra and Jamuna Floodplains, Sirajdikhan; deposits of Dhaleswari River)

Unit-D: Young Brahmaputra and Jamuna Flood plain and Unexposed Madhupur Tract

This unit comprises the active channel of the Brahmaputra and Jamuna River and adjoining areas of young floodplain formed since about 1780 when river changed into its present course (BRAMMER 1996). Besides this, the unit also comprises unweathered Madhupur tract Soil. Unit D has been divided into three subunits.

Subunit D1 soils fall in floodplain area showing a moderate to strong degree of ped development. Soil-geomorphic subunit D2 and D3 soils fall into comparatively elevated area from floodplain also showing moderate to strong degree of ped development.

Unit-E: Mixed floodplains of Brahmaputra, Jamuna and Meghna rivers

This unit comprises the floodplains of Brahmaputra, Jamuna, and Middle Meghna river. Besides this, the unit also comprises unexposed Madhupur tract. Unit E has been divided into seven subunits. Soil-geomorphic subunit E1 and E2 soils fall in floodplain area showing a weak to moderate degree of ped development. Soil-geomorphic subunit E3 soils fall in floodplain & Madhupur Tract area showing a weak to moderate degree of ped development. Soil-geomorphic subunit E4 soils fall in Middle Meghna River floodplain showing structureless to very weak degree of ped development. Soil-geomorphic subunit E5

falls in Old Meghna Estuarine floodplain showing a structureless to very weak degree of ped development. Soil-geomorphic unit E6 falls in Old Brahmaputra floodplain showing a very weak to weak degree of ped development. Soil-geomorphic subunit E7 falls in Young Brahmaputra and Jamuna floodplain showing a very weak to weak degree of ped development.

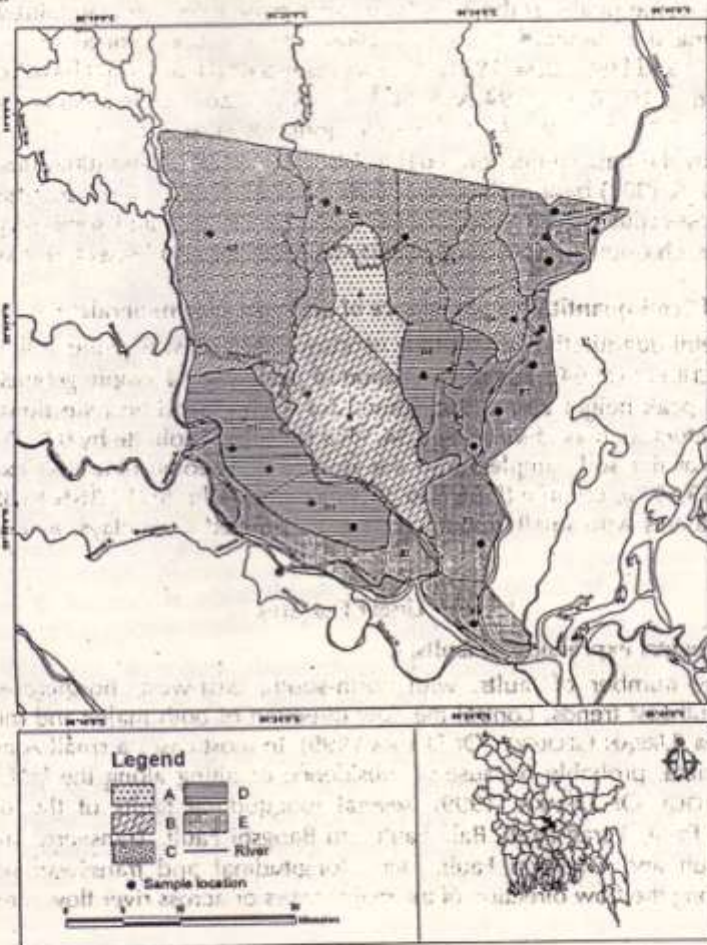


Fig. 1. Sample location, Soil-Geomorphic units & sub-units of the study area.

Mechanical Analysis and Clay Mineralogy of the Soils of Different Soil-Geomorphic Units

Mechanical Analysis

The grain size distributions of different horizons of the soil profiles were determined using the Standard Hydrometer method as described in ASTM1974 (D422). To describe the soil texture, the percentages of different fractions (sand, silt and clay) were plotted in triangular diagram and ascertained the texture of soils from clay, clay loam, loam, silt loam, sandy loam to sandy clay loam was ascertained.

Clay Mineralogy

The degree of weathering of soils may be determined through variation of the clay mineralogical composition of soils at various depths. Eighteen samples from B-horizons or AB-horizons of different soil profiles of different soil-geomorphic units were used to determine the clay mineralogical compositions of soils of the studied area. The identification of the peaks in the X-ray diffraction pattern for the clay mineral species was done following the standard X-ray diffraction interpretation procedure as described by WILSON (1987) and LINDHOLM (1991). Illite represents (001) and (002) basal reflections of X-ray diffraction at 10.40 Å - 9.94 Å; 5.34 Å - 4.84 Å. Kaolinite is identified by basal (001) reflections at 7.38 Å - 7.02 Å. Basal reflections (002) at 3.62 Å - 3.50 Å. Chlorite is represented by the basal reflection (001) at 14.87 Å - 13.81 Å and (002) basal reflection at 7.38 Å - 7.02 Å, (003) basal reflection at 4.80 Å - 4.33 Å and (004) basal reflection at 3.62 Å - 3.50 Å. Smectite are identified in the region of 17-14 Å and some mixed layer clays illite-smectite, chlorite-smectite and kaolinite-smectite are also present in minute amount.

Estimation of Semi-quantitative abundance of different Clay minerals

The semi-quantitative estimation of clay minerals was done following standard method of SCHULTZ (1964). For determination of peak areas a simple geometric calculation is made, i.e. peak height above background for each diagnostic reflections multiplied by correction factors such as chlorite by 0.54, illite by 1 and kaolinite by 0.5. The clay mineral composition of the soil samples from the studied soil-geomorphic unit exhibit that illite (36.39% to 59.59%), chlorite (9.66% to 35.12%) and kaolinite (17.36% to 39.03%) are the major constituents with small amount of smectite, mixed layer clays and non-clay quartz (Table 2).

Linear Features

Geomorphological expression of faults

A large number of faults, with north-south, east-west, northeast-southwest and northwest-southeast trends, control the flow direction of both major and minor streams of the study area (URBAN GEOLOGY OF DHAKA 1999). In most cases a small zone along fault is a low lying area, probably because of subsidence or tilting along the fault. According to URBAN GEOLOGY OF DHAKA (1999), several longitudinal faults of the study area are: Dhaleshwari Fault, Turag Fault, Balu Fault and Bangshi Fault. Transverse faults mentioned are Pagla fault and Dhamrai Fault. Here, longitudinal and transverse notice the fault alignment along the flow direction of the major rivers or across river flow direction.

Depression

All the streams (Shitalakhya, Balu) converged in the south-eastern part of the study area, suggesting a topographic depression. This depression may be tectonically induced. This area is referred to as Dhaka Depression.

Lineaments

The lineaments, in the study area, have been identified on the basis of major discontinuities observed in the remotely sensed images and characteristics of drainage patterns and are 20-50 km long. According to URBAN GEOLOGY OF DHAKA (1999), study area comprises Buriganga lineament, Shitalakhya lineament and Baunia lineament (Fig. 3).

The presence of ox-bow lakes and flooded areas

Oxbow lakes are mostly confined to the southwestern parts of the investigated area and along the Sirajdikhan-Bandar Lineament zone. Oxbow lakes commonly occur on the downthrown blocks of the Sirajdikhan lineament. Most of the lakes, if joined together, appear like past courses of the modern drainages. Large tracts on the Dhaka-Tongi block on the down-thrown sides of the Ruhitpur-Pagla lineament get waterlogged during rainy season.

Composite Profiles

Profile SNg-1 (Ghorashal, Narsingdi) in Sub unit E1 showing thick deposition of Holocene sediment over Pleistocene Madhupur deposits where upper portion's solum thickness is 137 cm and lower 198 cm. Profile SGk-1 (Kaliganj, Gazipur) in sub unit E2 containing peat deposition at 235-250 cm and solum thickness 175 cm. This two respective profile located in almost two kilometer apart; eastern and western side of the Shitalakhya river. It should be noticed that a prominent bending of river is observed here. And these significant criteria revealing neotectonic signature, from existing work of URBAN GEOLOGY OF DHAKA (1999). This is the zone of Tongi fault which may continue upto Ghorashal region and may be mentioned as Tongi-Ghorashal lineament.

In profile SKr-1 (Ruhitpur, Keraniganj) in Sub unit-D1 where sedimentation is going on upper profile over buried soil has upper solum thickness 28 cm and lower 165 cm respectively. It should be noted that a bending of Buriganga river and confluence of Balu and Shitalakhya river falls into the region of Pagla fault according to URBAN GEOLOGY OF DHAKA (1999). So this zone may be continued upto Ruhitpur area and may be referred to as Ruhitpur-Pagla lineament. Profile SMSk-1 (Kuchiamura, Sirajdikhan, Munshiganj) in Sub unit-E7 contains two peat layers at (92-98)cm and (127-131) cm depths. Buried BC, C1 & C2 are found. Profile SNF-1 (Fatullah, Narayanganj) in sub unit-E5 contains peat layer at 100 cm depth and buried C horizon is observed on downthrown block of Sirajdikhan-Bandar lineament. Location of Composite profiles is shown in Figure 2.

Based on above criteria five lineaments (Fig. 3) were identified from the investigated area and they are:

- > Tongi-Ghorashal Lineament
- > Dhamrai-Rupganj Lineament
- > Vakurta-Murapara Lineament
- > Ruhitpur-Pagla Lineament
- > Sirajdikhan-Bandar Lineament

Tectonic Blocks

Delineation of faults and soil-geomorphic units helped to decipher four major Tectonic blocks, e.g. Madhupur block, Dhaka-Tongi block, Rupganj- Keraniganj block and Narayanganj-Munshiganj block separated and bounded by transverse and longitudinal faults.

Madhupur Block

Madhupur Tract as a whole is a structural high. According to MORGAN & MCINTIRE (1959) Madhupur area, a northeasterly tilted fault block is bounded on the west by a series of six en echelon faults up-thrown on the east. The NW-SE Banar fault delineates the northeastern boundary, on the south east of the Madhupur is bounded by a basement-controlled fault zone. A "zone of weakness" between Barind and Madhupur blocks proposed by HIRST (1916) and confirmed by MORGAN & MCINTIRE (1959) represents a recently reactivated graben (KHANDOKER 1987). Madhupur Block separated from Dhaka-Tongi Block by Tongi-Ghorashal

lineament. Bangshi, Turag, Balu rivers in this block are also fault controlled rivers marked by URBAN GEOLOGY OF DHAKA (1999).

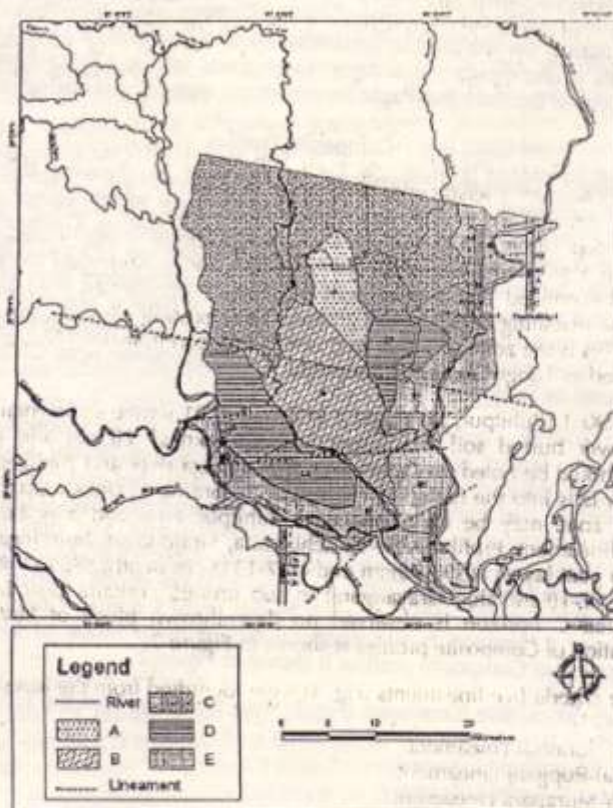


Fig. 2. Composite profiles position of the investigated area.

Dhaka-Tongi Block

Dhaka Tongi Block is bounded on the north by Tongi-Ghorashal lineament and on the south by Vakurta-Murapara lineament (Figure 4). Eastern boundary is marked by Arial Khan lineament and western by Dhaleswari Fault. In Dhamrai area, Dhaleswari river's tributary kamatali river converge with Turag river and sudden bending of Balu and Shitalakhya river prove the tectonic activity along Dhamrai-Rupganj lineament. Dhamrai-Rupganj lineament divides Dhaka-Tongi Block into two sub-blocks i.e., Tongi and Dhaka sub-blocks.

Tongi sub-block is bounded on the north by Tongi-Ghorashal lineament and bounded in the south by Dhamrai-Rupganj lineament whereas Dhaka sub-block starts from Dhamrai-Rupganj lineament on the north and bounded by Vakurta-Murapara lineament on the south. In Vakurta area, Dhaleswari river and Kaliganga river merge together bending in Murapara area. Madhupur Tract deposits are found at a relatively less depth below young floodplain. Major part of this area remains waterlogged for long period. Around Tongi and Joydevpur area

Madhupur clay is around 50 meter and in adjacent Kaliganj almost 80 meter thick but in Dhaka city, it rarely exceeds about 10 meters (URBAN GEOLOGY OF DHAKA, 1999).

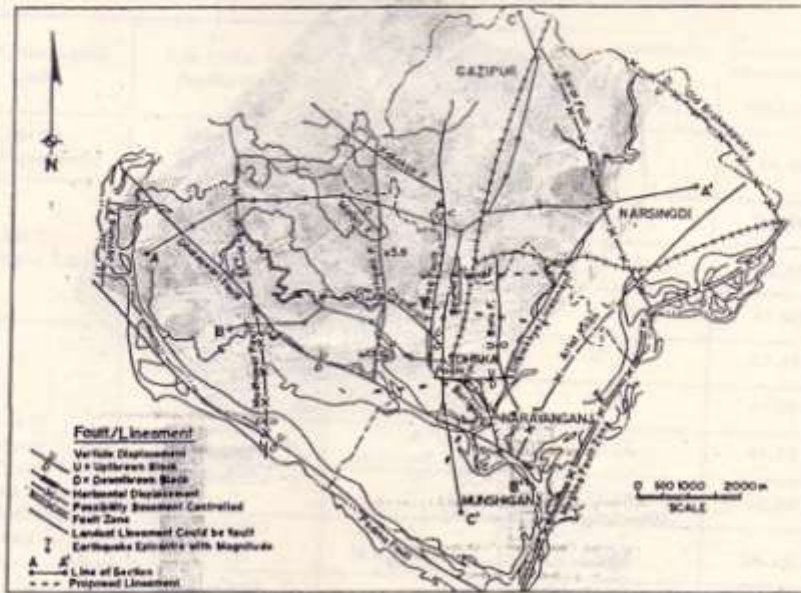


Fig. 3. Proposed Lineament superimposed on the Tectonic Map of Dhaka region (URBAN GEOLOGY OF DHAKA 1999)

Rupganj-Keraniganj Block

Rupganj-Keraniganj Block is bounded on the north by Vakurta-Murapara lineament and southern boundary is Ruhitpur-Pagla lineament. Balu fault and Dhamrai fault are the eastern and western boundaries respectively.

Narayanganj-Munshiganj Block

Narayanganj-Munshiganj Block, which is bounded on the north by Ruhitpur-Pagla lineament (extended Pagla fault) and on the south by Sirajdikhan-Bandar lineament; and eastern boundary of the block is marked by Shitalakhya lineament and western boundary by Dhaleswari fault.

Soil Chronoassociation

An integrated approach of utilizing field observations and laboratory analysis such as soil morphology, horizon thickness and development of solum (particularly B horizon), clay accumulation index, and degree of pedality, thickness and nature of clay cutan has been used to determine the degree of soil profile development in the study area. Based on the relative degree of developments, the soils of the area were divided into five groups from Group I to Group V, Group I having the least developed soils. These groups can be called the members of a soil-chronoassociation (MOHINDRA et al. 1992) and have been given the names QGSD1 to QGSD5 respectively (Table 4).

QGSD1 comprises soil-geomorphic sub unit D1 (profile: Skr-1) and sub unit E4 (profile: SRp-1), QGSD2: sub unit E5 (profile: SNF-1) and sub unit E6 (profile: SNBk-1), QGSD3: sub unit C4 (profile: SRg-1) and sub unit D3 (profile: SDd-1), QGSD4: sub unit G1 (profile: R3), sub unit E1 (profile: SNg-1) & sub unit D2 (profile: Skt-1) and QGSD5: sub unit C2 (profile: R5), sub unit C3 (profile: SGc-1), sub unit E3 (profile: SRb-1 & SRm-1).

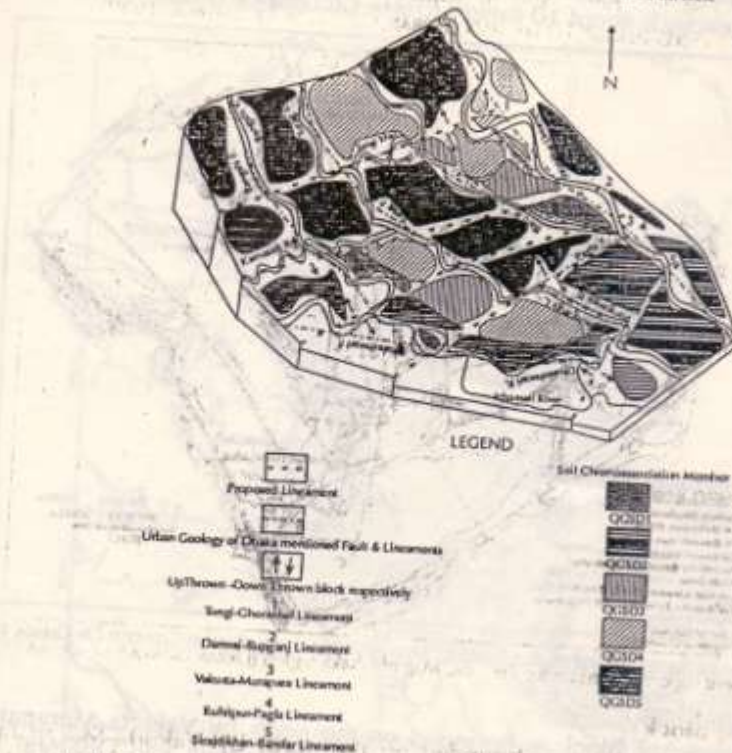


Fig. 4. Schematic model showing proposed lineaments of the study area.

Variation in pedogenic characteristics among different Members of Soil-chronoassociation

The systematic changes observed in the pedogenic characters of different soil-chronoassociation members are as follows:

a) Soil Morphology

Morphological characteristics such as structure, solum thickness and development of B horizon, texture, colour and Fe-Mn mottles and concretions, have been studied in detail (Table 4). Typical soil profiles from different soil chronoassociation are shown in the Figure 6. Structureless to very weakly developed horizonation is observed from QGSD1 soils. Weakly developed and weak to moderately developed soils encountered in QGSD2 and QGSD3 members respectively. Soils of QGSD4 are moderately developed and QGSD5 are moderate to strongly developed. Subangular blocky structure observed in QGSD2 to QGSD5 member. Thickness of Solum, B horizon thickness increase in general from QGSD1 to QGSD5 soils. Though there is some overlap in the range of these thicknesses in QGSD3 to QGSD5 soils. The thickness of B horizon increases in general from QGSD2 (25-35 cm) to QGSD5 (110-178 cm) soils. Patchy to broken, very thin clay cutan observed in QGSD1 to QGSD2 member; there is a general increase in thickness from QGSD3 to QGSD5 soil member but patchy to broken and thin clay cutan also observed in QGSD3 to QGSD5 soil member. Ferro-manganese concretions and mottles are common in the lower parts of the soil profile of member QGSD4 & QGSD5. The concretions are fine to medium size and constitute up to 2-5% of matrix. According to USDA Soil Taxonomy classification (SOIL SURVEY STAFF, 1975), most soils of the QGSD1 and QGSD2 are Fluvaquent Haplaquept and QGSD3 and QGSD4 are Aeric Fluvaquent Haplaquept and QGSD5 soils are Aeric Paleuquilt. Based on pedality soil members can be ranked as QGSD5 > QGSD4 > QGSD3 > QGSD2 > QGSD1.

Table 2: The percentage of different clay minerals in different horizons samples from different soil-geomorphic units.

Soil-Geomorphic Units	Sub Units with Profile Name	Horizons/depth	Semi-quantitative abundance of different clay minerals		
			Chlorite (%)	Illite (%)	Kaolinite (%)
Unit B : Madhupur Tract	Subunit:C1 (SDm-1)	B3 (1.67m-2.06m)	15.71	54.32	29.97
Unit C : Madhupur Tract	Subunit:C2 (R5)	B3 (0.89m-1.84m)	9.66	51.31	39.03
	Subunit:C3 (SGc-1)	B2 (0.87m-1.17+m)	12.47	54.24	33.29
	Subunit:C4 (SRg-1)	B (0.20m-0.61m)	17.36	51.08	31.56
Unit D: Young Brahmaputra and Jamuna Flood plain, Madhupur Tract	Subunit:D1 (SKs-1)	B2 (0.73m-1.15m)	27.61	37.35	35.04
	Subunit:D1 (SKr-1)	B (0.8m-0.28m)	26.10	41.08	32.82
	Subunit:D2 (SKa-1)	B2 (0.97m-1.14m)	23.56	44.52	31.92
	Subunit:D2 (SKt-1)	B (0.20m-0.42m)	23.38	42.88	33.74
	Subunit:D3 (SDd-1)	AB (0.22m-0.62m)	25.32	36.39	38.29
Unit E: Mixed floodplains of Brahmaputra, Jamuna and Meghna rivers	Subunit:E1 (SNG-1)	AB (0.25m-1.05m)	31.34	50.23	18.43
	Subunit:E2 (SCt-1)	AB (0.15m-0.70m)	34.69	47.95	17.36
	Subunit:E3 (SRk-1)	B2 (0.77m-1.17m)	26.92	48.37	24.71
	Subunit:E3 (SRb-1)	AB (0.20m-0.55m)	22.53	59.59	17.88
	Subunit:E3 (SRm-1)	AB (0.12m-0.56m)	32.85	48.84	18.31
	Subunit:E4 (SRp-1)	AB (0.18m-0.68m)	31.68	49.21	19.11
	Subunit:E5 (SNF-1)	B (0.10m-0.35m)	30.62	48.01	17.39
	Subunit:E6 (SNBk-1)	B (0.14m-0.40m)	35.12	43.25	21.63
	Subunit:E7 (SMSk-1)	B (0.15m-0.50m)	31.23	45.59	23.18

b) Textural variations

Grain size analysis of soils of different chronoassociation members indicate that most of the soils are medium to fine textured and lie in the clay, clay loam, loam, silt loam, sandy loam to sandy clay loam textural classes. Medium to coarse textured (loam) soils in QGSD1 do not show any significant variation in sand, silt and clay content with depth. These are weakly pedogenised sediments. Soils of other members are mainly clay loam to clay and become heavier (higher clay content) with greater soil development, especially in the B horizon. Increase of clay content in the B horizon over A or C horizon was taken here as pedogenic clay which is attributed to the translocation of clays from the upper to the lower horizons. Increase in pedogenic clay content in B horizon is a useful indicator of the relative age of soils (BIRKLAND, 1984). In QGSD1, there is no pedogenic clay, where as there is an appreciable increase in pedogenic clay content from QGSD2 to QGSD5 member soils. The clay accumulation indices (LEVINE & CIOLKOSZ, 1983) in different members are: QGSD2: 70-80; QGSD3: 348-360; QGSD4:480-756 and QGSD5:1260-2235.

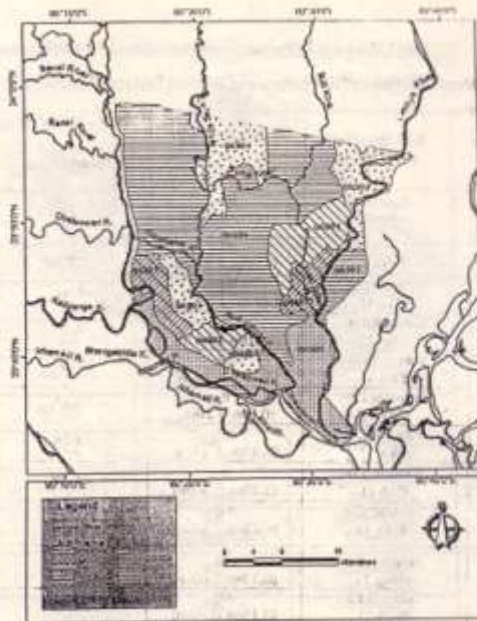


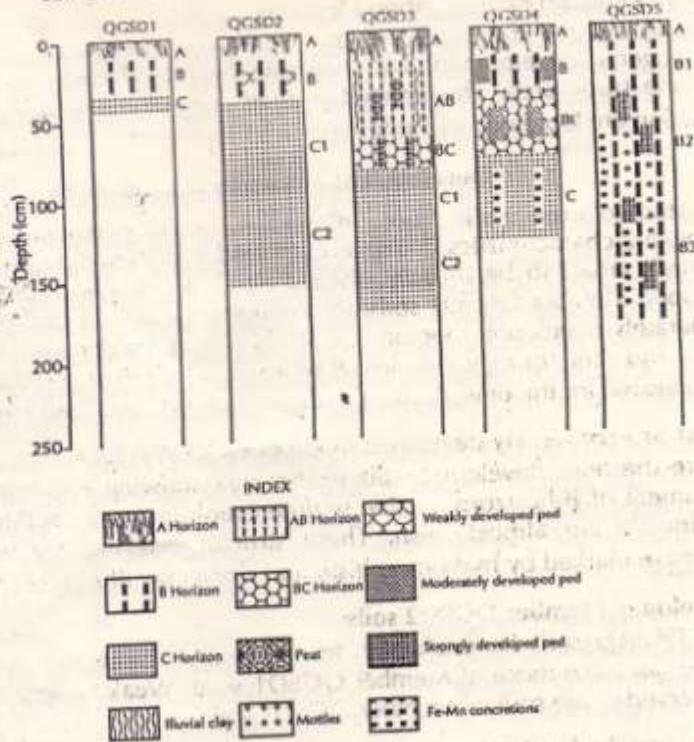
Fig 5 Soil-chronoassociation map of the study area

c) Clay Mineralogy

The major clay minerals observed in the soils of study area are illite, kaolinite and chlorite. Illite is the most dominant clay mineral in all the samples and next in abundance is kaolinite followed by chlorite (Table 2). Minor percentage of Smectite and mixed layer clays are also observed.

In the near surface environments, 1:1 clay minerals (kaolinite) is the stablest clay mineral show higher degree of weathering; and the 2:1 clay minerals (illite, smectite) and 2:1:1 clay minerals (chlorites) are less stable and show least weathering. The clay mineral abundances in different soil-chronoassociation members is very similar. Kaolinite abundances are higher in QGSD3 & QGSD4 members which may be partially inherited from QGSD5 member, as QGSD5 member is presently at the highest elevation in the local catena. In terms of clay mineral assemblages all the members of the soil-chronoassociation is at the ferrallitisation stage. But considering the intense surface weathering of the QGSD5 soils, strong ped development, strong clay illuviation, it seems that the QGSD5 soils are at the early phase of ferrugination stage.

The above observations suggest that clay mineral composition of Member QGSD5 soils probably formed due to mineral transformation during pedogenesis. Thus, the clay mineral composition of the older soils (Member QGSD5) is controlled partially by mineral transformation, whereas clay mineral composition of the Member QGSD3 & QGSD4 are partially inherited and partially neoformed but mineral transformation is less than that of QGSD5. And the clay mineral composition of QGSD1 & QGSD2 is dominantly inherited.



g. 6. Morphological features of typical pedons from different members of the Soil-chronoassociation.

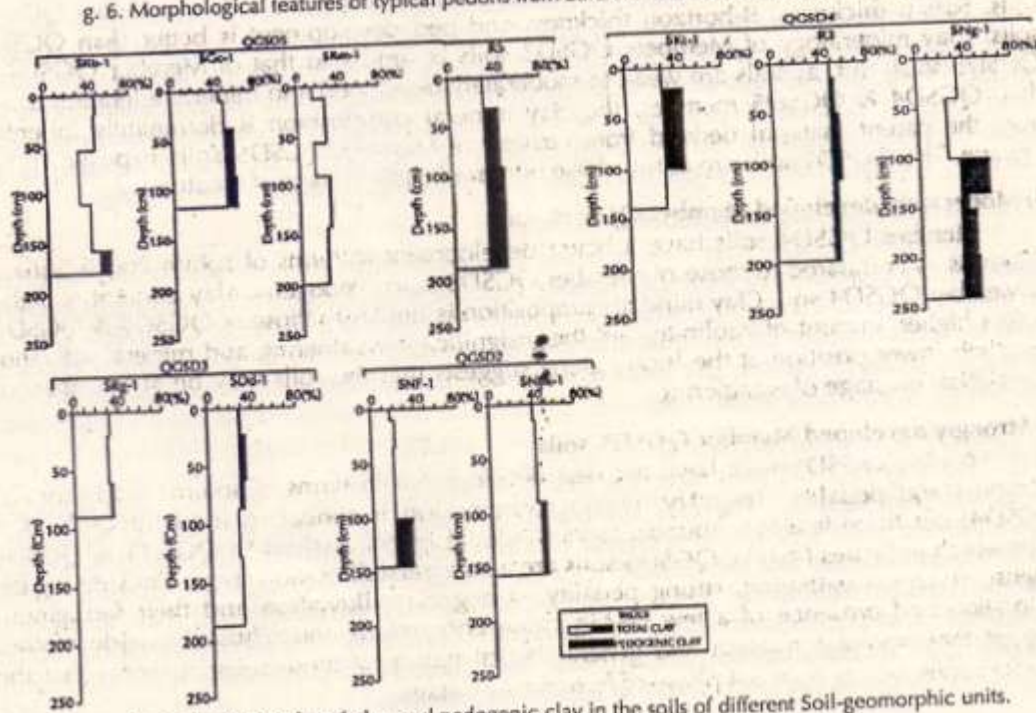


Fig. 7. Variation of total clay and pedogenic clay in the soils of different Soil-geomorphic units.

Relative ages of Soil- Chronoassociation Members

Relative ages of soil-chronoassociation members are assigned tentatively based on the degree of pedogenic development and available records (Table 3) of dates of different authors from the study area. The inferred relative ages of different members of the soil-chronoassociation are tabulated in Table 4.

Development of Landforms and soils

In the studied area, soils from different soil-chronoassociation members show different pedogenic characteristics. Integration of field and laboratory data suggests that the soils of the study area can be broadly divided into five groups: (a) Structureless or very weakly developed Member QGSD1 soils; (b) Weakly developed Member QGSD2 soils; (c) Weak to moderately developed Member QGSD3 soils; (d) moderately developed Member QGSD4 soils and (e) strongly developed Member QGSD5 soils. Important pedogenic processes responsible for the development of these soils are described below:

a) Structureless or very weakly developed Member QGSD1 soils

These are the least developed soils in the area showing A/C horizonation or only minor development of B-horizons. Active sedimentation is going on this unit. Biotite and muscovite minerals are almost fresh. These structureless to very weakly developed floodplain soils are marked by hydromorphism and slight clay illuviation.

b) Weakly developed Member QGSD2 soils

Member QGSD2 soils have a better development in terms of solum and B-horizon thickness as compared to those of Member QGSD1 soils. Weak to very weak alteration of minerals is observed in the soils of Member QGSD2 soils.

c) Weak to Moderately developed Member QGSD3 soils

Weak to very weak alteration of minerals is observed in the soils of Member QGSD3 soils. Solum thickness, B-horizon thickness and ped development is better than QGSD2 soils. Clay mineralogy of Members QGSD3 soils is similar to that of Member QGSD4 & QGSD5 soils. But, as soils are weak to moderately developed and mineral alteration is less than QGSD4 & QGSD5 member, the clay mineral composition is dominantly inherited from the parent material derived from erosion of Member QGSD5 soils exposed in the Terrace. The QGSD3 soils are at the phase of fersiallisation stage of weathering.

d) Moderately developed Member QGSD4 soils

Member QGSD4 soils have a better development in terms of solum and B-horizon thickness as compared to those of Member QGSD3 soils. Pedogenic clay content is higher in Member QGSD4 soil. Clay mineral composition is similar to those of QGSD3 & QGSD5, with a higher amount of kaolinite. But the insignificant weathering and mineral alteration and their lower position at the local catena suggests that the soils may be at the phase of fersiallisation stage of weathering.

e) Strongly developed Member QGSD5 soils

Member QGSD5 soils have the best development in terms of solum and B-horizon thickness and pedality. The clay mineral composition is similar to those of QGSD3 & QGSD4. But there is a low abundance of Kaolinite in comparison to QGSD3 & QGSD4 soils which indicates that the QGSD5 soils are also at fersiallisation stage. Considering the intense surface weathering, strong pedality, strong clay illuviation and their ferruginous coloration and presence of a few Fe-Mn oxide concretions and diffuse Fe-oxide mottles suggest their recent formation and general 'relict' nature of these soils; it seems that the QGSD5 soils are at the initial phase of ferrugination stage.

Table 3: Proxy records of dates from the study area

Profile No. with Geographic position of the present study	Correlated proxy records with geographic location	Sample type & depths	¹⁴ C Calibrated (cal B.P.)
Profile No.: (SMGk-1) Location: Kuchlamura, Sirajdikhan, Munshiganj Latitudes: N 23°39'24" Longitudes: E 90°22'49" Depth: 1.27-1.31m (below surface)	Location: Sony (left Bank of Balu river at the eastern margin of the Dhaka city) Latitudes: N 23°49' Longitudes: E 90°29' (RASHID et al. 2009)	Peat (lower layer) +1.80m above the mean sea level	1820-1530
Profile No.: (SMSk-1) Location: Kuchlamura, Sirajdikhan, Munshiganj Latitudes: N 23°39'24" Longitudes: E 90°22'49" Depth: 0.92-0.98m (below surface)	Location: Sony (left Bank of Balu river at the eastern margin of the Dhaka city) Latitudes: N 23°49' Longitudes: E 90°29' (RASHID et al. 2009)	Peat (lower layer) +0.90 m above the mean sea level	4080-4030
Profile No.: (SNF-1) Location: Fatullah, Narayanganj Latitudes: N 23°43'49" Longitudes: E 90°36'52" Depth: 1.00-1.20m (below surface)	Location: Sony (left Bank of Balu river at the eastern margin of the Dhaka city) Latitudes: N 23°49' Longitudes: E 90°29' (RASHID et al. 2009)	Peat (lower layer) +0.90 m above the mean sea level	4080-4030
Profile No.: (SGk-1) Location: Kalliganj, Gazipur Latitudes: N 23°39'24" Longitudes: E 90°21'52" Depth: 2.35-2.50m (below surface)	1) Location: Kachpur (near Dhaka city) Latitudes: N 23°41' Longitudes: E 90°30' (HASAN 1986) 2) Location: Sony (left Bank of Balu river at the eastern margin of the Dhaka city) Latitudes: N 23°49' Longitudes: E 90°29' (RASHID et al. 2009)	Peat (lower layer) 2.5-3.0 m below the surface	1) 6460 ± 80 2) 6670-6410

Role of paleoclimate and Sea level changes

The paleoclimatic and sea level changes seem to have played a significant role in the development of landforms and soils of the study area. The sea-level curve during the Quaternary for the region is yet to be established. However, results of CHAPPELL (1994) and SHACKLETON (1987) regarding Eustatic sea-level changes and geomorphological evolution of the region is correlated. A 120-m fall of eustatic sea level during the LGM (22-18 ka) observed from the Bay of Bengal (WIEDICKE et al. 1999) is comparable to global eustatic fall (CHAPPELL 1994; SHACKLETON 1987). Sea level has fluctuated several times with some stillstands during the Late Pleistocene and Holocene periods. During the sea level low stands, the rivers in the Bengal lowland were entrenched. According to CULLEN (1981), there is an onset of humid monsoon climate during 10-12 ka which supports the deposition of parent material on the QGSD4 (old flood plain). Transgression event of 7000 cal B.P. described by UMITSU (1993) & GOODBRED & KUEHL (2000) caused the development of peat or wet land during 5000 yr B.P.

Table 4: Typical features of the members of the Soil Chronoassociation.

Member	Age (Year B.P.)	Soil geomorphic units, profile no.	Soil classification (according to USDA Soil Taxonomy, 1975)	Solum thickness (cm)	Thickness of B Horizon	Structure of B Horizon	Colour of B Horizon	Column	Texture	Mottles and Fe-Mn concretions	Clay accumulated on index (CAI)
QGSD1	<500	Unit E, SRp-1	Fluvisolentic Haplaquept	68	50	Structureless	Olive (5YR4/4, dry) to dark olive gray (5YR3/2, wet)	Patchy to broken, very thin	Silty Clay loam to Silt loam	Nil	-
QGSD2	>500-2000	Unit E, SNBk-1	Fluvisolentic Haplaquept	40	26	Weakly developed, fine to very fine, subangular blocky structure	Light gray (5YR7/1, dry) to Dark gray (2.5YR3/4, wet)	Patchy to broken, very thin	Clay to Clay loam	Nil	70-80
QGSD3	4000-7000	Unit D, SDd-1	Aeric Fluvisolentic Haplaquept	87	65	Weak to Moderately developed, subangular blocky structure	Weak red (2.5YR4/2, dry) to very dark gray (2.5YR3/3, wet)	Patchy to broken, thin	Clay loam to Sandy Clay loam	Nil	348-360
QGSD4	10000-12000	Unit D, SK-1	Aeric Fluvisolentic Haplaquept	81	61	Moderately developed, subangular blocky structure	Light olive brown (2.5Y5/4, dry) to Yellowish brown (10YR 5/4, wet)	Patchy to broken, thin	Clay, Clay loam to Sandy Clay loam	Common, small to few, spherical to irregular iron-manganese concretions present.	480-736
QGSD5	>18000	Unit C, RS	Aeric Paleudult	164+	172	Moderate to Strongly developed, subangular blocky structure	Dark yellowish brown (10YR 6/4, dry) to red (5YR 4/8, wet)	Patchy to broken, thick	Clay to clay loam	Many, small to medium, spherical to irregular, hard iron-manganese concretions	260-2335

Paleoclimate fluctuated from subhumid to semiarid from about 25 ka to about 16.5 ka. Since 16.5 ka, the climate has varied between hot humid and subhumid, with short periods of more aridity (SIROCKO *et al.* 1993; SIROCKO, 1996). It seems that the thin cutan present in Member QGSD5 soils, characteristic of subhumid to semiarid climates; the presence of a few Fe-Mn oxide concretions and diffused Fe-oxide mottles indicates their probable formation during the later hot humid to subhumid phase.

Role of Tectonics

Bengal Basin lies in one of the most seismically active zones of the world. Shitalakhya-Dhaleswari interfluvium falls into Zone II of seismic zoning Map of Bangladesh (HOSSAIN 1988). Tectonics seems to have affected the development of soils and landforms significantly as discussed below:

The northern boundary of the i) Madhupur Tract (QGSD5) ii) Old flood plains (QGSD4 & QGSD3) and iii) Young flood plains (QGSD2 & QGSD1) are marked by Ghorashal-Tongi, Dhamrai-Rupganj and Sirajdikhan-Bandar lineament respectively. All these members bordered by east Shitalakhya lineament and west by Dhaleswari Fault (Figure 4).

These proposed lineaments along with the earlier discovered faults (URBAN GEOLOGY OF DHAKA 1999) control the geomorphology of the area and in turn the local catena in the study area. In the region, QGSD5 is at the top of the local catena having the best soil development in the area. QGSD4 & QGSD3 are at the middle portion of the local catena having occupied the old floodplains with moderate development and QGSD2 & QGSD1 are the bottom of the local catena where QGSD2 member occupy very weakly developed soils and in member QGSD1 active sedimentation is still going on.

Conclusions

Five soil-geomorphic units with fourteen sub units have been recognized from the study area. Ripening, ferrollysis, acidification, clay eluviation and illuviation are the major soil forming processes in the study area which were useful to divide the area into soil-geomorphic units.

Based on pedality, pedogenic clay content, clay accumulation index (C.A.I), solum thickness, thickness of B Horizon and clay mineral composition, soils from different soil-geomorphic unit may be ordered according to their maturity as Unit B & Unit C > Unit D > Unit E. It should be mentioned that Unit A could not be investigated due to excessive urbanization.

Based on pedogenic characteristics and proxy records of dates from the study area, soils from the different soil geomorphic units are grouped into five soil-chronoassociation members (QGSD1 to QGSD5, with QGSD5 being the oldest). The relative ages of different soil-chronoassociation members are assigned tentatively QGSD1: <500 yr; QGSD2: 0.5 ka-2ka; QGSD3: 4-7 ka; QGSD4: 10-12ka and QGSD5: >18ka.

From the Clay mineralogical data it can be evident that, all the soil-chronoassociation members showing fersiallisation stage of weathering but soils formed during the Late Pleistocene (QGSD5 member soils) are generally in the early stage of ferrugination. Which is reflected by their intense surface weathering, moderate to strong pedality, higher clay

accumulation index, relatively thick cutan and overall ferrugination color.

Five transverse lineaments such as Tongi-Ghorashal, Dhamrai-Rupganj, Vakurta-Murapara, Ruhitpur-Pagla and Sirajdikhan-Bandar were identified based on alluvial morphology, composite soil profile and difference in pedogenic characteristics of soil chronoassociation members. These five transverse lineaments along with earlier identified longitudinal faults bound four tectonic blocks in the study area are: Madhupur Block, Dhaka-Tongi Block, Rupganj-Keraniganj Block and Narayanganj-Munshiganj Block. The neotectonic activity controls the sedimentation and pedogenesis in the area.

During 22-18 ka (LGM) sea level low stands and subhumid-semiarid climate, the rivers of Bengal low land were entrenched and it marks the final phase of terrace formation on the Madhupur Tract with QCSD5 soil chronoassociation member. Period between 12 to 10 ka, with humid monsoon climate supports the deposition of parent material of older floodplain (QCSD4); later transgressive effect of sea at 7 ka initiates the depositional regime of QCSD3 soils. Final phase of soil formation started at 1.5 ka in young floodplain (QCSD2). Since 500 yrs B.P. active sedimentation is going on the young floodplain with QCSD1 soils.

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শীতলক্ষ্যা-ধলেশ্বরী ইন্টারফ্লুভের মৃৎ-ভূ-গাঠনিক ক্রমবিকাশ

মোঃ শরীফ হোসেন খান, রাজিব কুমার সাহা এবং শিরীন আখতার

সারসংক্ষেপ

মৃৎ-ভূ-গাঠনিক বৈশিষ্ট্যের আলোকে শীতলক্ষ্যা-ধলেশ্বরী ইন্টারফ্লুভে পাঁচটি ভিন্ন মৃত্তিকা-ভূমিরূপ একক চিহ্নিত করা হয়েছে। মৃত্তিকার ধীরে ধীরে বিকাশলাভ এবং প্রতিনিখিত্তমূলক বয়স বিবরণীর উপর ভিত্তি করে ১ সদস্য বিশিষ্ট মৃৎ-সময়ানুক্রমিক সংঘ-নির্ণয় করা হয়েছে এবং তাদের পরীক্ষামূলক বয়স যথাক্রমে কিউজিএস ১ থেকে কিউজিএসডি ৫: < ৫০০ বছর, ৫০০-২০০০ বছর, ৪০০০-৭০০০ বছর, ১০০০০-১২০০০ বছর এবং > ১৮০০০ বছর। মৃৎ-সময়ানুক্রমিক সংঘের সর্বকনিষ্ঠ সদস্য কিউজিএসডি ১, অন্তরীকৃত বা অতি দৃ এবং কিউজিএসডি ২ দুর্বলভাবে গঠিত যা পানিমাশী বৈশিষ্ট্য প্রদর্শন করছে। দুর্বল থেকে পরিমিতভাবে গা মৃত্তিকা (কিউজিএসডি ৩), পরিমিতভাবে গঠিত মৃত্তিকা (কিউজিএসডি ৪) এবং দৃঢ়ভাবে গঠিত মৃৎ (কিউজিএসডি ৫) ফারসিয়ালাইটাইসেশন আবহাওয়াজনিত ক্ষয়ের ধাপ প্রদর্শন করছে। সুতীত্র পৃষ্ঠ আবহাওয়াজনিত ক্ষয়, প্রবল পেডালিটি, প্রবল ক্রে-ইলোভিয়েশন এবং সর্বোপরি ফেরোজিনেশন রং ৪ প্রতীয়মান হয় যে, কিউজিএসডি ৫ মৃত্তিকা ফেরোজিনেশন আবহাওয়াজনিত ক্ষয়ের ধাপের প্রাথমিক পর্য বিদ্যমান এবং অল্প আয়রন-ম্যাঙ্গানিজ কনক্রিশন এবং বিকীর্ণ আয়রন-অক্সাইড মটলের উপস্থিতি কিউজিএস ৫ মৃত্তিকার নব গঠনের এবং 'রেলিষ্ট' প্রকৃতির আভাস দেয়।

শীতলক্ষ্যা-ধলেশ্বরী ইন্টারফ্লুভের ভূ-গাঠনিক এবং মৃত্তিকার ক্রমবিকাশে নিও-টেকটোনিক গুরুত্বপূর্ণ ভূমি পালন করেছে। পাললিক অঙ্গসন্ধান, সংমিশ্র মৃৎ-পরিলেখের অবস্থান এবং মৃৎ-সময়ানুক্রমিক সংঘের মৃত্তিক চরিত্রের বৈশিষ্ট্যের উপর ভিত্তি করে পাঁচটি তির্যক চ্যুতি: টপ্পী-ঘোড়াশাল, ধামরাই-রূপগঞ্জ, ভাকুর্তা-মুড়াপা কুহিতপুর-পাপলা এবং সিরাজদিখান-বন্দর সনাক্ত করা হয়েছে, পূর্বে সনাক্তকৃত খাড়া চ্যুতি ও নতুন পা তির্যক চ্যুতি এলাকাটিকে চারটি টেকটোনিক ব্লকে বিভক্ত করেছে। এই চ্যুতিসমূহ স্থানীয় কেটেনার বহিরাব নিয়ন্ত্রন করছে যেখানে, কিউজিএসডি ৫ মৃত্তিকা (মধুপুর অঞ্চল) স্থানীয় কেটেনার শীর্ষে, মধ্যভাগে কিউজিএস ৪ ও কিউজিএসডি ৩ (পুরাতন অববাহিকা) এবং কিউজিএসডি ২ ও কিউজিএসডি ১ (নতুন অববাহি নিম্নভাগে অবস্থানরত যা সক্রিয় পলি সঞ্চয়ণ, মৃত্তিকার উৎপত্তি এবং ক্ষয় দ্বারা নির্ণীত।

২০ থেকে ১৮ হাজার বছর (এল, জি, এম) পূর্বে এবং অর্ধগুরু -অর্ধঅর্ধ আবহাওয়ায় যখন সামুদ্রিক সি বাংলার নিম্নভূমির নদীসমূহকে পরিষ্কার মত কেটে ফেলেছিল তখন সর্বশেষ টেরাস গঠিত হয়েছিল, যে বৈ কিউজিএসডি ৫ মৃৎ-সময়ানুক্রমিক সংঘের মৃত্তিকাতে (মধুপুর অঞ্চল) পাওয়া গেছে। ১০ থেকে ১২ হাজার ২ এর মধ্যে শুষ্ক মৌসুমী আবহাওয়ায় পুরাতন অববাহিকার মৃত্তিকা (কিউজিএসডি ৪) এর মূল গাঠনিক উপা সঞ্চিত হয়েছিল, তারপর ৭ হাজার বছর আগে সামুদ্রিক অবনমন কিউজিএসডি ৩ মৃত্তিকার সঞ্চয়ণকাল হিে পরিগণিত হয়। ১৫০০ বছর পূর্বে, কিউজিএসডি ২ মৃৎ-সময়ানুক্রমিক সংঘের সর্বশেষ মৃত্তিকা গঠনের পরিগণিত হয়। কিউজিএসডি ১ এ, সক্রিয় পলল সঞ্চয়ণ চলমান এবং মৃত্তিকা গঠনের অত্যন্ত প্রারম্ভিক হিসেবে বিবেচিত।