CHAPTER - II

GANGES DELTA : THE AREA OF STUDY

2.1 GANGES DELTA : GENERAL CONSIDERATIONS

The Ganges delta is the world's largest delta and it occupies the lower part of the Bengal Basin. This delta is located at the northern apex of the Bay of Bengal and its area is confined within the Bhagirathi-Hoogli river in the west and the Padma-Meghna estuary in the east. The northern boundary of the delta is delimited by the main channel of the Ganges[1] or the Padma (Podda) itself.

The Delta of the Ganges covers a total area of 60,500 sq.km in Bangladesh and West Bangal (India). Actually, the delta has come into existence by three mighty rivers of the region, the Ganges, the Brahmaputra and the Meghna. This huge tract of alluvial land has been developed at the southern portion of the Bengal Basin by the combined depositional activities of the Ganges, its various distributaries and the other large and small streams of the region. It should be mentioned that the Ganges delta is also designated as the 'Ganges-Brahmaputra Delta' (Miah,1975) or the 'Ganges-Brahmaputra-Meghna Delta' (Pramanik, 1983). But as the role of the Ganges in the formation of the delta is dominant and for the fact that the Brahmaputra and Meghna have become two tributaries to the Ganges in the region -- their claims to the associated with the disignation of

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[1]The Ganges is called 'Ganga' in India and 'Padma' in Bangladesh. The river is also known as 'Podda' among the native people of Bangladesh. In its lower courses the Ganges (Padma) is merged with the Meghna and flows as the Meghna to the Bay of Bengal.

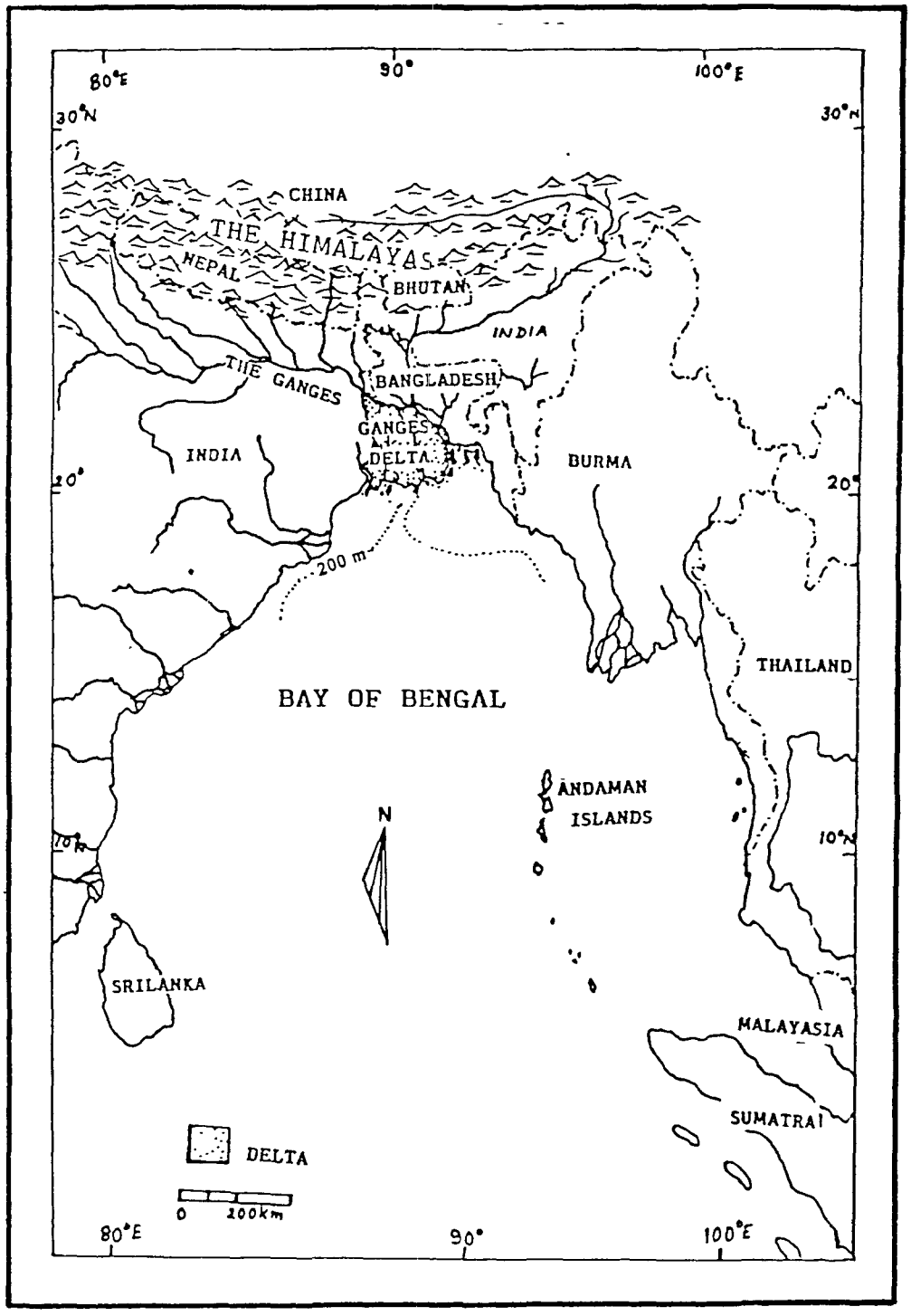
The delta have become insignificant. Considering this aspect Bagchi (1944) and Rob (1989-a) have attributed the delta to the Ganges only.

The deltaic characters and features are restricted to the tract of the basin (i.e., Bengal Basin) south of the Ganges-Padma between Bhagirathi-Hoogli on the west and the Padma-Meghna on the east. This delta is a tract of vast alluvial flat roughly resambling the Greek letter "Δ" (delta) and commences at the off-take of the Bhagirathi near Gaur of Murshidabad district in West Bengal (India).

With regard to its geographical location, the apex of the Ganges delta is at latitude of 24°40' N and 88°0' E longitude and the extremity stretches as far down as 21°30' N latitude. The longitudinal extension of the base of the delta is from 88° E to 91°50' E longitude (Fig. 2.1).

The delta stretches over a vast area in the south-western part of Bangladesh and the southern part of West Bengal of India and is formed in the northern part of the Bay of Bengal where the Ganges the Brahmaputra and the Meghna — three mighty rivers plunge into the sea. The shape of this alluvial tract is triangular and the western limit of the delta stretches along an almost uneven north-south line while the eastern limit has entered deep into the south-eastern Bangladesh giving the delta's eastern limit a north to south-easterly boundary. The northern apex of the delta is narrower and widens gradually

Fig. 2.1 : Geographical Location of the Ganges Delta



Source : Rob, M.A., (1989), Fluvial Morphology of the Gangetic Delta (Un-pub. M.Phil. Thesis), A.M.U., Aligarh, India.

towards the south following a rather south-easterly direction. The shape of the southern part of the delta is arcuate and this line is extended from west to east touching approximately the same parallel of latitude. But this southern extremity of the coastal part of the Ganges delta forms a long stretch of broken and estuarine tract criss-crossed by numerous distributaries of the Ganges. The apex of the delta is locted at the off-take of the Bhagirathi, some 480 km from the Bay of Bengal where the gradient of the Ganges is 9.0 cm in 1.0 km and the delta lies between the Bhagirathi-Hoogli on the west and the Padma-Meghna on the east.

The Ganges delta is not a single delta and not all parts of the tract known as the Ganges delta have formed by the commonly assumed process of riverine alluviation at or near the base level of erosion. Both physiographic and tectonic evidences indicate that a substantial part of it had formed by recession of the sea concomitent with upliftment of the basement complex of Bengal Basin during the Pleistocene period (Sengupta, 1966). The major delta unit of the Ganges alongwith a number of similar deltaic smaller units formed by the numerous rivers falling into the Ganges distributary system have togather formed the complex system of the Ganges delta (Basu and Chakraborty, 1970-a).

During the last few centuries the Ganges and its distributaries have been playing vital role in the formation and evolution of the delta. Besides, the role of the Bay of Bengal in

the formation and the evolution of the delta can not be ignored. The southern part of the delta is influenced by maritime environment and is characterized by low wave energy, high tidal range normally low littoral drift and a narrow basin resulting in the formation of finger-like depositional features passing off-shore areas into alongated tidal current ridges of the Bay of Bengal (Pramanik, 1983). Coastal and marine processes are very active in the delta and high tides in the Bay of Bengal have given rise to an extensive tidal plain of predominately fine grained sediments and this is why Galloway (1975) and Reading (1980) have classified it as the 'tide dominated delta'.

The shifting courses of the rivers of the Ganges delta exhibit another typical characteristic of the delta rivers. The delta was built west to east from east of the point where the Ganges enters the Bengal Basin (viz., east of the Rajmahal Hills). The successive deltaic deposits lie parallel to the main distributaries of the Ganges (Coleman, 1969). This may be assumed that the delta grew by forming successive overlapping lobes. According to Bagchi (1944) and Chowdhury (1964) the main channel of the Ganges shifting towards east changing its former channels, the Bhagirathi-Hoogli and the Bhairab, and presently the main channel of the Ganges is flowing diagonally towards south-east through the Padma of Bangladesh and meets the Meghna River at the eastern part of the delta and finally debouches onto the Bay of Bengal as a huge estuarine channel

Fig. 2.2 : Satellite Imagery of the Ganges Delta

Source : LANDSAT, MSS Band-7 (1977-'78).

after the name of the Meghna.

The Ganges delta comprises a vast fertile and populous landmass of West Bengal (India) and Bangladesh (Fig. 2.2). More than 60 million people inhabit this deltaic tract and agriculture is the mainstay of the majority of the population. Large cities and towns like Calcutta, Khulna, Barisal, Jessore, Faridpur, Nadia etc. have flourished here. The delta-rivers act as sources of irrigation and water supply for the agricultural practices in the area. Besides, the active channels of the deltaic region also serve as major communication linkages. The Sundarbans, one of the world's largest mangrove forests is situated in the southern coastal part of the delta. The forest bears immense economic as well as ecological significance in the region.

The fluvio-maritime geomorphic processes are active in the delta and erosional and depositional processes of both fluvial and marine origions have been functioning in the region. The major rivers like the Ganges, Brahmaputra and Meghna drain a huge volume of water to the Bay of Bengal over this deltaic tract (Table 7.3). The total catchment area of these river systems is about 1.55 million sq.km (Fig. 4.1). The rivers are tidal near the sea with a maximum tidal range of 6.7 m (BWDB, 1985). The discharge of water during flood exceeds 1.7 million m^3/sec and carry about 2.4 billion tons of sediments annually (Coleman, 1968 and Miah, 1975). The delta rivers carry about

1500 m.a.f. (i.e., million acre feet) of run-off water to the Bay of Bengal every year of which only less than 100 m.a.f. of run-off water is generated by rainfall within the deltaic region (BWDB, 1985).

The northern portion of the delta is facing an acute drainage failure while the southern part experiences increasing soil salinity. In the estuarine eastern part of the delta, a huge accretion is taking place. Besides, the main channels of the delta are decaying gradually (Rob, 1989-a and Bagchi, 1944). Moreover, the average elevation of most of the parts of the delta is very low. The gradual deterioration of the ecological balance in the region and rapid depletion of the ozone-layer in the atmosphere of the earth have threatened the deltaic coast of the Ganges with a future size in the sea-level which might engulf most of the deltaic areas by turn of the century (Brammer, 1989). These requires an elaborate morphological study of the Ganges delta.

2.2 DELIMITATION OF THE GANGES DELTA :

There exists a controversy regarding the exact boundary or delimitation of the Ganges delta. However there is a general agreement among the geographers and geologists that the delta-area lies within the lower part of the Bengal Basin and it extends upto the Bay of Bengal. But dissension arises out of the exact inland limits of it. The extent of the delta has been defined and estimated in varied ways by different scholars and

authors. Owing to the lack of proper appreciation of morphological, structural and hydrological characteristic of the deltaic regions there are different views with regard to the extent of the Ganges delta (Fig. 2.3).

Charles Lyell (1889) first tried to delimit the Ganges delta. He called it the 'Ganges and Brahmaputra delta'. He considered that the Ganges delta had two heads and the delta was the product of the two rivers -- the Ganges and Brahmaputra. According to Lyell, the limits of the delta cover the areas north of the Padma, the Ganges-Brahmaputra Doab, the Meghna-Brahmaputra valley and the Pliestocene terraces of the Bengal Basin. Lyell's inclusion of the North-Bengal, the Eastern Bengal and the flood plains of the Brahmaputra and the meghna rivers within the deltaic territory has no scientific justification. His inclusion of the Pliestocene old-alluviam terraces is not based on any explanation.

Mukerjee (1938), in his book 'Changing Face of Bengal' has quite arbitrarily included the whole part of eastern Bengal lying in the east of the Jamuna (Brahmaputra), whereas without assigning any valid reason he has excluded the districts of Barisal and Faridpur[1] from his delimitation of the delta. Moreover, he has divide the delta into 'the Old delta' and 'the

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[1]The name of the districts of the deltaic region referred in this thesis necessarily indicates the former or greater districts of the deltaic Bengal region.

New delta' which also does not bear any scientific basis.

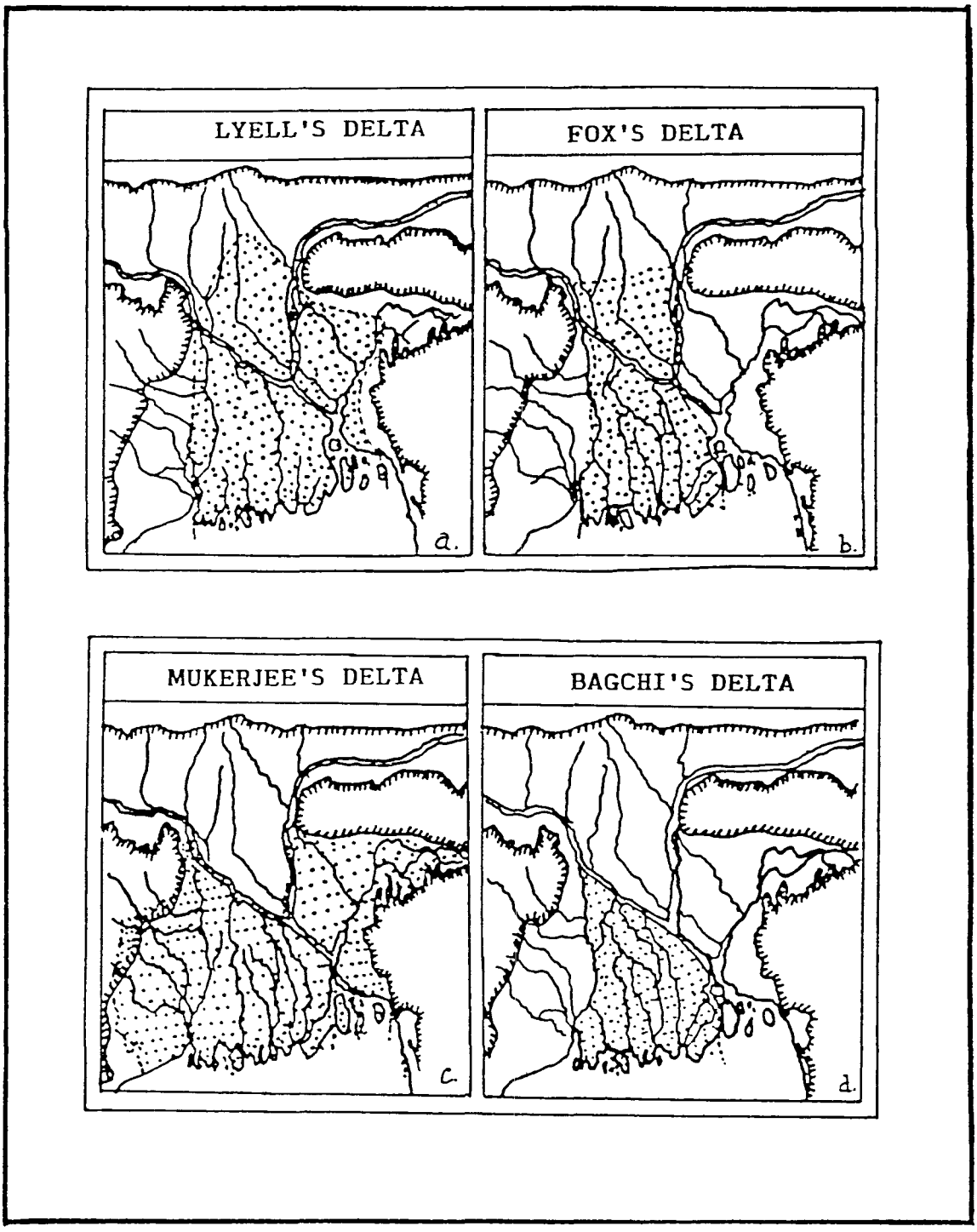
Although Fox (1942) has justifiably considered the eastern and the western limits of the delta -- he failed to delimit the correct northern extent of the delta and erroneously included the areas from the Rajmahal to the sought of the Shillong Plateau as part of the delta.

Chatterjee has excluded the most active part of the Ganges delta including Faridpur and Barisal districts of Bangladesh from the limits of the delta (quated in Bagchi, 1944). His delimitation lacks scientific validity.

Despite the fact that Strickland (1940) did not incorporate the northern alluvial cones and Pliestocene terraces within his demarcation line he has incorrectly included parts of the flood plains of the Ganges, Brahmaputra and Meghna within his delta boundary.

According to Bagchi (1944), "the area between the Bhagirathi and the Meghna (i.e., the combined waters of the Ganges and the Meghna) is the only region bounded by the distributaries of a river, where physiographic and hydrographic characters constituting a delta are distinctly observed". Bagchi therefore seperates the non-deltaic areas from the deltaic ones on the basis of structure, hydrography, origin and landforms. His scheme of delimiting the Ganges delta covers a triangular tract of land with its apex at Gaur and its base, the Bay of Bengal.

Fig. 2.3 : Delimitation of the Ganges Delta by Lyell, Fox, Mukerjee and Bagchi



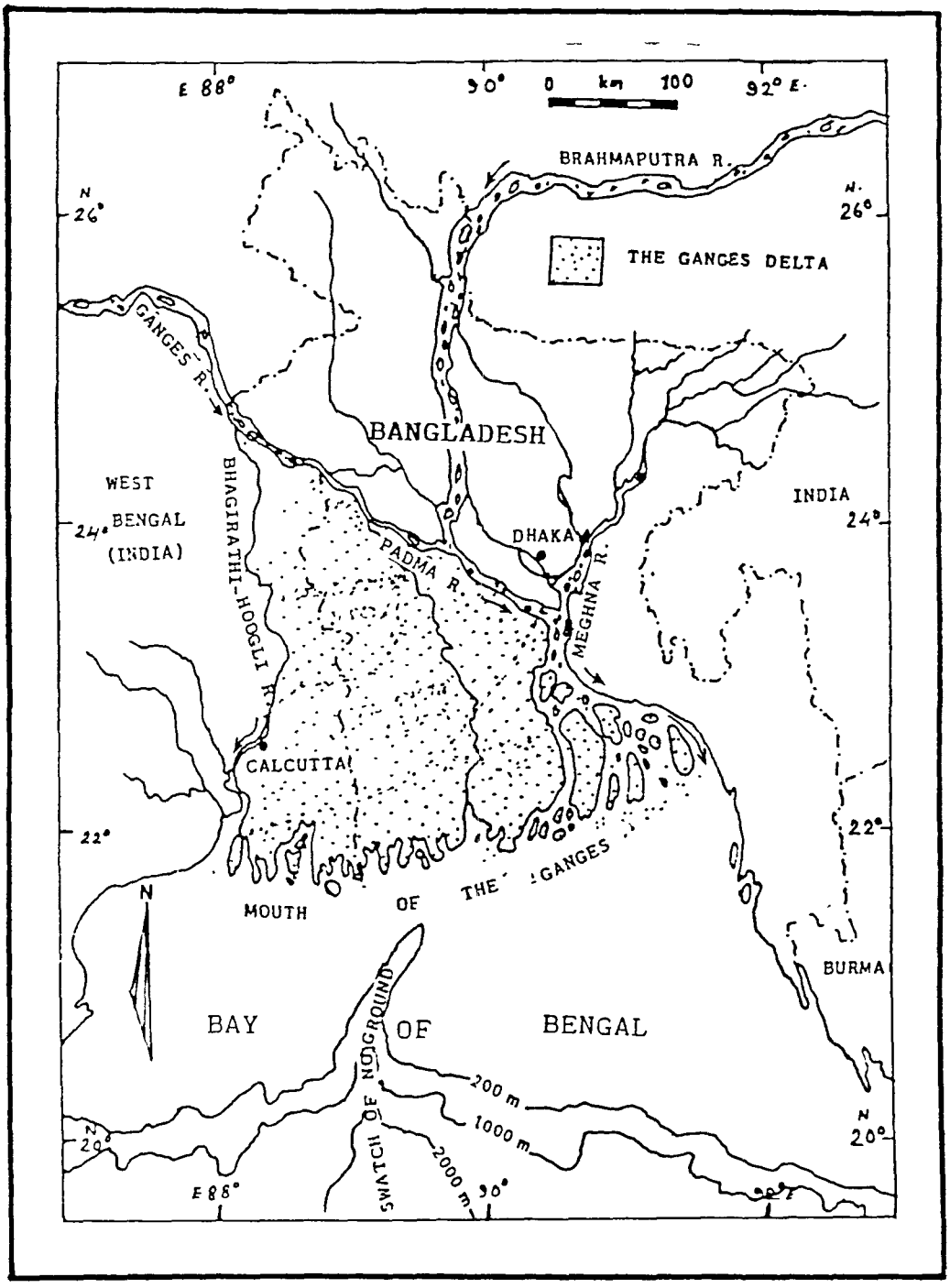
Source : Rizvi, A.I.H., (1964), "The Limit of the Ganges Delta", Dhaka University Studies, Dhaka.

Bagchi (1944) does not incorporate the off-shore deltaic islands of the Meghna mouth within his area of the delta and this omission seems to be a major flaw in Bagchi's delimitation of the delta. Excepting this omission his demarcation carries scientific velidity and is generally acceptable (Fig. 2.3-d).

Considering the slope, physiography and hydrographic characteristics of the Boral, Dhaleswari and Buri-Ganga rivers of Bangladesh, Rizvi (1964) has incorporated a narrow tract of land lying close to the north of the main channel of the Ganges (Padma) within the boundary of the delta. Rizvi has attributed these streams at the left hand distributaries of the Ganges and Brahmaputra respectively. Rizvi has further assumed that these channels are the former courses of the Ganges, but as these channels scarcely carry the Ganges discharge today, and that there exists doubt about the contribution of these rivers in the formation of the deltaic land, their inclusion by Rizvi in his delimitation of the delta creates confusion.

Considering the existing physico-hydrological characteristics of the rivers and the land area of the lower Bengal Basin the true scientific demarcation of the delta can be drawn by delimiting the Bhagirathi-Hoogli distributary channel as the western limit, the main Ganges-Padma-Meghna channel as the northern and eastern limits and the Bay of Bengal as the southern boundary of the delta. In this scheme of demarcation of the Ganges delta Rizvi's 'northern tract' would be outside the

Fig.2.4: The Actual Limits of the Ganges Delta



Source : The Author's Delineation of the Ganges Delta.

delta boundary and Bagchi's omission of the Meghna-mouth off-shore islands would be rectified by inclusion of these within the delta territory (Fig 2.4).

2.3 REVIEW OF LITERTURE :

There are not many studies in the realm of fluvial morphology of the Gangetic delta. Although the Ganges and its huge delta had been drawing attention of many travellers, scholars and researchers from early times, and a number of articles and books are being published on the field in the recent years, yet most of the contributions remain confined mainly to the descriptive accounts of the area along with some superficially done spatio-temporal studies of the rivers and streams of the delta. In some legends and travel accounts of the ancient periods only the geographical location of the Ganges delta and course of the river were mentioned. However, most studies done in the modern period on the Ganges delta incorporate a score of aspects ranging from the description of the geological and physiographic settings of the region to the changes in the courses of the delta-rivers and from the study of demographic characteristics of the area to the agro-economic activities of the people of the region. Geologists, geographers, engineers, historians and economists have contributed substantially in these studies. In the very recent years a few researchers including geographers have been showing interest in the hydrological and

morphological studies of the delta. But unfortunately their interest obviously lacks a complete fluvio-morphic approach of study.

In the Ramayana, secred book of the Hindus, we witness the most ancient mentioning about the lower courses of the Ganges. In this lesendary work we find that in the period of Valmiki, the author of Ramayana, the Bhagirathis was a flourishing channel carrying the major discharge of the Ganges past Rajmahal (Rob, 1989-b). This book was written approximately in 2,000 B.C. Among the other ancient references next comes the mentioning of Megasthenes of Greece. In 300 B.C. Megasthenes confirmed the appearance of the Padma channel along with the island of the sandwip of the Bay of Bengal (Kalota, 1978). In A.D. 150, Ptolemy recorded the flow through the 'Kambysion' mouth near sagar Island as the principal channel of the Ganges (Chowdhury, 1982-a). This statement of Ptolemy however differs from that of Megasthenes who stated that the main channel of the Ganges was the present eastern branch and in those days this branch would marke the boundary of the delta of the Ganges (Chowdhury, 1982-b). Besides these ancient citations there can be seen some description of the geographical features of the Ganges and its delta in the writings of the mediaeval period's Muslim scholars of Arabia or central Asia countries.

Among the various studies of the early modern period on the drainage network and other physical features of the Ganges delta the contributions of Major Rennell still remain as

pioneering initiatives to the study of the area. After the conquest of Bengal by the East-India Company, Rennell was entrusted with the task of surveying the rivers and the land. He performed his task successfully. Even today his work is often refered to for comparison of the data with those of the modern ones. As outcome of his elaborate survey work Rennell's famous 'Atlas of Bengal' was published in 1780 (Rennel, 1914). In this atlas the Ganges delta is mapped elaborately. The general surface features of the delta as well of the basin are depicted for the mid-eighteenth century in the map. In the 'Notes on the Physical Geography of Bengal' -- a commentary on Rennell's Atlas done by Lt. Col. F.C. Mirst (1925) -- elaborate discussion on the rivers, flood-plains, highlands and the lowlying areas of these days can be seen (Chowdhury, 1982-c). Besides, Rennell himself has published one valuable article on the Ganges and the Brahmaputra Rivers which revealed some important morphological aspects of the delta region (Rennel, 1781).

The first precise article on the Ganges delta was written by Baird Smith in 1859 (Smith, 1859). It was an attempt of mere describing the delta area from the geographical point of view. However, the attempt bore very little qualitative accounts of the delta rivers, viz., their distribution, courses, etc. The next and the most indepth study on the Ganges delta of the mid-nineteenth century was made by James Fergusson (1863). Although his paper is mainly a qualitative appraisal of the delta, yet it encompasses a vast scope under four broad heads,

viz., i) general considerations, ii) physical changes in the valley of the Ganges, iii) historical evidence of changes in the delta of the Ganges, and iv) increase of the delta seaward. In this lengthy study the author has highlighted on some critical points which, in the light of the modern knowledge of Science, could not have escaped controversy and criticism. These points include proposition on oscillation of rivers, processes and causes of elevation of deltas, siltingup of the Sylhet-Jheels, gap in the eastern seaward face of the delta, retrocesson of junctions of tributary streams with main rivers. Moreover, the author has added some informative accounts on silt contents in the Ganges waters and the 'Swatch of No Ground' of the Bay of Bengal. Besides, his article incorporates some nice maps, diagrams and tables.

Precise appraisal of the deltaic processes leading to the development of the spill channels and shifts in the river courses, find mention in a paper by Thomas Oldham in the proceedings of the Asiatic Society of Bengal in 1872 (Oldham, quoted by Begchi, 1972).

The following contributions on the various aspects of the Ganges delta comprise a series of studies made by different scholars and researchers in the first half of the twentieth century. Most of these studies have examined the geological, hydrological and morphological aspects of the delta and its surrounding areas. However, all these attempts were rather

qualitative as well as descriptive in nature. The studies were done by the following scholar and researches :

Major R.H. Colebrook (1901),

E. Vredenburg (1908),

F.D. Ascoli (1910),

C. Adams Williams (1918),

H.G. Reaks (1919), E.H. Pascoe (1919), W.H. Thompson (1919),

W. Willcocks (1920),

R.K. Mukherjee (1938),

C. Strickland (1940),

S.C. Majumdar (1942),

K. Bagchi (1944).

In the beginning of the 20th century Major R.H. Colebrook (1901) published a pioneering paper on the courses of the Ganges through Bengal (Colebrook, 1901). In the article the author has simply described the courses and the surroundings of the different distributaries as well of the main channels of the Ganges from a geographical point of view.

The next important study on the geology of the Ganges delta was done by E. Vredenburg (1908), an eminent geologist of the early 20th century. He presented the paper in a scholarly lecture delivered in the 'Hemchandra Memorial Series of Lectures' organized by the Calcutta University (Vredenberg, 1908). The paper presented by Vredenburg was based on the author's

extensive studies on the geological and tectonic aspects of the Ganges and its other distributaries along with their resultant delta. In 1918, another important study on the rivers of the delta of the Ganges was performed by C. Adams William, the then Chief Engineer of the Department of Irrigation of the Government of Bengal (William, 1919). William studied the changes in the rivers and their courses in a historical perspective. His study has investigated the history of the deltaic rivers from 1750 to 1918 A.D. In the course of his study william found a trend of substantial changes in the courses of the major channels of the delta rivers. This study revealed a significant eastward shifting tendency of the main channel of the Ganges while the previous courses had been showing noticeable aggradational developments.

Besides the contribution of Vredenburg another paper dealing with the geological aspects of the delta region of the Ganges was published jointly by Pascoe and Hayden in 1919 (Pascoe and Hayden, 1919). This work was also based mainly on secondary sources of study and obviously maintained a typical qualitative tradition of those days.

Ascoli's paper (1910) entitled 'The Rivers of the Delta' deals primarily with the hydromorphic aspects of the various streams of the Ganges delta (Ascolie, 1910). In the paper Ascoli has focussed on the erosional and depositional processes of the delta rivers. He has tried to concentrate the discussion on the shifting nature of the channels of the area.

This paper, too, lacks much scientific interpretation of the processes and products of these rivers.

H.G. Reaks (1919) contributed significantly to the knowledge of the delta by publishing a report on the physical and hydrological characteristics of the rivers of the Ganges delta (Reaks, 1919). In this report he brought out the results of some scientific obsrvations. viz., the discharges of the various delta rivers, sediment characteristics and level of water in the major channels of the Ganges delta. Moreover, he tried to correlated all these variables with the physico-climatological condition of the delta region.

In the next year Sir William Willcocks (1920) was invited to deliver his Readership Lectures by the University of Calcutta, since published by the same University, on 'Ancient System of Irrigation in Bengal' in which the speaker elucidated the significance of river alignments in the delta and elaborated on the indigenous character of the overflow system of irrigation (Willcocks, 1920). In course of his survey Sir, William was convinced of the artificial nature of most of the waterways of Bengal which are now called deadrivers because of their decaying conditions. Besides, he maintained that these streams has been laid down in position according to a plan and designed to carry floodwater of the Ganges and that they could be restored to their former position at reasonable cost and effort. He also warned against improper use of these channels leading overflow irrigation

in future. This study of Willcocks on the delta rivers however can rightly be attributed as one of the milestones on the studies of the Ganges delta.

Another noteworthy study towards morphological approach on the Ganges delta was done by C. Strickland (1940). While discussing the various aspects of the formation of deltas, Strickland made special mention on the hydrographic processes of the Ganges and the Brahmaputra of the eastern part of Bengal. Eventually by focussed on the deltaic formation of the southern part of the river basins and highlighted on the role of these two mighty streams in delta-formation. This study also obviously failed to incorporate some important processes and products of the fluvial orgin within the scope of the study.

'The Changing face of Bengal', a treatise on the hydrological changes of the deltaic rivers of Bengal written by Mukherjee (1938) outlines the role of communication and transportation in the economic activities of Bengal. This was followed four years later, by an analysis of hydrological problems from the pen of Majumdar (1942), a leading engineer and hydrologist of Bengal. Majumdar studied the decaying nature of the delta rivers while dealing with the changing nature of trade and commerce in Bengal. In his book, 'the Rivers of Bengal Delta', the author has mantioned the human interference as the reason for the decaying tendency of the delta rivers. In the same work Majumdar has tried to cast some light on the river

dynamics with a view to prevent disastrous floods and choking of river channels through alluviation. Moreover, the author has scientifically studied the various stages of formations within the deltaic region. This work also followed the typical descriptive approach and failed to follow a sound scientific method of investigation and study.

Soon, afterwards, a geographical treatise was published on Ganges delta written by Bagchi (1944) in which the deltaic processes and their demographic consiquences were elaborated. Great stress has been laid in the work of Bagchi on the dynamics of the Ganges delta and its influence on the nature of the distribution of population in it for a period of fifty years in the first half of the present century. In course of treatment it was found necessary by the author to define the extent of the deltaic region in Bengal and a name that would be appropriate for it. According to the author the extent of this deltaic tract is confined within the two farthest distributaries of the Ganges, i.g., the Bhagirathi in the west and the Padma-Meghna channel in the east (Bagchi, 1944-d). The name that has been proposed by author is 'the Ganges delta' (Bagchi, 1944-e). In the course of his studies the author has classified the delta region into three sections, viz., moribund, mature and active parts of the delta. Moreover, he tried to elaborate the different stages in which the delta came into existence and the associate hydrographic characters, in its different portions. However, the

central object in studying the hydrography of the Ganges delta was to bringout in details the nature of the distribution of population in different parts of the deltaic region and how far it is influenced by geographical conditions.

In addition to these studies some other general yet significant reports on the physical aspects of the Ganges delta were published in the form of books, articles and survey reports. Among these 'The Satistical account of Bengal' by Hunter (1875) bears some valuable data and information of the Ganges delta. This report also incorporates an excellent map of Bengal which depicts a clear hydrological scene of the delta region.

Another survey report of this category can be found in a geological text written by Pascoe (1965) in which he has attributed the delta as 'the Ganges Brahmaputra Delta'. Pascoe has included it among the Khadar' or floodplain deposits of the Ganges basin (Pascoe, 1965-a). Highlighting on the shifting nature of the delta-channels, he has stated that the present delta area comprised a large area in which the ground has been raised above the general flood level by the main branches of the Ganges which in the part traversed it. He observed that the eastern part of the delta was more backward, the marshes or 'Jheels' were more extensive, and the banks of the streams were less consolidated and the eastern part, in his opinion, was the main depositing area. Moreover, Pascoe stated the role of Brahmaputra in the delta building processes from a historical perspective.

However, this report, too, lacks sufficient empirical support and it seems to be based mainly on the older information of secondary nature.

Among the geological studies of the Bengal Basin and the delta of the Ganges the paper produced by Morgan and McIntire (1958) stands on a sound position and is marked by some originality. This joint publication of the two famous geologists appeared in the 'Bulletin of the Geological Society of America' and was entitled 'Quaternary Geology of the Bengal Basin'. This study gives some new ideas and provokes some deep thoughts about the formation and the origin of the Ganges delta. This study includes paleoclimatological influences on the formation of the Bengal Basin and the delta and it indicates the presence of a series of deltas in the region. The authors have emphasized the tectonic upliftment and subsidence of the surrounding areas of the delta and mentioned the movements responsible for the development of the delta.

Another significant contribution towards the morphological studies of the Ganges delta was made by Geddes (1960), an eminent geographer from the U.K., by publishing one lengthy article in the 'Transaction and papers of the institute of British Geographers'. The author elaborated some morphological reasonings while describing the alluvial morphological features of the Indo-Gangetic Plain and its significance of mapping in geographical studies. In the course of this study evidence on

the structural relationship of the Indian plateau to the Himalayas has been reviewed and the major relief of the plains including the Ganges delta is mapped. The complex forms of Bengal area are outlined alongwith other studies of the Indus and the Ganges flood plains in relation to their adjacent mountains and plateaues. Forms and processes are illustrated in the study by re-contoured manuscript maps of three regions. This work carries sufficient originality and scholarly touch.

In course of this literature review it should be mentioned that the partition of Bengal in 1947 affected researches in the Ganges delta. With the political division of the deltaic region between West Bengal and East Pakistan (Now Bangladesh), the researchers and scholars of these two countries made the study of the delta belonging to their own countries. Thus a trend of partial survey of geomorphological, geological, ecological or other environmental aspects of the delta developed on the basis of this politically divided delta into two neighbouring countries. However, a few studies, like those of Chowdhuri do not fall in the above mentioned group. Chowdhury's 'Morphological Analysis of the Bengal Basin' (1959) covers both the parts of Bengal. His work includes a vast range of studies covering all the erosional, depositional and transportational activities of the Bengal rivers. In his study Chowdhuri tried to classify the various stream patterns that are seen among the Bengal rivers. Obviously, his studies cover all the streams and

rivers of the Ganges delta area. Moreover, he studied the coastal part of the Bengal Basin along with its morphological settings. The only drawback of this painstaking investigation is that this work lacks sufficient empirical and quantitative supports through field investigation. The vast scope of this study is mainly confined within the investigation of stream-characteristics, their processes and the resultant products of topographic features.

In 1964, Chowdhury contributed another paper on the Canges delta which investigated the gradual shifting of the Ganges from west to east in delta-building operations (Chowdhury, 1964). With the help of different maps and aerial photographs he tried to explore the changing courses of the main flow of the Ganges channel. In the paper the author has focussed on the geological and tectonic settings of the delta and tried to correlated these with the shifting of the Ganges course.

Rizvi (1964), a geographer of the then East-Pakistan, tried to delineate the precise boundary of the Ganges-delta. According to his study the Ganges delta may be delimited by its western distributary, the Bhagirathi, its north-eastern and eastern distributary, the Baral-Dhaleshwari-Meghna channel, and the Bay of Bengal. Many writers, not adhering to Rizvi's definition have drawn arbitrary lines to demercate the extent of the delta. Their view are considered critically by the author to show that a proper appreciation of deltaic characteristics is

essential for a correct delimitation of the Ganges delta. As a measure of comparison Rizvi has incorporated several maps of the Ganges delta drawn by other geographers and one by the author himself showing the limit of the delta.

Deb (1956) has suggested that the Gangetic alluvium has been developed from the top, contrary to the processes of normal deltaic formations. He tried to findout some palaeoclimatological and geophysical aspects of the Gagetic delta through the examination of the sedimentary material collected from the bore-holes of several tube-wells in the deltaic portion of West Benghal. In his paper Deb has highlighted on several aspects related to the origin of the delta, viz., probable limit of the Bay of Bengal towards the north, rivers of the Indo-Gangetic plain, their origin and history, formation of the Rajmahal Gap, geodetic anomaly of the Indo-Gangetic Alluvium and its significance, and lastly, the physiography during the late pliestocene time and the instability of the region.

After the partition of Bengal in 1947, the then 'East Pakistan Inland Water Transportation Authority' (EPIWTA, 1967), and 'the East Pakistan Water and Power Development Authority' (EPWAPDA, 1978 & 1980, revised) separately conducted several important surveys on morphological, hydrological and sedimentological aspects of the province which virtually included the rivers of the coastal areas of the Ganges delta in the eastern part of Bengal.

Since the emergence of Bangladesh (1971) a series of studies on the morpho-hydrological aspects of the deltaic portion of the country were made by different development authorities of the country. Among these studies, the surveys made by the 'Bangladesh Water Development Board' (BWDB, 1978) deserves mention. Through these indepth investigations the BWDB and its other wings have studied the morphological features and processes of major rivers of Bangladesh which ultimately covedred all the major rivers within the deltaic portion of the country. Moreover, they have studied some other coastal morphological and environmental aspect of the delta. The researches and surveys of the Space Research and Remote Sensing Organization of Bangladesh (SPARRSO), which have been done in the recent years, also deserve some mention. The SPARRSO's most significant contribution to the knowledge of the Ganges delta is the study of the changing Morphology of the coastal areas of Bangladesh (SPARRSO, 1981). Besides, the organization is conducting some studies on the sedimentological and other morphological aspects of the delta and coastal belt of the country.

In recent years significant contibutions have been made to the knowledge of the Ganges delta by scholars from Bangladesh and India, among whom the name of Miah,Pramanik and Islam of Bangladesh and Mallik, Chatteerjee, Bagchi, Paul and Basu of West Bengal need to be mentioned. Each of the above mentioned scholars worked on various aspects of the morphological,

hydrological or sedimentology of some parts of the Ganges delta or their streams and rivers.

Miah (1975) worked on the changing morphology of the active part of the delta. They investigated the coastal part of the estuarine Bangladesh with the help of different old maps and some recent aerial photographs. Miah, alongwith Islam, conducted a survey on the Island Ecosystem of Bangladesh (Miah and Islam, 1983).

Pramanik contributed a series of papers on the coastal part of the Ganges delta of Bangladesh-portion with the help of satellite data (Pramanik, 1980, 1981, 1982, 1983, 1989). In 1980 and 1981 he presented two seperate papers on the morphological changes in the southern parts of Bangladesh (Pramanik, 1980/1981). Besides, he presented some other papers jointly with other researchers on coastal morphology of the Gangetic Southern Bangladesh. All of his studies were mainly based on analyses of old maps, satellite imageries and field investigations. Some of his studies cover sedimentological and hydrological aspects of the delta region.

In order to bringout some comprehensive knowledge about the delta, Islam (1978) contributed a paper in the journal of the University of Sheffield Geological society. His paper reviewed some characteristics of the Ganga-delta covering from the tectonic settings to tidal and marine influences in the

formation of the delta.

Khan (1979) studied the fluvial morphology of the Ganges. He concentrated on the changing courses of the main channel of the River Padma in Bangladesh and studied erosional and depositional processes of the river while discussing the shifting of the courses of the channel.

Mallik (1976) made sedimentological studies of the deltaic waters of the coastal zone of the Bay of Bengal. An Indian sedimentologist, mallik studied the delta sediments of the continental shelf of the Bay with the help of field samples collected by the Geological Survey of India in 1976. His study reveals that the shelf sediments at the mouth of the Hoogly River of the Ganges delta consist of sands, silts, clays, and their various admixtures. They bulk of the sadiments consists of relatively fine to very fine sand. According to his study, there is variation in lithology in the vertical and horizontal directions and this also suggests growth of the delta in different stages.

Chatterjee wrote several articles and presented a number of papers on the different aspects related to the morphological and hydrological problems of the Ganges delta. His paper on the Hoogly-Bhagirathy Basin (1972) has examined the morphological aspects of the Bhagirathi-Hoogly river of the delta. In this paper the author has tried to explain the existing decaying condition of the channel from a fluviomorphological

perspective. Chatterjee has put forward sound arguments supporting the installation of the controversial Farakka Barrage on the Ganges. In 1960, jointly with bagchi Chatterjee published another article on hydrographic features of the 'Adiganga Bhumi, (Chatterjee and Bagchi, 1960). This attempt was a palaeo-geomorphological work which tried to reveal the prehistorical aspects of the courses and the formation of the Ganges highlighting on its basin and delta.

Paul (1988) has studied the morpho-ecological dynamics of the coastal part of the Western Ganges delta. Although in his study much attention has been given to the ecological and environmental situation of the Sundarban Swamp areas -- yet, the scope of his study did not leave the fluvio-hydrological proceses of the streams of the area aside. Moreover, he has studied some important sedimentological aspects of this part of the delta.

Basu (1967) has examined the fluvio-geomorphological aspects of the Bhagirathi-Hoogly river of the western part of the Ganges delta. His studies include the evolution of the Bhagirathi-Hoogly river, its fluvialdynamics, physical and hydrological characteristics and silt behaviour.

From the foregoing riview of studies on the various aspects of the Ganges delta it can be summerised that inspite of the numerous researches and studies on different morphological aspects of the delta area none of them covers the whole of the area complete from the view point of fluvio-morphological

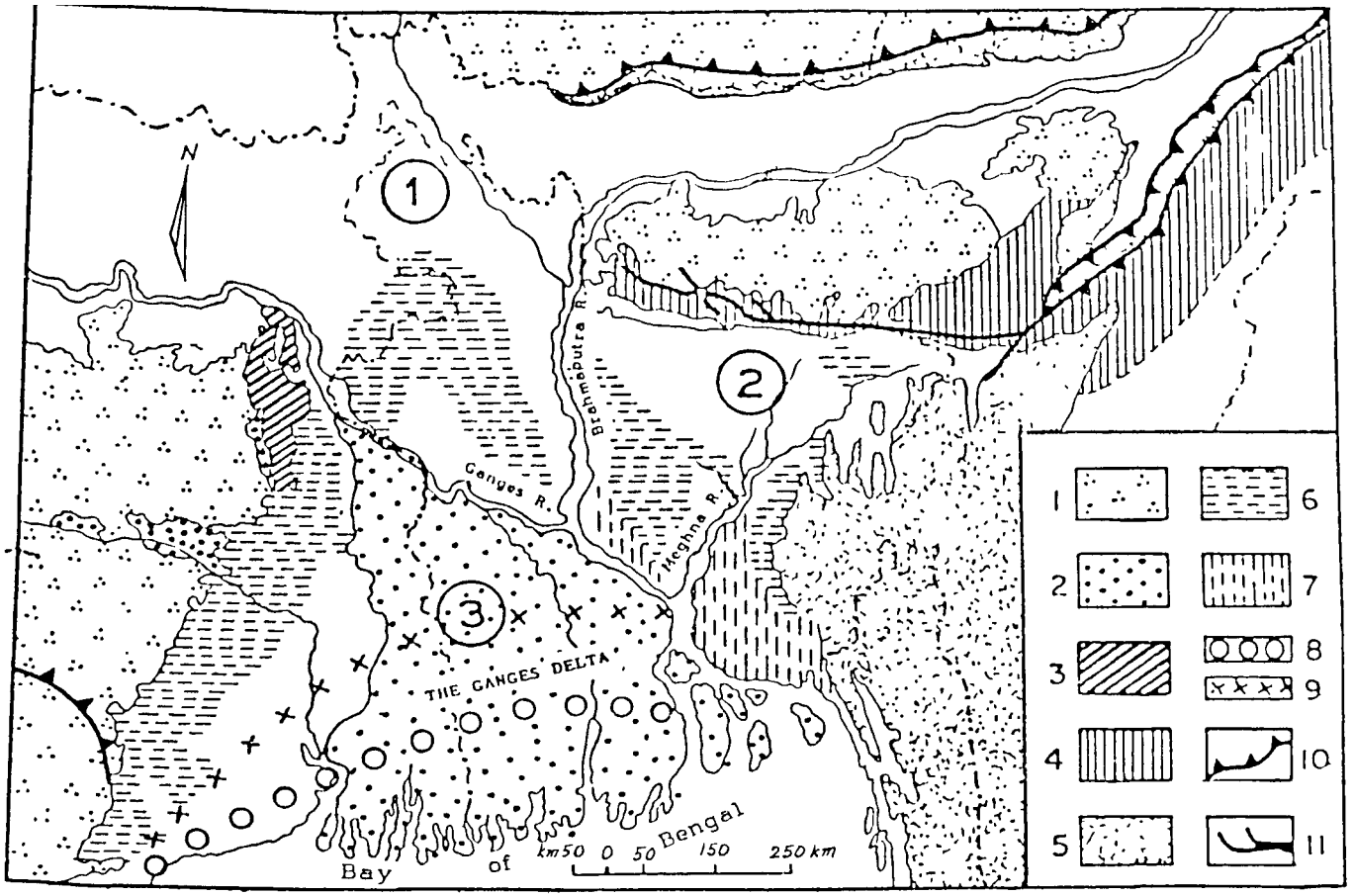
studies of the delta. However, all the afore-mentioned studies can contribute substentially to the future indepth and complete study of the Ganges delta from different aspects of research and investigation.

2.4 GEOLOGY AND TECTONICS OF THE GANGES DELTA :

The Ganges delta occupies the seaward margin of the Bengal Basin which owes its origin to the formation of the Himalayas and the Indo-Burman ranges (Islam, 1978). However, the Bengal Basin, as it is seen today, was conspicuous during the Oligocene to Miocene period and presently is characterised by mostly thick and monotonous unfossiliferous neogene sediments (Khan, 1980). The delta of the Ganges has been under sedimentation, accretion and erosion processes since its emergence.

The Bengal Basin, of which the Ganges delta is a part, is delimited on the west by the outcropped pre-Cambrian rocks of the Indian shield and to the north by the Shillong Plateau. The eastern margin of the basin is demarcated by hills along the NNW-SSW and N-S trending frontal fold zones of the Neogene phase of the Indo-Burman Orogenic Belt (Fig. 2.5).

Bakhtine (1966) has sub-divided the Bengal Basin into shelf, slope or hinge zone and the basin foredeep areas. The geosynclinal Bengal Foredeep in the south and south-east, where



(1) NORTH BENGAL BASIN

1. Archaean - Granitoids
2. Gondwana Sedimentaries Faulted Basin
3. Rajmahal Trap (Plateau)
4. Eocene to Oligocene- Naga-Patkoi Hills

(2) SYLHET BASIN

5. Mio-Pliocene (Lusai Hills)
6. Lateritic-Ferallitic Form
7. Tippera-Noakhali-Barind Plains
8. Approx. limit of land Built by Marine Agencies
9. Approx. Southern Boundary of Riverine Delta

(3) GANGES DELTA

10. Thrust Faults
11. Normal Faults

N

Source : Chatterjee and Mukhopadhyaya (ed.), West Bengal (1970).

the Ganges delta came into existence got filled with sediments and has greater tectonic mobility. The thickness of the sediments reaches more than 18,000 m in the deltaic region of Hatia-Barisal-Patuakhali in the southern part of the Bangladesh (Mirkhamidov and Mannan, 1981). These deltaic sediments belong completely to the Quaternary period deposited about 2.4 million years ago (Master Plan Organization, 1986).

The Bengal Basin occupies a remnant of the seaway that was closed some eight million years ago as the Indian Continental Plate reached Asia. During the period of infilling with sediments, the basin generally deepened, and sea-level has varied considerably as compared to its present position. The modern Ganges delta was formed by the deposition of sediments eroded by the Himalayan rivers and of the Ganges, Brahmaputra and Meghna river systems.

During the late Miocene-Pliocene-Pleistocene periods, in between 25 to 2 million years ago, the Great Himalayan Orogenic uplifts took-place in the north-eastern and eastern parts of the Gangetic Basin. These uplifts occurred following the successive periods of rising and falling of sea-levels and subsidence which took place during the Eocene and Oligocene-Miocene periods. Periodic rises in sea-level and reduced coarse-grained sediment inflow covered the sandy bed of the estuary with marine clay. After this, as deposition of coarse-grained sediments increased during the early pliestocene, the deltas of the ancient

Brahmaputra extended across the estuary. The role of subsidence accelerated and was accompanied by uplift, gentle folding, and west-ward tilt of the eastern margin of the basin.

Subsidence is a common earth movement in the deltaic part of the Bengal Basin. Faridpur Trough and Khulna-Sundarbans areas are two principal regions where subsidence is much more active. In these regions calculated values of subsidence range from 0.6 mm/year to 5.5 mm/year (M.P.O., 1985).

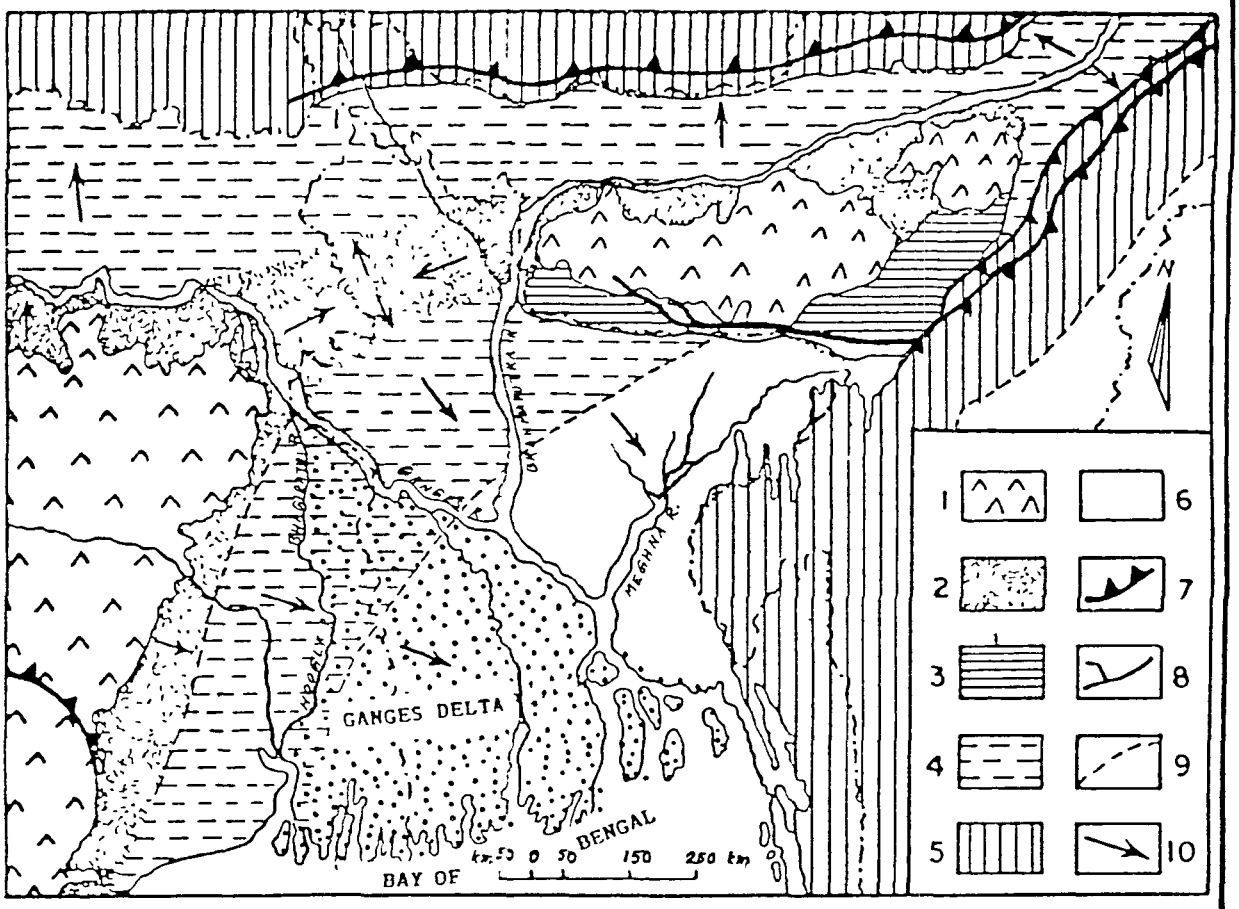
Fergusson (1863) is of the opinion that some 4000 - 5000 years have elapsed since the northern boundary of the Bay of Bengal was at or near the Rajmahal and the delta has been formed by deposition.

The Bay of Bengal was created at a date later than the uplift of the Arakan Yoma arc of the Himalayan Orogeny (i.e., Indo-Burman ranges). The collision of the Indian plate in late Paleocene initiated the rivers of the Himalayas and Indo-Burman (Arakan Yoma) ranges and down buckling along the plate margins, as the subducting Indian plate along the Indus-Brahmaputra suture got jammed due to buoyancy constrains (Deb, 1956). This situation helped the generation of the central gneisses in the Himalayas through heat transfer by fluids, local fracturing, and perhaps by local melting, which culminated by the Miocene in underthrusting of the Indian Plate along the main central Thrust and the rapid rise of the Himalayas and the

Indo-Burman ranges (Islam, 1978). The incipient Bengal Basin, occupying a distal part in the acute angle between the two areas, developed during the Miocene into a molasse foredeep (eastern terminal part of the Indo-Gangetic molasse foredeep) and received its share of the huge detritus (clastics), eroded from the rising Himalayas. Buoyancy constraints, physical behaviour of the underthrusting slab and abnormal structure of the upper mantle probably limited the possible length of underthrusting and relayed it to the 'Main Boundary Thrust' in early Pleiocene (Le Fort, 1975) and has led to the release of an unusually high amount of sediments carried by the Ganges-Brahmaputra system of the region. The upper course of the Brahmaputra occupies the zone of subduction while the Ganges and its tributaries run across the 'Main Central and Main Boundary Thrusts' (Fig. 2.6).

From the foregoing discussion it can be assumed that the Ganges delta is located in a tectonically most active mio-geosynclynal area and its genesis can not be explained by the simple infilling of a shallow continental shelf with the sediments brought down by the Ganges, Brahmaputra and Meghna river systems. Recent geophysical investigations in the delta (Morgan and McIntire, 1959) indicate a slope of the basement complex towards the Naga-Lushai geosyncline, i.e., towards south-east and the basement of the southern part of this deltaic region has a continuous cover of basalt (Chakraborty, 1970). This basement complex of the deltaic basin is rising since the

Fig. 2.6 : Tectonic Framework of the Ganges Delta and its Surrounding Areas



1. Exposed Shield
2. Burried Shield
3. Uplifted Segments of Zone-4
4. Transitional Zone Between Shield & Geosyncline
5. Orogenic Belts
6. Deeper Parts of Naga-Lusai Geosyncline
7. Thrust Fault
8. Normal Faults
9. Hinges in the Basements
10. Direction of Slope of Basement

Source : Chatterjee and Mukhopadhyay (ed.), West Bengal (1970).

Pleistocene (Chakraborty, 1970). The Eocene Hinge Zone Passes through the north-western part of the delta in a south-west north-east direction and this plexure has been detected at a depth of 7,000 m below Calcutta. The western and northern parts of the delta beyond this Hinge zone is geologically a transitional zone between shield and geosyncline. Rest of the delta, lying in the south and south-eastern side of the Hinge zone constitutes the deeper parts of the Naga-Lushai Geosyncline.

Interpretations of the Landsat imagery have revealed the structural control over the deltaic rivers. Sesoren (1984) has identified a 'zone of weakness' in the eastern part of the Ganges delta passing between the Madhupur-Tipperra surface and following the Meghna river at the north-east of the Bengal Basin and cutting the Ganges tidal floodplain in the south-west. In the lower Bengal Basin the 'zone of weakness' generally follows the approximate trend of the Brahamaputra (Jamuna)-Ganges (Padma)-Meghna river system. Earlier Krishman (1953) referred to this 'zone of weakness' on the basis of evidences. According to Krishman, this zone of weakness was caused by either a subsiding trough of a single major fault at depth. These tectonic situations (i.e., the presence of a zone of weakness, a series of echelon faults and subsiding depressions) indicate a geological and structural unrest in the deltaic region of the Bengal Basin and the all answers to the questions related to the morphological changes (i.e., shifting courses of the deltaic rivers) in the delta could be linked with these tectonic situations.

The study of surface deposition reveals that the whole deltaic tract is covered with different forms of sediments ranging from clay, silt, sand and some marine deposits. In the northern and north-eastern portions of the delta meander deposits and swamp deposits are predominant. In the mid - delta where moribund condition is prevailing, inter-stream alluvial deposits are found. Pure deltaic deposits and undefferentiated swamp and deltaic deposits can be seen in the southern part of the delta. However, the swamp and marine types of the recent deposits are found in the coastal and estuarine parts of the delta.

In the southern part of the Bengal Basin where the Ganges delta has taken its shape the approximate limit of land built by marine agencies is marked by a convex line stretching from the Midnapur coast in the west tc the mouth of the Meghna in the east. This line goes deep in Khulna district (Bangladesh) where it reaches about 112 km. inland from the sea (Fig. 2.5). The line of the approximate southern limit of riverine delta runs roughly parallel to the line of limit of land built by marine agencies in the north and this line also starts from the Midnapur coast and enters further inland and finally reaches the confluence of the Padma and the Meghna. The deepest part of this line rests at least 240 km away from the coast (Fig. 2.5).

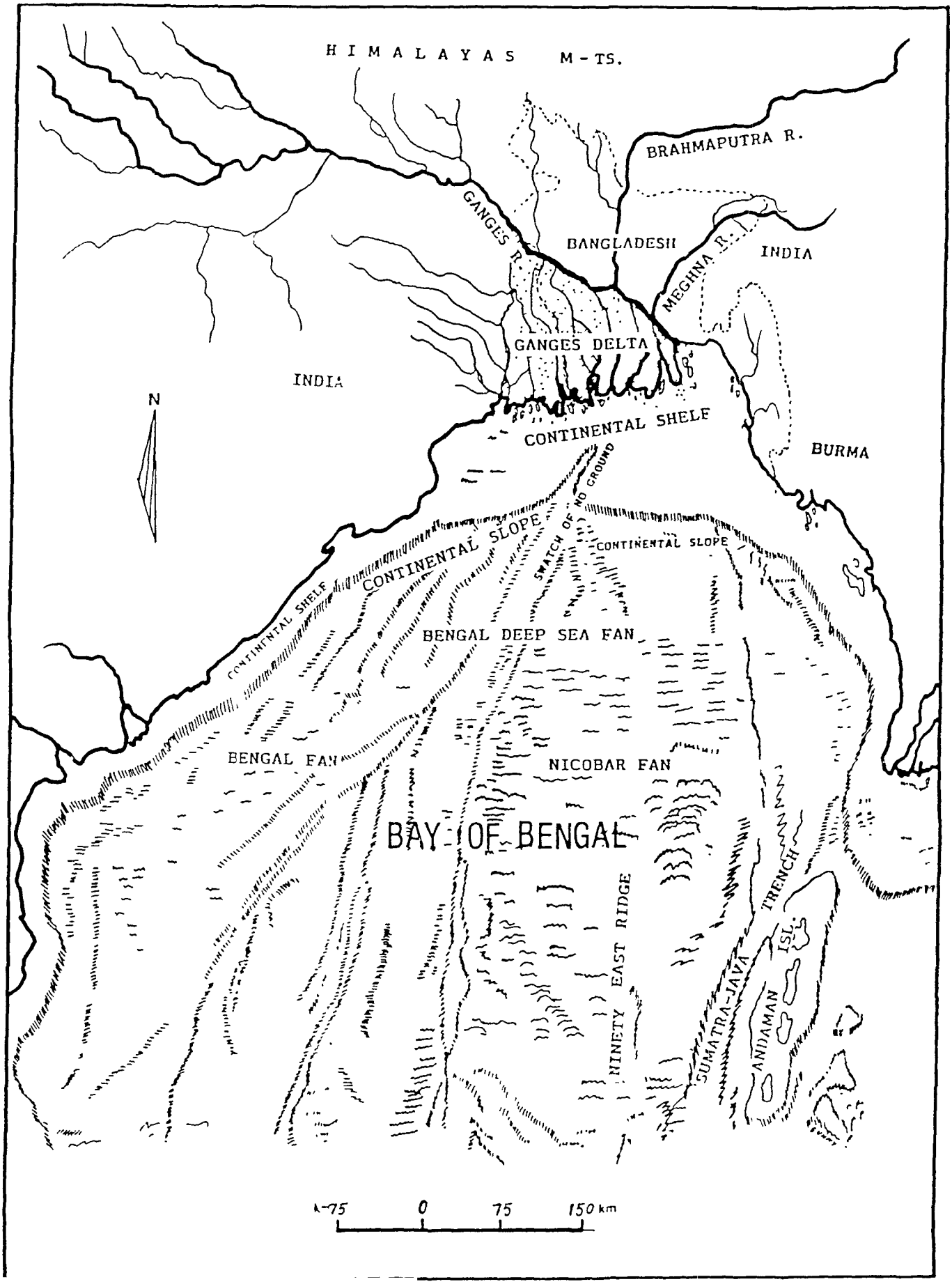
2.5 COASTALMORPHOLOGICAL AND OCEANOGRAPHIC CHARACTERISTICS :

The southern fringe of the Bengal Basin, where the Ganges delta has come into existence infact extends towards the Bay of Bengal for a considerable distance. The origin and evolution of the Bengal Basin are directly related to the genesis and structure of the Indo-Gangetic trough, the northern remnant of the Bay, itself is overlaid and filled by sediments thousands of metres thick (Pramanik, 1989).

The Bay of Bengal is a north-eastern shallow extension of the Indian ocean. It is located between latitudes 5°-22° N and longitudes 80°-95° E. The Bay comprises about 2.2 million km^2 and is bounded by India and Srilanka to the west, India and Bangladesh to the north and Burma and the northern Malayasia to the east. The International Hydrographic Bureau has defined the southern boundary of the Bay of Bengal to a line extending from Dondra Head at the southern extremity of Srilanka to the extreme north point of the Sumatra (Indonesia). The Bay is approximately 1,600 km wide and its average depth is about 790 m. The recorded maximum depth in the Bay of Bengal is 4,500 m (Encyclopaedia Britanica, 1980). The Andaman and Nicobar groups of Islands are the major oceanic archipelagoes while Sandwip, Hatia, Bhola, Saugar Dwip, etc. constitute the off-shore islands of the Bay of Bengal (Fig. 2.7).

The sea-floor topography of the Bay of Bengal is characterized by features like the Bengal Deep Sea Fan,

Fig. 2.7 : The Bay of Bengal: Bathymetric Features



the Ninety East Ridge, the Nicobar Fan, the Swatch of No Ground, the Burma Trench and the Chagos East Coast Trench.

The Ninety East Ridge occupies the central part of the Bay and follows the north-south direction along the 90°E longitude. This ridge is about 5,000 km long and extends from 15° N to 30° S latitudes. The Bengal Deep Sea Fan lies to the west of the Ninety East Ridge and the Fan extends from 20° N to 7° S latitudes covering a length of nearly 3,000 km and width of 1,000 km (Curray and Moore, 1974). This fan has been developed in the shallow and wide shelf-margin of the Bay of Bengal. This fan is the submarine continuation of subaerial delta and accumulation of sediments of sub-deltaic Bengal Basin (Islam, 1978). The fan covers as area of about 3 million sq. km (Curray and Moore, 1971). The sediments laid down at the mouths of the Ganges are distributed over the entire fan fairly evenly by many turbidity currents mostly issuing from the Swatch of No Ground (Islam, 1978).

The Nicobar Fan lies to the east of the Ninety East Ridge in the Bay and in the eastern margin of this fan there lies the Andaman-Sunda Submarine Trench. In the coastal shelf of the Ganges delta the most conspecuous marine topographic feature is the 'Swatch of No Ground', a submarine canyon which lies about 24 km south of the delta coast. It crosses the continental shelf diagonally in a south-westerly direction and has a seaward continuation of about 2,000 km down the Bay of Bengal. At its

northern apex the 'Swatch of No Ground' attains a depth of about 30 to 60 metres and cuts the shelf to depths of about 1,000 metres below the adjacent level of the sea-floor (Chowdhury, Hoque and Pramanik, 1988). This submarine canyon exerts a pronounced influence on the morphogenic characteristics in the deltaic section of the Bengal Basin and greatly influences the tidal processes, sediment movements and deposition and other coastal phenomena in the deltaic coast and shelf zone of the Bay.

Having a relatively long but narrow and steep-sided depression in the eastern part of the Bay of Bengal the Burama Trench presents another striking morphological feature in the Bay. The Chagos-East Coast (Bangladesh) Trench (Rahman, 1975) extends from the mouth of the Passur river (south of the Sundarbans) to Srilanka and further south (Fig. 2.7).

The coastal belt of the Ganges delta extends from the Hoogli-Bhagirathi mouth in the west to the Meghna estuary in the east. This coastal area of the delta is confined roughly in an area between 80°0' E to 91°0' E longitudes and 21°30' N to 22°30' N latitudes. The present longitudinal extent of the coastline of the Ganges delta is about 315 km. Some prominent morphological characteristics of the coast of the delta include the presence of a vast network of rivers; a large number of islands or sand-bars in between channels; a funnel shaped and shallow northern margin of the Bay where the coast-line of the delta appears. Moreover, the coastal areas of the delta is characterized by

an enormous discharge of run-off laden with sediments, strong tidal and wind actions, tropical cyclones and the associated storm surges.

2.6 CLIMATIC SITUATIONS IN THE GANGES DELTA :

2.6.1 Temperature :

The climate of the Ganges delta is of tropical monsoon type with distinct dry season in the low sun period. January is the coldest month when temperature sometimes falls below 10°C. However, the ameliorating effect of the sea makes the climate in the delta quite pleasant. Summer months are hot and oppressive with average temperature above 30°C and absolute maxima may approach 38°C or 40°C (Table 2.1 and Fig. 2.8).

TABLE 2.1

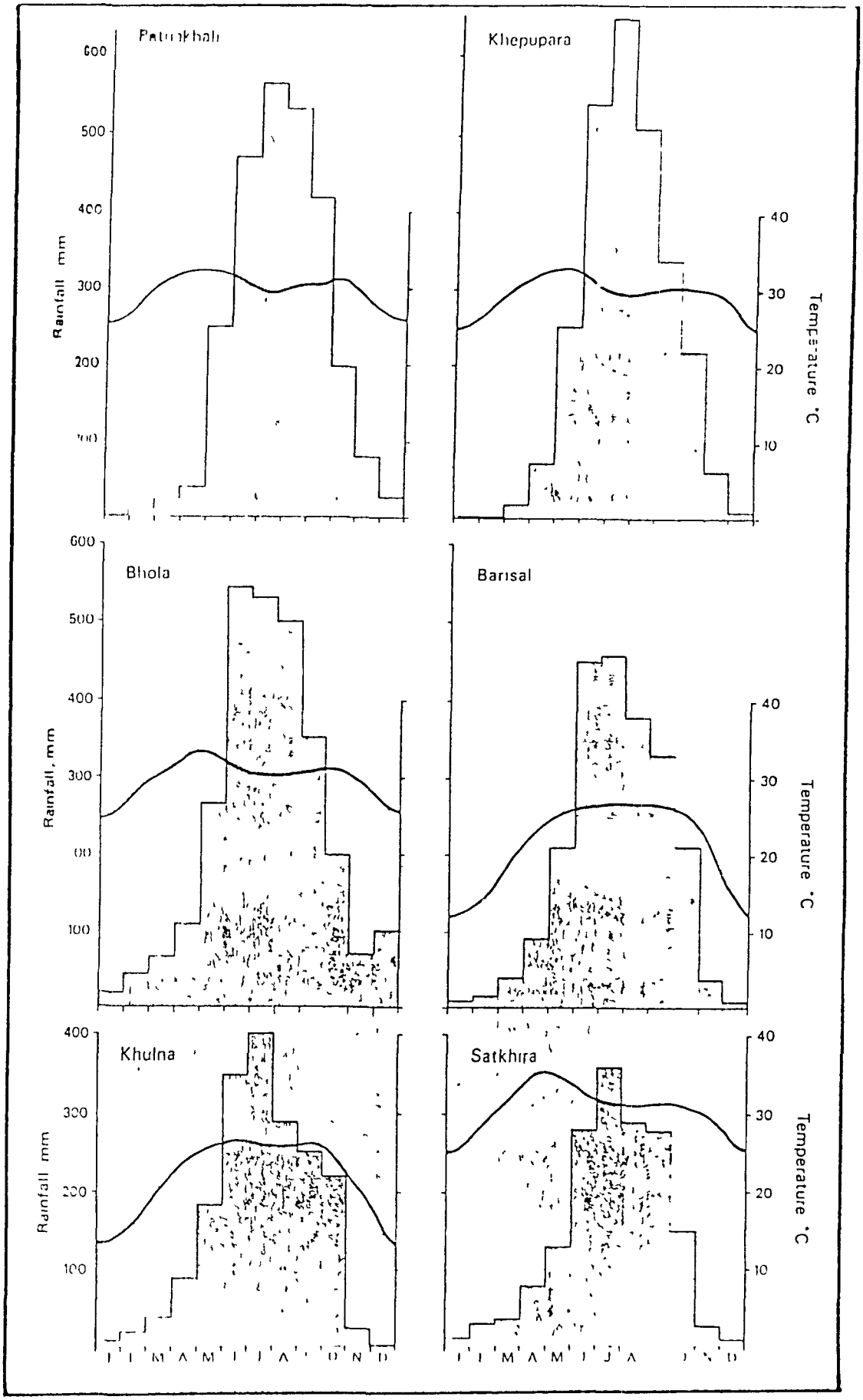
Maximum and Minimum Temperatures in the Ganges Dalta

(in °C)

Station	Period	Mean annual maximum	Mean Max. hottest month	Mean annual minimum	Mean min. coldest month
Barisal	1947-80	30.3	33.7 Apr.	21.7	12.9 Jan.
Bhola	1965-80	30.1	33.0 Apr.	20.8	11.9 Jan.
Khepupara	1974-80	29.8	32.7 May	22.2	14.4 Jan.
Khulna	1964-80	31.1	34.8 Apr./May	22.0	13.8 Jan.
Patuakhali	1973-79	29.4	32.4 May	20.4	12.4 Jan.
Satkhira	1947-80	31.3	35.6 Apr.	21.3	12.4 Jan.
Calcutta*	1947-82	31.6	35.7 May	21.9	13.6 Jan.

Source : Bangladesh Meteorological Department. *Calcutta Port Authority.

Fig. 2.8 : Rainfall and Temperature for Six Deltaic Stations



Source : Meteorological Department of Bangladesh, Dhaka.

2.6.2 Rainfall :

In the deltaic region of the Ganges rains begin in the months of April-May and continues till October. The rainfall in the months of March, April and May is because of the 'Nor' Wester storms'. These suddern and violent storms usually develop in the afternoon and are accompanied by thunder, lightning and torrential rain for a short duration.

In the middle of June the monsoon sets in with abundant and widespread rainfall which may exceed 2,000 mm in many southerly stations in the delta (Table 2.2). The intensity of rainfall is highest in July to October (Fig. 2.8). The intensity of rainfall is higher in the south and south-eastern

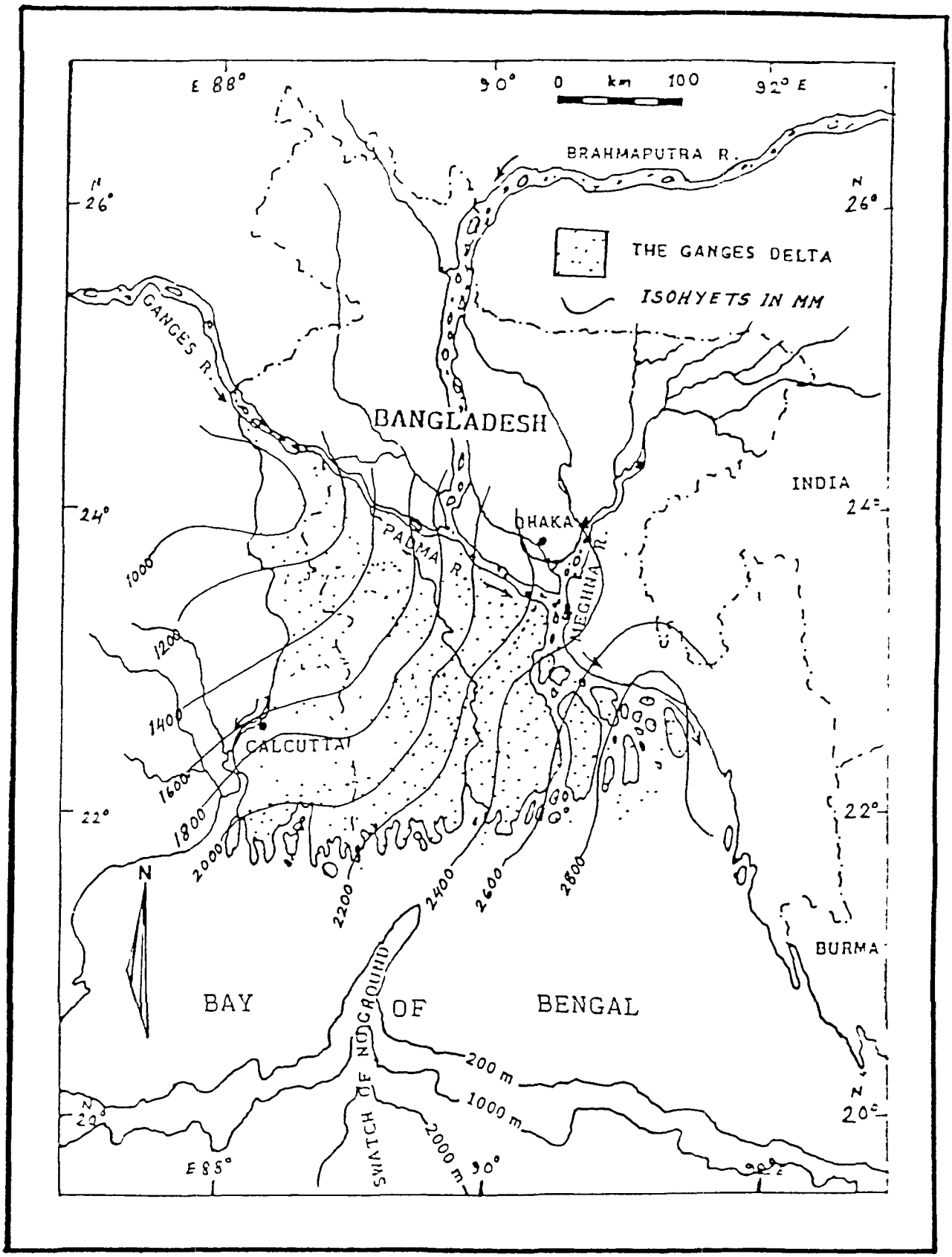
TABLE 2.2

Mean Annual Rainfall in the Ganges Delta
(in mm)

Station	Longitude	Latitude	Period	Mean Annual rainfall
Barisal	90° 19' E	22° 42' N	1947 - 80	2,300
Bhola	90° 39' E	22° 41' N	1965 - 80	2,186
Khepupara	90° 14' E	21° 59' N	1974 - 80	2,703
Khulna	89° 35' E	22° 48' N	1947 - 80	1,849
Patuakhalli	90° 21' E	22° 22' N	1974 - 80	2,503
Satkhira	89° 04' E	22° 42' N	1947 - 80	1,722

Source : Bangladesh Meteorological Department and Bangladesh Water Balance Unit.

Fig. 2.9 : Distribution of Rainfall in the Ganges Delta



Note : Isohyets Prepared from Rainfall Data Collected from Various Sources.

parts of the delta. The distribution of the average rainfall makes the isohyets swing round in a curve from the south towards the east and then towards the north-west (Fig. 2.9). The south-eastern coastal areas of the delta experience an annual average of about 2,800 mm rainfall. The 1,800 mm isohyet passes south of Khulna town (Bangladesh) and Calcutta (India). The same isohyet line also crosses just north of Faridpur town and most of 24-Parganas, Khulna, Barisal and the estuarine islands of the Padma-Meghna mouth enjoy annual rainfall ranging from 1,800 mm to more than 2,800 mm. To the north of the 1,800 mm isohyet line the annual average downpour decreases gradually towards north and south-western parts of the delta. Northern parts of the districts of Khulna, whole of Faridpur and Jessore districts, most of Kustia and Nadia districts fall within the isohyets of 1,800 mm (in the south) and 1,400 mm (in the north-west). Only the district of Murshidabad in West Bengal of the deltaic region receives an annual average rainfall of less than 1,400 mm.

2.6.3 **Seasonality :**

Like the climate of the tropical lower Bengal Basin, the Ganges delta and its adjoining areas experience four district seasonal weather types (ESCAP, 1988). These seasonal weather patterns of the Ganges delta are mostly governed by the south-west and the north-east monsoon winds. These climatic types are :

i) the dry winter season from December to February,

ii) the transitional period from March to May,

iii) the monsoon season from June to September, and

iv) the second transition period from October to November.

The dry winter season is frequented by rainfall under the influence of the dry air circulation of land origin mostly from the north-east monsoon.

The transitional period is also termed as the pre-monsoon season and is characterized by short-duration thunderstorms of terragenic sources. These storms are normally accompanied with violent winds which are locally known as Kaal Baishakhy or the 'Nor' Westerly' storms.

The monsoon season is characterized by heavy rainfall under the influence of the south-west monsoon, with 75% of the total annual downpour occurring in this period.

The second transitional period is termed as the post-monsoon season and is normally characterized by the occurrences of violent tropical cyclonic storms of the Bay of Bengal.

2.6.4 **Atmospheric Pressure :**

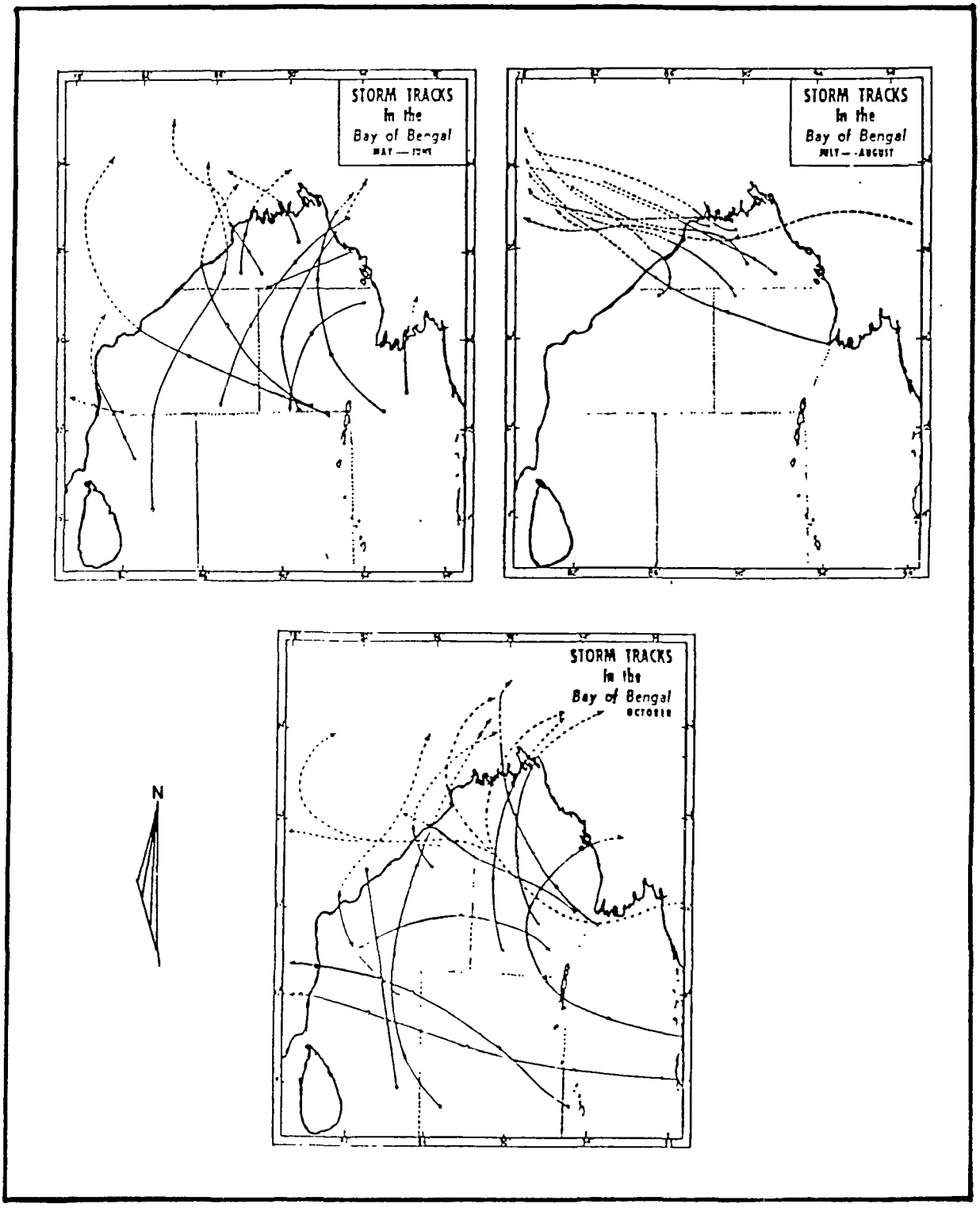
During the cooler months (mid-November to mid-February) the delta of the Ganges stands at the edge of the vast high pressure area of the Gangetic plain. The mean pressure is 1,020 millibars in January here. As a result there is a flow of

air down the Brahmaputra and the Ganges valleys towards the delta. Considerable changes take place in the next few months. From March to September, it becomes an area of low pressure, the average being 1,005 millibars. The Inter-Tropical Zone of Convergence moves north till it is over northern part of the Bengal Basin. The reversal of winds consequent in pressure changes in May-June and October-November often causes violent storms (i.e., cyclones).

2.6.5 **Cyclones :**

The tropical cyclones are very common yet devastating natural phenomena in the Bay of Bengal and its northern deltaic land areas. These severe storms normally occur in the south-eastern Bay and advance in a northerly or north-westerly direction. Often these cyclones turn north-easterly or easterly towards the Chittagong or Burma coasts (Fig. 2.10). Cyclones generally cause damage in the ways of storm surges, floodings due to excessive cyclonic downpour and wind-destructions. The velocity of the cyclonic storms normally rises upto 200 to 250 km per hour and results in loss of life and property in the deltaic coasts and plains. The most catastrophic happening, however, is the cyclonic surge engendered by a billowing water-mass. Generally such cyclonic surges become very swift and move landward along with the progressing storms. Surge-water maintains a higher elevation than the normal sea-level. As the

Fig. 2.10: The Tracks of Cyclonic Storms in the Bay of Bengal



Source : Chatterjee, S.P., (1948), Bengal in Maps, Calcutta.

cyclonic-storm approaches the shallow coastal water of the Ganges delta, the surge intensifies and flares up into the deltaic plain with its ruthless fury. The coincidence of the cyclonic move with a spring or eb-tide tends to intensify or reduce the height of the surge and its resultant damage. Storm surges caused by the

TABLE 2.3

The Month-Wise Distribution of Depressions and Cyclonic Storms in the Bay of Bengal During 1950 to 1975

Month	No. of depressions	No. of cyclones	Total No. of depressions & cyclones
January	1	3	4
February	1	0	1
March	0	0	0
April	3	2	5
May	11	18	29
June	33	4	37
July	36	3	39
August	41	4	45
September	41	11	52
October	27	24	51
November	5	26	31
December	6	11	17

Source : Bangladesh Meteorological Department.

recent cyclones in the deltaic coast of the Bay of Bengal were measured at 3 to 6 metres in height. The tropical cyclones are generally formed during the pre and post-monsoon seasons in the months of October, November and March and April, while the

monsoonal depressions, another type of tropical storms, occur during the south-west monsoon period in the months of July, August and September. Some of the devastating cyclones which ravaged the coastal part of the Ganges delta were those of the Urir-Char Cyclone of May, 1985, the coastal deluge cyclone of November, 1970, the great cyclone of 1919, the Bakarganj cyclone of 1876 and the Barisal cyclone of 1584 (Table 2.3). The very recent cyclone of the Bay of Bengal of May, 1991, which has almost destroyed the entire south-eastern coastal belt of Bangladesh would be written as one of the most catastrophic natural calamities in the history of the world hazards. More than 0.2 million people have been died and more than 3.0 million people have been affected in this devastating cyclone.