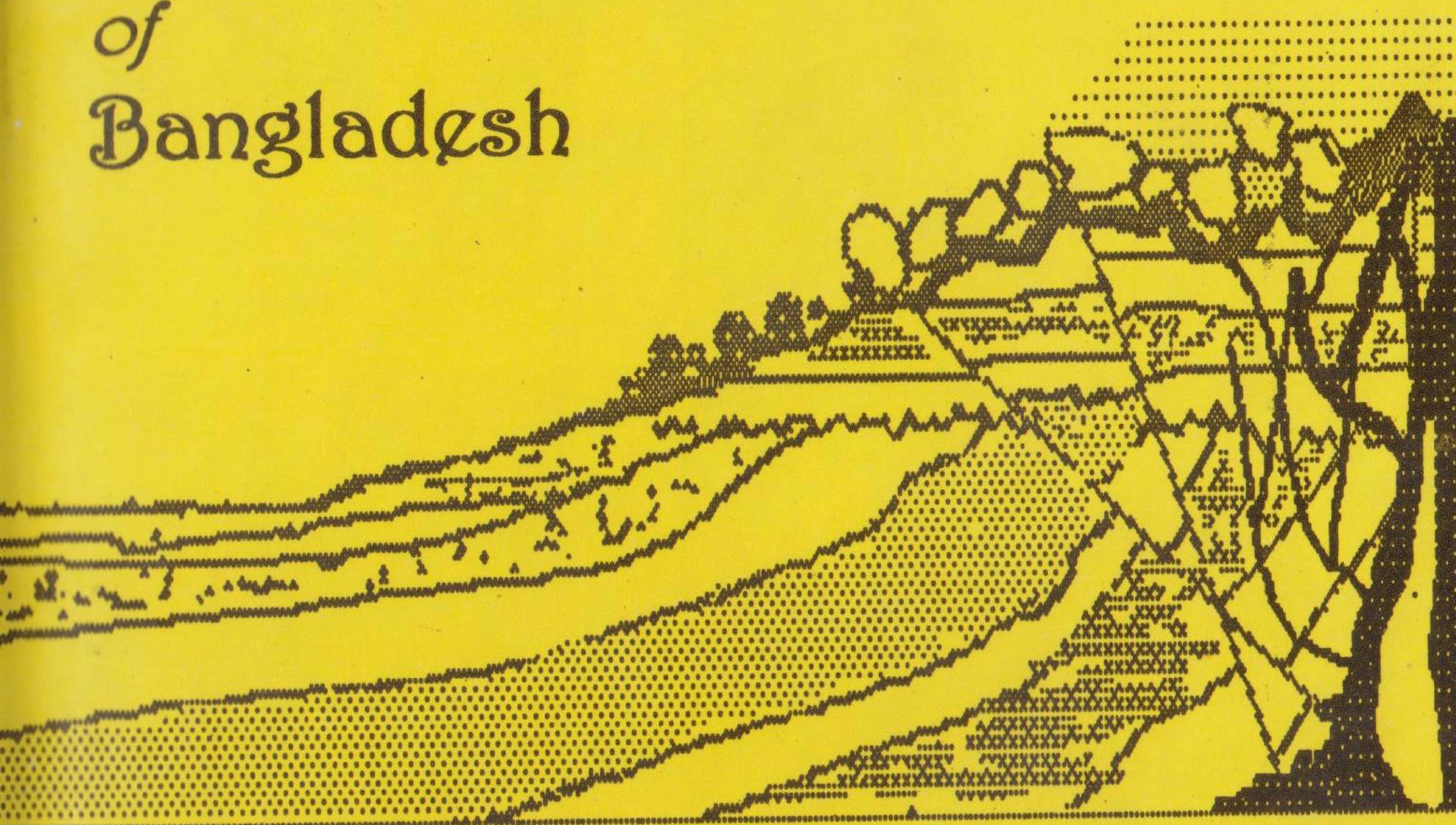
An Introduction to
The Quaternary Geology
of
Bangladesh



Md. Hussain Monsur

A complimentary research of
IGCP 347
Quaternary Stratigraphic Correlation of the Ganges-Brahmaputra Sediments

FORWARD

I am very pleased to see the book by Dr. Md. Hussain Monsur, Associate Professor of Geology, Dhaka University, entitled **An Introduction to the Quaternary Geology of Bangladesh,** coming out on the eve of the seminar of IGCP project 347.

Bangladesh, one of the largest delta basin of the world, is covered for two third of her area by Quaternary sediments. The importance of Quaternary geology for this country need not be emphasized. Since the work of Morgan & McIntire (1959) limited number of studies have taken rigorous approach in solving the versatile problems of Quaternary geology of the land.

Dr. Md. Hussain Monsur has been carrying out research work on the Quaternary geology of Bangladesh for good number of years. He has published many papers on the above topic in national and international journals. He has been the primary initiator in formulating the IGCP project 347 and rightfully deserves major part of the credit for materializing the present seminar.

I hope that this book will find its place among the participants of the seminar in their quest for the Quaternary of Bangladesh. It will also be a handy guide for the graduate and post graduate students in geology.

Dhaka
20 November 1995

Dr. Badrul Imam
Professor and Chairman
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PREFACE

There is a scarcity of latest books and Journals on geology in Bangladesh. Particularly, the demand for current literature on Quaternary geology is unquestionably great. As a teacher of Quaternary Geology of post-graduate students of Dhaka University, I always face much difficulties because of absence of adequate books on the subject. In addition, I face much more difficulties when I start teaching the Quaternary Geology of the Bengal basin.

The ideas of our National geologists on the Quaternary geology of the Bengal basin echo the concepts of Morgan and McIntire who published a report about half a century ago. Now-a-days, the Quaternary researches are much more diversified. In that context, the initial concept on the Quaternary geology of the Bengal basin should be revised. This book is written with some new concepts, thoughts and ideas.

Recently, International Geological Correlation Programme (IGCP) of the Division of Earth Sciences of UNESCO combined with the International Union of Geological Sciences (IUGS) has accepted the project no. 347, entitled, **Quaternary Stratigraphic Correlation of the Ganges-Brahmaputra Sediments and of the Indian Subcontinent.** The approval of the project has intensified the speed of Quaternary researches not only in Bangladesh but also in India and Nepal. The programme is led by Professor G.S. Ghatak in India and Dr. Prokash Chandra Adhikary in Nepal. In this respect, I am very much grateful to Dr. Khandaker Mosharraf Hossain, His Excellency, the Minister for Energy and Mineral Resources of the Peoples Republic of Bangladesh, Dr. Vladislav Babuska, the IGCP Secretary of UNESCO and Professor Roland Paepe of the

Thanks to Prof. Dr. Hussain Monsur…………

By

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Free University of Brussels, Belgium for providing me all sorts of cooperation. As being the Project Leader, I thought to collect all the available information on the Quaternary geology of the Bengal basin and to publish them in the form of a book in a very concise way, so that it may serve as a guide for Quaternary stratigraphic correlation of our Subcontinent.

However, I would like to thank Prof. Monirul Hoque (Member, UGC), Mr. Abu Bakr (Ex. DG of GSB), Prof. Badrul Imam, Dr. Syed Humayun Akhter, Mr. S.K. Datta, my two beloved students Md. Rezaul Halim and Shamsul Abedin Tarafder and my wife Mrs. Rehana Akhter for their encouragement and cooperation in writing this book.

On the eve of the International Seminar of IGCP 347 and organizational meeting for future planning, I hope this book will serve as a handy guide for stratigraphic correlation in the field as well as in the library.

In addition, I hope, this book will fulfill the growing demand for text book for graduate and post-graduate students.

Dhaka, Md. Hussain Monsur
22 November 1995

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CHAPTER - ONE

1. Quaternary Stratigraphy

1.1. Introduction

The Ganges-Brahmaputra delta in the north-eastern corner of Indian subcontinent is the largest delta with one of the thickest sedimentary sequence in the present world where the Tertiary-Quaternary sedimentary column is more than 20 km thick. The Neogene stratigraphic units of the area are diachronic in nature (Imam and Shaw, 1985). The Bengal Basin is mostly covered with Quaternary sediments. Deltaic flood plain with some Pleistocene terraces constitute the major part of the basin (Fig.1). A number of these Pleistocene terraces extends inside the territory of neighboring India. The network of the Ganges-Brahmaputra river systems are responsible for the deposition of this thick sedimentary sequence. These two mighty rivers are originated from the Himalayas and discharge into the Bay of Bengal through Bangladesh for a considerable geological time.

The so-called Madhupur Clay or reddish-brown deposits which makes the beautiful scenery of the Lalmai hills, Madhupur and Barind tracts attracted the general attention of the geologists as early as nineteen fifty's when Morgan and McIntire (1956) published a report at the Louisiana State University, after their reconnaissance survey over the Bengal basin. Afterwards, Islam (1974), Alam and Khan (1980), Hassan (1986) studied the Madhupur Clay with the similar approach as was shown by Morgan and McIntire in 1959. Bakr (1977) has introduced a new lithostratigaphic unit name Chandina Formation for the Holocene

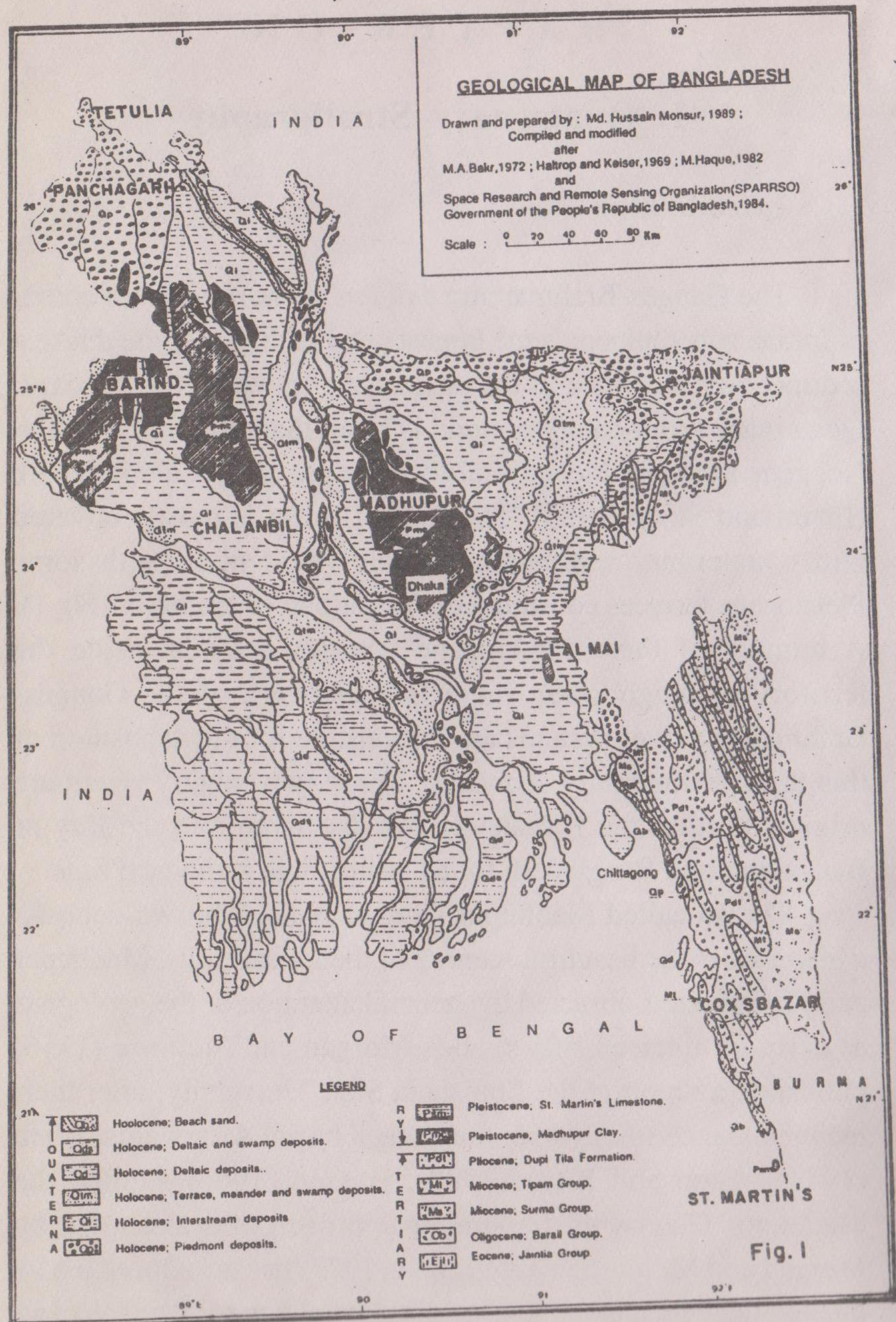


Fig. I

deposits exposed around the township of Chandina in Comilla district.

Much more detail investigations of the Quaternary deposits exposed in the Barind, Chalanbil, Panchagarh, Dahagram-Angarpota, Madhupur, Lalmai, Jaintiapur, areas and also St. Martin's, Kutubdia, Maiskhali Islands were carried out after nineteen ninety's (Akhter and Hoque, 1993; Monsur, 1990; Monsur and Hossain, 1992; Monsur and Paepe, 1992, 1993, 1994; Monsur and Kamal, 1994; Monsur and Paepe, 1994; Monsur, 1994; Monsur, 1995; Morshed, 1994; Saha, 1994). Detail stratigraphical, sedimentological, palaeomagnetical, pedological, micromorphological studies were carried out in order to establish a systematic Quaternary stratigraphy and to infer a depositional environment. A systematic studies of coastal plains of onshore and near shore islands revealed a cyclicity of Holocene sea-level rise.

For clear understanding, the stratigraphy of different geomorphic units of the Bengal basin are discussed separately in the following texts.

1.2: Quaternary stratigraphy of the Madhupur area

The Madhupur area has been considered as an area which comprises the Vawal and Madhupur Garghs (Fig.1 & 2). This area of about 4058 sq.km., extends in Dhaka, Mymensingh and Tangail districts. The so-called Madhupur Clay or reddish-brown deposits are exposed on some north-south trending elongated flat landmasses abruptly elevated from the surrounding floodplains (Fig.2).

In the Madhupur area (Fig.2), Quaternary deposits are subdivided into two Formations (Monsur and Paepe, 1994, Monsur, 1995) and are called : i) **Madhupur Clay and Sand Formation** (lower unit), represented by reddish-brown sand, sandy-clay and clay; and ii) **Basabo silty-clay Formation** (upper unit), represented by yellowish brown to bluish-grey sand to clay. The lower boundary of the Madhupur Formation is

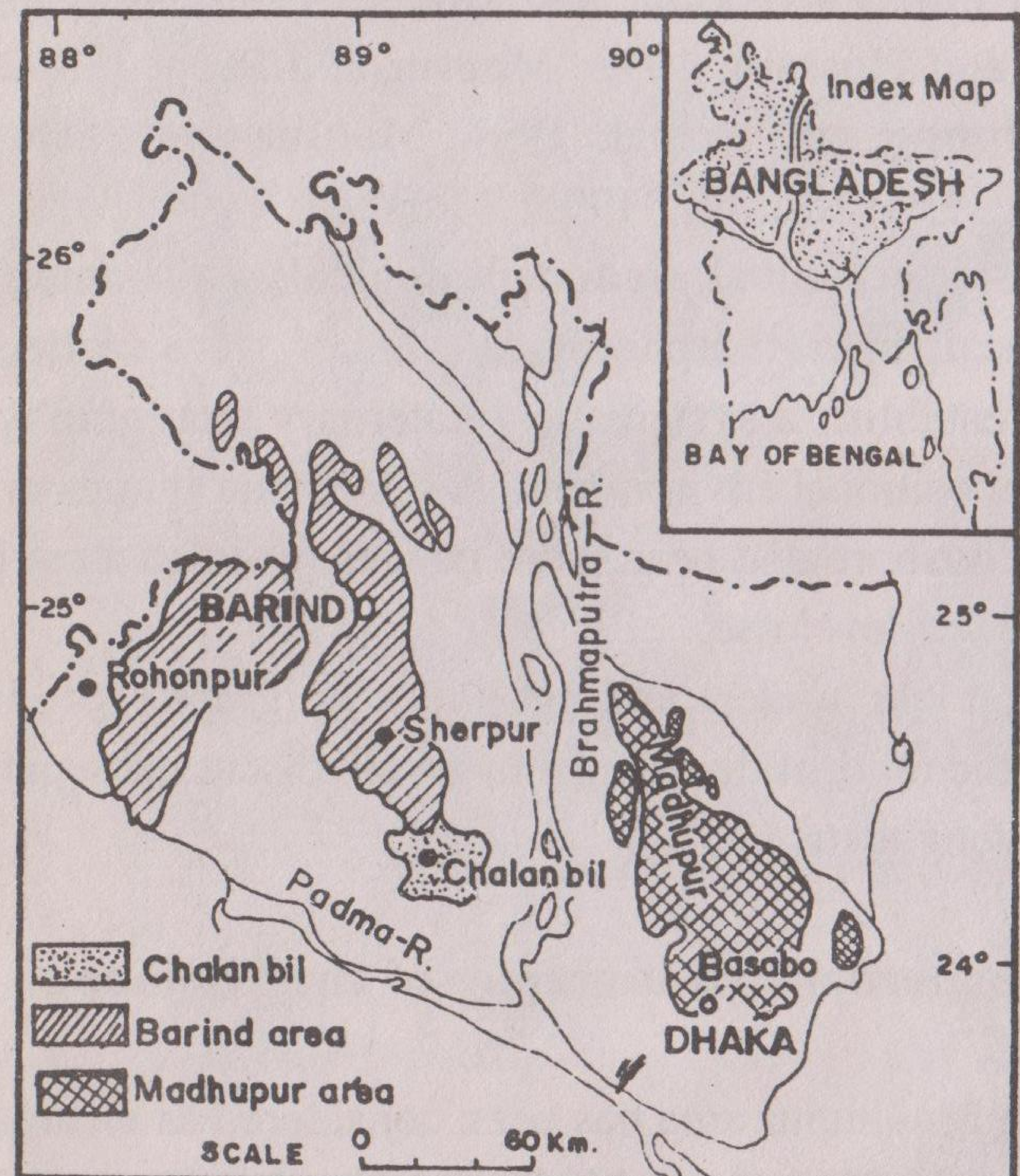


Fig.2 : Map showing the three major geomorphic units: Madhupur, Barind and Chalanbil

represented by the Quartz-chalcedony Gravel layer which is called **Comilla Quartz-chalcedony Gravel Bed** (Chap 1.3). The thickness of this Formation is about 14 to 20m. The Madhupur Formation has further been subdivided into three Members (lower subunits) and two Beds (upper subunit) based on the presence of two palaeosol horizons: S6 and S7 (Fig.3).

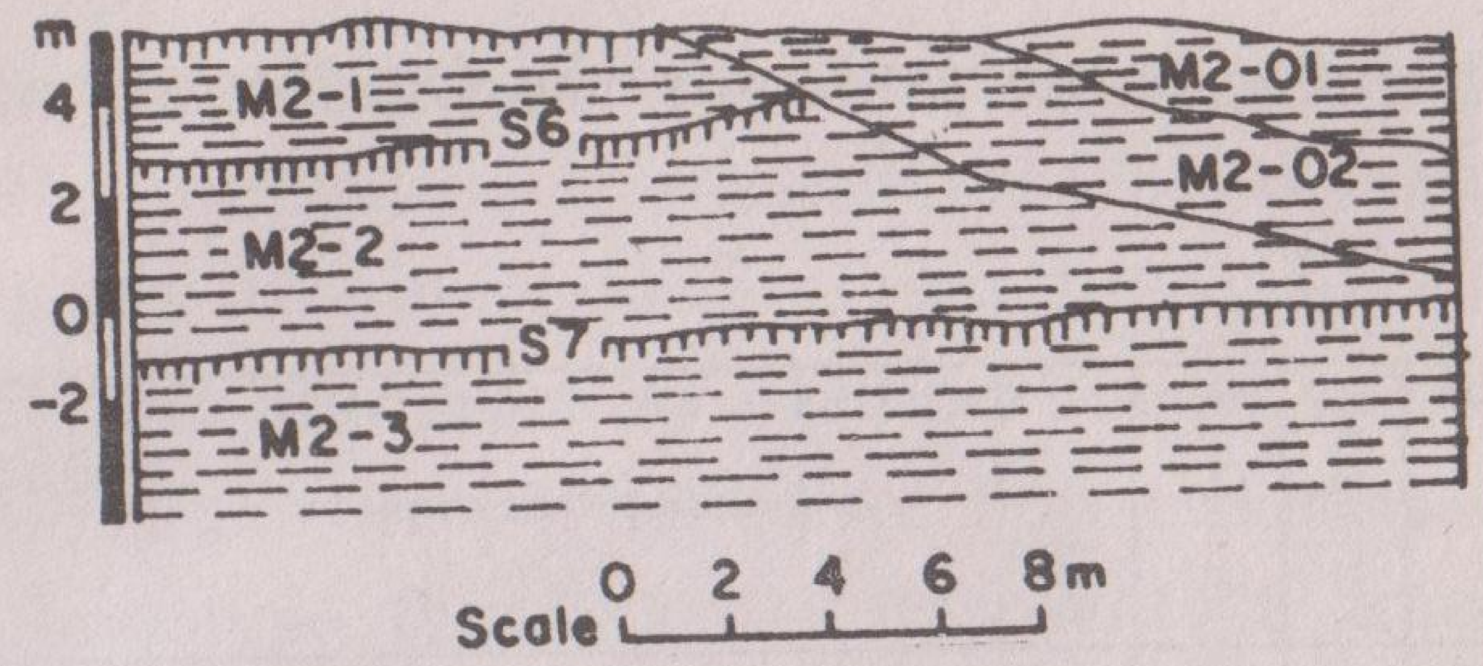


Fig.3: Stratigraphic cross section at Mirpur, Dhaka city. M2-3, M2-2, M2-1 represent respectively, Bhaluka Sand, Mirpur Silty-clay and Dhaka Clay Members of the Madhupur Formation. M2-02 and M2-01 are, respectively, the lower and upper Kalsi Beds. S6 and S7 are palaeosols.

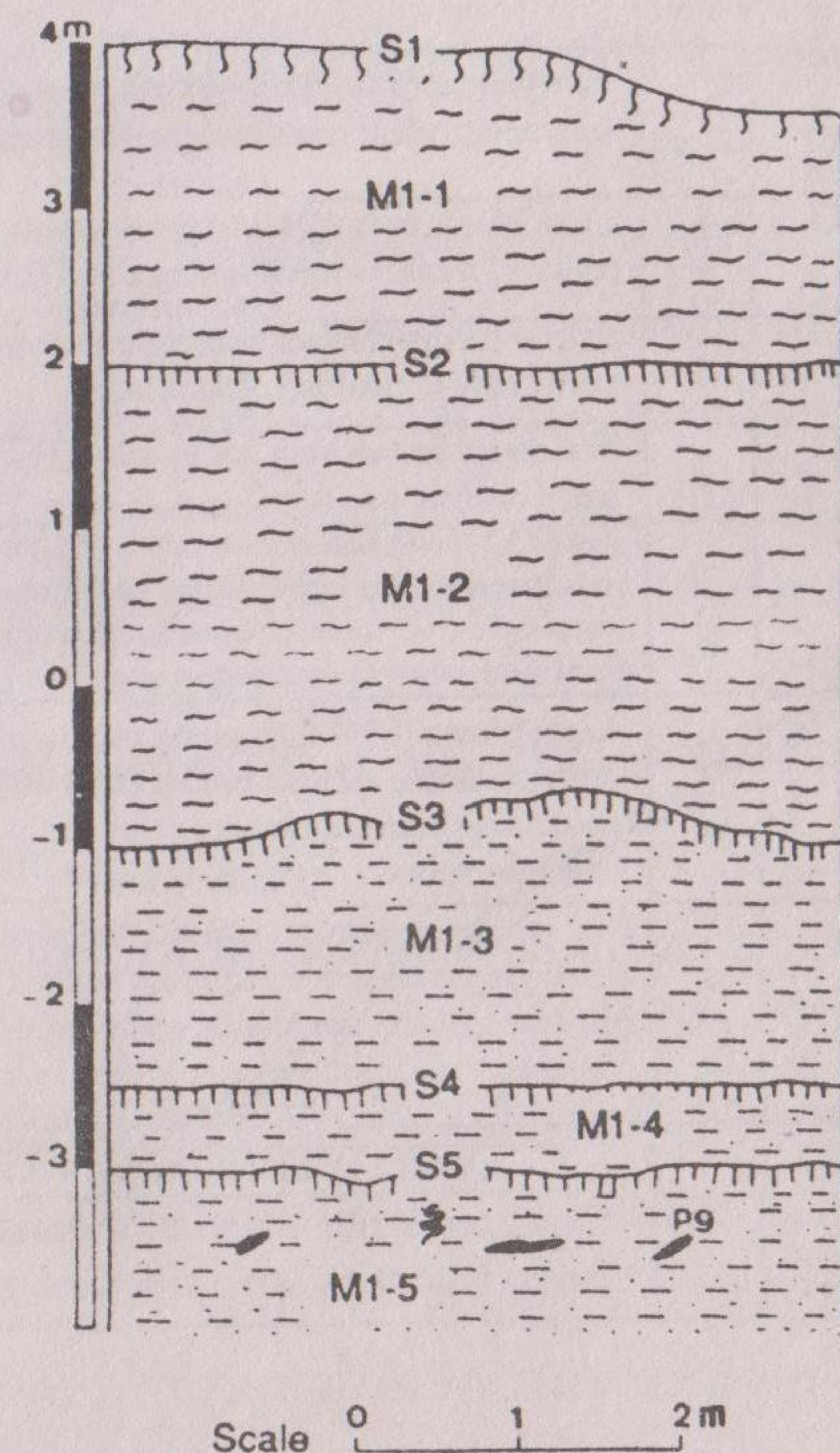


Fig.4: Stratigraphic cross section of the Basabo Formation at Kalibari pond, Basabo, Dhaka city. M1-5 to M1-3 Gulshan Sand Member. M1-2 & M1-1 Matuail Clay Member. S1 to S5 palaeosols.

Table 1: Stratigraphic table for the Madhupur area.

Chronostratigraphy: Series	Chronostratigraphy: Sub-Series	Formation	Member	Bed	Lithologic description	Thickness (m)
HOLOCENE	Sub-Atlantic	Basabo Silty-clay	Matuail Clay	Silty clay	Pale olive (5Y 6/4) very sticky silty clay with modern soil on top. Unconformity	5
	Sub-Boreal			Clayey silt	Light yellowish brown (10YR 6/4) very sticky clayey silt, containing plenty of plant roots and iron concretions. Unconformity	
	Atlantic		Gulshan Sand	Silty clay	Yellowish red silty clay. Unconformity	It varies
	Boreal			Clayey silt	Pale yellow (5Y 7/3) clayey silt, containing wood fragments, plant roots and iron concretions. Unconformity	
	Pre-Boreal			Sand	Light bluish grey (5B 7/1) sand-silt-clay to sand. It contains roots, wood fragments and Fe-concretions. Unconformity	
PLEISTOCENE	Middle	Madhupur Clay and Sand	Kalsi Beds	1	Pale yellowish brown with light brown spotted sandy clay (contains volcanis ash?) Unconformity	2
	Lower			2	Yellowish brown very sticky silty clay, containing iron concretions Unconformity	4
			Dhaka Clay	M2-1	Red (2.5 YR 4/6) with reddish yellow (7.5 YR 6/6) reduction spots. It is highly weathered and powdery. It contains Fe-concretions, pipe-stems, calcareous nodules, plant roots, micas and manganese spots. Unconformity	5
			Mirpur Silty-clay	M2-2	Light brown (5YR 4/6) sandy clay to clayey sand with moderate reddish brown (10R 4/6) spots, containing iron concretions, pipe stems, plant roots and Mn- spots. Unconformity	4
			Bhaluka Sand	M2-3	Pale yellowish brown (10R 6/2) silty-sand to sand. It is highly micaceous and cross bedded, contains Mn-spots. Micas are biotitic and highly oxidized. It contains some intraformational clay layers. Unconformity	4
PLIOCENE		Dupi Tila			Quartz-chalcedony Gravel Bed. Oxidized sands with intraformational clay beds. It contins large silicified woods	

The Members are called **Bhaluka Sand Member** (Lower Member, M2-3), **Mirpur Silty-clay Member** (middle Member, M2-2) and **Dhaka Clay Member** (upper Member, M2-1). The lower (M2-02) and upper (M2-01) Beds of this

Formation are called **Kalsi Beds** (Fig.3). Similarly, the Basabo Formation has also been subdivided into two Members: **Gulshan Sand Member** (lower subunit, M1-5, M1-4 and M1-3, Fig.4) and **Matuail Clay Member** (upper subunit, M1-2 & M1-1). The presence of buried soil horizons represents the Boundary Stratotype. Figs. 3 and 4, represent the stratigraphic sections of these two Formations at the type localities Mirpur and Basabo in Dhaka city. Lithologic descriptions of these Formations are given in the stratigraphic table for the Madhupur area (Table 1)

1.3 : Quaternary stratigraphy of the Lalmai Hills area

The reddish brown deposits are widely exposed in the Lalmai hills area. The Lalmai hills are situated in the Comilla district of Bangladesh. The Lalmai hills represent a north-south elongated low hill range of about 16 km long and about 2-3 km wide (Fig.5). The Lalmai hills area lies between the latitudes 23°20'N to 23°30'N and longitudes 91°05'E to 91°10'E (Fig.1). It covers an area of about 33 sq. km. The hill range runs through the middle of Comilla district. The average height of the hills is about 12 meters but some peaks rise up to about 40 meters or more. Most of the hill tops are covered with reddish-brown soil which makes a beautiful scenery of the hill range. Some of the hill tops represent table surfaces and these table surfaces are separated from each other by deeply incised valleys. The northern part of the hill range is locally known as **Mainamati,** which merely echoes the memory of king Govinda Chandra's mother Mainamati, while the southern part is known as Lalmai or **'Red Hill'** from the red colour of soil (Alam and Khan, 1980). In geological and geomorphological view point, the area

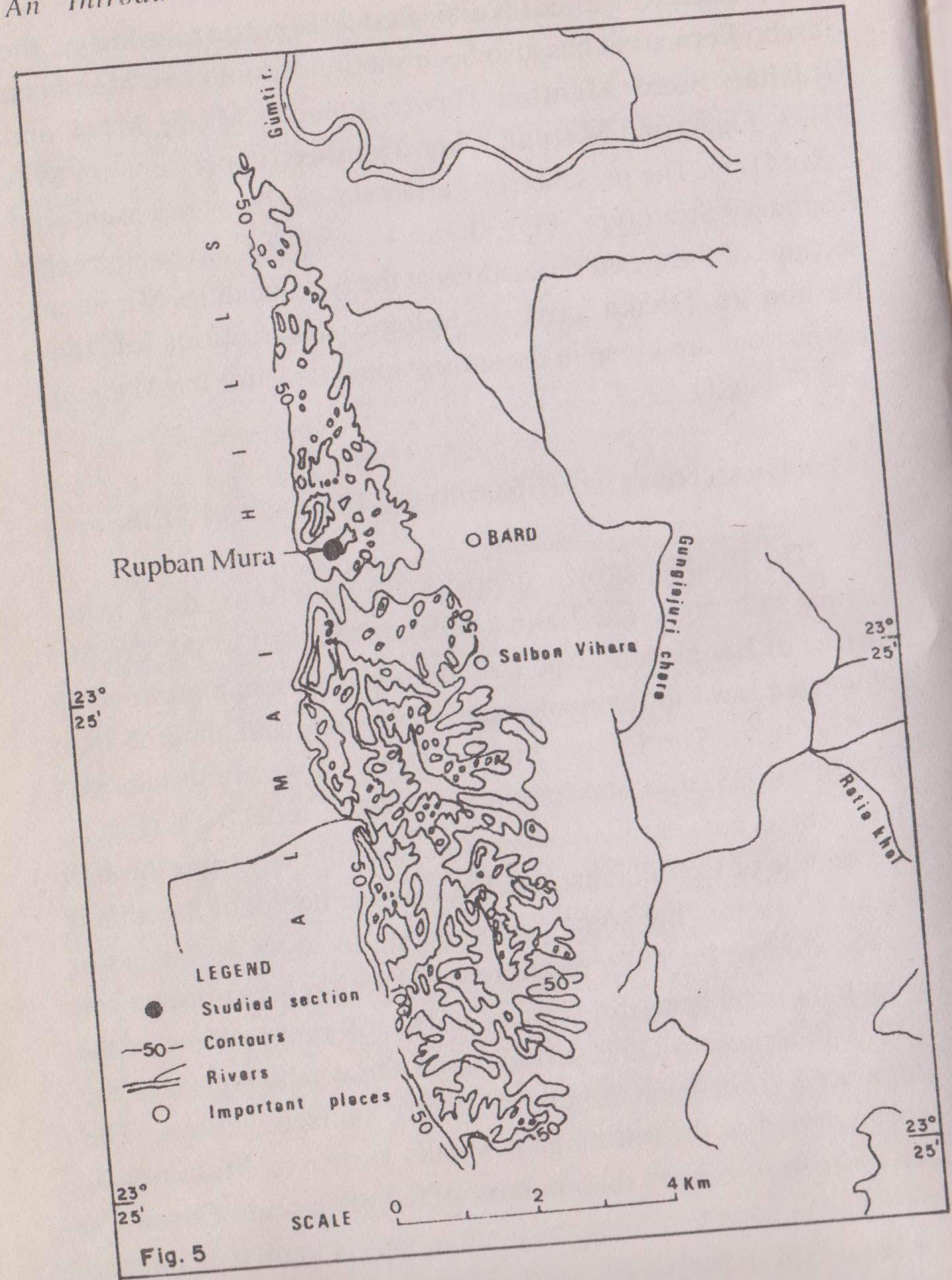


Fig.5 : Map showing the location of the Lalmai Hills area.

in this text will be called as **Lalmai Hill Range**.

The reddish-brown deposits of the Madhupur area attracted the adequate attention of the geologists since as early as 1956, when Morgan and McIntire, published a report at Louisiana University, after their reconnaissance survey over the Bengal basin under the heading "Quaternary Geology of the Bengal basin" (Morgan and McIntire, 1956, 1959). As a preliminary survey, the research contained much merits. In fact, the so called lithostratigraphic nomenclature derived from their reconnaissance survey. The research was mainly morphostratigraphically based and they considered the reddish-brown deposits exposed in the Madhupur, Barind and Lalmai hill areas as "the Pleistocene terrace" which they assumed to be identical with the Mississippi terrace but they could not establish conclusively the existence of multiple terrace system in the Bengal plain. Later on, Geological Survey of Bangladesh paid attention and published some geological reports regarding the Madhupur Formation (Bakr, 1977; Alam and Khan, 1980). A detail sedimentological and stratigraphical research was performed by Hassan (1986) in his doctoral dissertation. In addition, some palaeomagnetical and micromorphological research were performed by Monsur (1992, 1990).

The lithostratigraphic classification serves to organize systematically rock strata of Earth into named units which represent the principal variations of these rocks in lithologic character. Deep reddish brown to light yellowish brown colour with white reduction spots combine to form typical textures which are striking characteristics of the so-called Madhupur Clay or the deposits capping the Lalmai hill tops. Sometimes, these textures of sediments are also common in some younger deposits of different environments. Hence, it is a quite difficult task to establish systematic lithostratigraphy of these deposits.

The reddish brown deposits exposed in the Lalmai Hill area are grouped together and are called **Madhupur Clay and Sand Formation.** The reddish brown deposits exposed in the Lalmai Hill area is the extension of the reddish brown deposits of the Madhupur area. Sometimes, these deposits maintain the subsurface lithologic continuity. The reddish brown islands by the side of the Dhaka-Comilla road section indicate such a continuation and the wide extension of the initial surface of the Madhupur Formation. Sometimes, this Formation had completely been eroded away by Late Pleistocene and Early Holocene erosional activities. Hence, the nomenclature **"Madhupur Clay"** which was introduced by Morgan and McIntire (1959) and its modification **"Madhupur Clay and Sand Formation"** (Monsur, 1994) were restored and were being extended to the Lalmai Hill area and was called as **"Madhupur Clay and Sand Formation"**. The lower boundary of this Formation is defined by the **Comilla Quartz-chalcedony Gravel Bed** (Monsur, 1994). The maximum exposed thickness has been recorded at BDR Camp section at Cotbari, Comilla and is about 15m (Fig.6). At Uttarkhan near Dhaka city the borehole data shows the highest thickness of this Formation and it is about 50m. This Formation has been subdivided into the following subunits:

i) the upper clay subunit

ii) the middle clayey-sand subunit

iii) the lower sand subunit

i) the upper clay subunit:

This is the topmost subunit of the Madhupur Formation

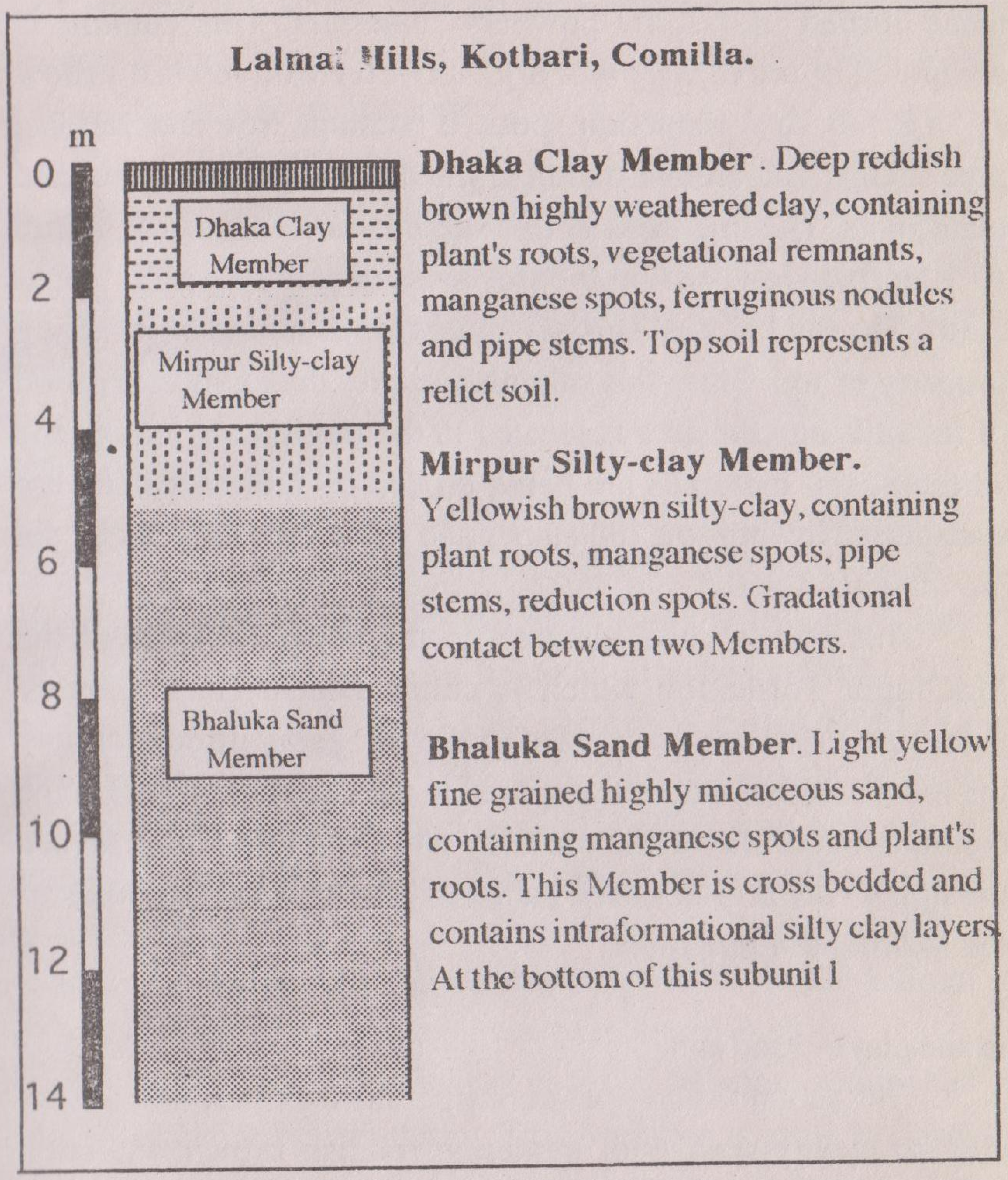


Fig.6 : Stratigraphic cross section of the hillock at the western side of the BDR camp staff quarter, Cotbari, Lalmai, Comilla.

which makes the beautiful scenery of the Lalmai Hill area (and also the Barind and Madhupur tracts). This subunit caps almost all the hill tops of the Lalmai hills. This subunit is highly weathered. The intensity of weathering is extremely high and the rocks turned into some powdery materials. This subunit is composed of red (2.5YR 4/8, dry) silty-clay with reddish yellow (7.5YR 6/6, dry) reduction spots. It contains iron concretions, pipe stems, calcareous nodules, micas, manganese spots and plant roots. The thickness of this subunit varies from 2m to 3m. At Ranirbanglow section the thickness of this subunit is about 2.3m. The thickness of this subunit depends on the engineering property of soil. Since this subunit occupies the topmost position of the hills and the area is located in the monsoonic region, the surfacial soil materials are being eroded by rain drops and are transported towards the hill slopes and foot of the hillocks by the gravitational force.

This unit is quite identical to the upper Member of the Madhupur Formation which is called Dhaka Clay Member (Monsur, 1994). As it was said in the foregoing discussion that the reddish brown deposits exposed in the Lalmai Hill area is the continuation of the Madhupur Clay and Sand Formation. Hence the upper clay unit has been called as **Dhaka Clay Member** of the Madhupur Formation.

ii) the clayey sand subunit

This subunit is composed of light brown (5YR 5/6) sandy-clay to clayey-sand with moderate reddish brown reduction spots. The thickness of this subunit is about 3-4m. This subunit has gradational contact with the upper and middle Members of the Madhupur Formation. This subunit has been called as **Mirpur Silty-clay Member** (Monsur, 1994) as this is equivalent or similar to the middle Member of the Madhupur Formation. In the Madhupur area, the contacts between the upper and middle Members and also between the middle and lower Members are, respectively, represented by palaeosol

layers S6 and S7. In the case of the Lalmai Hill area, such a palaeosol has not been recognized. Hence, the classification was based on the change of lithology.

The colour of this Member is the most striking characteristics. It has deep red oxidation spots. This subunit also contains iron concretions, calcareous nodules, micas and manganese spots. Micas are generally biotitic. Lower part of this Member is mottled.

iii) The lower sand subunit

The lower subunit of the Madhupur Formation is represented by yellowish brown (10YR 6/2, wet) highly micaceous medium to fine cross bedded sand with light brown (5YR 5/6, wet) reduction spots. It contain iron concretions, plant roots and organic remnants. This subunit is called **Bhaluka Sand Member** (Monsur, 1994). This Member has the highest thickness. The exposed thickness at BDR camp section at Cotbari is about 10m (Fig.6). The contact between the middle and lower Member is also gradational. In Madhupur area this contact is represented by the palaeosol layer S7. In the Lalmai Hill area no such palaeosol layer has been recognized.

In the Madhupur Formation, only this Member retains the primary sedimentary structures. This Member is cross bedded. This Member contains intraformational sandy-silt layers. This Member overlies the Dupi Tila Formation of Pliocene Series. The boundary between the Madhupur and the Dupi Tila Formations is represented by the first quartz-chalcedony gravel layer at the base of this Member which is called **Comilla Quartz-Chalcedony Gravel Bed** (Monsur, 1994). These Gravels are represented by smooth quartz-chalcedony gravels of

1 to 1.5 cm elongation. This gravel bed makes a marker horizon or key bed all over the basin.

1.4: Quaternary stratigraphy of the Barind area

The Barind area falls in the central part of north Bengal and covers an area of about 7680 sq.km. The area comprises about six north-south elongated isolated exposures of reddish brown deposits (Fig.2). Previously, the reddish-brown deposits exposed in the Barind area were also called Madhupur Clay (Morgan and McIntire, 1959), Alam and Khan (1980), Islam (1974). The Barind and Madhupur area are quite apart from each other and there is no lithologic continuity. Hence, the Quaternary

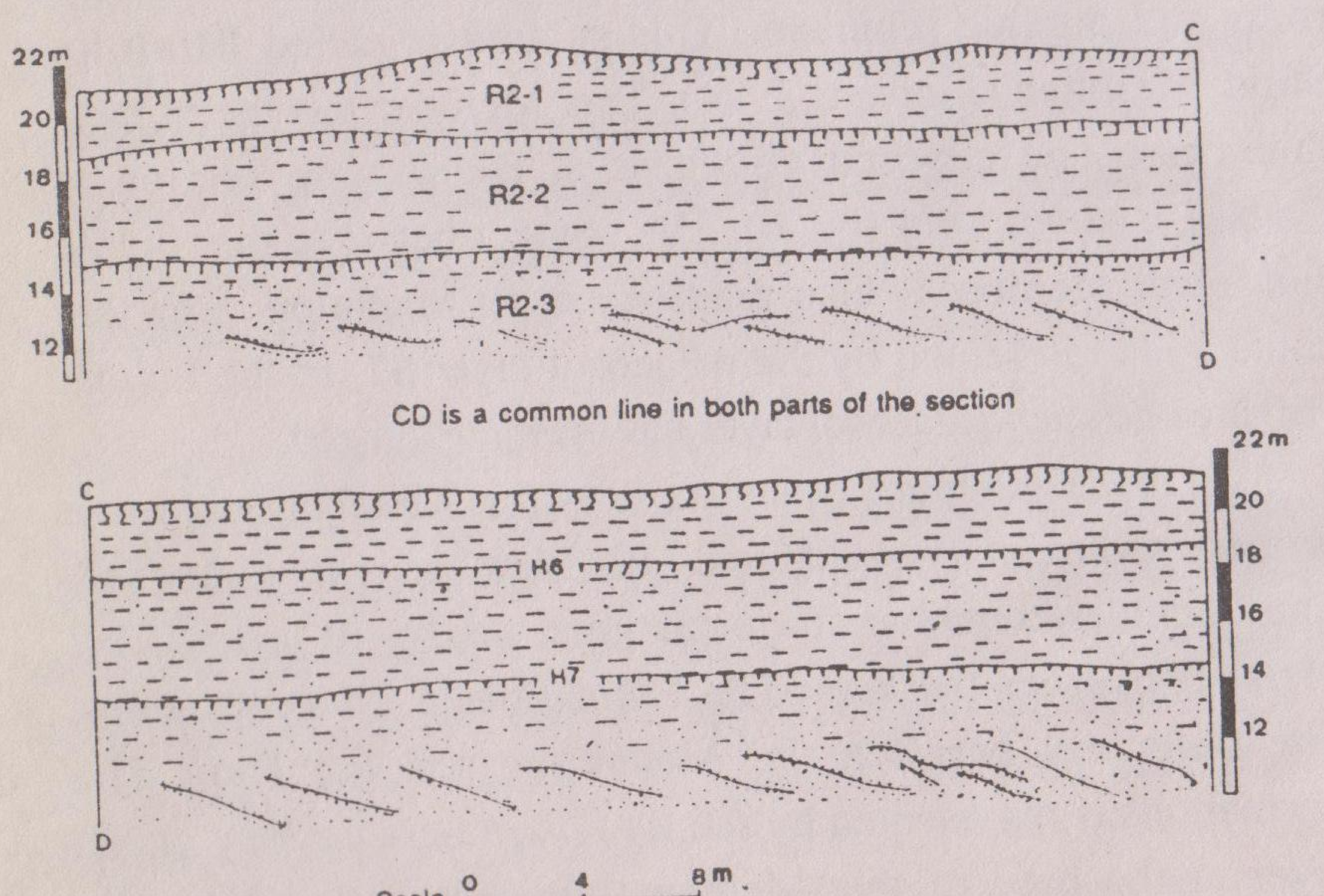


Fig.7: Stratigraphic cross section of the Barind Formation. R2-3: Gujorghat Sand Member; R2-2: Nachole Silty-clay Member and R2-1: Sherpur Clay Member. H6 and H7 are palaeosol horizons.

deposits exposed in the Barind area are considered separately since Barind tract is a different geomorphic unit. However, the Quaternary deposits exposed in the Barind area are subdivided into two broad units: i) **Barind Clay and Sand Formation** (Monsur and Paepe, 1992), represented by deep reddish-brown, highly oxidized and weathered clay silty-clay and sand with ferruginous concretions, calcareous nodules, plant roots, pipe stems and manganese spots; and ii) **Rohonpur Silty-clay Formation**, represented by yellowish grey, silty-clay to clay with organic matter and plant roots.

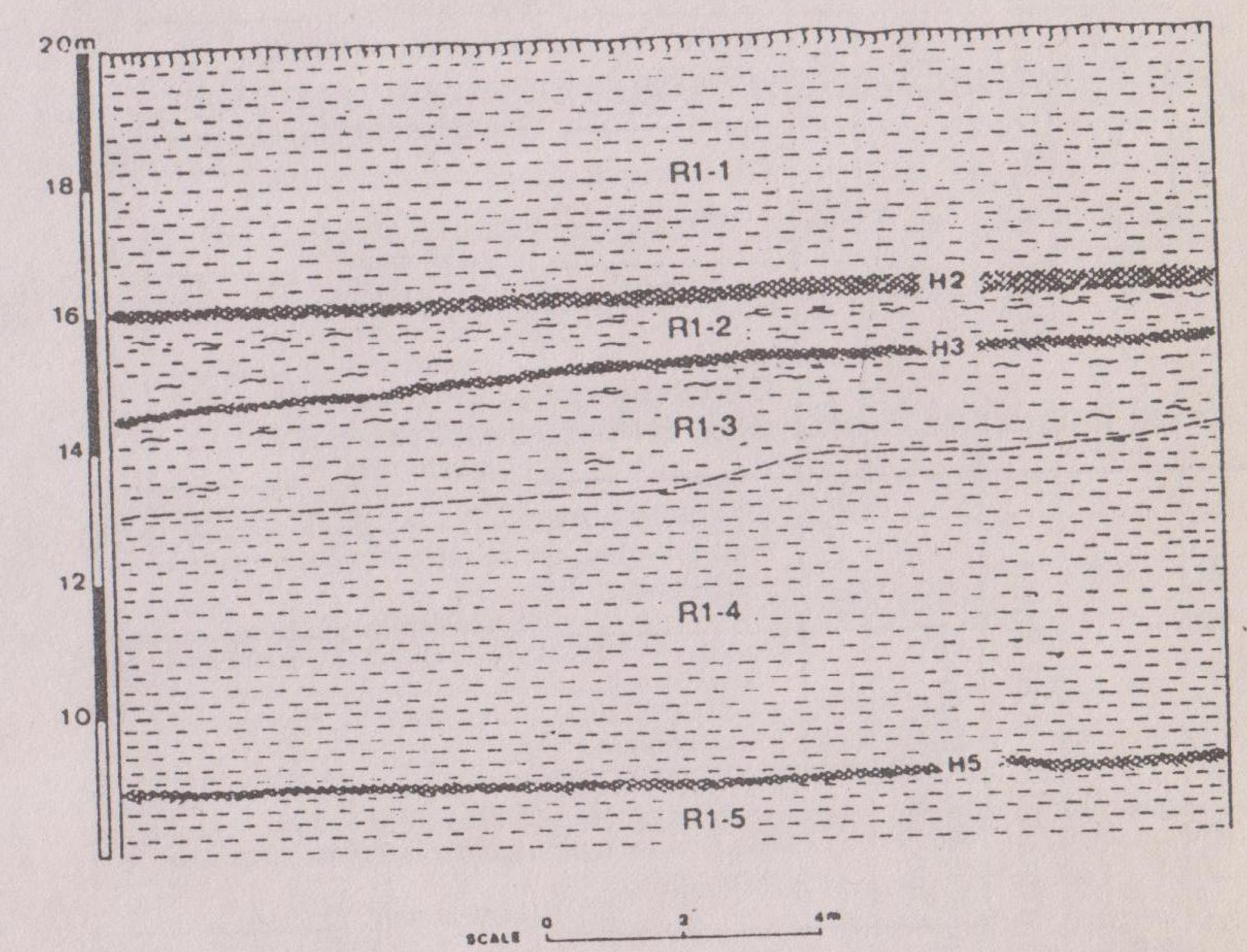


Fig.8: Stratigraphic cross section of the Rohonpur Formation. R1-5 to R1-1 are the subunits. H2 to H5 represent buried soils.

The Barind Formation has further been subdivided into three Members (lower subunits) and one Bed (upper subunit) based on the presence of two palaeosol horizons (Fig.7). The

Members are called **Gujorghat Sand Member** (Lower Member, R2-3), **Nachole Silty-clay Member** (middle Member, R2-2) and **Sherpur Clay Member** (upper Member,

Table 2: Stratigraphic table for the Barind area.

Chronostratigraphy		Formation	Member	Bed	Lithologic description	Thickness (m)
Series	Sub-Series					
HOLOCENE	Sub-Atlantic	Rohonpur Silty-clay		1	Light grey silt, containing ferruginous and calcareous nodules and micas Unconformity	4 to 10
HOLOCENE	Sub-Boreal	Rohonpur Silty-clay		2	Geyish-brown clayey-silt, containing micas and mangabese spots Unconformity	
HOLOCENE	Atlantic	Rohonpur Silty-clay		3	Olive-brown clayey silt, contaioning micas Unconformity	
HOLOCENE	Boreal	Rohonpur Silty-clay		4	Light olive brown silty clay Unconformity	
HOLOCENE	Pre-Boreal	Rohonpur Silty-clay		5	Olive brown silty clay, containing micas and ferruginous nodules Unconformity	
PLEISTOCENE	Lower	Barind Clay and Sand		Gouripur	Yellowish brown silty clay to sand-silt-clay, containing iron concretions Unconformity	4
PLEISTOCENE	Lower	Barind Clay and Sand	Sherpur Clay		Strong brown (7.5YR 4/6) with very pale brown (10YR 8/4) reduction spotted clayey silt. It contains Fe-concretions. pipe-stems, calcareous nodules. plant roots, micas and manganese spots. Unconformity	3
PLEISTOCENE	Lower	Barind Clay and Sand	Nachole Silty-clay		Brownish yellow (10YR 6/8) with pale brown reduction spotted sand-silt-clay. It contains Fe-concretions. pipe-stems, plant roots, micas and manganese spots. Unconformity	5
PLEISTOCENE	Lower	Barind Clay and Sand	Gujorghat Sand		Yellowish brown (10YR 5/8) silty-sand to sand. It is highly micaceous and contains manganese spots. Micas are biotitic and highly oxidized. This sand is cross bedded. Unconformity	4
PLIOCENE		Dupi Tila			Quartz-chalcedony Gravel Bed Oxidized sands with intraformational clay beds. It contins large silicified woods	

M2-1). The upper Bed of this Formation is called **Gouripur Sand-silt-clay Bed.** Similarly, the Rohonpur Formation has also been subdivided into five subunits (R1-5 to R1-1, Fig.8) based on the presence of four palaeosol horizons (H). The presence of buried soil horizons represent the Boundary Stratotype. Figs.7 and 8, represent, respectively the stratigraphic sections of these two Formations at the type locality Gujorghat and Bhagalpur stream at Rohonpur in Chapai Nawabgonj district. Lithologic descriptions of these Formations are given in the stratigraphic table for the Barind area (Table 2).

1.5: Quaternary stratigraphy of the Chalanbil area

The famous Chalanbil means a lake or marshy land in which water flows during the flood season (Fig.1). In fact,

Table 3 : Stratigraphic Table for the Chalanbil area.

Chronostratigraphy		Formation	Member	Bed	Lithologic description	Thickness (m)
Series	Sub-Series					
HOLOCENE	Sub-Atlantic	Chalanbil Silty-clay		Sand-silt-clay	Olive (5Y 5/3) to grey (5Y 5/1) silty clay to sand-silt-clay. Very sticky clay, containing Fe-concretions and plant roots. Unconformity	1-5
HOLOCENE	Sub-Boreal	Chalanbil Silty-clay		Silty clay	Light yellowish brown (2.5Y 6/4) silty-clay, containing plant roots and Fe-concretions. The lower part is mottled. Unconformity	3
Pleistocene	Lower	Barind	Gujorghat Sand		Pale yellowish brown (10R 6/2) silty-sand to sand. It is highly micaceous and cross bedded, contains Mn-spots. Micas are biotitic and highly oxidized. It contains some intraformational clay layers. Unconformity	3
PLIOCENE		Dupi Tila			Quartz-chalcedony Gravel Bed Oxidized sands with intraformational clay beds. It contins large silicified woods	

during the rainy season (monsoon time) rivers are overloaded and the surplus water flows over the flood plain of the Chalanbil towards the mighty river Jamuna (Brahmaputra). The Chalanbil covers an area of about 500 sq.km. Roughly, the Chalanbil is extended from the village town Singra upto the village Naogaon (from the west towards the east) and Chatmahor to Bastul (from the south towards the north).

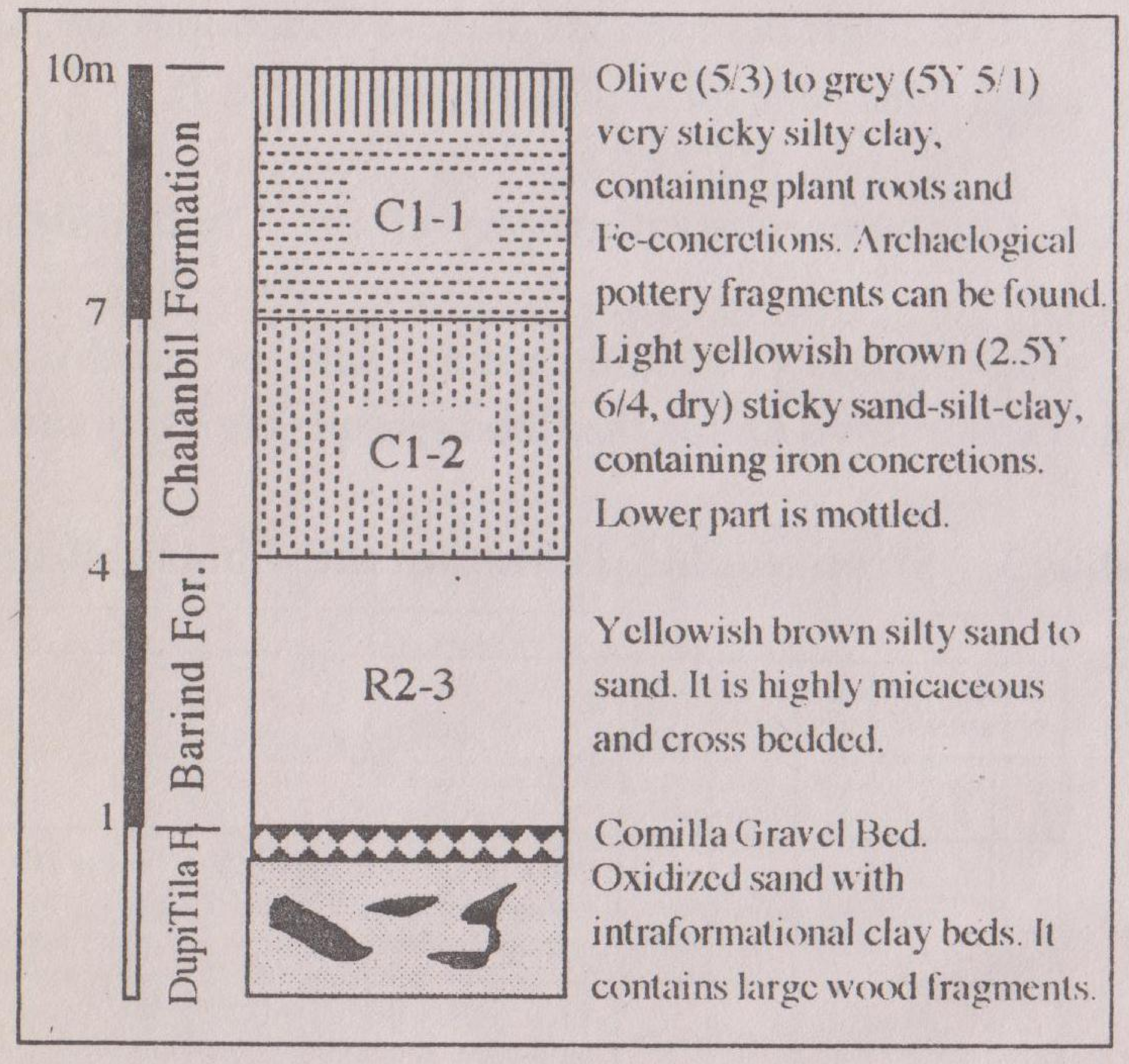


Fig.9 : Stratigraphic ross section of the Chalanbil Formation at Kushabari village (heart of the Chalanbil), Tarash, Sirajgonj.

The environmental of change in Chalanbil area is quite prominent. Only about 200 years BP, the heart of the Chalanbil had never been dried up even during the peak of the dry season.

As a result, it was a good site for gathering wild buffaloes during the dry (hot) season which created several pools and depressions. The ancient natives of the Chalanbil area used bows and arrows or some small fired clay balls to drive away the wild buffaloes or animals. It was a good suite for bird to live in the winter season.

The Chalanbil was quite visible from the top of the gigantic temple at Lakshindar Medh at Gokul More near Mahasthan Gargh during 7th to 12th Centuries A.D. The romantic folk tale of Behula and Lakshindar is very much popular in Bengal villages. It is said that Lakshindar, son of Chand Sawdagar lived in Mahasthan Gargh (Pundranagar) and parents of Behula (wife of Lakshindar) lived at Binsara, a village in the Chalanbil area near Tarash Thana. Hence, the Chalanbil area has some archaelogical importance.

The wide area of Chalanbil is covered by Holocene fluvial deposits. The observation of different boreholes, pond and canal digging led to subdivide the deposits into the following units (Fig.9) : i) the upper sticky silty-clay unit (C1) which is called **Chalanbil Silty-clay Formation** (Monsur, 1993), ii) the Chalanbil Formation is underlain by the micaceous sand unit (C2) which is called Barind Formation. The Barind Formation is underlain by the Quartz-chalcedony Gravel layer (Comilla Gravel Bed) of Dupi Tila Formation of Pliocene age. The Chalanbil Formation has also been subdivided into two subunits: i) the lower silty-clay subunit-C1-2 and the upper sand-silt-clay subunit-C1-1 (Fig.9, Table 3).

1.6: Quaternary stratigraphy of the Dahagram-Pañchagarh area

Dahagram-Panchagarh area is situated at the northern extremity of Bangladesh (Fig.10) and represents an alluvial fan since many rivers issuing from the Terai regions at the foot of Himalayan ranges. These rivers very often change their courses. The entire region has a very gently undulating topography lying above the present day flood level. The interfluves of the rivers are slightly domal shaped specially in the Panchagarh area. The palaeoriver system left a number of terraces at northern margin of Tetulia. These are the fluvial terraces, made up of sandy gravels. In the north, the area merges with the sub-montane terrain of the Himalayas known as Dooars.

The whole area (Tetulia, Panchagarh, Dalia, Patgram, Dahagram and Angarpota) is covered with a series of gravel beds alternated with coarse to medium sand layers. These gravel beds were considered as piedmont deposits (Khan, 1991). These gravels are quite fresh with high sphericity and roundness values. These gravels are composed of granite, quartz and quartzite, gneiss and schistose. The thickness of these gravel beds sometimes exceeds 20 meters. These gravels beds are called **Panchagarh Gravel Beds** (Morshed, 1994). The Panchagarh Gravels are overlain by a series of sand or silty-sand layers which are called **Boalmari Sand Formation.** Panchagarh Gravel Beds belong to the upper Pleistocene Series whereas the Boalmari Sand Formation belongs to the Holocene Series. Boalmari Formation contains four buried soil horizons which help to subdivide the deposits into 5 subunits of Holocene Epoch. A holostratotype at Boalmary type section is given in the Fig.11.

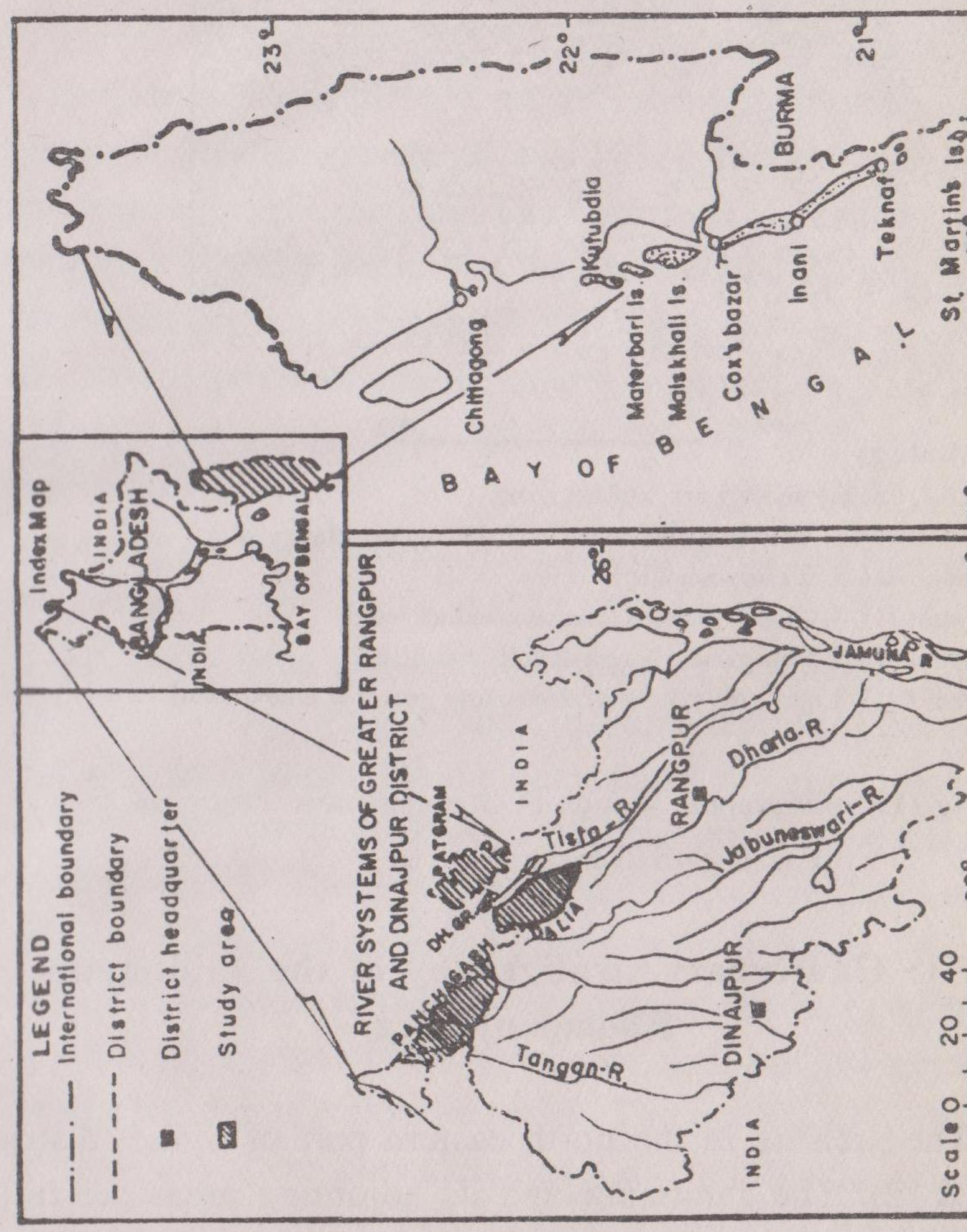
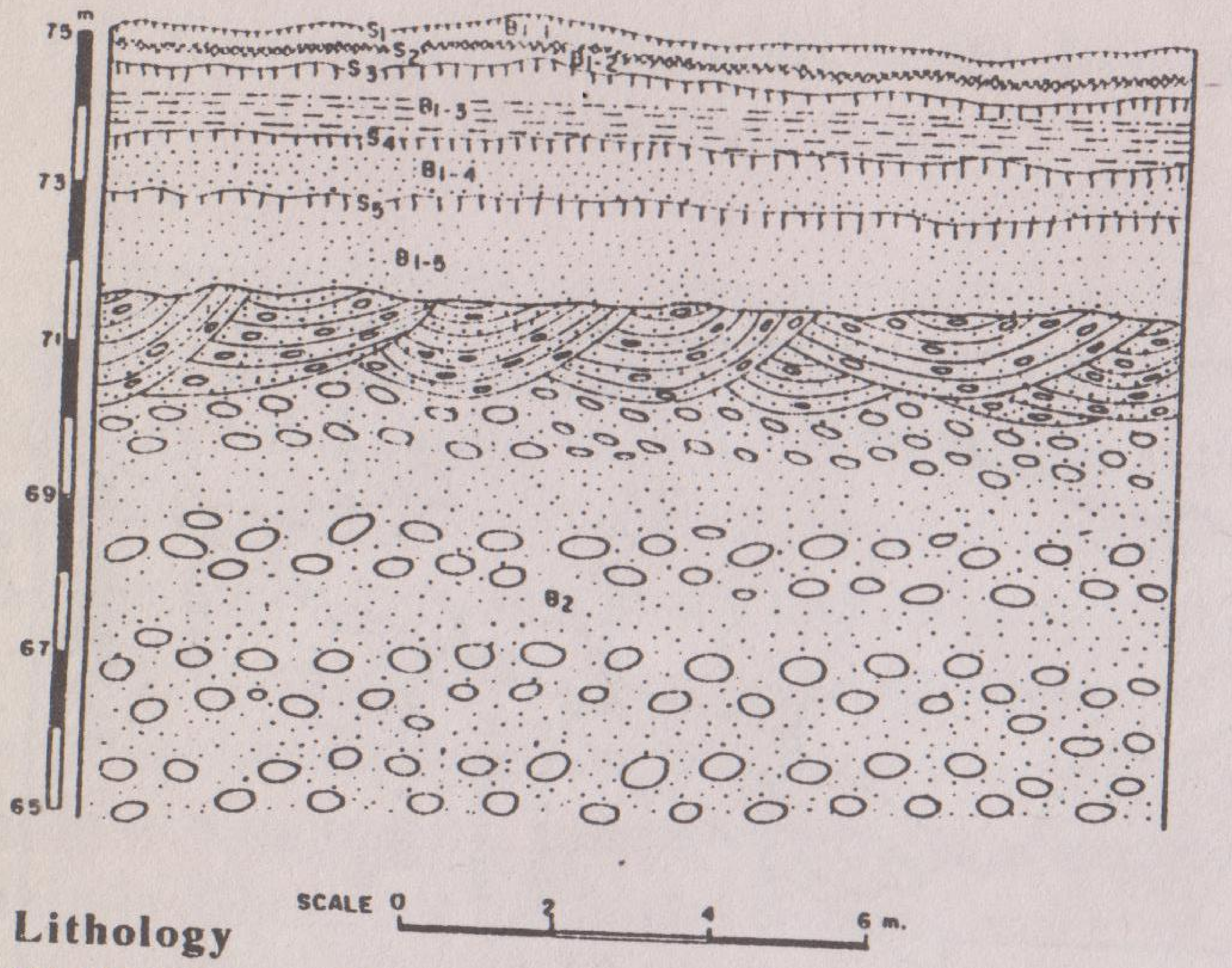


Fig.10: Location map of Panchagarh and St. Martin s, Area



Lithology

S1, S2, S3, S4 and S5 are soil horizons.
Subunit-B-1 : Alluvium; Subunit-B1-2: Dark grey clayey silt;
Subunit-B1-3: Yellowish silt;
Subunit-B1-4: Coarse grained micaceous black sand;
Subunit-B1-5: Fine grained greyish yellow sand;
Subunit-B2: Light grey coloured alternating gravel & coarse sand.

Fig.11: Stratigraphic section at Boalmari near Tetulia in Panchagarh district.

1.7.1: Quaternary stratigraphy of the Jaintiapur-Bholagonj area

The area lie in the north eastern part of Sylhet district (Fig.1&12). The Jaintiapur and its adjoining areas are hilly region which are the extension of the Assam-Meghalaya Hill Range. North of the area lie the great Jaintia and Khasi Hills of India. The hills are gently undulated. The regional topography of the area is characterized by low rounded hillocks with numerous gullies, spurs, cliffs and scarps. The hillock are separated by flat

to steep valleys. The Bholagonj and its adjoining areas are a piedmont alluvial plain of the Khasi-Jaintia Hills.

In the hilly region of the Bengal basin Quaternary deposits are exposed in the valley areas. It is quite interesting to note that thick gravel deposits cap the hill tops of the Jaintiapur and Bholagonj areas. These gravel deposits are highly weathered and thought to be Pleistocene age (Evans, 1932). The gravel deposits unconformably overlie the Dupi Tila Formation are called Dihing Formation. It is more likely that the gravel deposits which cap the Jaintiapur hill tops belong to the Dihing Formation. These gravels are composed of granite, quartz and quartzite, sandstone and shally materials. The gravels of the high terraces unconformably overlie the Surma Group of sediment (erosional unconformity). They are highly weathered with high roundness and sphericity.

The gravel beds exposed at Jaintiapur, Mukambari, Sona Tila, Pather Tila and Muslimnagar hill tops represent the older terraces or high terraces. On the other hand, the gravel beds of the present river system at Dauki and Sripur make some terraces of Holocene epoch. These may be called as younger terraces or low terrace. Simultaneously, the gravel beds at Binda Tila hill tops represent the older terrace or high terrace and the gravels of the present river system of Bholagonj area represent low terrace or younger terrace of Holocene epoch. The gravels of high and low terraces have been considered as a single lithostratigraphic unit and are called **Sona Tila Gravel Beds and Bholagonj Gravel Beds** (Saha, 1994). Fig.13, represents a stratigraphic cross section of Sona Tila Gravel Beds at Jaintiapur Locality.

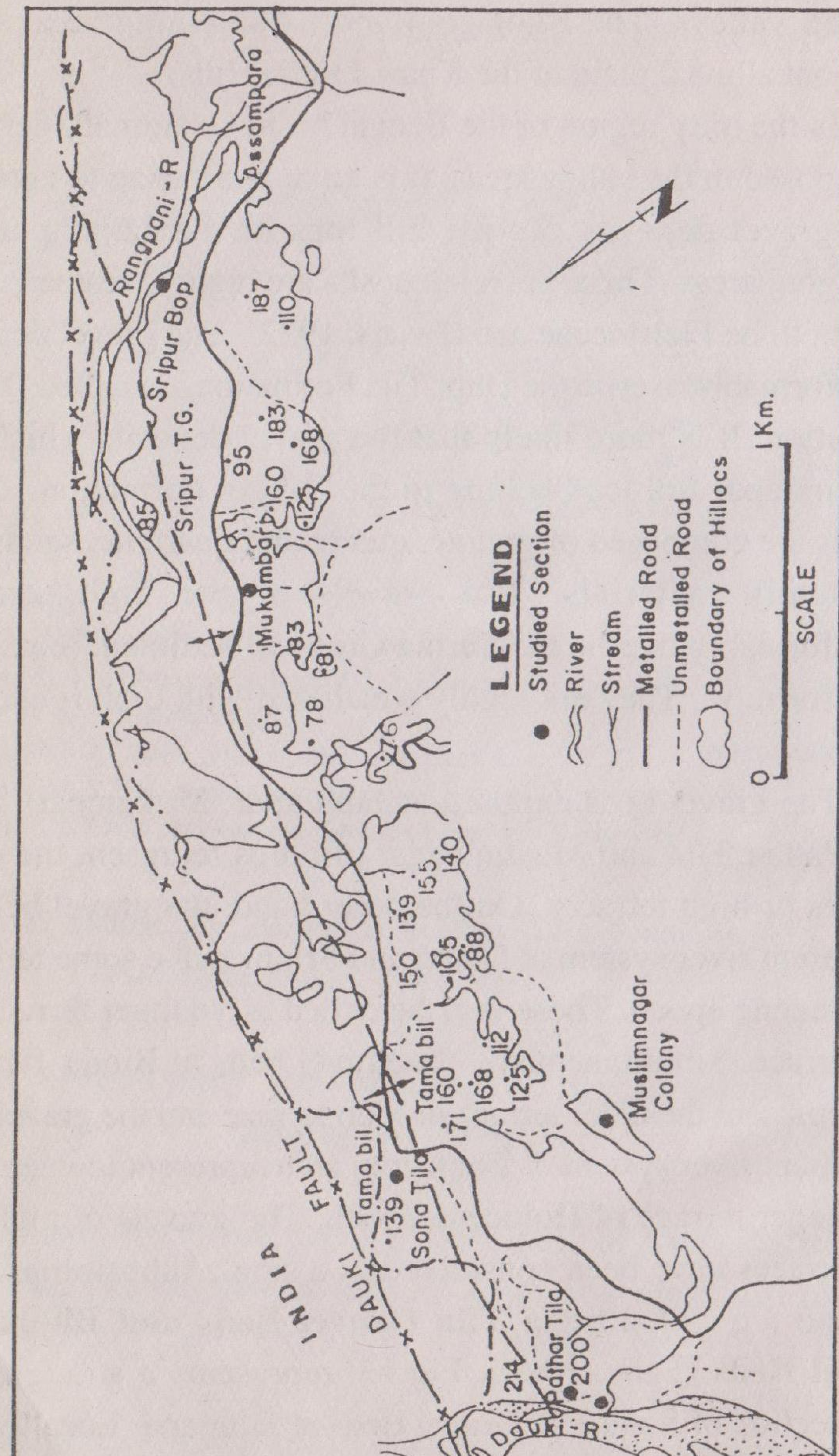


Fig. 12: Location map of the Jaintiapur Area

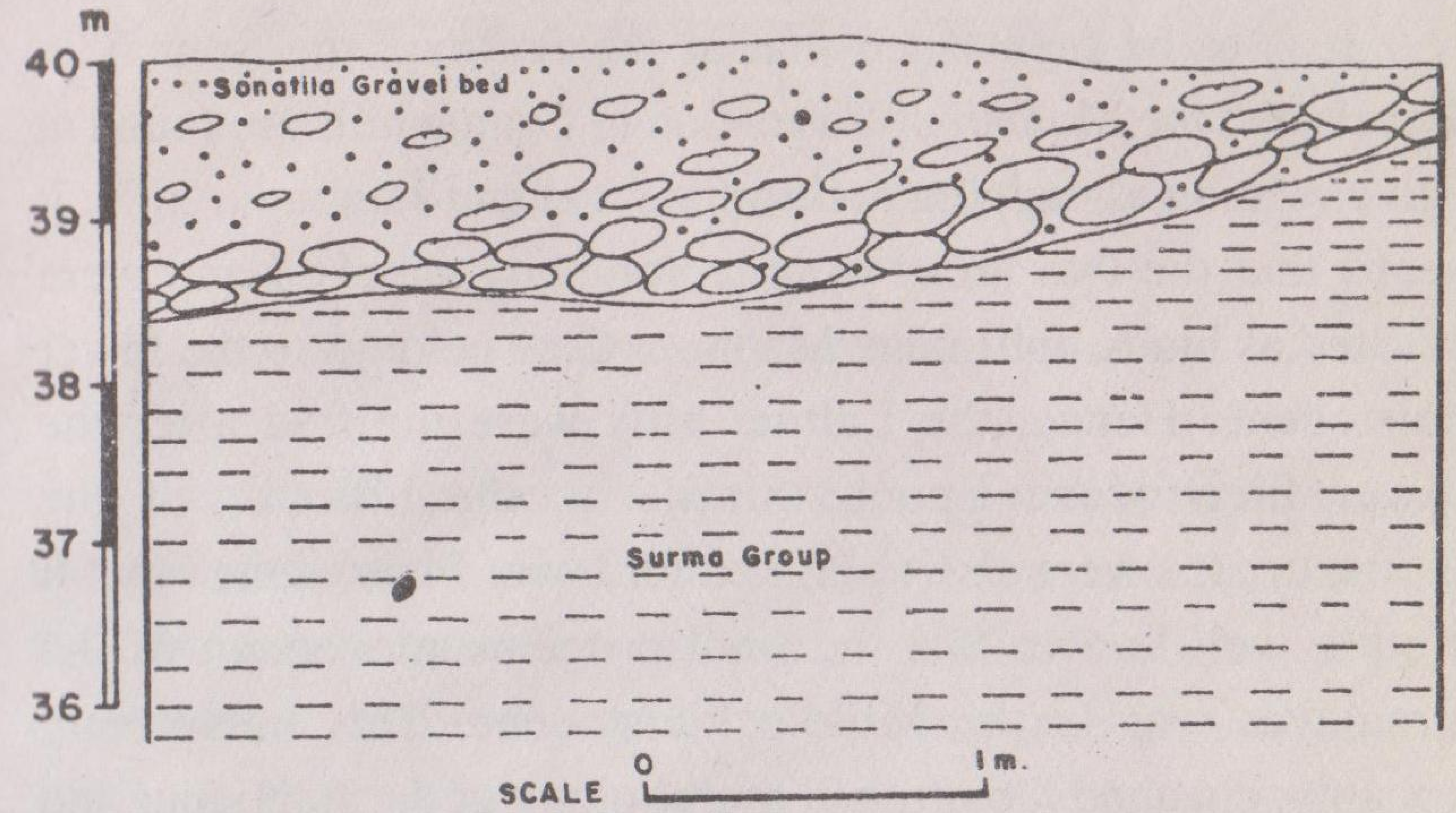


Fig.13: Stratigraphic cross section at Sona Tila. Sona Tila Gravels are unconformably underlain by the Surma Group of sediments. At Jaintiapur locality, this erosional contact is visible and is quite distinct along the road.

1.7.2 : Depositional history of the Sona Tila and Bholagonj Gravel Beds.

Sona Tila and Bholagonj Gravel Beds belong to the Dihing Formation. In the early literature, it was mentioned that the Dihing Formation belongs to the Plio-Pleistocene age as they were affected folding and thrusting which had affected he Assam Tertiaries. Considering the weathering level, the gravels of the hill tops of Jaintiapur area (high terrace) seem to be lower Pleistocene age and are synchronous with the Madhupur Formation.

It is quite likely that Sona Tila Gravels represent the upstream coarsest deposits of some palaeoriver system and the Madhupur Clay Formation represents down stream finer sediments.

It is to be mentioned that at present day, the Sona Tila Gravels and the Madhupur Formation in Lalmai hills are found at high elevation as capping rocks of Lalmai and Jaintiapur hills. It means that the two areas were tectonically shocked and were elevated as block uplftment. Madhupr Clay belongs to the lower Pleistocene. Hence, the Lalmai hills were uplifted after the Lower Pleistocene Epoch. Similarly, the hillocks of the Jaintiapur area were also uplifted after lower Pleistocene time. It is quite well known that the final orogenic movement of the Himalayas was in the Middle Pleistocene. This movement, probably, changed the original morphology of the Jaintiapur and Lalmai hills. The new courses of the present river system left some Upper Pleistocene and Holocene terraces along their banks (low terreace).

1.7.3 : Economic importance

Bholagonj-Jaintiapur gravels are being used for roads and building constructions. Similarly, Gravels of Dahagram-Angarpota, Patgram, Dalia, Chapani, Kaligonj, north and south Kharibari, Boalmari, Vojonpur, Tetulia of greater Rangpur and Dinajpur districts, are also used as constructional materials. The Tista barriage is built up with our own local gravels. These gravels are exploited in a private level with local contractors. They are ruining the crop lands. It is suggested that the Government should take care of these gravels and take initiative for exploitation in a scientific way to minimize the exploitation costs and to save the crop lands for future generation.

CHAPTER-TWO

2. Pedological Studies

2.1 : Micromorphological studies

• Palaeosols or Geosols are becoming widely recognized in ancient siliciclastic alluvial and deltaic sequences. The average sedimentation rates in terrestrial setting are low. As a consequence, sediments will have a residence time of tens of years to thousands of years within the upper part of the weathering profile. Within this zone, effectively the zone of soil formation. These sediments can be radically modified by a variety of biological, chemical and physical processes associated with pedogensis (Allen and Wright, 1989).

Soil is natural body formed in the surface material of the earth under the influence of climate, biota, topography and time. It will have vertically differentiated layers due to the relative intensities of biological, chemical and physical weathering and translocation of the products. A vertical section through these layers exhibits a soil profile (Valentine and Dalrymple, 1976).

Palaeosol are the soil horizons of the past. Palaeosol represents stable stratigraphic key horizons and may reflect environmental climatic condition of the past which no longer exist today. A palaeosol in stratigraphic horizon represents a depositional break (unconformity) in normal lithologic sequence. Soil is a climatic indicator and it develops in an area of wide lateral extension. Therefore, the presence of palaeosol in stratigraphic horizon represents in one hand, a marker horizon which can be used as a synchronous level and on the other hand, it can be used as a geochronological tool for stratigraphic

About 200 representative oriented undisturbed samples were collected from different stratigraphic horizons of the Quaternary deposits exposed in the Madhupur, Barind, Lalmai hills and Chalanbil areas.

First of all, the natural remanent magnetization of all the samples were measured with a cryogenic super conducting magnetometer. Based on the results of first measurements,

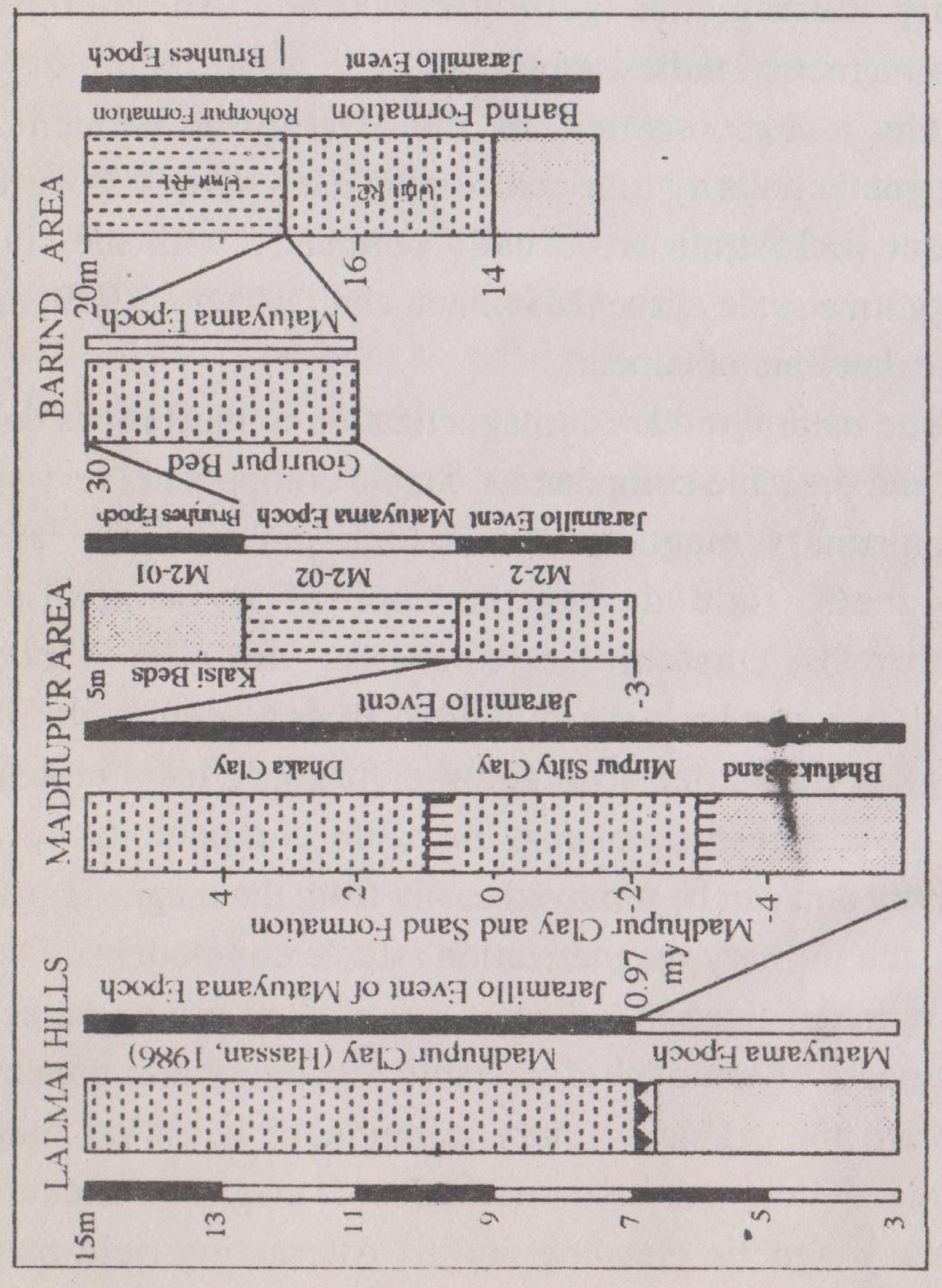


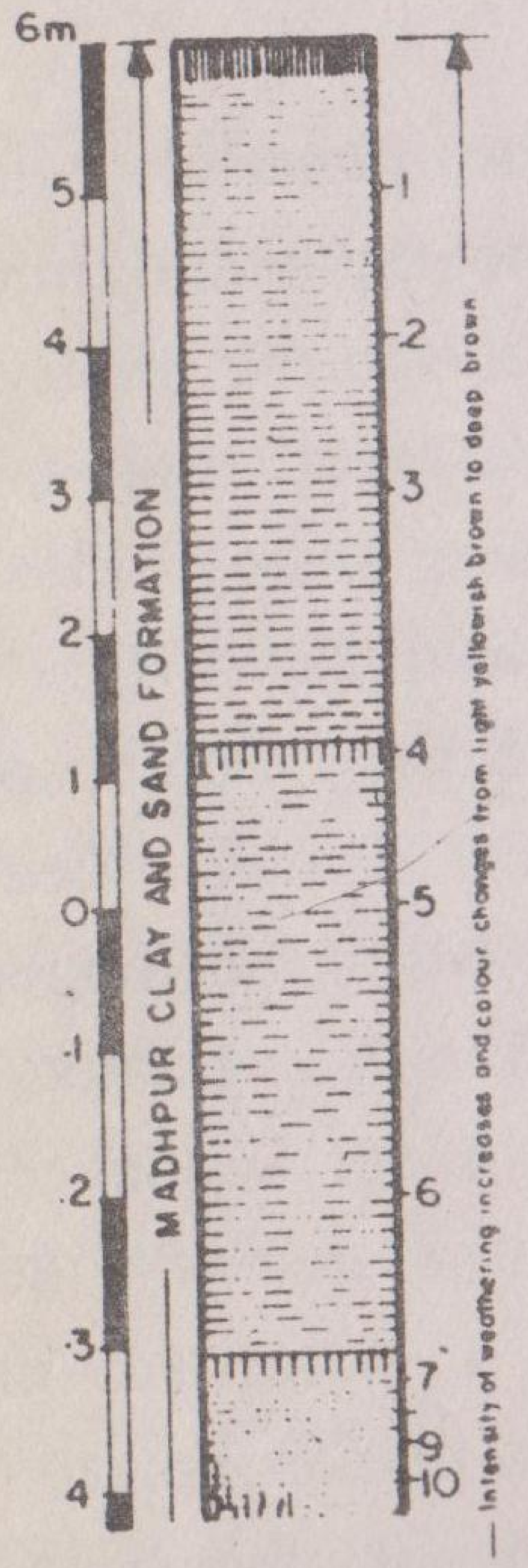
Fig.15: Palaeomagnetic results of the Quaternary deposits exposed in the Madhupur, Barind and Lalmai hills areas

several pilot specimens, representing each lithologic unit, were chosen for alternating field and thermal demagnetization test to identify the stability of natural remanence. From these tests thermal magnetic cleaning was preferred and 260°C temperature was selected for magnetic cleaning of the rest of the samples. The results of the palaeomagnetic investigations are shown in the Fig.15.

Palaeomagnetic investigation indicate that the Rohonpur (unit-R1), Chalanbil (unit-C1) and Basabo Formations have normal polarity. The Basabo Formation have five subunits which were dated by C-14 dating method. From the radiocarbon dating, it was found that the maximum possible age of the lower part of the Basabo Formation is about 12780 yrs BP. The Basabo, Rohonpur, Boalmary and Chalanbil Formation were correlated and they belong to the Brunhes Magnetozone (Holocene Series). The upper Kalsi Bed (M2-01) has normal polarity, probably, belongs to the Brunhes Magnetozone (Middle Pleistocene). The lower Kalsi Bed (M2-02) and the Gouripur Bed of the Barind Formation have the reversed polarity. These two Beds belong to the Matuyama Magnetozone (within the time limit of 0.90 to 0.73 my BP). The boundary between the upper and lower Kalsi Beds represents the Brunhes-Matuyama boundary (0.73 my BP). Gouripur Bed and the lower Kalsi Bed can be correlated with the lower Pleistocene Series. All the Members of the Barind and Madhupur Formations have normal polarity (Fig.15) which probably belong to the Jaramillo event (0.90 - 0.97 my BP).

The sediments below the Quartz-chalcedony gravel bed showed reversed polarity which belongs to Matuyama Magnetozone. The Quartz-chalcedony gravel Bed seems to be the age of 0.97 my BP. From the palaeomagnetic investigation, correlation of lithosequences of hundreds or thousands of kilometers apart. Hence, the recognition of palaeosol horizons in stratigraphic section is quite important.

In the Quaternary sequence of Bangladesh, palaeosol were used for the bases for stratigraphic subdivision. Recognition and identification of palaeosols in the Madhupur and Barind Formations in the Madhupur and Barind areas and also in the Lalmai hills areas, were carried out by micromorphological studies (Monsur, 1992). Micromorphological descriptions of undisturbed soil samples has been given in the Fig.14. Plates 1, illustrates the pedofeatures and microstructures of thin section of strongly impregnated palaeosols of the Madhupur Formation.



Micromorphogical description of samples in the type section at Kalsi brickyard, Mirpur, Dhaka city.

Deep reddish brown colour, pedal soil with vughy microstructure. Chambers, channels, vughs, vesicles and planar voids are very common. Minerals are highly weathered. C/F relation is porphyric. Root channels are traceable. Fine materials have speckled or dotted appearance and have grano and porostriated b-fabric. Microlaminated iron rich clay coating, quasicoating. Depletion, cryptocrystalline and amorphous pedofeatures are available. Strongly impregnated Fe-Mn nodules. Complete and incomplete infilling of voids. (Sample nos. 1, 2 and 3).

Yellowish brown apedal soil, channel and pellicular microstructure ; macro- and mesovughs, chambers, channels and vesicles (void space about 5%). Micas are highly weathered; porphyric distribution, grano- and porostriated b- fabric. Textural, depletion, cryptocrystalline and amorphous pedofeatures. Microlaminated iron rich limpid clay typic and crescent coatings of voids. Strongly impregnated ferruginous nodules. (Sample nos. 4, 5 and 6)

Light yellowish brown apedal soil with pellicular microstructure, macro- and mesovughs, chambers, channel and vesicles available. Void space about 4%. Micas are moderately weathered. Mineral grains are fresh. Locally oriented grains. Chitonic distribution and bridged grain microstructure. Typic and crescent coating of voids. Cryptocrystalline and amorphous pedofeature. Strongly impregnated Fe-nodules. (Sample nos. 7,8,9 and 10).

Fig.14 : Micromorphological descriptions of samples in the type section at Kalsi brickyard, Mirpur, Dhaka city.

One of the most distinctive aspects of some palaeosol is colour mottling reflecting localized changes in oxidation and reduction (Monsur, 1990). In the Plate 1, there is a distinct

Plate 1: a) Depletion pedofeature and quasi-coating of void. b) Chambers connected with channel. c) Channel microstructure. d) Manganese coatings (Mangan), porphyric distribution and channel microstructure.

boundary between the iron-depleted reduction zone (white spaces) and iron-rich oxidation zone (blackspaces). This kind of colour mottling is a common feature of the Madhupur and Barind Formations. The mechanism of their formation can be explained in the following way: In sediments, where ground water table is close to the surface, the subsoil layers below the surface horizons are permanently saturated and topsoil can be periodically submerged, depending on the extent of the seasonal fluctuation. Soil that develop in this way is called Gley Soil (Allen and Wright, 1989). The lower Members of the Madhupur and Barind Formations, sometimes, have this characteristic.

When the sediments are further above the ground water table, soil will develop under the influence of percolating rainwater. Whenever such soil has impervious layer, water may stagnate on top of such a layer during the part of a year. If the stagnating water has a distinct effect on the development of soil, such soil is called a **Pseudogley Soil.** The upper palaeosol layer of the Madhupur Formation represents such a soil horizon. **Gley soil** normally features a grey, reduced subsurface horizon below the upper permanent ground water table, that may have oxidized iron compounds along cracks and root holes.

However, the appearance of reddish brown colour, oxidation-reduction characteristics, types of colour mottling and the formation of Pseudogley indicate that the soil forming processes were quite active in the case of the Madhupur and Barind Formations of the basin.

Micromorphological studies of the Madhupur and Barind Formations indicated that the upper part of the Formations represent a strongly impregnated soil with vughs, vesicles, chamber and channel microstructures having amorphous and cryptocrystalline pedofeature. On the other hand, the lower

Members represent weakly impregnated soil with bridge grain microstructure.

It is quite clear that the deposits had undergone pedogenic processes. All the pedofeatures indicated that these are *in situ* developed soil and do not represent a transported or re-deposited soil materials. In the case of the Madhupur Formation, only two buried soil horizons were recognizable during the field observation. The samples below and above these soil horizons have exactly the similar pedofeatures. It means that the deposits include not only two soil layers, but several.

Buried soil can be differentiated and recognized easily by horizon after horizon. Buried palaeosol were developed by catastrophic floods. But there were also numerous minor floods in the flood plains which only a few centimeter of sediments might have deposited. Many ecosystems can cope with this degree of disturbance and continue to grow and incorporate this materials into the pre-existing soil, to form a cumulative one (Retallack, 1983). Hence, the Barind and Madhupur Formations represent such a cumulative palaeosols, formed progressively with the alternate increment of a few millimeters or centimeters of sediments by numerous minor floods in the depositional basin.

After the deposition of the lower part of these Formations cumulative palaeosols were formed. At the top of these Formations modern soil developed which is, in fact, a relict soil of the pre-existing palaeosol materials. The pedofeatures indicated a wet-humid palaeoclimate. Absence of large trees and the presence of grass type vegetation, and also the formation of these cumulative palaeosol indicates that the depositional basin was a flood plain.

2.2 : The reasons fòr appearance of reddish brown colour of the Madhupur and Barind Formations

The reddish brown colour of the Madhupur and Barind Formations is clearly related to the iron compounds. The present author has tried to explain how these iron compounds were formed which ultimately caused the deep reddish brown to light yellowish brown colour of these deposits. In this context, only the the petrographical observations with the aid of a polarizing microscope and the literature reviews are discussed (Monsur, 1992; Hassan, 1986).

Iron in sediments can be divided into: a) the iron present in primary minerals, the nature of which will depend on the type of parent materials undergoing weathering; b) the iron present in secondary minerals and c) free iron.

The primary iron-containing minerals are usually associated with igneous rocks, such as, ferromagnesian silicates (pyroxene, olivine and amphibole) biotite micas and the iron ores, comprising hematite, ilmenite and magnetite. The iron containing secondary minerals can not be defined as clearly owing to their heterogeneity (Oades, 1963). Biogenic products and chemical constituents, such as, calcite and dolomite, formed at the place of deposition usually contains less than 1% iron, except where the deposition has occurred in shallow seas, when oolite and perhaps iron minerals, as for example chamosite and/or siderite may be found.

Iron present in many minerals occurring in the weathering sequence from the ferromagnesian silicates through the biotite micas and illite clay minerals to hematite and/or goethite and many other iron containing minerals. Clay minerals containing iron as an essential element are the "hydromicas", illites,

chlorites, vermiculite, chamosite, glauconite, griffithite and granulite.

A detailed study of clay minerals of the Madhupur Formation has been perfomed by Hassan (1986). He found the above mentioned iron rich clay minerals, such as, illite, chlorite and vermiculite. The sediments of the Madhupur and Barind Formations contain a lot of ferromagnesian minerals (quite fresh in the lower part of these Formations) derived from the Himalayan mountain ranges. These sediments undergone intensive weathering processes and released Fe ions in a free state. In the Madhupur and Barind areas these iron compounds are distributed throughout the sections in the form of nodules or in association with clays.

Pipestems are associated with roots channels. The plant roots are capable of oxidizing iron and it was observed that the rhizosphere system of hydrophyte plants tend to be more efficient in producing oxidative condition in the soil than mesophytic type. Pipestem are characteristic of poorly drained soils. The orange brown colour is, however, associated with dead roots, while roots are still living a pale blue or grey colour. The abundance of pipestems in the Madhupur and Barind tracts is in accordance with this statement.

A lot of papers explains the formation of iron compounds in red beds. Among the iron oxides the authigenic hematite (aFe_2O_3), goethite (aFeOOH), Lepidochrocite (gFeOOH) and hydrated-ferric-oxides gel ($Fe(OH)_3.H_2O$) are important. The colours of the upper, middle and lower Members of the Madhupur Formation are, respectively, moderate reddish brown (10R 4/6), light brown (5YR 5/6) and pale yellowish brown (10YR 6/2). Similarly, the colours of the three Member of the Barind Froamtion from top to bottom are respectively, strong brown (7.5YR 4/6), brownish yellow (10YR 6/8) and yellowish brown (10YR 5/8). The colour of authigenic hematite and goethite are respectively 2.5 YR and/or redder, and 10YR. The abundance of these two minerals is probably responsible for the colour variation of these Formations.

Well oxygenated upper Members of these Formations favoured the formation of hematite. Moreover, there is a possiblity of formation of hematite from the aging ferrihydrite. According to Oades 1963), hematite occurs in drier and more highly oxidized zones, usually nearer the surface, whereas goethite occurs more typically in wetter though well oxidized zones, often in subsurface horizons. The stratigraphic position of Madhupur Formation in the Lalmai hills is quite high in comparison to the Madhupur and Barind tracts. The ground mass of thin sections of the soils from the Lalmai hills showed redder than any other sections (Monsur, 1992). This is because of higher concentration of hematite in Lalmai hills which is in accordance with the statement of Oades (1963). The higher concentration of goethite or limonite in the lower Members of both these Formations, probably, resulted in the yellowish brown or pale yellowish brown colour.

CHAPTER - THREE

3. Palaeomagnetism and rock magnetism

3.1 : Paleomagnetic studies

It was discovered that the earth magnetic field changes its polarity during the geological time. An increase of palaeomagnetic studies, combined with K-Ar dating of young volcanic rocks, resulted in the first establishment of a geomagnetic polarity time scale in the early sixty's. Polarities of different rock strata are usually compared with the standard polarity time scale curve (Mankinen and Dalryple, 1979) and the relative dates are obtained.

The natural remanent magnetization in most rocks contains stable and unstable components. Stable component (very strong) is the primary magnetization which indicates the ambient geomagnetic field during the time of its acquisition (or deposition). Unstable components are the secondary magnetization which the magnetic grains acquire during the geological time after acquisition of primary magnetization or deposition. These secondary unstable components have low coercivity and can be removed easily from the magnetic grains to isolate the primary magnetization (stable component). Only the primary magnetization indicates the ambient geomagnetic field. The process of removal of unstable secondary components and to isolate the stable primary component is called magnetic cleaning. There are two methods of magnetic cleaning: i) Thermal magnetic cleaning and ii) Alternating field magnetic cleaning.

it was found that the beds which gave reversed polarity were isolated and occurred as fluvial terraces. Therefore, it can be assumed that the red beds in the Bengal basin are, probably, a combination of several fluvial terraces which are yet to be recognized. These isolated terraces were formed during the geological time, probably, with a long time gap. The existence of Kalsi Beds in the Mirpur brickyard indicates that the erosional processes by fluvial current was also active even in the lower Pleistocene time.

To establish an ideal polarity time scale, it is necessary to have sediments which were deposited during the geological time without any time gap. The deposits of the Bengal basin have several unconformities. Therefore, it is not easy to correlate the obtained polarities with the standard geomagnetic polarity time scale. For confirmation it needs absolute dating. But unfortunately, no datable materials were available. In this case, the author has tried to correlate in most possible ways.

Most of the lower Pleistocene deposits have deep reddish brown colour, such as, Rocourt soil of Belgium, Chinese loess deposits, Pikermi soil of Greece. Deep reddish brown colour of the Madhupur and Barind Formations is quite striking. The appearance of reddish brown colour of these deposits is due to the oxidation and hydration of iron, i.e. the formation of iron minerals, such as, hematite, goethite, limonite, maghemite etc. Curie temperature of hematite is higher than the curie temperature of magnetite. Hence, alternating field magnetic cleaning seems to be appropriate. But hematite contains so feeble remanence that it does not affect the primary magnetization.

It is to be mentioned that several pilot samples were collected from the Surma Group of sediments exposed in the Jaintiapur area. These samples contain very feeble remanence.

Moreover, there are many hiatus (unconformity) in the stratigraphic sequences. So, it was very difficult to correlate the obtained results with the standard palaeomagnetic time scale.

Most part of the section was covered with alluvium or vegetation. Hence, it was not possible to get a reliable stratigraphic section in the Jaintiapur area.

3.2: Magnetic susceptibility of the Quaternary deposits

The determination of initial magnetic susceptibility of rocks is quite important for the estimation of magnetic components of sediments. Magnetic susceptibility plays a vital role for aeromagnetic interpretations, soil horizon recognition and also acts as an important indicator for any chemical change effecting the magnetic grains. The magnetic susceptibility can be defined as the induced magnetization of the magnetic minerals divided by the applied field. The initial susceptibility of ferromagnetic minerals depends on the size, shape, initial stresses and composition.

The Pleistocene sediments of the Madhupur and Barind areas are highly oxidized. The oxidation of sediments involved the formation of new magnetic minerals and thus the initial suceptibility of rocks changed as well.

The present author has estimated the magnetic susceptibility of the Quaternary sediments during his Doctoral research (1990, Monsur, 1995). Some of the magnetic susceptibility of the Madhupur, Barind, Basabo, Rohonpur and Chalanbil Formations are given in the Table 4. Susceptibilities of the Madhupur Formation are placed against the stratigraphic position and are shown in the Fig.16. From the Fig.16, it can be seen that the susceptibility decreases downward from the upper

Member of the Madhupur Formation. Exactly, the similar trend can be observed in the case of the Barind Formation. The upper parts of the Madhupur and Barind Formations are highly weathered (except the Kalsi Beds). Moreover, the pedogenic process was quite active in the upper part of these Formations. The pedogenic process enhanced the concentration of Fe-ion which ultimately oxidized to form new magnetic minerals.

Table 4 : Magnetic susceptibilities of the Quaternary deposits exposed in the Madhupur, Barind and Chalanbil areas

Formation	Unit	Sample no.	Susceptibility $X10^{-6}$ SI.U.	Formation	Unit	Sample no.	Susceptibility $X10^{-6}$ SI.U.
Barind Formation	R2-1	Gus10	306	Madhupur Clay and Sand Formation	M2-1	K2S1	693
		Gus11	586			K2S2	692
		Gus12	531			K2S3	663
	R2-2	Gus13	466			K2S4	533
		Gus14	446		M2-2	K2S11	264
		Gus15	454			K2S21	320
	R2-3	Gus16	157		M2-3	K2S31	232
		Gus17	250			K2S41	287
Rohonpur Formation	R1	DhS11	148			K2S51	446
		DhS12	141			K2S61	347
		DhS13	188		M2-01	K3S1	110
		DhS14	198			K3S2	168
Basabo Formation	M1	G3S5	105			K3S3	171
		G3S4	104		M2-02	K3S4	183
		G3S3	169			K3S5	173
		G3S2	170			K3S6	187
Chalanbil Formation		TS7	198			K3S7	155
		TS8	199			K3S8	141

Thus, the upper parts of the Barind and Madhupur Formations exhibit higher susceptibilities. Lower parts of these Formations

show low susceptibilities because of less oxidation and weakly developed soil.

The susceptibilities of the Kalsi Beds range from about $100x10^{-6}$ to $200x10^{-6}$ SI unit, which are very much closed to the susceptibilities of Basabo, Rohonpur and Chalanbil Formations. These Holocene deposits are not so much oxidized and their susceptibilities are very low (Table 4).

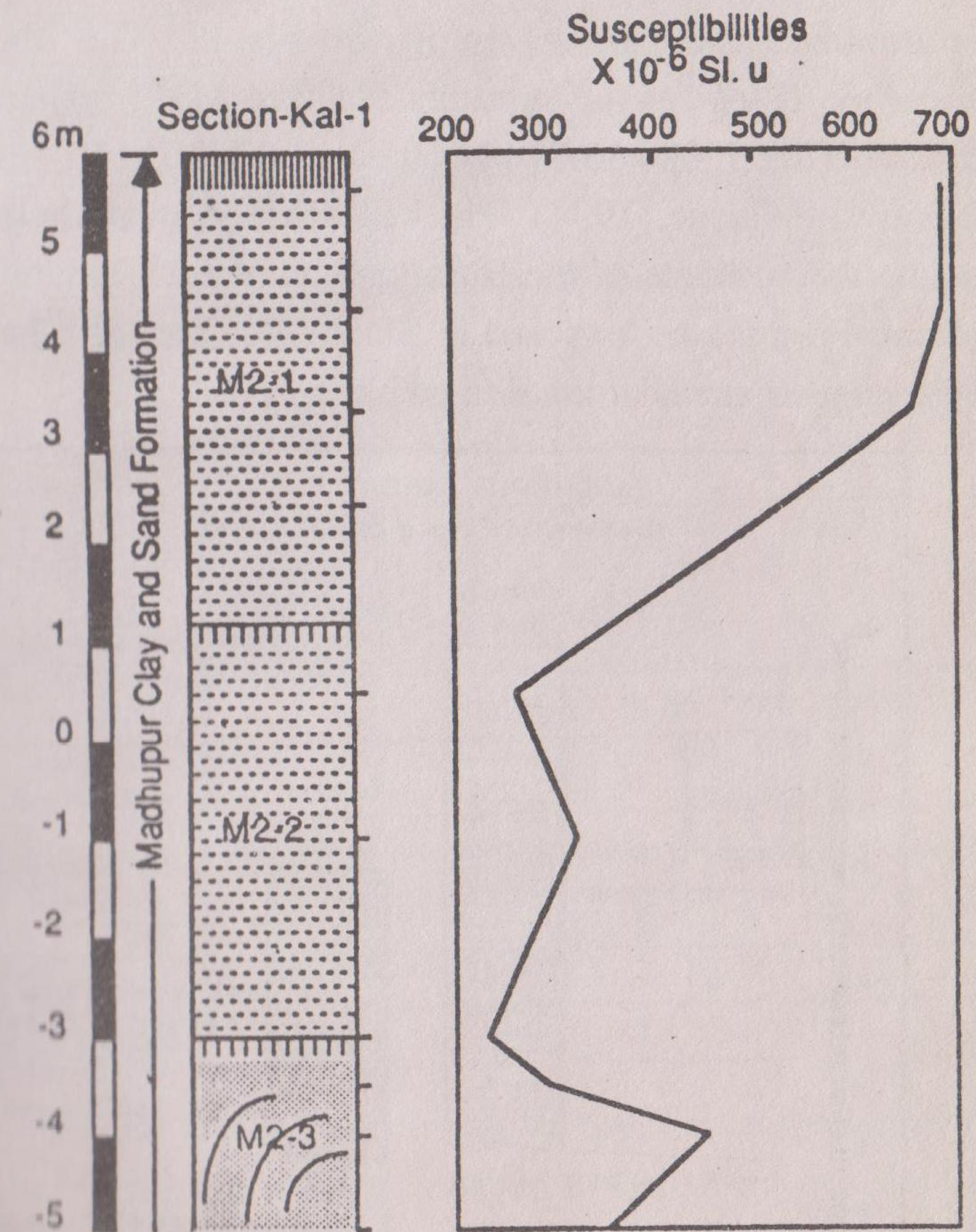


Fig. 16 : Magnetic susceptibilities are placrd against the stratigraphic position of the three Members of the Madhupur Formation at the type locality Kalsi brickyard, Mirpur, Dhaka city.

CHAPTER-FOUR

4. Radiocarbon dating

Several peat samples were collected from the Basabo Formation exposed at Gulshan Lake, Dakshingaon and Kalibari pond in the Dhaka city. The position of the peat samples and their obtained ages are given in the Fig.17. The obtained radiocarbon dates for the subunits M1-2 to M1-5 respectively are: 4040±70, 5730±60, 8940±105 and 12780±140 year BP (Monsur and Paepe, 1994). The radiocarbon dates helped to correlate the subunits of the Basabo, Rohonpur, Chalanbil and Boalmari Formations, exposed in Madhupur, Barind, Chalanbil and Panchagarh areas of the Bengal basin (Table 5).

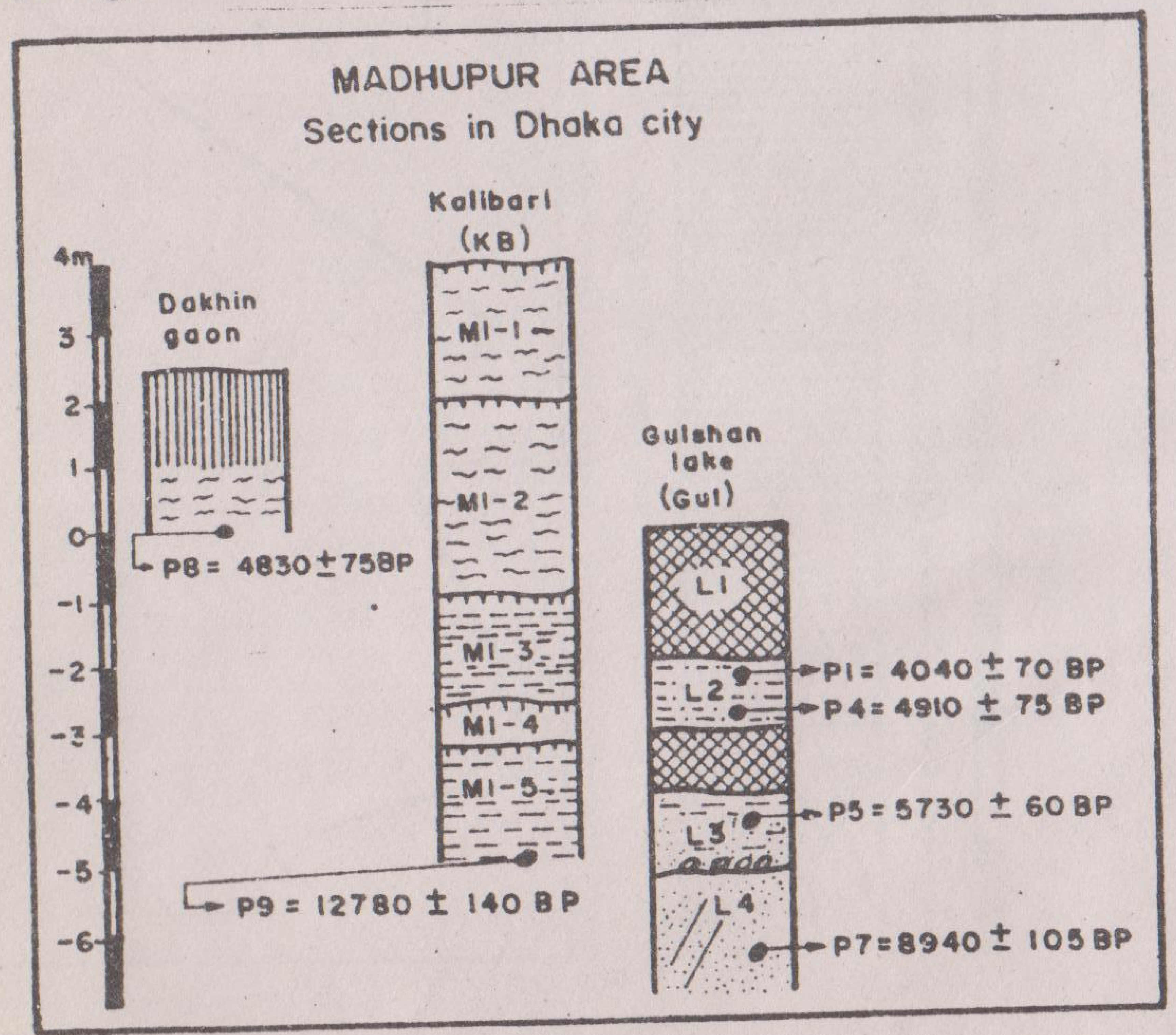


Fig.17 : Stratigraphic section showing the suite of peat samples and their respective radiocarbon dates

Chronostratigraphy				Absolute time (Year BP)	PANCHAGARH AREA			MADHUPUR AREA				BARIND AREA			Chlanbil area		
Erathem	System	Series	Sub-Stage		Formation	Lithologic Column	Texture /Soil	Formation	Member	Lithologic Column	Magneto Stratigraphy	Formation	Lithologic Column	Magneto Stratigraphy	Formation	Lithologic Column	Magneto Stratigraphy
CENOZOIC	QUATERNARY	HOLOCENE	Sub-Atlantic		BOALMARI SAND		S1 Alluvium B1-1	BASABO SILTY-CLAY	Matuail Clay	M1-1	Brunhes Epoch	ROHONPUR SILTY-CLAY	R1-1	Brunhes Epoch	CHALANBIL SILTY-CLAY	C1-1	Brunhes epoch
			Sub-Boreal	2700			S2 Clayey silt B1-2			M1-2			R1-2			C1-2	
			Atlantic	5000			S3 Silt B1-3		Gulshan Sand	M1-3			R1-3		EROSION		
			Boreal	8000			S4 Sand B1-4			M1-4			R1-4				
			Pre-Boreal	9000			S5 Sand B1-5			M1-5			R1-5				

Table-5 : Correlation of Holocene deposits exposed at different areas.

Placing the recent deposits on top, the two subunits of the Chalanbil Formation are correlated with the Sub-atlantic and Sub-boreal Substages of Holocene Series. Based on the correlation scheme, it can be conceived that before 5000 yrs BP, the Chalanbil area was under the process of erosion.

CHAPTER-FIVE

5. Mineralogical and sedimentological Studies

5.1 : Heavy mineral studies

Heavy mineral studies of Madhupur and Barind Formations were carried out by Hassan (1986) and Monsur (1990). The main objectives of the heavy minerals studies were to : i) correlate different stratigraphic units and subunits of the Madhupur and Barind Formations, ii) to characterize the Quaternary sediments in terms or heavy mineral associations and iii) to infer the provenance of the Pleistocene sediments.

Some common characteristics of heavy mineral assemblages in the different lithostratigraphic units of the different areas can be found (Monsur, 1990) :

a) the abundance of garnet separates the Basabo Formation from the underlying Madhupur Formation.

b) Homogeneous distribution of green and brown hornblende is the striking characteristics of both the Basabo and Chalanbil Formations.

c) the inavailability of biotitic mica and abundance of opaque minerals are the striking characteristics of the upper Members of both the Madhupur and Barind Formations.

d) the appearance of the green hornblende is the main characteristic of the lower Members of the Madhupur and Barind Formations.

A comparative abundane of the heavy minerals of the Pliocene (Dupi Tila Formation), Pleistocene (Mdhupur and Barind Formations) and Holocene Series are given in the Fig.18. From the Fig.18, it can be seen that the percentages of

ubiquitous minerals of the Pliocene Series are much higher, whereas garnet dominates the holocene Series.

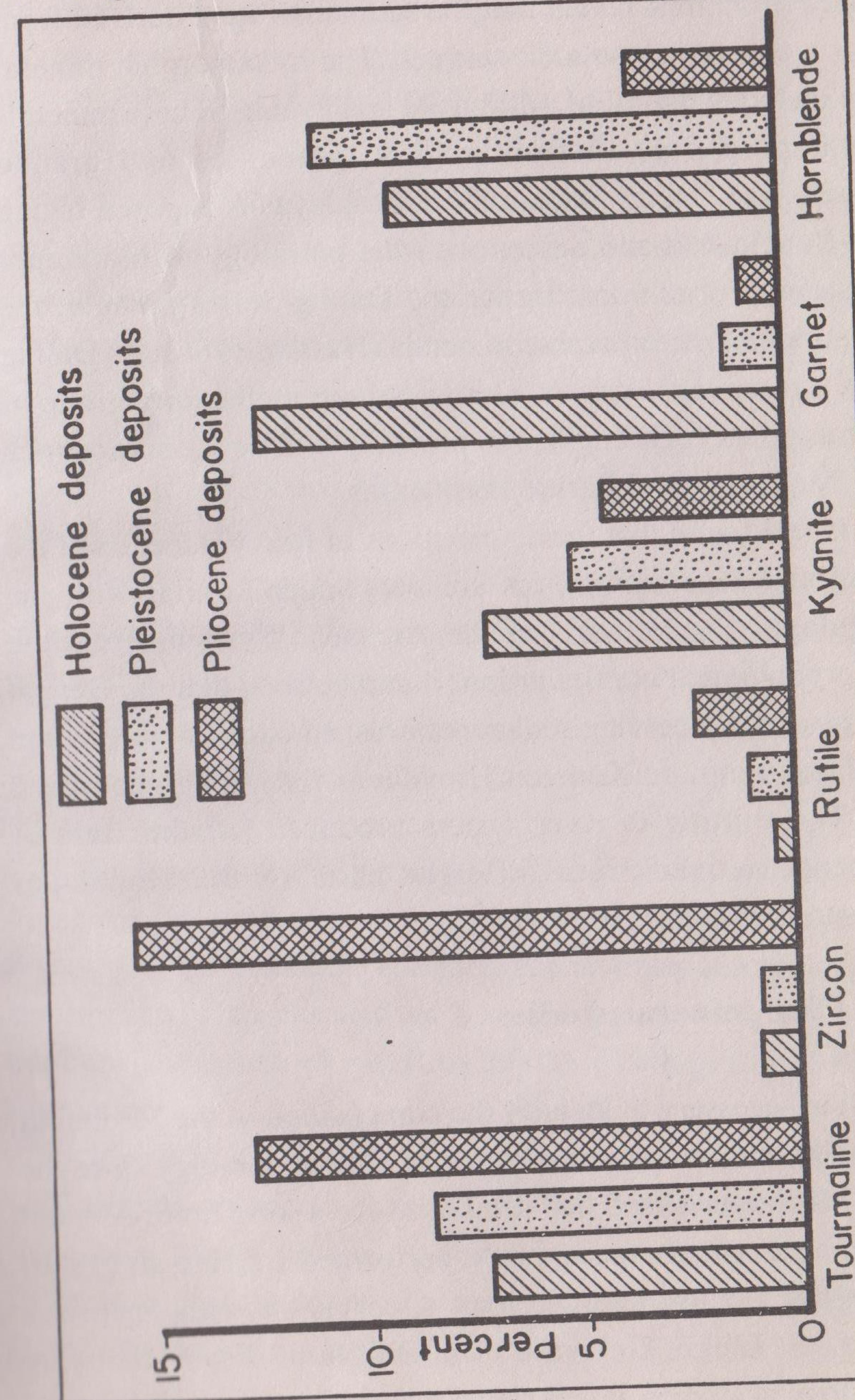


Fig. 18 Comparison of heavy minerals of different formations

The heavy mineral associations of the Madhupur and Barind Formations reveal that the sediments were derived from gneissic and schistose rock sources. The metamorphic mineral group includes staurolite, sillimanite and kyanite. These minerals are naturally derived from schists, granulites and granite gneisses. The Daling Series of the Himalayas is exposed facing India-Bangladesh and agrees with the petrology of Madhupur and Barind Formations. Hence the Daling Series prbably, the source rock of metamorphic minerals (Hassan, 1986). As Daling Series is a schistose group, it may also supply the mica group of minerals. Hence, Daling Series probably will be the source rock of the Madhupur and Barind Formations.

It was found that the distributions of heavy minerals of the Barind and Madhupur areas are very much similar with the mineralogical association of the Archaean System. From the geomorphological configuartion, it can be seen that the Bengal basin has been receiving sediments, washed out from the Assam Himalayas upto the Kumaon Himalayas for a long geological time. The shifting of river system produced an admixture of sediments derived from different parts of the Himalayas (Monsur, 1990).

5.2 : Clay mineral studies

It is necessary to identify the composition of the Madhupur Clay and Sand Formation in terms of clay mineralogy since the term "Madhupur Clay" has been used for a long time. A detail clay mineralogical studies were performed by Hassan (1986) during his Doctoral research in supervision with Professor Thorez of Liege University in Belgium. From the clay mineralogical studies, it was found that the Madhupur Formation

has two components (Hassan, 1986). The first main component includes the halloysite and illite. The second is a minor component. The minor component includes mainly the mixed layers: $(10 - 14_{sm})I$, $(10 - 14_{v})$, $(10 - 14_{c})$, C^2, $C - (14_{c} - 14_{v})$, $(14_{c} - 14_{v})$, $(10 - 14_{sm})14$, $(10 - 14_{sm}) - 14_{sm}$, Sm and Al_{17}.

A second series belongs to the sediments of the Chandina Formation belonging to the Holocene Series. Here, also the sediments include two main components. The first component includes the Kaolinite and illite. The second component includes: $(10 - 14_{sm})I$, $(10 - 14_{v})$, $(10 - 14_{c})$, C, $C - (14_{c} - 14_{v})$, $(14_{c} - 14_{v})$, V, $(10 - 14_{sm})14$, $(10 - 14_{sm}) - 14_{sm}$, Sm and Al_{17}. The mixed layers are almost the same as was found in the Madhupur Formation.

The Madhupur Formation is very much swelling. Addition of a little amount of water increases a great volume of the clay. It means that the clay expands in the presence of water.

Illite looks fine mica-like minerals. It exhibits a deficit of K^+ and with excess of water in comparison with normal mica, but without swelling properties.

Smectite is a group name of expanding clay minerals. The presence of smectite and illite-smectite mixed layer are responsible for swelling. The presence of water quickly expands the interlayer spaces and as a result the clay expands. This explains the cause of swelling of the Madhupur and Barind Formation.

It is to be mentioned that the weathering of ferromagnesian and silicate minerals resulted in the development of clay integrown which ultimately formed the clay minerals. Some rerpresentative peaks of the clay minerals of the Madhupur Formation are shown in the Fig.19.

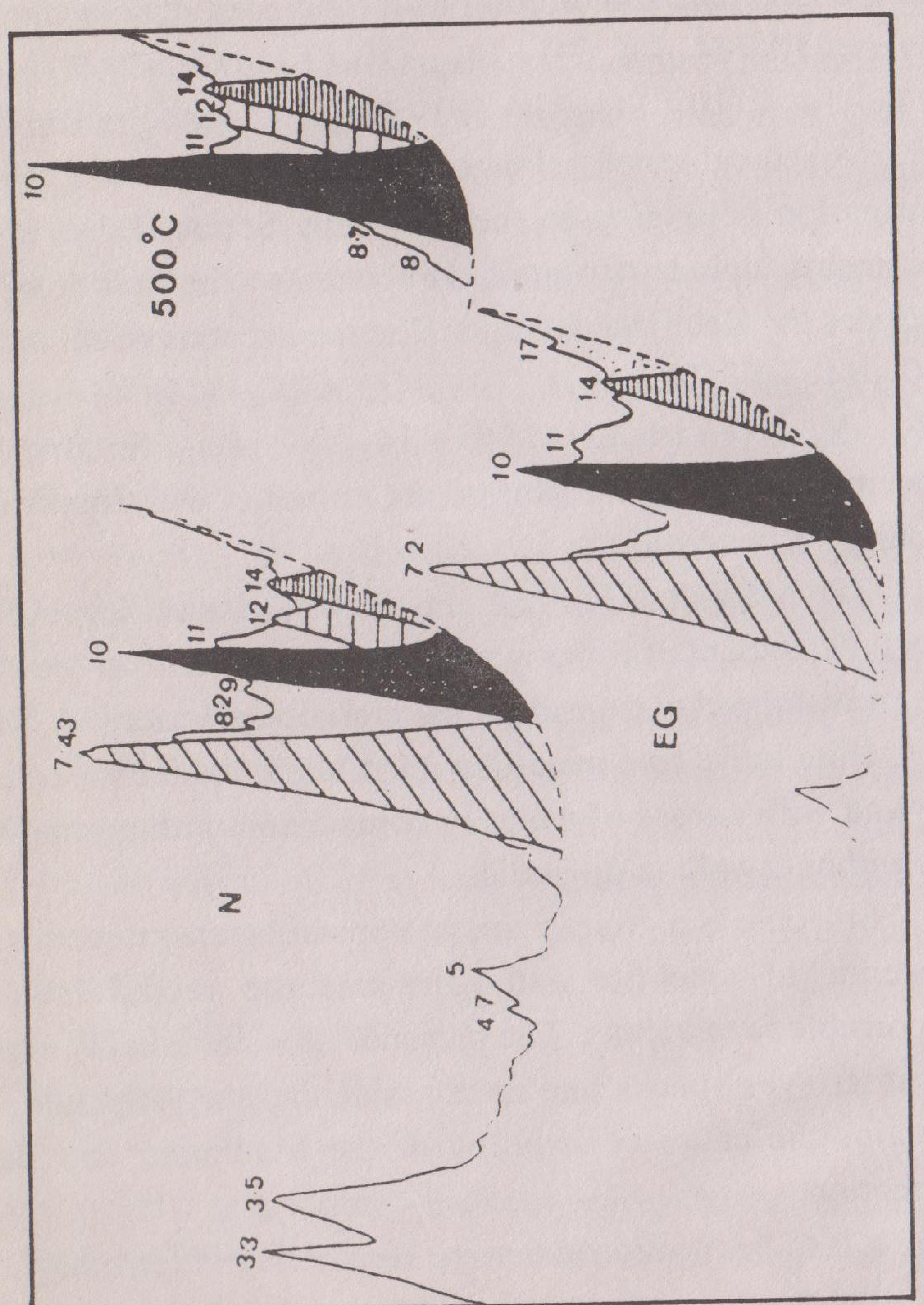


Fig.19 : Showing the peaks of illite and of the mixed layers. N-natural condition; EG-treatment with ethylene glicol and after heating 490-500°C (Hassan, 1986).

5.3 : Sedimentological studies

Detail sedimentological researches of these Madhupur and Barind Formations were carried out by Hassan (1986) and Monsur (1990, 1995). The main purposes of these sedimentological researches were to infer the ancient depositional environment with the application of sedimentological parameters.

A number of attempts have been made to introduce a rigorous and objective approach to the comparison and interpretation of grain size frequency distribution by means of statistics. But unfortunately no method seems to interprete the ancient environment precisely. This is because of the fact that depositional basin has its own physical, chemical and biological characteristics which may or may not always be similar to the characteristics of adjacent basin. In addition, the tested samples in the applied discriminatory techniques, were taken from river bars, beach, shallow marine or dune sand. The stratigraphic world is not solely composed of beach, river bars or dune sands. Hence, the results obtained from the sedimentological studies in search of depositional environment is not reliable.

Here in this text, some textural characteristics are discussed. The general term "Madhupur Clay" has been used for a long time since Morgan and McIntire published a report from the Louisiana University in 1956 on these reddish brown deposits. The upper part of the Formation is highly weathered. That's why, the term Madhupur Clay has probably wrongly implied. Fig.20 shows the grain size distribution of the Madhupur Formation in a stratigraphic section. From the Figures it is clear that the major parts of these Formation occupy the sand fractions. Only the upper part is dominated by clay materials.

Lithostratigraphic boundaries are usually fixed up by the observation with the nacked eyes. The changes of lithology and physical characteristics of sediments are put forward to subdivide the lithostratigraphic units. In the case of Madhupur and Barind Formations, the subdivions were based on the presence of palaeosols (Monsur and Paepe, 1992, 1994). The gradational boundary of these Formations makes a problem to fix up accurately the lithostratigraphic boundary. Sedimentological parameters were used to fix up the lithostratigraphic boundaries more precisely. Fig.21 shows such a sedimentostratigraphical approach to fix up the boundaries in subdividing the lithostratigraphic units of the Madhupur and Barind Formations.

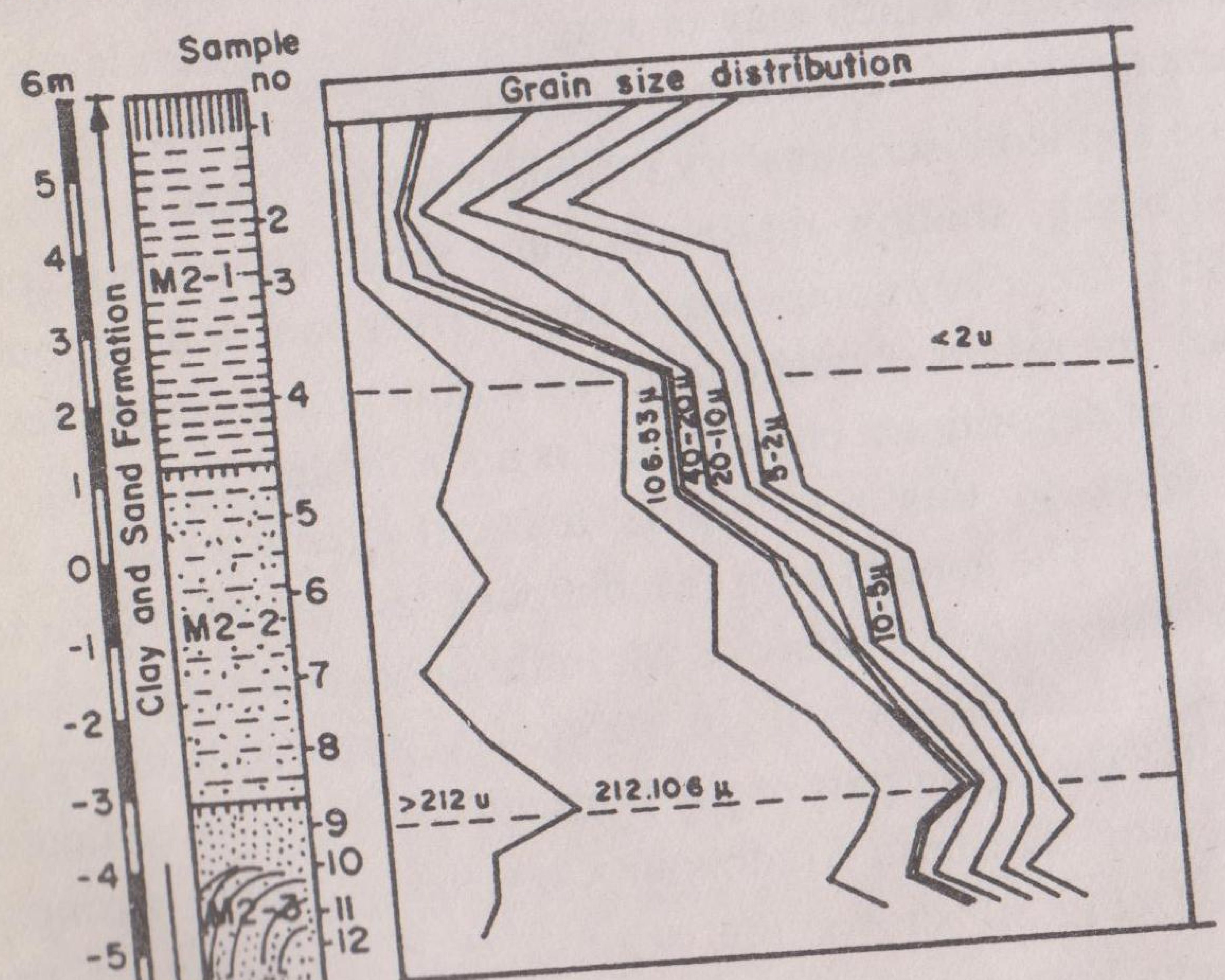


Fig.20 : Grain size distributions are placed against the stratigraphic position of the Madhupur Formation. Decrease of clay materials results the increase of the fractions between 212 - 106 microns.

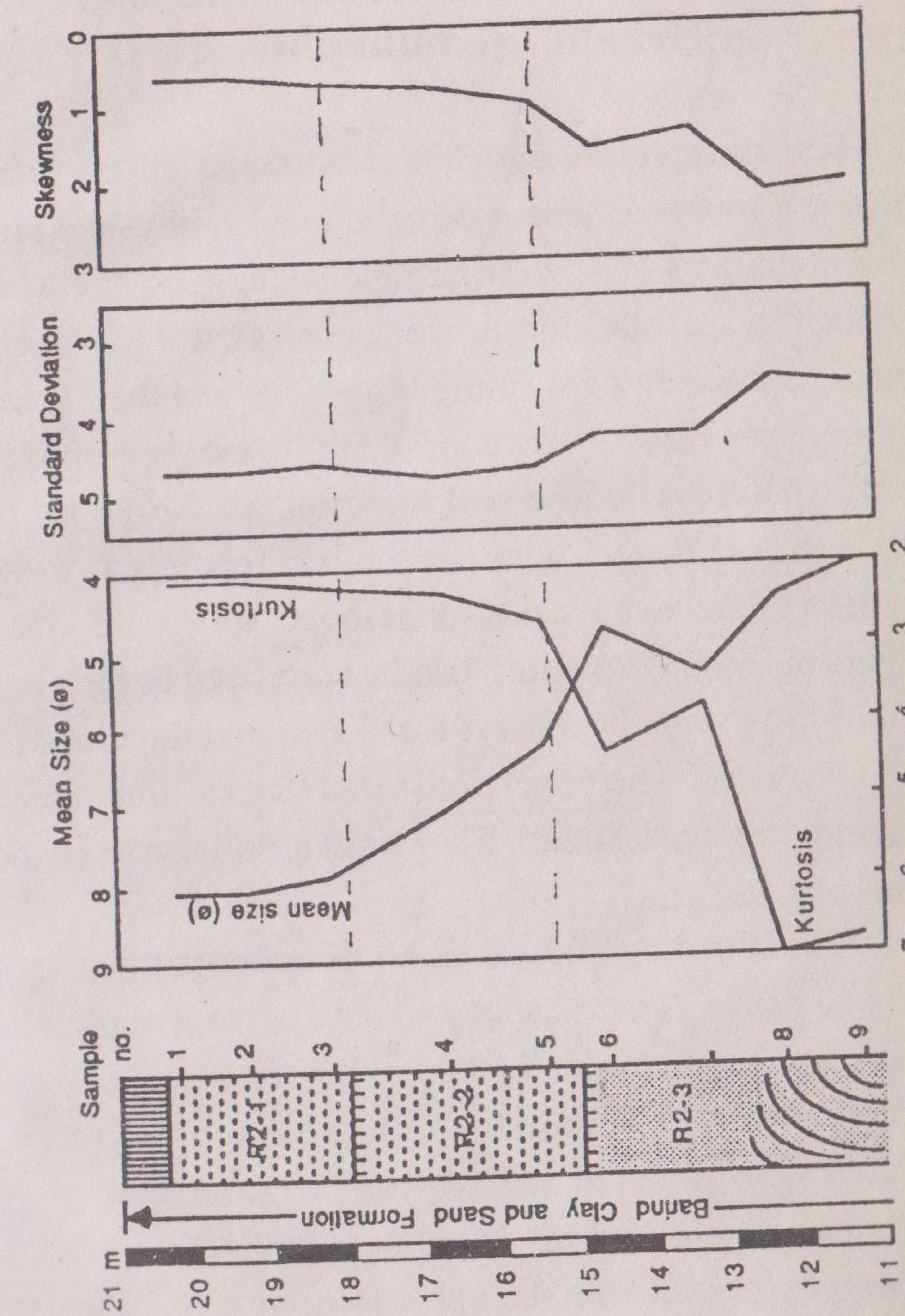


Fig.21 : Sedimentostratigraphical approach to subdivide the lithostratigraphic units and subunits. The sedimentological parameters are placed against the stratigraphic position of the Barind Formation

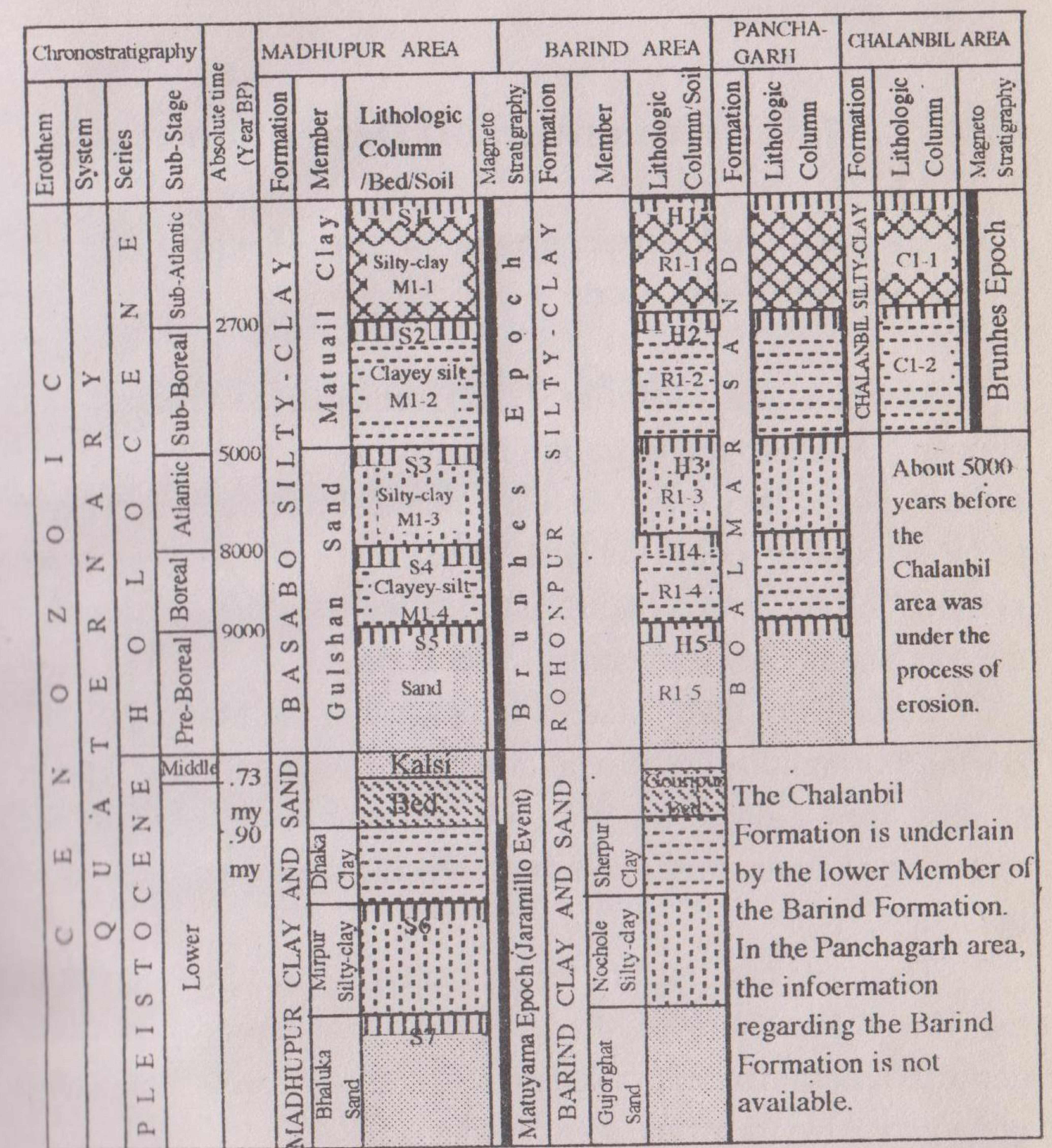
CHAPTER - SIX

6. Correlation of Quaternary deposits of the different geomorphic units.

The stratigraphic units and subunits of all the areas were discussed. From the palaeomagnetic results, physical properties of sediments and their stratigraphic sequences, the Madhupur and Barind Formations were correlated. All these two Formations have upward fining sequences and their weathering gradients are quite identical. Both these two Formations represent palaeosols. The soil horizons on the upper part are strongly impregnated whereas in the lower parts of these Formation represent weakly developed soil materials. Three Members of these Formations can be correlated as they belong to the Jaramillo event. The lower Kalsi Bed and the Gouripur Bed can be correlated. The upper Kalsi Bed has its equivalent bed in the Barind area near Amura. The correlation scheme is shown in the Table 6.

Soil is climatic indicator and it develops in an area of wide lateral extension. Hence, palaeosol represents a marker horizon in stratigraphic sequence. Based on the presence of four buried soil horizons five subunits of the Basabo Formation are correlated with the five subunits of the Rohonpur as well as Boalmari Formations. Two subunit of the Chalanbil Formation have been correlated with the upper two subunits of the Basabo, Rohonpur and Boalmari Formations. Based on the radiocarbon datation, the five subunits of these Formations were correlated with the chronostratigraphic scale of the Holocene Series. In the earlier chapter, the correlation scheme of Holocene deposits are shown separately.

Table 6 : Correlation scheme of the Quaternary deposits exposed at different areas.



In the correlation scheme, Pleistocene deposits are correlated with the chronostratigraphic scale based on the palaeomagnetic results. On the other hand, Holocene deposits are correlated with chronostratigraphy based on the radiocarbon dating. Palaeosols were used for regional correlation of the Holocene Series.

CHAPTER-SEVEN

7. Environment of Deposition

7.1 : Depositional Environment of the Madhupur and Barind Formations

Morgan and McIntire (1959) considered the red bed deposits (Madhupur and Barind Formations) as the "Pleistocene terrace" which they assumed to be identical with the Mississippi terraces, but they could not find the existence of multiple terrace systems in the Bengal plain. But they were on the opinion that the Madhupur Clay represents fluvial deposits.

Sedimentological studies indicate that the Madhupur and Barind Formations are fluvial deposits. Although these type of studies, now-a-days, are not so much important, even if, the matching of cumulative curves with the fluvial deposits has some meanings.

The cross bedding and ripple marks are quite prominent in the lower Members of these Formations. Moreover, these deposits contain wood fragments and plants roots which are quite indicative for a fluvial environment.

A series of buried soils can be found in the fluvial flood plain. It was discussed that the Madhupur and Barind Formations contain two buried palaeosols. It is more likely that the Madhupur and Barind Formations represent cumulative palaeosols formed progressively with the increment of a few millimeter or a centimeter of sediment per year by numerous

floods in the depositional basin (Monsur et al., 1992). Therefore, the presence of buried palaeosol supports the statement of fluvial environment of deposition.

Hence, it can be inferred that the depositional environment of the Madhupur and Barind Formation is fluvial. The lower Members of these Formations represents channel pattern and the middle and upper Members probably represent flood plain deposits.

7.2 : Late Quaternary monsoon climatic episodes and the depositional history of the Bengal basin

The peak of the last glaciation (18 kyr BP) was evidenced by dry climatic condition over the Bengal basin. The Himalayas were considerably high and were glaciated. Melt water was flowing through a number of palaeoriver system over the Bengal basin. By that time the eustatic sea-level was about 100 to 130m below the present Mean Sea Level. Hence, the rivers were narrow and were deeply incised (Swatch of No Ground in the Bay of Bengal is a strong evidence).

The monsoonic climate started changing between 18 to 15 kyr BP. At about 12 kyr BP, south-west monsoon became prominent which caused heavy rainfall. Therefore, at the end of the last glaciation (about 10,000 yrs BP) amplified monsoon water plus deglaciated melt water from the Himalayas enormously flowed through these narrow palaeoriver systems which were overloaded and overflowed. Due to the strong hydrodynamic condition, the initial Barind and Madhupur surfaces were highly dissected, created some local pools and depressions, left a number north-south elongated reddish-brown islands or terraces. The north-south elongation of the reddish-brown terraces indicates the north-south directional water flow which supports this statement. The Chalanbil area represents such a dissected depression even today (Monsur, 1995). During this time, general morphology of the Madhupur and Barind tracts took their present shape (Fig.22). But the Lalmai hills and the

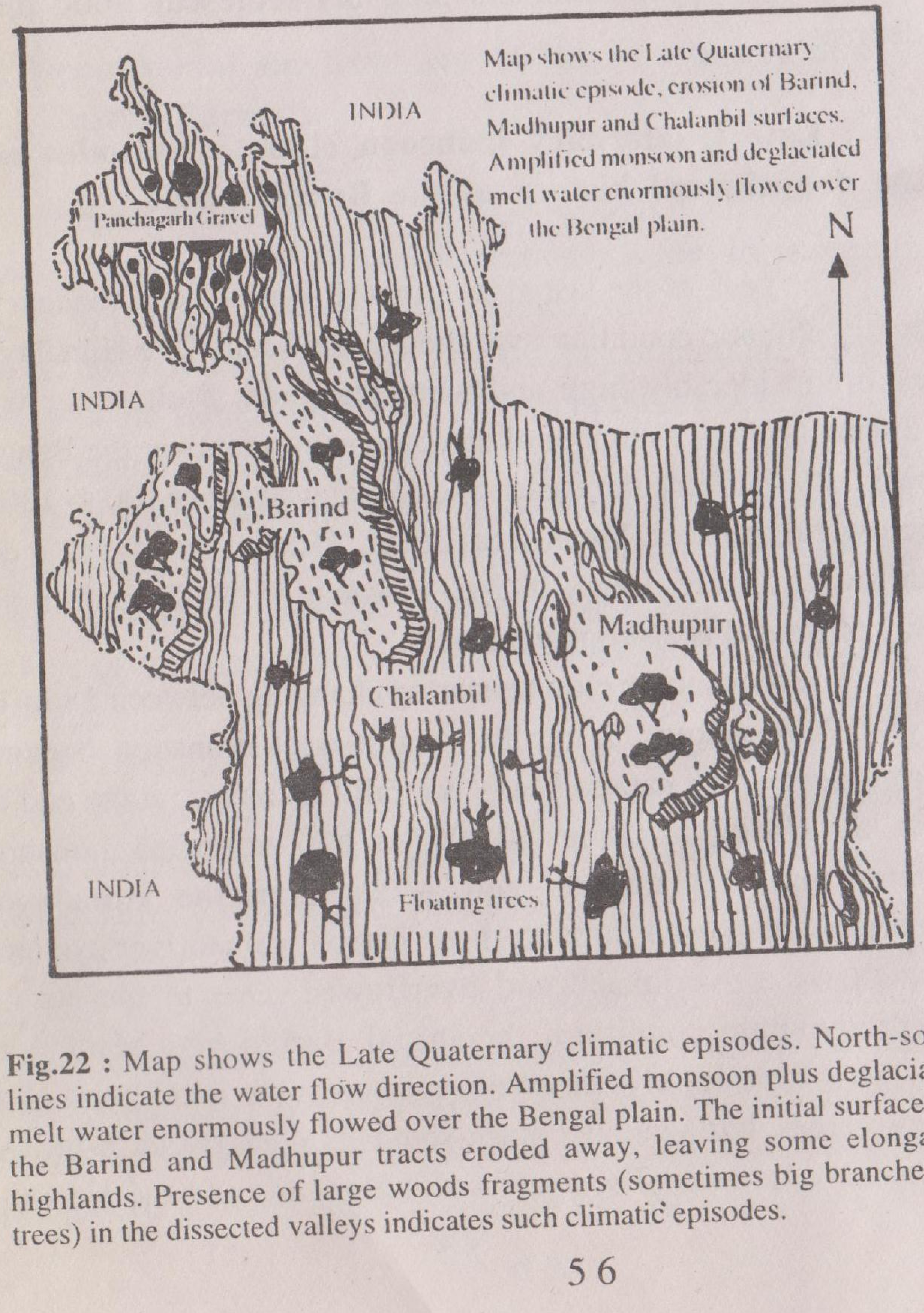


Fig.22 : Map shows the Late Quaternary climatic episodes. North-south lines indicate the water flow direction. Amplified monsoon plus deglaciated melt water enormously flowed over the Bengal plain. The initial surfaces of the Barind and Madhupur tracts eroded away, leaving some elongated highlands. Presence of large woods fragments (sometimes big branches of trees) in the dissected valleys indicates such climatic episodes.

Madhupur locality represent a tectonically uplifted blocks. Lalmai hill tops formed a kind of table surface. At the beginning of the Holocene, sea-level started rising very rapidly. About 5,500 yrs BP, sea-level attained its maximum height. The hydrodynamic condition of the river system was changed. Erosional activities ended and the erosional surfaces were filled up by the Holocene deposits. Due to the tremendous current, boulders and gravels from the Himalayas were carried away very far towards the south and were deposited over the vast plain extended from Tetulia to Dahagram (Panchagarh Gravel Beds). These upper Pleistocene gravels can be found in the Brahmaputra river valley as far as Sirajgonj.

Heavy rainfall of the late Pleistocene Epoch generated a tremendous current in the hilly areas, like, Patheria hill ranges. The soft sands of Bokabil Formation were quickly eroded away leaving large concretions in the stream valleys. Huge concretions can be found in the stream sections of Patheria, in and around Borolekha in Sylhet district. (Some sandstones of the Bokabil Formation contain large concretions of calcium carbonate).

In the Barind and Madhupur tracts, middle and lower Members of the Barind and Madhupur Formations are overlain by Holocene deposits (Basabo and Chalanbil Formations). The Holocene infilling was not as high as the initial Madhupur surfaces. That's why, the Barind and Madhupur tracts apparently seem to be elevated compared to the surrounding flood plain. This apparent elevation of the flat surfaces of the Madhupur and Barind is an erosional feature and does not indicate a tectonic event.

CHAPTER-EIGHT

8. Holocene sea-level and the marine transgressions of the eastern coast of the Bay of Bengal

Several authors introduced Holocene sea-level curves. In this regard, there are two schools of thoughts: one group believes rapidly fluctuating sea-level hypothesis (Fairbridge, 1961; Curray, 1965) and the other group believes smoothly varying sea-level hypothesis (Jelgersma, 1961; Shepard, 1963).

The contribution of climate to the sea-level fluctuations more rationally supports the rapidly fluctuating sea-level hypothesis. Minor climatic change results a small scale marine transgression. The existence of supratidal flat worldwide is the result of the high stand sea-level of 6000 - 5000 yrs BP.

During the maximum high stand of sea-level (about 5500 yrs BP), oceanic waves acted on the foot of the hillocks from Cox's Bazar to Teknaf. About 18,000 yrs BP, shore line of the Bay of Bengal was some hundreds of killometers southward from the present coast. At the end of the last glaciation, eustatic sea-level started rapidly rising and the shoreline of the Bay of Bengal started shifting northward (Fig.23, Monsur and Kamal, 1994). Holocene sea-level along the eastern bank of the Ganges estuary was accompanied by coastal erosion. A wide hilly area was existing westward from the present Cox's Bazar-Teknaf coast (i.e in the eastern bank of the Ganges estuary). These hillocks were made up of the Bokabil and Tipam Formation. These were the soft rock sediments and washed out quickly by the wave action. Only the concretions those can be found in the Bokabil Formation remained on the shoreline and in the

continental shelf (yet to be explored). In the supratidal flat these concretions can be found under a thin venial of alluvium sediments. In a wide area towards the southern part of Teknaf town, these concretions are overlain by the recent sediments and can be found within the ancient beach sand. These concretions are extensively exposed at Inani beach and St. Martin's Island. High concentration of these concretions can be found at the palaeochannel sections where they were rolled out by the center of gravity along the 'V' shaped valleys and accumulated on the stream beds. Due to the invasion of the sea with erosion, the hillocks with their valleys and streams were eroded away leaving the concretions on the palaeobeach. Therefore. high concentration of these concretions along the beach indicates a

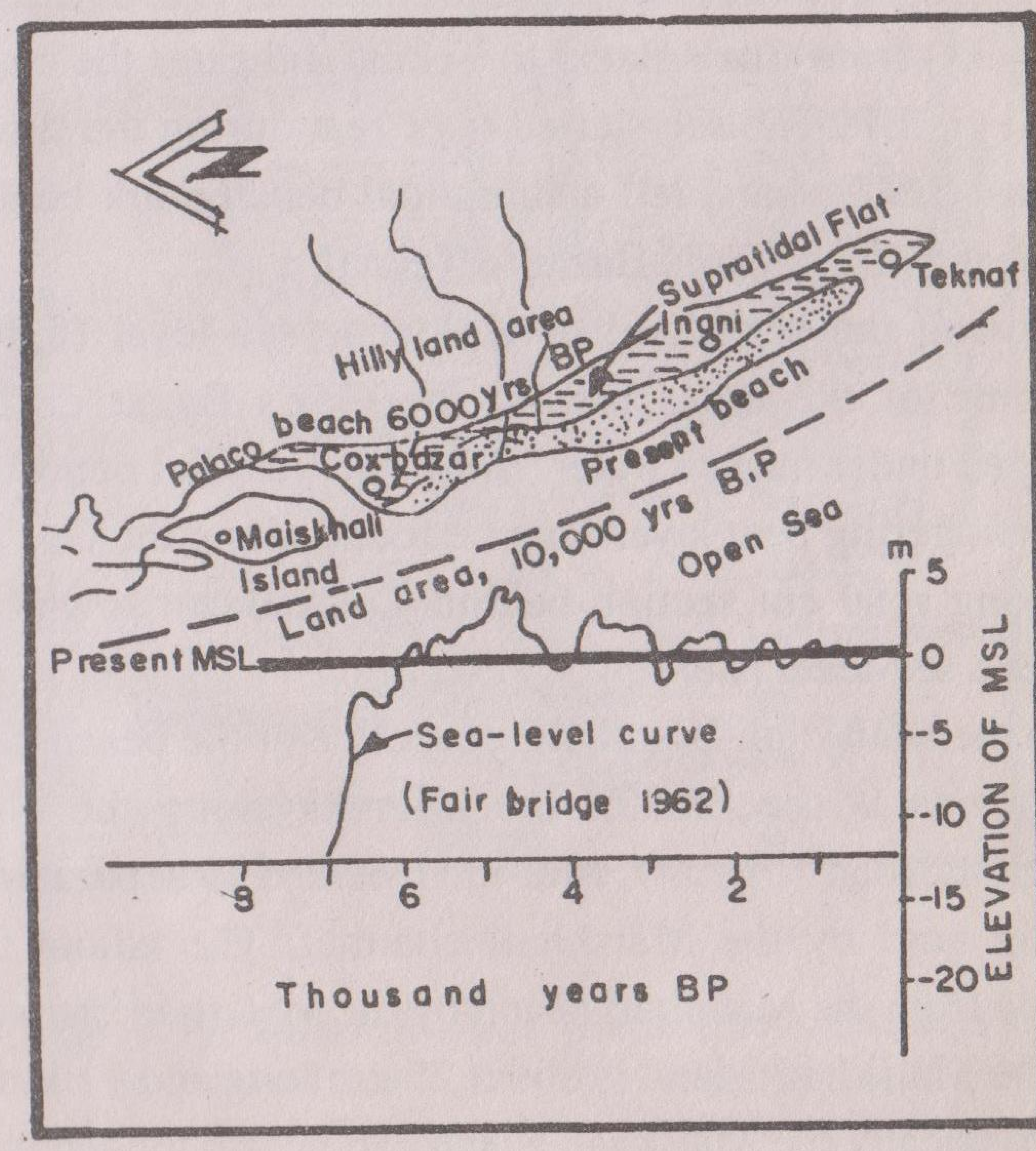


Fig.23 : Map shows the present and palaeobeach of the Cox's Bazar-Teknaf coast.

palaeochannel or palaeovalley of some undulated or hilly surfaces. These concretions are underlain by Bokabil Formation (shale).

The existence of these concretions under the beach sand or recent deposits of the supratidal flat from Cox's Bazar to Teknaf indicates a palaebeach of the highstand (raised) Holocene sea-level. These concretions, probably, made a bed on the eastern shelf of the Bay of Bengal (from Cox's Bazar to Teknaf) due to the rise of sea-level and its erosional activities. Age of this bed covers the whole Holocene time. Existence of these concretions at the elevated beach indicates a sea-level rise. According to Fairbridge the maximum sea-level was about 5,500 yrs BP. Hence eastern extremity of the supratidal flat (i.e. at the foot of the hillocks) from Cox's Bazar to Teknaf indicates the coast line of 5,500 yrs BP. The sea started to retreat during the time span of the last 5,500 years, left a supratidal bench mark behind the present beach from Cox's Bazar to Teknaf.

During the highstand of Holocene sea-level (5,500 yrs BP), some of the areas behind the Cox's Bazar cliff were submerged under marine water. Holocene tidal flat deposits with the interfingering peat layers can be found along the Cox'Bazar-Chittagong road cut section behind Cox's Bazar town. It also indicates a sea-level rise.

In the Maiskhali Island, the coast line or the beach of 5,500 yrs BP, was at the foot of the hillocks along the Nalbila-Ganakghata road (Fig.24). Maiskhali island is separated from the main land by the Maiskhali channel. The island is also separated from the Materbari island by the Materbari channel.

The Maiskhali island is about 25 km long and 11 km wide. Morphologically the Maiskhali island can be subdivided into two equal halves : Eastern and Western halves, by a north-south

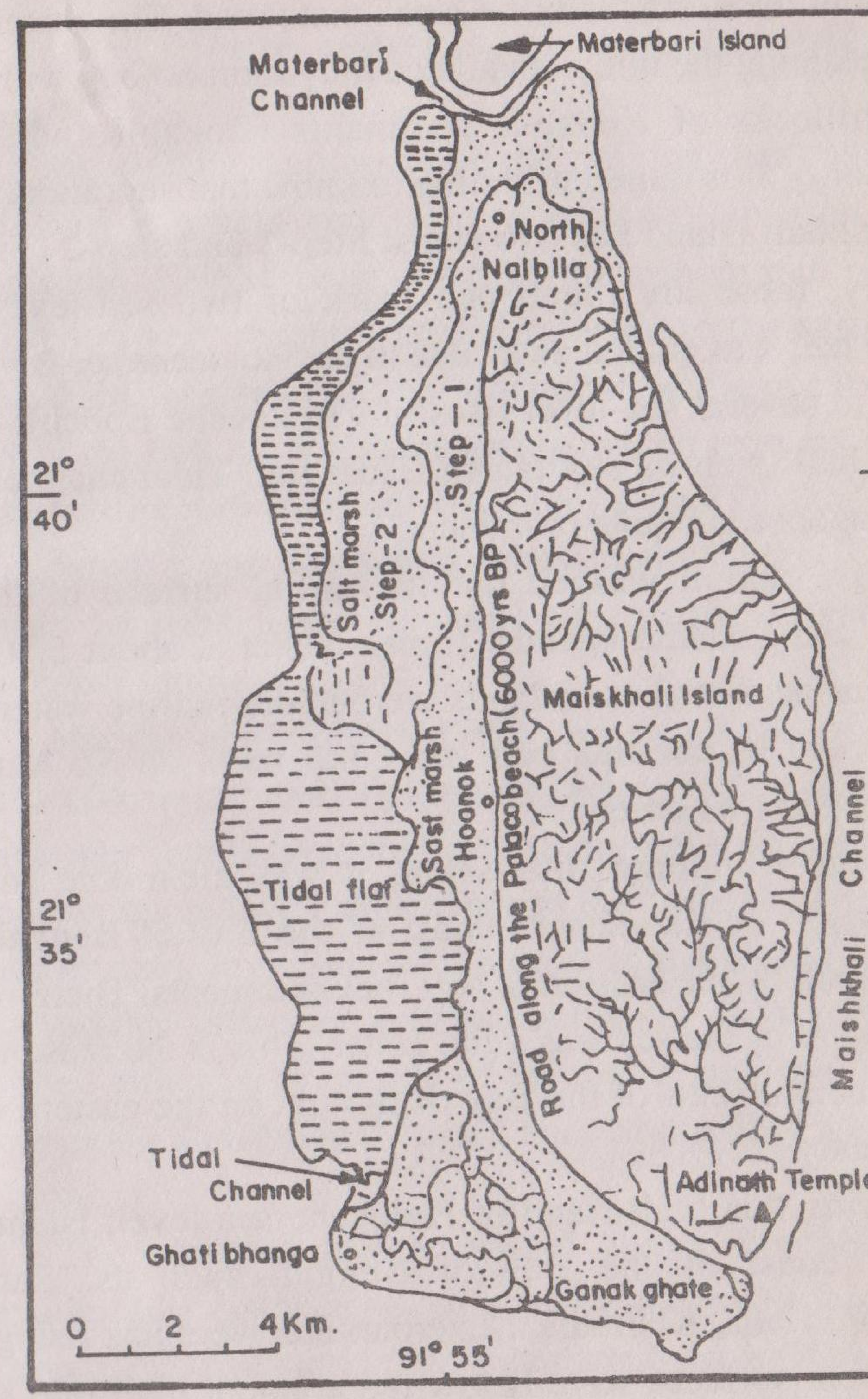


Fig.24 : Map of the Maiskhali Island. Western half represents salt marsh area and the eastern half is still retaining the original hilly morphology. Western half was eroded away due to the Holocene sea-level rise (or due to several sea-level rises of Pleistocene Epoch). In the western half (step-2), salt marsh, Tidal flat, Tidal channels and coastal lagoons are quite prominent

elongated ancient (about 5,500 yrs BP) coast line which runs parrallel to the north Nalbila-Ganakghata road. The eastern half is still retaining the initial undulated hilly morphology with some minor hillocks of Neogene sediments (Bokabil and Tipam Formations). It is quite interesting to know that supratidal flat in the Maiskhali island has two steps: Step-1 and step-2 (Fig.24). Probably, these are the bench mark of two sea-level rise. Western half was eroded away due to the Holocene sea-level rise (or due to several sea-level rises of Pleistocene Epoch). In the western half (step-2), salt marsh, Tidal flat, Tidal channels and coastal lagoons are quite prominent.

Wave action washed out the initial surface of the St. Martin's and Sonadia Islands. It means that at about 5,500 yrs BP the surfaces of these Islands were under marine water. The development of coquina bed and coral reefs on St. Martin's Island support this statement.

In the foregoing discussion, it was clear that marine transgression on the eastern coast of the Bay of Bengal was accompanied by the erosion of soft rock sediments. Therefore, the invasion of the sea was quite faster. This is the reason why the continental shelf of the Bay of Bengal on the eastern coast slopes gently (2° - 8°).

During this high stand of Holocene sea-level, islands of southern coast of the Bay of Bengal, such as, Sandip, Nijhumdip, Hatia, Kutubdia, Materbari etc. were just rising and their present surfaces were below the ambient high tide level. After 5,500 year BP, the Holocene sea-level started dropping and the surfaces of these Island came into the aerial exposition.

CHAPTER-NINE

9. Some aspects of neo-tectonics

Most of the authors have the opinion that the Madhupur and Barind tracts represent a tectonic uplifted surfaces. Fergusson (1963) believed that the Madhupur region was uplifted in very recent time and refereed to the earth-quake of 1762. He suggested that the Madhupur jangle occurs along the axis of the belt of **Volcano action** which extends in a north-western direction through Chittagong and Dhaka. Fergusson considered a numerous low lakes in the Sylhet basin to be caused by subsidence compensatory to the elevation of the Madhupur jungle.

Morgan and McIntire (1959) noted a series of en-echelon faults (six in number) flaking the western side of the uplifted Madhupur jungle. According to them, uplift of the Barind and Tippera coupled with subsidence of the Sylhet basin and Deltaic plain resulted in torsion of the crust in the Bengal plain. They believed that surface en-echelon faulting of the Madhupur jungle resulted either from torsion of the region or from the effect of shear along a postulated buried fault or possibly a combination of both.

The courses of the Bengal rivers changed during a considerable distance, even, during the historical time. For example, the diversion of the Brahmaputra river is important. By the early 1770's the major diversion of the Brahmaputra occurred into its present channel, west of the Madhupur jungle. There is no complete agreement as to when this diversion down the Jenai (probably the present name ``Jamuna" has been derived from the name ``Jenai") river of Runnel (1781) occurred. A generally accepted more rational explanation of LaTouche (1910) can be cited. He felt that the old Brahmaputra course flowed through the east of Madhupur jungle which was a relic of the old delta face of the Ganges. He considered the entire Bengal basin (excluding the Sylhet basin) as the sole regime of the Ganges prior to the sudden increase in Brahmaputra water volume. He suggested that the diversion of the additional water volume of the Tista river from the Ganges to the Brahmaputra in 1787 was the final action that trigegered the diversion of the Brahmaputra river down the old Jenai channel west of the Madhupur jungle. Therefore, for about 200 years Brahmaputra river was laterally shifted about 100 km westward.

Bagchi, (1944) described a beautiful explanation from the mythological stories of Ramayana, Mahabharata and from the writings of Ptolemy (150 A.D.) and Megasthenes and Periplus (300 B.C.). Kanangopal Bagchi (1944) was sure that the birth of the Padma (the principal course of the Ganges) took place before 300 B.C. Before the birth of the Padma, the Bhagirathi was the principal course of the Ganges. It means that in early times, the Ganges was discharging its water into the Bay of Bengal about 200 km more westward (through the Bhagirathi river) from the present point of discharge of the river Mehgna.

Some geologists give more emphasis on the fact that the courses of Bengal rivers changed due to the uplift of the Madhupur and Barind tracts. They believe that due to the neotectonics, Madhupur area is uplifting very slowly, and as a result , the old Brahmaputra river changed its course and shaped into the present position (Jamuna). Other group of geologists believe that due to the neotectonic effect (still active), the courses of the Ganges river system laterally has been shifting from the west towards the east. The gradual uplift of western part of the

basin resulted in the shifting of the Ganges river towards the east

However, the opinion of the present author differs. The author believes that the Barind and Madhupur tracts represent not a tectonic block, but an erosional feature. In fact, the Lalmai hills and the locality of Madhupur, resulted due to the block uplift during the middle Pleistocene time. But the rest of the areas of Madhupur and Barind tracts represent an erosional feature.

In stratigraphic sections of the central part of the Madhupur and Barind, all the three Members can be seen. But in the marginal areas, the middle or lower Member is overlain by the Holocene deposits. This is because of the fact that the upper or middle Member of these Formations were eroded away and on the erosional surface the Holocene Series had been deposited.

Very close to the main reddish-brown terraces, some small terraces can be found. Sometimes these may have underground lithologic continuity with the main island (or terrace) by the middle or lower Members of these Formations or sometime they do not have any lithologic continuity. It means that all the deposits of the Madhupur and Barind Formations were eroded away and the dissected surfaces were filled up with the recent sediments. That's why, there is a lack of lithologic continuity.

In the foregoing discussion, the author has mentioned that during the Late Pleistocene time, amplified monsoonic rainfall and deglaciated melt water enormously flowed over the Bengal plain. As a result, the Madhupur and Barind surfaces were eroded away leaving these reddish brown islands, created some pools and depressions. The Holocene sea-level rise changed the hydrodynamic condition of the palaeoriver system. As a result, these dissected surfaces were filled up with the alluvial sediments. But the initial Madhupur and Barind surfaces remained as an elevated islands.

It is quite interesting to know when the Chittagong hill ranges came into being. Cox's Bazar - Teknaf beach more or less parallel to the axial line of an anticline. High dip of some beds along the beach indicates local faulting of Neogene sediments.

From the discussion regarding Holocene marine transgressions, it was clear that undulated or hilly surfaces were existing in and around Cox's Bazar-Teknaf during pre-Holocene time. So, it can be assumed that the Cox's Bazar folded belt originated not after 10,000 to 15,000 yrs BP i. e. they were originated before upper Pleistocene-Holocene time (Monsur and Kamal, 1994).

Chittagong and Jointiapur hill ranges fall in the Arakan Yoma folded belt. All these hill ranges responded simultaneously during the tectonic activities. In Jointiapur area, lower Pleistocene boulder-gravels (Sonatila Gravel Beds, Shaha, 1994) are well exposed on hill tops of Sonatila, Mokambari and Jointiapur locality. Sphericity and roundness of these gravels indicate that they were river borne deposits. Therefore, those hills were elevated after the deposition of those gravels. From this evidence, it can be assumed that Jointiapur hills close to the margin of plainland were uplifted after lower Pleistocene time.

Since the Jointiapur and Chittagong hill ranges belong to the same tectonic belt, then probably, the Jaintiapur hills and the Cox's Bazar cliffs were uplifted synchronously. From the above discussion, it is clear that they were uplifted after Lower Pleistocene and not after Upper Pleistocene or Holocene epoch. Hence, their time of upliftment would be the Middle Pleistocene. This time of upliftment of these hill ranges coincides with the major or final orogenic movement of the Himalayas during Middle Pleistocene time.

References

Akhter, S.H. and M. Hoque, 1993 : Recent development of thermoluminescence study in geology. The J. NOAMI, v.10, n.1, p.29-37.

Alam, M.K. and M.R. Khan, 1980 : Madhupur Clay and its probable scope of economic uses. Seminar Issue, Petroleum and Mineral resources of Bangladesh.

Bagchi, K., 1944: The Ganges Delta. Department of Geography, Calcutta University, India, p.39-49.

Bakr, M.A., 1977: Quaternary geomorphic evolution of the Brahmaputra-Noakhali area, Comilla and Noakhali districts, Bangladesh. Records of the Geological Survey of Bangladesh. Vol.1, part.2, p.1-48.

Bullock, P., Fedoroff, N., Jongeriuos, A, Stoops, G., Tursina, T. and Babel, U., 1985 : Handbook for thin section description. Wolverhampton, England. 152p.

Chowdhury, M.M.M., 1994: Stratigraphy and Clast Lithological Analysis of the Gravel Beds Expoxed at Panchagarh-Dahagram-Dalia Area of Bengal Basin. M.Sc. Thesis. Geol.Dept., D.U.

Fairbridge, R.W., 1961: Eustatic changes in sea-level. Physics and Chemistry of the Earth. Vol.4, p99 - 185.

Hassan, M., 1986: Stratigraphical and sedimentological studies on Quaternary deposits of the Lalmai Hills (with relation to the Madhupur tract and the adjoining flood plain), Bangladesh. D.Sc. Dissertation, VUB, Brussels.

Imam, M.B. and H.F. Shaw, 1985 : The diagenesis of Neogene clastic sediments from the Bengal basin, Bangladesh. J.Sed. Petrol., v.55, n.5, p.665-671.

Islam, M.A., 1974: On the Madhupur clay. J. Bang. Nat. Geogr. Asoc. vol.2, no.1 and 2.

Islam, M.A., 1974-75: A preliminary study on the Cenozoic paleogeography of Bangladesh and adjoining regions. Raj. Univ. Stud., vol.IV.

Khan, F.H., 1991: Geology of Bangladesh. The University Press Limited.

LaTouche, T.H.D., 1910: Relicts of great ice age in the plains of northern India. Reprinted in report on the Hoogly river and its headquarters. The Bengal Secretariat book depot. Vol.1, p.21 22, 1919.

Mankinen, E.A. and Dalrymple, G.B., 1979: Revised geomagnetic polarity time scale for the interval 0-5my BP. J. Geophys. Res., 84, 615-626.

Monsur, M.H., 1990 : Stratigraphical and Palaeomagnetical Studies of Some Quaternary Deposits of the Bengal Basin. Doctoral dissertation, Free University of Brussels, Belgium.

Monsur, M.H. and R. Paepe, 1990: Heavy mineral characteristics of the Barind and Madhupur Formations of the Bengal basin, Bangladesh. Bang. J. Geol., v.9, p.41-46.

Monsur, M.H. and R. Paepe, 1992 : Quaternary stratigraphy of the Barind area of the Bengal basin, Bangladesh. Ind. J. Earth. Sci., v.19, n.2-3, p.79-84.

Monsur, M.H. and M.S.Hossain, 1992 : Palaeopedological and miromorphologiacal studies of the Lalmai Clay, Madhupur and Barind Formations of the Bengal Basin. Bang. J. Sci. Res., 10(2):143-152.

Monsur, M.H. and Paepe, R., 1994 : Quaternary stratigraphy of the Madhupur area of the Bengal Basin, Bangladesh. Bang. J. Sci. Res., v. 12, no.1, p.41-47.

Monsur, M.H. and A.S.M.M. Kamal, 1994 : Holocene sea-level changes along the Maiskhali and Cox's Bazar-Teknaf coast of the Bay of Bengal. The Jour. Noami, vol.11, no.1.p.15-21.

Monsur, M.H., 1995: Sedimentostratigraphical investigations of the Madhupur and Basabo Formations of the Bengal basin,Bangladesh. Dhaka Univ. J. Sci., 43(2):243-251.

Monsur, M.H., 1995 : Magnetic susceptibilities of the Quaternary deposits of the Barind and Chalanbil areas in comparison with the Madhupur Formation. Dhaka Univ. J. Sci., v.43, no.1, p.59-65.

Monsur, M.H. : On the depositional environment of the Madhupur and Barind Formations of the Bengal Basin. Asiatic Society (submitted).

Monsur, M.H. : Variation of magnetic susceptibilities of the Quaternary deposits of the Madhupur area. Bangladesh J. Sci. Res. (in press).

Monsur, M.H. : Textural characteristics of the Quaternary deposits of the Barind area of the Bengal basin. Bangladesh J. Sci. Res. (In press).

Monsur, M.H., 1995 : Procedure of removal of secondary magnetic components of the Quaternary sediments of the Barind area of the Bengal basin. Dhaka Univ. J. Sci., v.43, no.1, p.53-57.

Monsur, M.H. and R. Paepe, 1994 : Holocene stratigraphy and palaeoclimatical interpretation of the deposits of the Madhupur, Barind and Chalanbil areas of the Bengal basin (Bangladesh). Bangladesh J. Sci. Res., v.12, no.2, p.255-264.

Monsur, M.H. 1994 : Palaeomagnetic studies of the Quaternary deposits, exposed in the Madhupur area of the Bengal basin. Dhaka Univ. J. Sci., v.42, n.2, p.247-252.

Monsur, M.H. : A preliminary palaeomagnetic results of the Quaternary deposits exposed in the Barind area of the Bengal basin, Bangladesh. Bang. J. sci. Res.(in press)

Monsur, M.H. 1995 : Behavior of magnetic components of the sediments of the Madhupur area during the demagnetizatin tests. Bang. J. Sci. Res. 13(1):71-77.

Monsur, M.H., Paepe, R. and M.H. Rahman, 1993: Quaternary stratigraphy of the Chalanbil area of the Bengal basin. The Raj. Univ. Stud., part-B, vol.XXI, p.99-108.

Monsur, M.H., 1995 : Upper Pleistocene monsoon climatic fluctuations and the depositional history of the Bengal basin. J. Nepal Geol. Society. Special Issue,v.12, p.32.

Monsur, M.H. and M.M.M. Chowdhury : Late Quaternary climatic fluctuations and thedepositional history of the Bengal basin. J. Nepal Geol.Society (press).

Monsur, M.H., 1994: Some geological and economical aspects of the gravel deposits exposed in Dahagram-Panchagarh areas. Bengal Delta, Vol.1, No.1. p.8-9.

Monsur, 1993: Holocene sea-level changes along the Maiskhali Cox's Bazar-Teknaf coasts. BAAS 18th conference Issue, Sec.V, p.4.

Morgan, J.P. and W.G. McIntyre, 1959: Quaternary geology of Bengal basin, East Pakistan and India. Bull. Geol. Soc. Am. 70, 319-341.

Oedes, J.M., 1963 : The nature and distribution of iron compounds in soil. Soils and Fertilizers, v.XXVI, n.2.

Raju, A.T.R., 1968 : Geological evolution of Assam and Cambay Tertiary basins of India. Bull.Am. Assoc. Petrol. Geol., v.52, n.12, p.2422-2437

Retallack, G.J., 1981: Fossil soils: Indicator of ancient terrestrial environments, in Niklas, K.J., ed., Palaeobotany, palaeoecology and evolution. Vol.1, New York, Praeger Publishers, p.55-102.

Retallack, G.J., 1983: Palaeopedological approach to the interpretation of terrestrial sedimentary rocks: The mid-Tertiary fossil soils of Badlands National Park. South Dakota. Geol. Soc. Am. Bull. v.94, p.823-840.

Shaha, S.K., 1994 : Stratigraphical and lithoclast analyses of the gravel deposits exposed at Jaintiapur-Bholagonj areas of Surma basin. M.Sc Thesis,Geol.dept.,Dhaka Uni.