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Late Quaternary climatic fluctuations and the depositional history of the Bengal basin

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ABSTRACT

The peak of the last glaciation (18,000 years BP) was evidenced by dry climatic condition and a narrow palaeoriver system in the Bengal basin. At the end of the last glaciation (about 10,000 years BP), amplified monsoon water plus deglaciated melt water from the Himalayas enormously flowed through these palaeoriver systems. The rivers were overloaded and overflowed, deposited a series of gravel beds in north Bengal, and also caused the erosion of Madhupur, Barind and Chalanbil, leaving a north-south elongated landmass. Sea-level started rising, attained its maximum height at about 5,500 years BP. The lines drawn from Ganakghata to North Nalbila in the Maiskhali Island and also from Cox's Bazar to Teknaf (eastern extremities of salt marshes) represent such an elevated palaeobeach line. Holocene sea-level rise changed the hydrodynamic condition of river system and the deeply incised valleys were filled up with unconsolidated sediments. Holocene sea-level drop resulted the aerial exposition of the Hatia, Kutubdia, Sandip and other near shore islands of the Bay of Bengal.

INTRODUCTION

Holocene stratigraphy and sea-level changes along the coast of the Bay of Bengal (Monsur and Paepe, 1994a; Monsur and Kamal, 1994) reveal the climatic fluctuation during the Late Quaternary Period. Climatic fluctuation are directly related to the sea-level changes as well as related to the change in hydrodynamic condition of river system and sedimentary facies.

A series of gravel beds are widely exposed in northern part of the Bengal basin (Monsur, 1994). Detailed studies of these gravel beds were performed at Dahagram-Angarpota at Patgram, Vojanpur at Tetulia, Dalia, Chapani, Uttar and Dakshin Kharibari at Dimla Thana. In early literature's these gravels were considered as piedmont deposits (Chowdhury, 1990; Khan, 1991) as they were deposited very close to the Himalayan foot hills. These gravel beds contain large wood fragments or trees of different sizes and vegetational remnants. The depositional history of these deposits seems to be related with the Late Quaternary climatic fluctuations, specially with the monsoonic climatic changes (Monsur, 1994).

The Bengal plain is very close to the high tide level of the Bay of Bengal. Hence, a change in the Holocene sea-level directly related to the change in coastal plains. One or two meters of sea-level rise may affect the wide area of coastal region of the basin. To this effect, the eastern coast of the Bay of Bengal may reflect the signature of the Holocene sea-level changes as well as Holocene climatic variations. Wide salt marsh areas of the Maiskhali Island and Cox's Bazar-Teknaf coast probably bear the imprint of Holocene sea-level fluctuation (Fig. 1).

The main objective of this paper is to: i) establish a systematic late Quaternary stratigraphy of the gravel beds exposed in the northern part of the Bengal basin, ii) demarcate the Holocene raised coastline along the eastern coast of the Bay of Bengal, iii) subdivide the coastal region according to the coastal morphology and to iv) interpret the depositional history of the gravel beds and late Quaternary climatic changes. Hence, this paper aims to interpret the monsoon climatic fluctuation on putting forward two evidences: i) gravel deposits, seems to be result of strong climatic episodes, and ii) sea-level changes, caused the formation of a wide

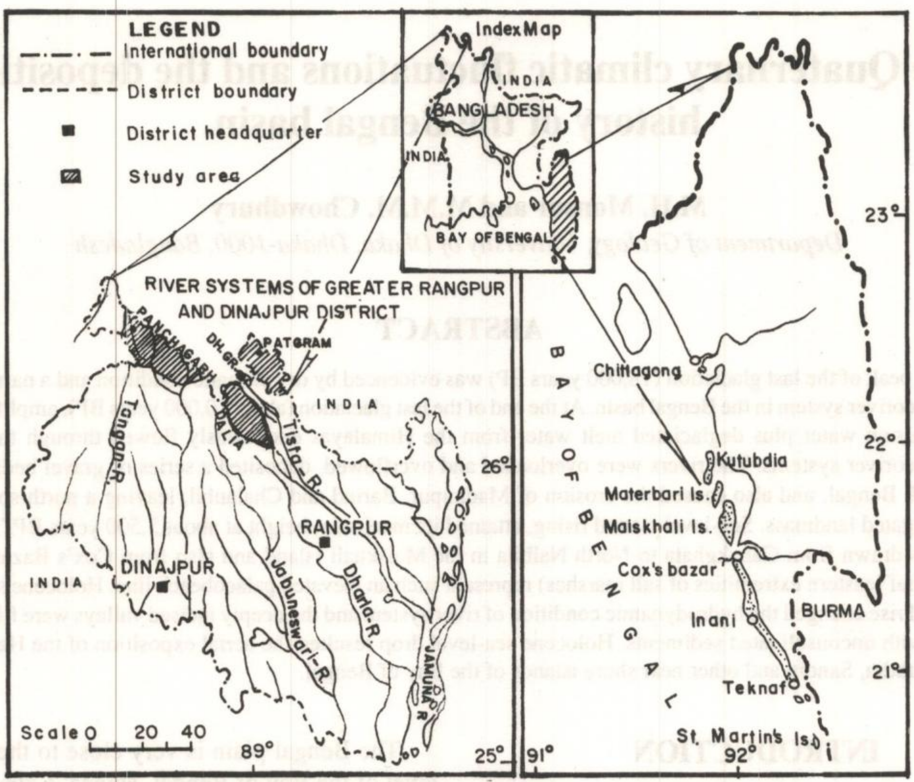


Fig. 1: Location map of the study area. On top: Key map. On left hand side: Dahagram-Panchgarh area. On the right hand side: Cox's Bazar-Teknaf area.

salt marsh areas and the deposition of a thick unconsolidated sediments in deep river valleys due to the change in hydrodynamic condition.

LITHOSTRATIGRAPHIC UNITS OF DAHAGRAM-PANCHAGARH AREA

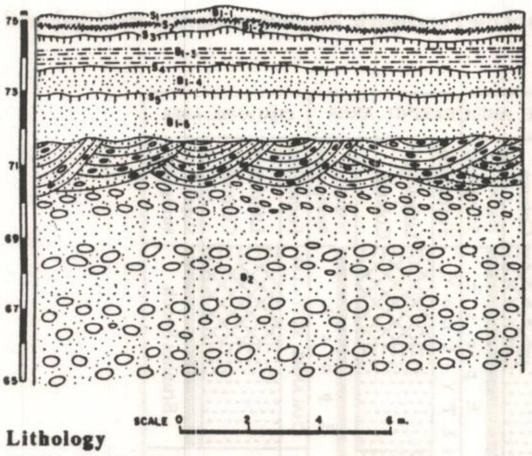
A wide area of the northern part of the Bengal basin is covered with a series of gravel beds. But no systematic stratigraphic work has been performed for this area. Detailed lithostratigraphic studies and laboratory analyses help to subdivide the exposed deposits into two broad units: i) the lower sandy-gravel beds and ii) the upper sandy-silt unit.

Lower sandy-gravel beds

This is oldest exposed sediment unit in the Panchagarh-Dahagram area. This unit as a whole appears to be light grey in colour and looks quite fresh in nature. In this unit, gravels of various sizes shapes, and compositions are found in a coarse to very coarse sandy matrix. The individual clast of gravel, has a size ranging between 2 mm up to 300 mm. They are represented by well rounded, elongated, spherical, tabular, discoidal shaped quartz, quartzite, granite, gneiss and schist. The sandy matrix are mostly composed of quartz and heavy minerals (9-12%). The sandy matrix of gravel beds have identical composition and contains sporadic pebbles of smaller sizes. The unit exhibits large scale cross-bedding at the top (Fig. 2). This unit is also called as the Panchagarh Gravel Beds.

Upper silty-sand unit

This member unconformably overlies the sandy-gravel beds and can be subdivided into the following 5 subunits based on the presence of palaeosol horizons (Fig 2).



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. 2: Stratigraphic section at the type locality Boalmari, Tetulia in Panchgarh district. Trough cross-bedding is quite prominent.

Subunit B1-5: This subunit is composed of fine grained yellowish grey sand with the thickness of about 1.5m and unconformably overlies the Panchagarh Gravel Beds. A soil horizon designated as S5 (organic carbon: 0.38%) is developed on top of this subunit.

Subunit B1-4: This subunit is represented by about 1 m thick coarse grained micaceous black sand. The soil horizon S4 (Organic carbon 0.58%) lies on top of this unit.

Subunit B1-3: This subunit is represented by yellowish coloured silt layer of about 1.5 m thickness.

Subunit B1-2: It represents a very thin grey layer of clayey silt with a soil horizon S2 (Organic carbon 1.45%).

Subunit B1-1: This is the modern soil unit, composed of alluvium sediments.

These above subunits are grouped together into a single lithostratigraphic unit of Holocene Series and can be named as the Boalmari Sand Formation. The Holocene Series exposed in the Madhupur, Barind and Chalanbil areas are called, respectively, as Basabo, Rohonpur and Chalanbil formations (Monsur and Paepe 1994, 1992; Monsur et al., 1993). The Basabo and Rohonpur Formations are subdivided into 5 subunits based on the presence of 4 palaeosol horizons (Table 1). It is to be mentioned that soil is a climatic indicator and it develops in an area of wide lateral extension. Hence soil represents a marker horizon. Therefore, it is most likely that each of the 4 soil horizons of Madhupur, Barind and Panchagarh areas represents the successive continuation of a single soil horizon. In this way, five subunits of each of the three geomorphic areas are correlated and the radiocarbon dating helped to correlate these subunits with the five substage of Holocene Series (Table 1).

LITHOCLAST ANALYSES AND THE RESULTS

Twenty clasts of each size fraction between 37.5 mm-15 mm and 15 mm-10 mm of five dominant rock types were selected for the measurement of sphericity and roundness indices. The roundness and sphericity values of 4 rock types (Quartz, Quartzite, Granite and Gneiss-Schists) of three localities; Panchagarh, Dahagram and Dalia are shown in Table 2. The average roundness of all rock types of size grades 37.5-15 mm is 0.57 and 15-10 mm is 0.48. The average sphericity value remains the same for the two grades of all rock types and it is 0.65.

Among the pebbles, the vein quartz is the less rounded ones having mean roundness of about 0.47 for the 37.5-15 mm clast in areas. The roundness decreases with size in the case of quartz pebbles. In the larger clasts (37.5-15 mm) most of them have the roundness between 0.4 to 0.6 while the smaller ones (15-10 mm) have the roundness between 0.3-0.6. Quartzite pebbles are more rounded than the quartz. The roundness of quartzite pebbles also decreases with the size.

Granite, gneiss and schist pebbles have higher roundness than the quartz and quartzite pebbles. However, no significant change in the roundness have been noticed with the size grades. Roundness increases with the distance they covered.

The sphericity values of the most of quartz, quartzite and granite pebbles lie between 0.6-0.8, regardless of sizes and locations. Gneiss and schist

Table 1: Correlation scheme of the lithostratigraphic subunits of the Panchgarh, Madhupur, Barind and Chalanbil areas of the Bengal basin with the Holocene Series.

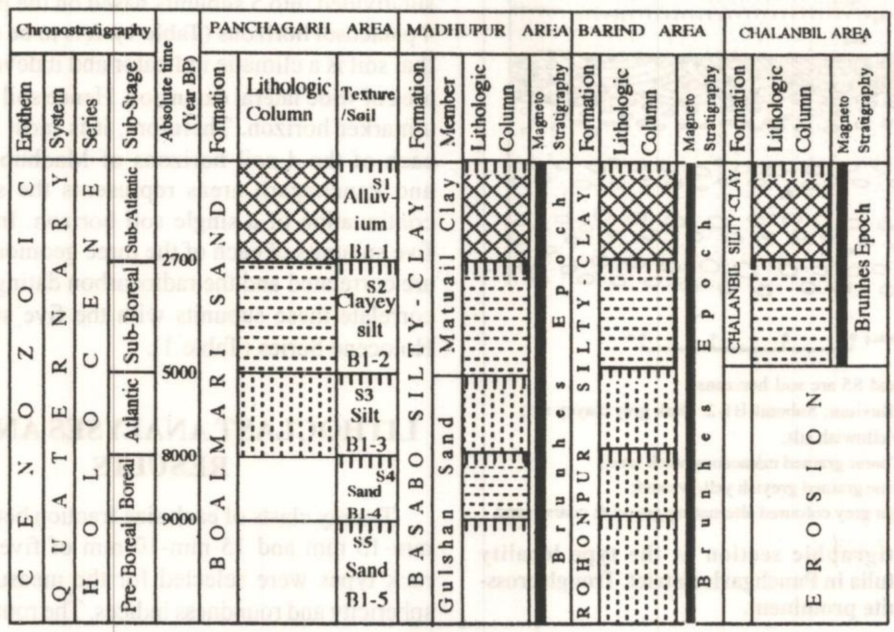


Table 2: Roundness and sphericity values of major clasts.

Rock types	Size of clasts 37.5-15 mm			Size of clasts 15-10 mm		
Location	Panchagarh	Dahagram	Dalia	Panchagarh	Dahagram	Dalia
	Average Roundness Values					
Quartz	0.46	0.47	0.46	0.39	0.42	0.31
Quartzite	0.52	0.61	0.63	0.41	0.45	0.48
Granite	0.55	0.63	0.64	0.50	0.53	0.62
Gneiss and Schist	0.56	0.63	0.64	0.47	0.60	0.63
	Average Sphericity Values					
Localities	Panchagarh	Dahagram	Dalia	Panchagarh	Dahagram	Dalia
Quartz	0.46	0.47	0.46	0.39	0.42	0.31
Quartzite	0.68	0.60	0.66	0.71	0.67	0.63
Granite	0.73	0.69	0.70	0.70	0.69	0.71
Gneiss and Schist	0.62	0.57	0.55	0.51	0.54	0.54

pebbles are comparatively less spherical. High roundness indicates high sinuousity fluvial channel. Now considering the small variations in the sphericity index among the pebbles of different areas of different clast sizes of a single rock type, it is clear that the sphericity of pebbles are largely controlled by the bedrock lithology of source area rather than the mode or agent of transport. This is because of the fact that the massive rocks like granite, quartzite, vein quartz and gneiss tend to yield fragments with high initial sphericity. The initial sphericity did not change a lot at the end of the transportation.

LATE QUATERNARY SEA-LEVEL CHANGES ALONG THE EASTERN COAST OF THE BAY OF BENGAL

The sea-level changes are directly related to the climatic fluctuation. The contribution of climate to the sea-level fluctuations more rationally supports the rapidly fluctuating sea-level hypothesis after Fairbridge (1962). Minor climatic fluctuation results a small scale marine transgression. The worldwide existence of supratidal flat is the result of high stand sea-level of 6000-5000 years BP (Fairbridge, 1962). The supratidal flat exposed at the Matamuhuri river valley and also in the western coast of the Maiskhali Island (western half of the Maiskhali Island, Fig. 3) resulted during the maximum high stand of Holocene sea-level.

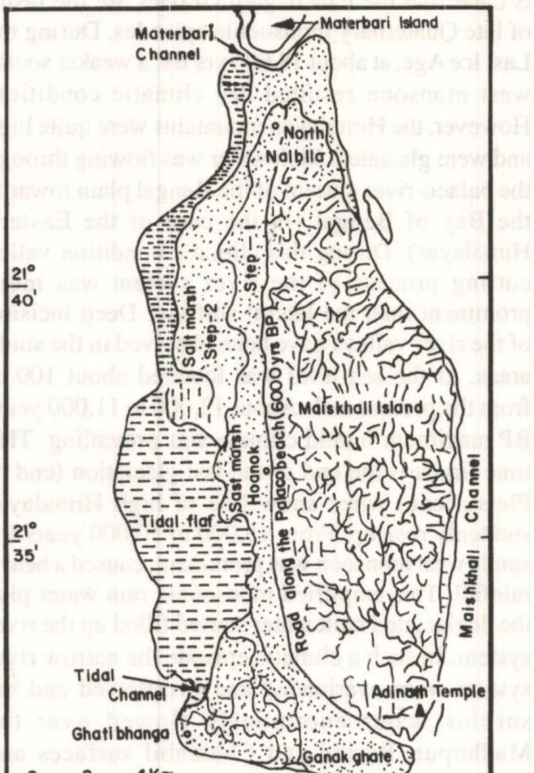


Fig. 3: Map of the Maiskhali Island showing the palaeobeach line of 6000 to 5500 years BP and the coastal morphology.

At about 18,000 years BP, shore line of the Bay of Bengal was some hundred kilometers southward from the present coast. Deep incised rivers were discharging their water very far towards the south around Swatch of No Ground in the Bay of Bengal. At the end of the last glaciation, eustatic sea-level started rising rapidly and the shoreline of the Bay of Bengal started shifting northward (Fig. 4). Holocene sea-level rise 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, Fig. 4). These hillocks were made up of the Bokabil and Tipam Formations. These were the soft rock sediments and were washed out quickly by waves. Hence, the marine transgression on the eastern coast of the Bay of Bengal was quite faster due to the sea-level rise along with the coastal erosion. It is why, the continental shelf of the Bay is so gently sloping (2°-8°). At about 5,500 years BP the waves were acting already at the feet of the cliffs from Cox's Bazar to Teknaf. During this high stand of Holocene sea-level (about 5,500 years BP), some of the areas behind the Cox's Bazar cliff were submerged under marine water. The existence of Holocene tidal flood deposits with interfingering peat layers are the proof of this statement.

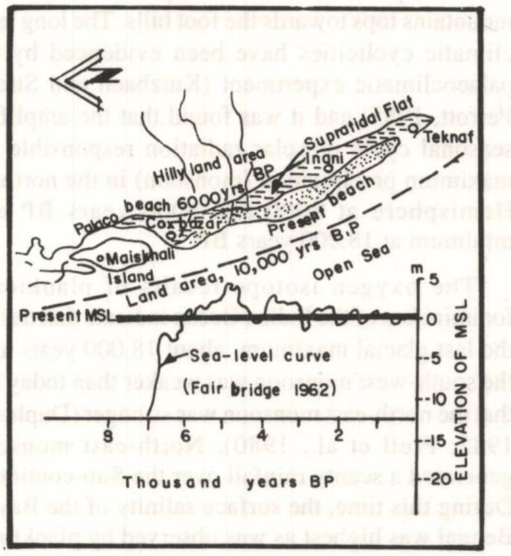


Fig. 4: Palaeocoast lines along the Cox's Bazar-Teknaf coast.

In Maiskhali Island, the cost line or the beach of 5,500 years BP was at the feet of the hillocks along the Nalbila-Ganakghata connecting road. The oceanic waves washed out the initial hilly surface of the Maiskhali Island. The beach sand exposed at along the Ganakghata-Nalbila connecting road is the proof of Holocene palaeo-beach of 5,500 years BP. The development of coquina bed and coral reefs on St. Martin's Island and also the occurrence of concretions (like the present day occurrence along the Inani beach) along with the palaeobeach sand near Teknaf High School are the evidences of Holocene high sea-level. Holocene raised sea-level resulted the formation of nearshore islands, such as, Hatia, Sandip, Kutubdia etc. Holocene sea-level drop after 6500 years BP resulted the aerial exposition of these islands (about 1-2m above the high tide level).

LATE QUATERNARY MONSOONIC CLIMATE AND DEPOSITIONAL HISTORY OF THE BENGAL BASIN

Climatic deterioration and the appearance of Ice sheet at the two poles and at the high mountain tops are the main characteristics of the Quaternary. During the Glacial Epochs the glacier advanced from the poles towards the equator or from the mountains tops towards the foot hills. The long term climatic cyclicities have been evidenced by the palaeoclimatic experiment (Kutzbach and Street-Perrott, 1985) and it was found that the amplified seasonal cycle of solar radiation responsible for maximum precipitation (monsoon) in the northern Hemisphere at 9000 and 6000 years BP and minimum at 18,000 years BP.

The oxygen isotope results of planktonic foraminifera of the Indian Ocean indicate that during the last glacial maximum, about 18,000 years ago, the south-west monsoon was weaker than today but that the north-east monsoon was stronger (Duplessy, 1982; Prell et al., 1980). North-east monsoon generated a scanty rainfall over the Sub-continent. During this time, the surface salinity of the Bay of Bengal was highest as was observed by planktonic foraminiferal assemblages. At the last glaciation, maximum lake levels in the northern tropics were low or falling (Kutzbach and Street-Perrott, 1985). This drying trend continued until 12,500 years BP, when water levels began to rise again. The monsoon climatic fluctuations and last glacial aridity in Rajasthan were also confirmed by radiocarbon dating, palynological and oxygen-isotope researches (Bryson and Swain, 1981, Singh et al., 1972; Van Campo, 1986). There were two important phases of the monsoon climate: i) a very arid period about 22,000-18,000 years BP and ii) a very humid period culminating at 11,000 years BP (Van Campo, 1986).

South-west monsoon was quite prominent at about 11,000 years BP and runoff of the Ganges-Brahmaputra river system was highest (Cullen, 1881). Consequently, surface salinity of the Bay of Bengal was lowest as was indicated by the oxygen isotope results (Duplessy, 1982).

From the highlights of the above discussions, it is clear that the Panchagarh Gravles are the result of late Quaternary monsoonic episodes. During the Last Ice Age, at about 18,000 yrs BP, a weaker south-west monsoon resulted dry climatic condition. However, the Himalayan mountains were quite high and were glaciated. Melt water was flowing through the palaeo-river system of the Bengal plain towards the Bay of Bengal (in the case of the Eastern Himalayas). During this climatic condition valley cutting process of the river system was more prominent than the lateral shifting. Deep incision of the river valleys have been observed in the study areas, as the sea-level was lowered about 100 m from the present msl. About 12,000 to 11,000 years BP maximum humid climate was prevailing. This time limits is the end of the last glaciation (end of Pleistocene) when snow line of high Himalayas suddenly rose up. From 15,000 to 10,000 years BP south-west monsoon was prominent, caused a heavy rainfall. This amplified monsoonic rain water plus the deglaciated melt water started filled up the river system. In such a climatic episode the narrow river system were overloaded and overflowed and the surplus water enormously flowed over the Madhupur, Barind and Chalanbil surfaces and discharged into the Bay of Bengal towards the south (Fig. 5). This water generated a tremendous current, initiating strong hydrodynamic condition due to which the till and other glacier borne deposits, lying over the pre-existing ice front, were carried out up to the Panchagarh-Dahagram areas of the Bengal basin. Sometimes, these gravels were carried as far as Sirajgonj.

Therefore, the Panchagarh Gravel Beds represent the melt water deposits of high roundness and sphericity values. The glacier borne till deposits of the last Glaciation in the Himalayan mountain region enhanced the normal influx of sediments of the palaeo-river system. The Madhupur, Barind and

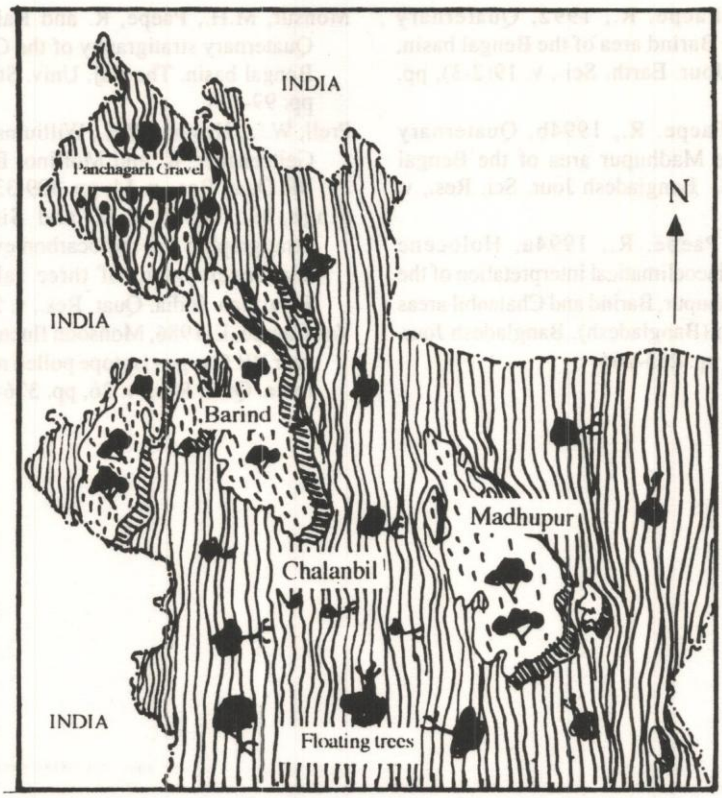


Fig. 5: Map showing the Late Quaternary climate episode, erosion of Barind, Madhupur and Chalanbil surfaces.

Chalanbil surfaces were highly dissected an created some local pools and depressions and also left a number of north-south elongated reddish-brown islands or terraces. The north-south elongation of the Barind-Madhupur terraces indicates the north-south directional water flow which supports this statement (Fig. 5). If the thick Holocene deposits were removed from the Late Pleistocene surfaces, the dissected topography and the buried river valleys of the Madhupur and Barind tracts would have been flashed out at a glance.

REFERENCES

Bryson, R.A. and Swain, A.M., 1981, Holocene variation of monsoon rainfall in Rajasthan. Quaternary Research, v. 16, pp. 135-145.

Chowdhury, M.M.M., 1990, Stratigraphy and clast lithological analysis of the gravel beds exposed at Panchagarh-Dahagram-Dalia area of the Bengal basin. M.Sc. thesis, submitted to Geol. Dept. Dhaka Univ., 134 p.

Cullen, J.L., 1881, Microfossil evidence for changing salinity patterns in the Bay of Bengal over the 20,000 years. Palaeogeogr. Palaeocli. Palaeoeco., v. 35, pp. 315-356.

Duplessy, J.C., 1982, Glacial to interglacial contrasts in the northern Indian Ocean. Nature, v. 195, pp. 494-498.

Fairbridge, R.W., 1962, World sea-level and climatic changes. Quaternaria, v. VI, pp. 111-134.

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

Kutzbach, J.E. and Street-Perrott, F.A., 1985, Milankovitch forcing of fluctuations in the level of tropical lakes from 18 to 0 kyr BP. Nature, v. 317, pp. 130-134.

Monsur, M.H., 1994, Some geological and economical aspects of the gravel deposits exposed in Dahagram-Panchagarh areas. Bengal Delta, v. 1(1), pp. 8-9.

Monsur, M.H. and Kamal, A.S.M.M., 1994, Holocene sea-level changes along the Maiskhali and Cox's Bazar-Teknaf coast of the Bay of Bengal. The Jour. Noami, v. 11(1), pp. 15-21.

Monsur, M.H. and Paepe, R., 1992, Quaternary stratigraphy of the Barind area of the Bengal basin, Bangladesh. Ind. Jour. Earth. Sci., v. 19(2-3), pp. 79-84.

Monsur, M.H. and Paepe, R., 1994b, Quaternary stratigraphy of the Madhupur area of the Bengal Basin, Bangladesh. Bangladesh Jour. Sci. Res., v. 12(1), pp. 41-47.

Monsur, M.H. and Paepe, R., 1994a, Holocene stratigraphy and palaeoclimatical interpretation of the deposits of the Madhupur, Barind and Chalanbil areas of the Bengal basin (Bangladesh). Bangladesh Jour. Sci. Res., v. 12(2), pp. 255-264.

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

Prell, W.L., Huston, W.H., Williums, D.F., Allan, W.H., Geitzenauer, K. and Molfino, B., 1980, 18,000 yr. BP. Quat. Res., v. 14, pp. 309-336.

Singh, G., Joshi, R.D. and Singh, A.B., 1972, Stratigraphic and radiocarbon evidences for the age and development of three salt lake deposits in Rajasthan. India. Quat. Res., v. 2, pp. 496-505.

Van Campo, E, 1986, Monsoon fluctuation in two 20,000 year BP. Oxygen isotope pollen records of Southwest India. Quat. Res., v. 26, pp. 376-388.