

# TERTIARY MOLLUSCS FROM THE WESTERN MARGIN OF BENGAL BASIN INDIA, WITH SPECIAL REFERENCE TO BIOSTRATIGRAPHY AND PALAEOENVIRONMENT

SUBIR BERA, MANJU BANERJEE and TAPESH CHANDRA LAHIRI\*  
PALAEOBOTANY AND PALYNOLOGY LABORATORY, DEPARTMENT OF BOTANY  
UNIVERSITY OF CALCUTTA, CALCUTTA-700 019.  
\* PALAEOLOGY DIVISION, GEOLOGICAL SURVEY OF INDIA, CALCUTTA.

## ABSTRACT

Tertiary molluscs recovered from six bore cores (PGD-1, 4, 5, 6, 8, 9) at Panagarh - Domra sector (23°30'36"N, 87°27'18"E) are studied for the first time from Bengal basin, India. The fauna is formed of twenty five taxa with fourteen bivalve, ten gastropod genera and one brachiopod member. Four molluscan assemblage zones (MAZ viz., MAZ I *Viviparus* cf. *V. bengalensis* - *Natica* sp., MAZ II *Ostrea* sp. - *Cyclina* sp., MAZ III *Natica rodatzii* - *Turritella* sp. - *Barbatia* cf. *B. kayalensis* and MAZ IV *Arca* sp. - *Astarte* sp. - *Terebra* sp. are identified. These zones are correlatable with the Planktonic foraminiferal zones (PFZ I and PFZ II) and Palynostratigraphic environment zones of Bengal basin (Bb. PEZ II-V) recovered from the same bore core sediments. The study explores a brackish deltaic environment for MAZ I and near -shore shallow marine environment of deposition for MAZ II, III and IV. Oligocene age for MAZ I, Early Miocene for MAZ II and late Early Miocene to Pleistocene age for MAZ III and IV are suggested.

## INTRODUCTION

The Tertiary molluscs of India are known from Palaeocene to Pliocene deposits of Rajasthan, Kutch, Gujarat, Meghalaya, Assam, Manipur, Tripura, Orissa, Kerala, Tamil Nadu, Jammu and Kashmir, Himachal Pradesh, Andaman and Nicobar Islands (Vredenburg, 1928; Wynne, 1872; Sen Gupta, 1964; Chatterji and Mathur, 1966; Nath, 1962; Fedden, 1884; Stoliczka, 1869; Mukherjee, 1928, 1939; Eames, 1936; Sarma, 1957; Mohanti, 1966; Bhalla and Dev, 1975; Kumar and Pichamuttu, 1933; Cossman, 1910; Khan *et al.*, 1973). There is no report of Tertiary and Quaternary molluscan remains from West Bengal part of Bengal Basin excepting the records of deltaic marine and fresh water molluscs from different stratigraphic levels of C<sup>14</sup> dated Holocene sediments of Bengal Basin (Banerjee and Sen, 1988).

The present paper deals with the first comprehensive account of Tertiary molluscan assemblages from the Western Bengal Basin, India (fig.1).

## REGIONAL GEOLOGY

The Bengal Basin in West Bengal, India and Bangladesh is bounded by the Archean Gneisses, Gondwanas, Rajmahal Traps in the West, Archean Shield of Shillong plateau, Garo hills towards north and east and Bay of Bengal in the south.

The sedimentary sequence in the West Bengal Basin unconformably overlies the Pre-Cambrian basement. The succession preserved in faulted troughs ranges in age from Gondwana to Recent. Roy Barman (1992) has reviewed the geological studies on the West Bengal Basin and compiled the stratigraphical succession

analysing corresponding environment of deposition (Table 2).

## WELL LOCATIONS AND LITHOLOGY OF MATERIALS STUDIED

The investigated molluscs were recovered from 6 bore cores (PGD-1, 4, 5, 6, 8, 9) near Durgapur, West Bengal (fig.1). Location of the bore cores and lithology of the studied materials are given in Table 1.

Table 1: Showing position of bore cores and lithology of the studied material

Name of bore core and location	Depth of sample (in m)	Lithology	Specimen No.
PGD-1 (23°26'N, 87°26'48"E)	131.0	Mottled clay	PGD-1/MRI-6
PGD-4 (23°32'24"N, 87°28'18"E)	92.60 101.0 115.0 121.0 139.34 155.22	Silver grey mudstone & clay " " " Dolomitic limestone White to dull clayey sandstone	PGD-4/MR59-76 PGD-4/MR42-58 PGD-4/MR22-41 PGD-4/MR11-21 PGD-4/MR23-10 PGD-4/MR1-2
PGD-5 (23°32'26"N, 87°29'E)	103.0 111.0 118.95	Silver grey mudstone & clay	PGD-5/MR14-15 PGD-5/MR6-13 PGD-5/MR1-5
PGD-6 (23°30'36"N, 87°27'18"E)	83.50 84.50 96.0 87.0 88.0 89.20 92.0 92.60 95.45 98.0	Silver grey mustone & marl Silver grey	PGD-6/MR139-144 PGD-6/MR134-138 PGD-6/MR128-133 PGD-6/MR118-127 PGD-6/MR109-117 PGD-6/MR103-108 PGD-6/MR93-102 PGD-6/MR83-92 PGD-6/MR63-82 PGD-6/MR56-62 PGD-6/MR39-55

Name of bore core and location	Depth of sample (in m)	Lithology	Specimen No.
PGD-8 (23°31'48"N, 87°26'54"E)	103.0	"	PGD-6/MR33-38
	113.20	"	PGD-6/MR17-32
	126.0	"	PGD-6/MR5-16
	149.0	Mottled clay	PGD-6/MR1-4
	225.5	"	Barren of molluscs
	104.0	Silver grey mudstone & clay	PGD-8/MR52-57
	105.25	"	PGD-8/MR34-51
	109.0	"	PGD-8/MR23-33
	115.0	"	PGD-8/MR18-22
	119.0	"	PGD-8/MR5-17
	168.0	White to dull clayey sandstone	PGD-8/MR1-4
PGD-9 (23°31'48"N, 87°26'54"E)	69.35	Silver grey mudstone & clay	PGD-9/MR14-23
	96.20	White to dull clayey sandstone	PGD-9/MR1-13

## METHODOLOGY

Most of the molluscan remains were extracted from the rock matrix using needles, scalpels and forceps. Fine brushes were used to remove the sediment adhering to the specimens. In case of specimens firmly adhering to the hard matrix of the rock, only the exposed parts were studied.

## NOMENCLATURE AND CLASSIFICATION

The nomenclature employed follows the rules of the International Code of Zoological Nomenclature (1985).

The systematic descriptions of the taxa are made following Preston (1915), Shipley and Reed (1959), Cox *et al.* (1969), and Davies (1975).

## OBSERVATION

321 molluscan specimens were recovered from the six bore cores studied. Twenty five taxa are identified which include twelve gastropods, twelve bivalves and one brachiopod. One gastropod and two bivalve taxa only could be identified up to specific level. The systematic description of the recovered molluscan taxa is given below.

## SYSTEMATIC PALAEONTOLOGY

### Family Tellinidae

#### Genus *Tellina* Linne

*Tellina* sp.  
(Pl. II, fig. 5)

**Description :** Single valve preserved, shell small (1 = 4.3 cm; b=1.2 cm), thin, inequilateral, equivalve; posterior dorsal margin nearly horizontal meeting the arcuate posterior margin in a sharp angle; umbones low; lunule not sharply differentiated; surface smooth except for fine incremental lines.

**Distribution:** Miocene of Quilon, Kerala, India (Dey, 1962), Late Early Miocene to Pleistocene (PGD-9).

**Remarks:** Prior to this present report it has been found in Quilon, Kerala, India (Dey, 1962). Deposit feeder and active burrower.

### Family Veneridae

#### Genus *Cyclina*

*Cyclina* sp.  
(Pl. I, fig. 8)

**Description:** Single valve preserved; shell solid, equivalve, inequilateral (1=1.9 cm, b=1.7 cm, Th = 3 mm). Umbo prosogyrate, more or less central; growth rings fine, concentric, closely spaced. Ventral margin well rounded, posterior and anterior margin almost identical, heterodontid dentition.

**Distribution :** Early Miocene (PGD-4), Late Early Miocene to Pleistocene (PGD-6).

**Remarks :** Five specimens, three from PGD-4 and two from PGD-6.

### Family Solenidae

#### Genus *Solen* Linne

*Solen* sp.  
(Pl. III, fig. 8)

**Description :** Both valves preserved. Shell straight, elongated, rectangular, more prominent towards the anterior side (1 = 3 cm, h = 8 mm, Th = 6 mm); dorsal

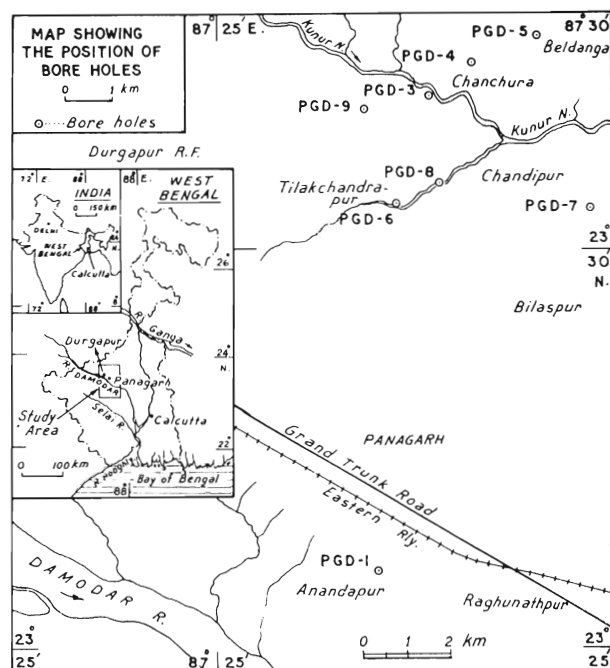


Fig. 1. Map showing the area of investigation.

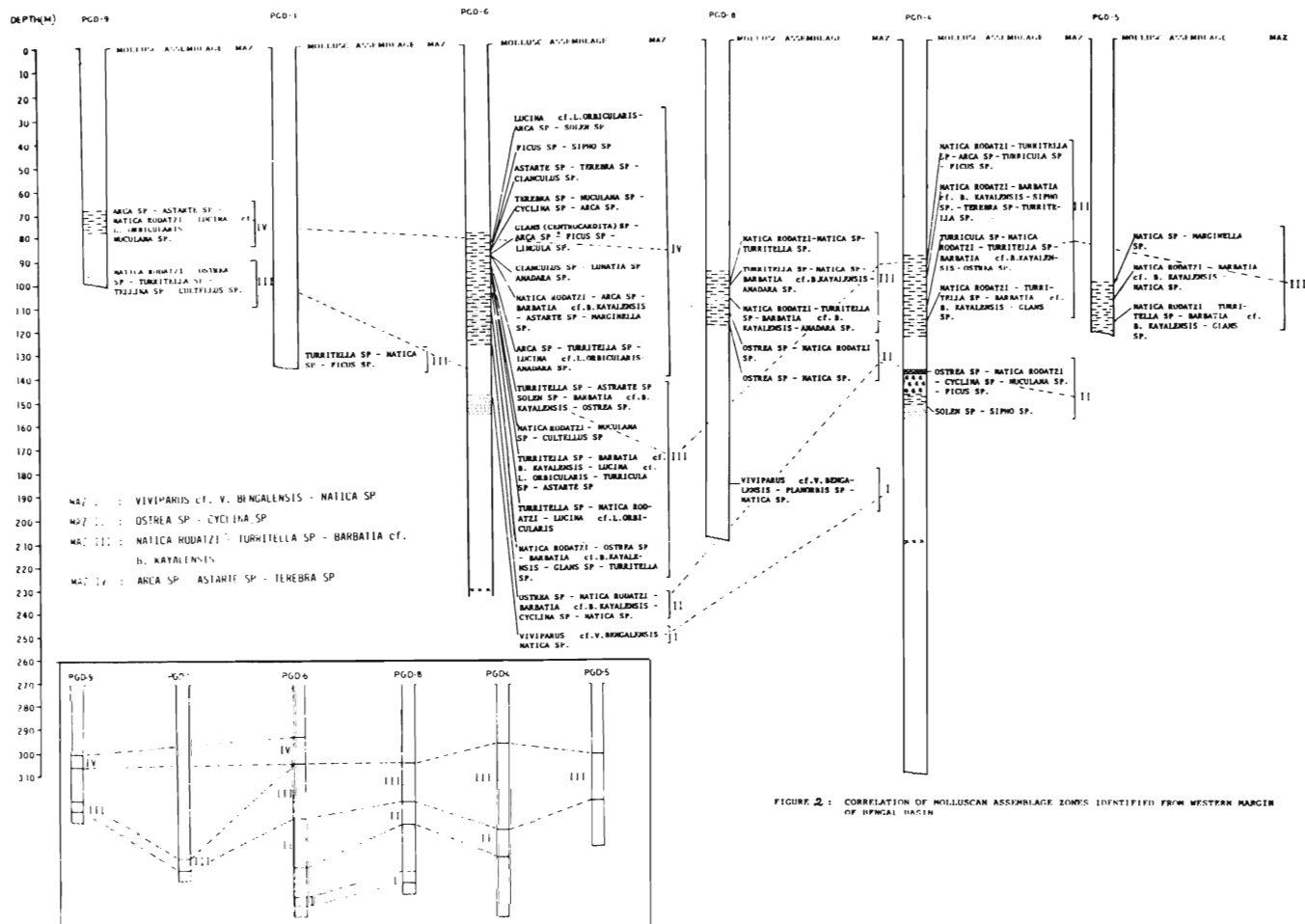


FIGURE 2 : CORRELATION OF MOLLUSCAN ASSEMBLAGE ZONES IDENTIFIED FROM WESTERN MARGIN OF BENGAL BASIN

Fig. 2. Correlation of molluscan assemblage zones recovered from western Bengal Basin.

margin nearly straight, ventral margin slightly umbo; umbo nearly terminal and continuous with the dorsal surface.

**Distribution:** Early Miocene (PGD-4), Late Early Miocene to Pleistocene (PGD-6,9).

**Remarks:** 3 specimens from PGD-6 and one from PGD-4. Early growth stages observed. Suspension feeder and active burrower in inshore fine sands.

#### Genus *Cultellus*

*Cultellus* sp.  
(Pl. III, fig. 2)

**Description:** Shell almost straight, elongated, having moderate size ( $l = 4.3$  cm;  $b = 1.2$  cm), very thin (0.5-1 mm); shell equivalve, long and narrow, umbo terminal, flattened.

**Distribution:** Miocene of Qilon, Kerala, India, Late Early Miocene to Pleistocene (PGD-6,9).

**Remarks:** One valve preserved; only two specimens are recovered from PGD-6.

#### Family Astartidae

#### Genus *Astarte*

*Astarte* sp.  
(Pl. I, fig. 7)

**Description:** Single valve preserved ( $l = 1.4$  cm,  $b = 1.3$  cm,  $Th = 0.5$  mm), trigono-rounded, moderately inflated. Posterior side truncated little and slightly extended than anterior. Umbo gently prosogyrate, strongly concentric.

**Distribution:** Late Early Miocene to Pleistocene (PGD-6,9).





**Remarks:** Twelve specimens, nine from PGD-6, two from PGD-4 and one from PGD-9, mostly juvenile.

#### Family Lucinidae

#### Genus *Lucina* Bruguiere

*Lucina* cf. *L. orbicularis* Desh. 1836  
(Pl. I, fig. 6)

**Description:** Single valve preserved ( $l = 4$  mm,  $b = 3$  mm,  $Th = 0.5$  mm), Shell rounded, equivalve, hinge with two cardinals and two laterals in each valve.

AGE	PLANKTONIC FORAMINIFERAL ZONE (PFZ)	BENGAL BASIN PALYNOSTRATIGRAPHIC ENVIRONMENT ZONE (Bb. PEZ)	LIT. HOLOGEN	CHARACTERISTIC MOLLUSCS	MOLLUSCAN ASSEMBLAGE ZONES (MAZ)	MAZ	ENVIRONMENT OF DEPOSITION
LATE EARLY MIOCENE TO PLEISTOCENE	PFZ-II: <i>Globigerina angustiumbilicata</i> - <i>Globigerina scitula</i>	Bb. PEZ-V		<i>Arca</i> sp., <i>Astarte</i> sp., <i>Terebra</i> sp., <i>Lingula</i> sp., <i>Ficus</i> sp., <i>Lunatia</i> sp., <i>Clanculus</i> sp.	<i>Arca</i> sp. — <i>Astarte</i> sp. — <i>Terebra</i> sp.	IV	NEAR SHORE SHALLOW MARINE
		Bb. PEZ-IV		<i>Natica rodatzii</i> , <i>Turritella</i> sp., <i>Barbatia</i> cf. <i>B. Kayalensis</i> , <i>Lucina</i> cf. <i>L. Orbicularis</i>	<i>Natica rodatzii</i> — <i>Turritella</i> sp. — <i>Barbatia</i> cf. <i>B. Kayalensis</i>	III	
EARLY MIOCENE	PFZ-I: <i>Globorotalia opima opima</i> — <i>Globigerinoides quadrilobatus primordius</i>	Bb. PEZ-III		<i>Ostrea</i> sp., <i>Cyclina</i> sp., <i>Natica rodatzii</i> , <i>Barbatia</i> cf. <i>B. Kayalensis</i> , <i>Tellina</i> sp.	<i>Ostrea</i> sp. — <i>Cyclina</i> sp.	II	DELTAIC
OLIGOCENE	Foraminifera absent	Bb. PEZ-II		<i>Viviparus</i> cf. <i>V. Bengalensis</i> , <i>Natica</i> sp.	<i>Viviparus</i> cf. <i>V. Bengalensis</i> — <i>Natica</i> sp.	I	




 Silver grey mudstone and marl  
 White to dull clayey sandstone  
 Mottled clay

Fig. 2a. Molluscan assemblage zones and environment of deposition along stratigraphic succession in the western margin of Bengal Basin.

**Distribution:** Late Early Miocene to Pleistocene (PGD-4, 6, 9).

**Remarks:** Twelve specimens, eight from PGD-6, and two each from PGD-4 and PGD-9, mostly juvenile. Suspension feeder and active deep burrower.

**Family** Arcidae

**Genus** *Anadara* Gray

*Anadara* sp.  
(Pl. I, fig. 1)

**Description:** Shell small (l = 1.6 cm, h = 9 mm) moderately thick Th = 1.5 mm), strongly inflated, highest at the posterior end; umbo low, prosogyrate, leaving a median groove; anterior end short, rounded; posterior end vertically truncated. Close set crenate ribs present on the valve; cardinal area narrow; hinge line long; margin of the valve deeply fluted.

**Distribution:** Late Early Miocene to Pleistocene (PGD-4, 6, 8).

**Remarks:** Four specimens, three from PGD-6 and one from PGD-4; mostly single valves preserved; both the valves found preserved in PGD-6 at 92.00 m depth.

**Genus** *Barbatia* Gray

*Barbatia* cf. *B. kayalensis* Dey, 1962  
(Pl. I, fig. 3)

**Description:** Shell small (l = 1.4-1 cm; h = 0.8-1.1 cm; Th = 1.5-6 mm), transversely oval, inequilateral, moderately inflated; dorsal and ventral margin sub parallel, anterior margin somewhat rounded, posterior margin more strongly curved. Umbo prosogyrate; a vague median depression runs from the umbonal region to the ventral margin. Ornamentation imbricate, produced by the superposition of the concentric threads on the radial ribs and not uniform all over. Cardinal area narrow.

**Distribution:** Miocene of France; Miocene of Quilon, Kerala, India (Dey, 1962). Early Miocene (PGD-4), Late Early Miocene to Pleistocene (PGD-5, 6, 8).

**Remarks:** Ten specimens, seven from PGD-6 and three from PGD-4. Suspension feeder; byssate nestler among stones, branching coral.

**Genus** *Arca* Linne

*Arca* sp.  
(Pl. I, fig. 10)

**Description:** Shell small (l = 1.6-1.1 cm; b = 8.5-6.0 mm; h = 3-2.5 mm; Th = 0.5-1.0 mm), elongate, inequi-

lateral; anterior end inflated, posterior margin broadly keeled and compressed; umbo prosogyrate; a shallow median depression runs from umbonal region towards the ventral margin coinciding with the byssal gape; radial ornamentation consists of ribs of unequal size. The ribs are coarser, sharply sculptured and separated by slightly narrower furrows. The radial ribs are crossed by weak concentric threads; cardinal area wide; hinge long and straight.

*Distribution* : Miocene of Quilon beds, Kerala, India (Dey, 1962); Late Early Miocene to Pleistocene (PGD - 4, 6, 9).

*Remarks* : Twelve specimens, nine from PGD-6, two from PGD-4 and one from PGD-9.

#### Family Nuculanidae

##### Genus Nuculana Link

*Nuculana* sp.  
(Pl. I, fig. 2)

*Description* : Shell small (1 = 1.7-1.3 cm; b = 8-7 mm), thin (0.5-1 mm), inequilateral, dorsal and ventral margin subparallel, umbo prosogyrate; cardinal area narrow, hinge oblique.

*Distribution* : Miocene of Quilon, Kerala, India (Dey, 1962); Early Miocene (PGD-4), Late Early Miocene to Pleistocene (PGD-6,9).

*Remarks* : Five specimens, four from PGD-6 and one from PGD-4. At least 2 specimens were of juvenile stage. Deposit feeder, shallow burrower.

#### Family Ostreidae

##### Genus Ostrea Linne

*Ostrea* sp.  
(Pl. II, fig. 7; Pl. III, figs. 6-7)

*Description* : Gryphaeoid shaped valves, large (1 = 7.5-4.1 cm; b = 3.7-2.5 cm), shell thick (Th = 4-3 mm), fairly straight beaks, a nearly central adductor muscle scar that is circular to subcircular in shape; left valve hinge with an elongate central depression flanked by two raised ridges, shell gives a shiny appearance. Cardinal areas high and triangular.

*Distribution* : Miocene of Quilon. Early Miocene (PGD-4, 6, 8, 9).

*Remarks* : Eighteen specimens, six from PGD-6, two from PGD-8 and ten from PGD-9; mostly adult left valves. Suspension feeder; epifaunal cemented.

##### Genus Glans Megerle von Muhlfield

*Glans* (*Centrocardita*) sp.  
(Pl. II, fig. 4)

*Description* : One valve preserved; shell small (1 = 1.1 cm - 0.7 cm; b = 8 mm - 6 mm), moderately thick (Th = 1.5 - 1.0 mm). Radial ridges and furrows radiating from the umbo.

*Distribution* : Early Miocene (PGD-4), Late Early Miocene to Pleistocene (PGD-5,6).

*Remarks* : Eight specimens, one from PGD-4, five from PGD-6 and two from PGD-5; both juvenile and adult. Suspension feeder, shallow infaunal.

#### Family Naticidae

##### Genus Natica Scopoli

*Natica rodatzki* Schepman, 1900  
(Pl. II, fig. 1)

*Description* : Shell oblong, subglobose, deeply umbilicated; spire small (0.5 mm - 1 cm), last whorl large (2.5 mm - 1.8 cm); apex obtuse; last whorl slightly concave and striated at the suture, then rounded. Aperture semicircular, columellar margin. Thickly callously enamelled, with a copious central callosity, shell white.

*Distribution* : Miocene of Quilon, Kerala, India; Early Miocene (PGD-4,6), Late Early Miocene to Pleistocene (PGD-4, 5, 6, 8, 9).

*Remarks* : Its occurrence is of special interest since this is a rare species of which only a few specimens have so far been discovered living. Thirty eight specimens, twenty two from PGD-4, one from PGD-5, thirteen from PGD-6, two from PGD-9; mostly juvenile with a distinct series of growth.

*Natica* sp.  
(Pl. I, fig. 11)

*Description* : Shell subglobose having moderately devoted spire; total length 1 cm - 8 cm, length of the spire 4 mm - 2.5 mm, and that of body whorl 6.5-6.0 mm; breadth of the spire 2 mm and that of body whorl 0.5 mm, dextral, aperture oval (diam. 4 mm), suture canalliculate; umbilicus completely closed by semicircular umbilical callous.

*Distribution* : Oligocene (PGD-6), Early Miocene (PGD-4,6), Late Miocene to Pleistocene (PGD-1, 4, 5, 6, 8, 9).

*Remarks* : Fourteen specimens, two each from PGD-1, PGD-4, and PGD-5, four from PGD-6, three from PGD-8 and one from PGD-9; specimens with distinct growth stages.

#### Family Ficidae

##### Genus Ficus Roding

*Ficus* sp.  
(Pl. II, fig. 3)

Table 2: Generalised Lithostratigraphic Column of West Bengal (After Roy Barman, 1992).

AGE	GENERALISED LITHOLOGIC DESCRIPTION	LITHOSTRATIGRAPHIC UNITS WITH ENVIRONMENTS	
		SHELF FACIES	BASIN FACIES
RECENT - PLEISTOCENE PLIOCENE	Loose gravel, sand, silt Silt with minor sandstone, claystone, calcareous bands	BENGAL ALLUVIUM DEBAGRAM FORMATION	BENGAL ALLUVIUM RANAGHAT FORMATION
LATE	Siltstone, minor sandstone, Claystone	BL PANDUA FORMATION	BD MATLA FORMATION
MIOCENE MIDDLE EARLY	Siltstone, sandstone, carbona- ceous shale	BD SM DIAMOND HARBOUR FORMATION	BD SM
OLIGOCENE EARLY	Medium grained sandstone with sandstone, shale lignite lignite	BL BURDWAN FM. MEMARI FM. SM DN	
LATE	Calcareous shale	CO BL KOPILI FM BL SM	
EOCENE MIDDLE	Foraminiferal & algal limestone with interbedded sandstone	BL SM	
EARLY		SYLHET LIMESTONE	
LATE PALAEOCENE EARLY	Coarse-medium grained sandstone with lignite & coaly shale	JALANGI FORMATION CO	
LATE CRETACEOUS EARLY	Kaolinic sandstone shale	BL GHATAL FM. BOLPUR BL FORMATION ES CO	LEGEND CO = CONTINENTAL ES = ESTUARINE BL = BRACKISH LAGOONAL
PERMOCARBONIFEROUS	Basalt flows sand, shale Sand, shale, coal	RAJMAHAL TRAP PRE-TRAPPEANS GONDWANAS	BD = BRACKISH DELTAIC SM = SHALLOW MARINE DN = DEEPER, NERITIC
PRE CAMBRIAN	Gneiss with dolerite, sills & dykes	BASEMENT	

*Description* : Small (length of the shell 1.3 cm - 8 mm; length of the body whorl 7 mm - 1.0 cm and of spire 1.5 mm - 3 mm), lower abapical side broken, body inflated in two whorls; aperture not seen; both vertical and horizontal striations crossing each other; apical angle obtuse intersecting spiral and axial threads making the body whorl cancellate.

*Distribution* : Late Early Miocene to Pleistocene (PGD-1, 4, 6).

*Remarks* : Nine specimens, two from PGD-4, six from PGD-6 and one from PGD-9; juvenile and adult forms. Active predators in sand or on rocky shores.

*Family* Turritellide

*Genus* *Turritella* Lamarck

*Turritella* sp.  
(Pl. II, fig. 9)

*Description* : Shell conical, (1 = 9 mm - 3.5 cm, maximum breadth 3 mm - 1.5 cm), protoconch broken away, whorls flattened, probably 7-10 in number, increasing gradually in size; ornamentation consisting of spiral cords. Suture impressed the anterior slope of the sutural channel being much steeper than the posterior slope; other lip as shown by the growth lines antecurrent with a band situated on the posterior half of the whorl.

*Distribution*: Pliocene of Western Pakistan, Miocene of Quilon, India. Early Miocene and Late Early Miocene to Pleistocene (PGD-1, 4, 5, 6, 8, 9).

*Remarks*: Thirty nine specimens, seven from PGD-4, twenty six from PGD-6, five from PGD-8 and one from PGD-9; specimens with different growth stages. Algal browsers.

PGD-4

Depth in m.	92.60	101.0	115.0	121.0	139.34	155.22
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<i>Lucina</i> cf. <i>L. orbicularis</i>					R	
<i>Anadara</i> sp.			R			
<i>Glans</i> ( <i>Centrocardita</i> ) sp.						R
<i>Barbatia</i> cf. <i>B. kayalensis</i>		R		R		R
<i>Nuculana</i> sp.						R
<i>Arca</i> sp. C						
<i>Ostrea</i> sp.				R	R	R
<i>Cyclina</i> sp.					R	
<i>Solen</i> sp.						R
<i>Natica rodatzii</i>	C	A	C	C		R
<i>Natica</i> sp	R	R	R	R		R
<i>Turritella</i> sp.	C	T	C	R		
<i>Sipho</i> sp.		R	R	R		
<i>Ficus</i> sp.	R					R
<i>Terebra</i> sp.		R				
<i>Turricula</i> sp.	C		C			

*Solen* sp.

Depth in m.	92.60	101.0	115.0	121.0	139.34	155.22
Name of taxa						

*Natica rodatzki*

<i>Lucina</i> cf. <i>L. orbicularis</i>					R	
<i>Anadara</i> sp.			R			
<i>Glans</i> ( <i>Centrocardita</i> ) sp.						R
<i>Barbatia</i> cf. <i>B. kayalensis</i>		R		R		R
<i>Nuculana</i> sp.						R
<i>Arca</i> sp. C						
<i>Ostrea</i> sp.				R	R	R
<i>Cyclina</i> sp.					R	
<i>Solen</i> sp.						R
<i>Natica rodatzii</i>	C	A	C	C		R
<i>Natica</i> sp	R	R	R	R		R
<i>Turritella</i> sp.	C	T	C	R		
<i>Sipho</i> sp.		R	R	R		
<i>Ficus</i> sp.	R					R
<i>Terebra</i> sp.		R				
<i>Turricula</i> sp.	C		C			

89.20	92.0	92.60	95.45	98.0	103.0	113.20	126.0	149.0
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[illegible]

## PGD-8

Depth in m.	104.0	105.25	109.0	115.0	119.0	168.0
Name of taxa						
<i>Anadara</i> sp.		R	R			
<i>Barbatia</i> cf. <i>B. kayalensis</i>		C	C			
<i>Ostrea</i> sp.				C	A	
<i>Natica rodatzii</i>	C		C	R		
<i>Natica</i> sp.	R	A			C	R
<i>Turritella</i> sp.	R	A	C			
<i>Viviparus</i> cf. <i>V. bengalensis</i>						R
<i>Planorbis</i> sp.						R

## PGD-9

Depth in m.	69.35	96.20
Name of taxa		
<i>Lucina</i> cf. <i>L. orbicularis</i>		
<i>Arca</i> sp.	R	
<i>Nuculana</i> sp.	R	
<i>Astarte</i> sp.	R	
<i>Ostrea</i> sp.		C
<i>Solen</i> sp.	R	R
<i>Cultellus</i> sp.	R	
<i>Natica rodatzii</i>	R	C
<i>Natica</i> sp.	R	
<i>Tellina</i> sp.		R
<i>Turritella</i> sp.		R

**Family Marginellidae****Genus Marginella** Lamarck

*Marginella* sp.  
(Pl. II, fig. 9)

**Description :** Shell small (length of the shell 5 mm - 1.5 cm; spire 1 mm - 3 mm; body whorl 4 mm - 1.2 cm; Width 1.5 mm - 4 mm; height 1.5 mm - 4 mm), stout, cylindrical, with the periphery coinciding with the shoulder of the body whorl; base attenuated; spire short but distinct; aperture narrow, dilated anteriorly; outer lip broadly thickened with a strong marginal varix, compressed towards the middle; parietal wall calloused.

**Distribution :** Late Early Miocene to Pleistocene (PGD-5,6).

**Remarks :** Six specimens, one from PGD-1, three from PGD-5 and two from PGD-6.

**Family Terebridae****Genus Terebra** Bruguiere

*Terebra* sp.  
(Pl. II, fig. 8)

**Description :** Shell medium sized (length of the shell 1.9 cm breadth 1 mm - 3 mm) having 12 whorls, elongate, sutural band occupying about one third of the whorl and delimited by a shallow furrow; ornamentation consisting of sigmoid axial ribs with equally wide or slightly narrower interspaces; aperture wide, elongate, anteriorly emarginate with an angular canal at its posterior end. Columellar lip shining.

**Distribution :** Miocene of Quilon, Kerala, India. Late Early Miocene to Pleistocene (PGD-4,6).

**Remarks :** Eight specimens, six from PGD-6 and two from PGD-4. Active infaunal predator on annelids.

**Family Turridae****Genus Turricula** Schumacher

*Turricula* sp.  
(Pl. II, fig. 2)

**Description :** Shell small (total length 1.1 cm; length of the spire 2 mm and that of body whorl 9 mm); fusiform, spire elevated, height equal to that of its aperture and canal combined. Protoconch small, smooth, blunt, probably consisting of 2 whorls, subsequent whorls compressed at the suture, increasing rapidly in size; ornamented with both axial ribs and spiral lines; aperture lenticular, slightly oblique, parietal wall calloused.

**Distribution :** Miocene of Quilon, Kerala, India, Late Early Miocene to Pleistocene (PGD-4,6).

**Remarks :** Twelve specimens, eight from PGD-4, three from PGD-6 and one from PGD-9.

**Family Trochidae****Genus Clanculus** Montfort

*Clanculus* sp.  
(Pl. I, fig. 9)

**Description :** Shell globose (length of the shell 1.4 cm, breadth 8 mm, thickness 2 mm), umbilicate, spire conical, suture subcanaliculate, whorls convex, spirally lirate, bearing granules, last whorl rounded, sculptured with granulose ridges, those at the base widely separated by deep furrows; interspaces striated bearing delicate spiral threads; aperture oblique, sub tetragonal, umbilicus narrow, deep with a crenulate margin.

**Distribution :** Miocene of Quilon, Kerala, India; Late Early Miocene to Pleistocene (PGD-6).

**Remarks :** Four specimens are recovered from PGD-6.

**Family Viviparidae****Genus Viviparus** Jousseaume



*Viviparus* cf. *V. bengalensis* (Lamarck, 1882).  
(Pl. I, fig. 5)

**Description :** Shell small (total length 1.2 cm - 5 mm; length of the spire 5 mm - 2 mm; length of the body whorl 7 mm-3 mm); shell elevatedly conical, thin; whorls convex, smooth striated. Aperture oval (1 = 2 mm, b = 1.5 mm), suture impressed.

**Distribution :** Oligocene (PGD-6,8).

**Remarks :** Four specimens are recovered from PGD-6; fresh water.

**Family** *Limnaeidae*

**Genus** *Planorbis* Geoffroy

*Planorbis* sp.  
(Pl. I, fig. 4)

**Description :** Shell small (diameter 1.1 cm - 7 mm; height of the shell 1.5 mm - 1 mm), sinistral, spire flattened; aperture nearly oval to circular (diameter 1 mm); Ornament of growth lines only.

**Distribution :** Oligocene (PGD-8).

**Remarks :** Four specimens, three from PGD-6 and one from PGD-8; fresh water - quasi marine.

**Genus** *Sipho*

*Sipho* sp.  
(Pl. III, fig. 1)

**Description :** Shell small (length 8 mm, width 3.5 mm, height 2.5 mm; length of spire 3 mm and that of body whorl 5 mm), aperture oval (= 2 mm, b = 1 mm), dextral, suture canaliculate.

**Distribution :** Early Miocene, Late Early Miocene to Pleistocene (PGD-4,6).

**Remarks :** Nine specimens, six from PGD-4, one from PGD-6 and two from PGD-8.

**Genus** *Lunatia* Gray

*Lunatia* sp.  
(Pl. III, figs. 3-4)

**Description :** Shell small (length of the shell 7 mm, width 3 mm, height of the shell 2.5 mm), spire very small, body whorl larger in comparison to spire.

**Distribution :** Late Early Miocene to Pleistocene (PGD-6).

**Remarks :** Two specimens are recovered from PGD-6.

**Family** *Lingulidae*

**Genus** *Lingula* Bruguiere

*Lingula* sp.  
(Pl. II, fig. 6)

**Description :** Biconvex, more or less equivalve, tongue shaped (1 = 2.1 cm, b = 1.4 cm, Th = 1 mm), smooth external surface with delicate concentric growth lines; hinge line curved, hinge area absent. Shell composed of alternating chitinous and calcareous layers.

**Distribution :** Late Early Miocene to Pleistocene (PGD-6).

**Remarks :** Only two well preserved specimens are recovered from PGD-6. Normally this taxon indicates sea shore as it lives in a tube in the sand on the sea shore, usually found between tide marks or in shallow water not exceeding 31 metres.

Table 4 : Molluscan assemblage zones recovered from western margin of Bengal Basin, India.

Assemblage zone	Lithology	Type section with depth range in m.	Characteristic fauna	Remarks
MAZ IV: <i>Arca</i> sp. <i>Astarte</i> sp. <i>Terebra</i> sp.	Silver grey mudstone & marl	PGD-6 (92.0-83.5)	<i>Arca</i> sp.- <i>Astarte</i> sp. - <i>Terebra</i> sp. <i>Lingula</i> sp. - <i>Ficus</i> sp. - <i>Lunatia</i> sp. - <i>Clanculus</i> sp.	The brachiopod <i>Lingula</i> is represented in this zone
MAZ III: <i>Natica rodatzki</i> - <i>Turritella</i> sp. <i>Barbatia</i> cf. <i>B. kayalensis</i>		PGD-6 (113.20-92.0)	<i>Natica rodatzki</i> - <i>Turritella</i> sp. <i>Barbatia</i> cf. <i>B. kayalensis</i> - <i>Lucina</i> cf. <i>L. orbicularis</i>	
MAZ II: <i>Ostrea</i> sp.- <i>Cyclina</i> sp.		PGD-6 (126.0-113.20)	<i>Ostrea</i> sp. - <i>Cyclina</i> sp. - <i>Natica rodatzki</i> - <i>Barbatia</i> cf. <i>B. kayalensis</i> - <i>Tellina</i> sp.	
MAZ I: <i>Viviparus</i> cf. <i>V. bengalensis</i> - <i>Natica</i> sp.	Mottled clay	PGD-6 (149.0)	<i>Viviparus</i> cf. <i>V. bengalensis</i> - <i>Natica</i> sp.	

## MOLLUSCAN ASSEMBLAGES AND STRATIGRAPHIC ZONATIONS

Frequency count of the molluscan remains recovered from each of the six bore cores studied has identified distinct assemblage pattern (Table 3).

Correlation of the mollusc assemblages recovered from the six bore cores distinguishes four molluscan Assemblage Zones (MAZ) from older to younger sequence (fig. 2; Table 4) viz., - MAZ I *Viviparus* cf. *V. bengalensis* - *Natica* sp., MAZ II *Ostrea* sp. - *Cyclina* sp., MAZ III *Natica rodatzii* - *Turritella* sp. - *Barbatia* cf. *B. kayalensis* and MAZ IV *Arca* sp. - *Astarte* sp. - *Terebra* sp.

The criteria followed for distinguishing the assemblages in the individual bore cores and comprehensive assemblage zones are from bottom to top:

- i) First occurrence of *Natica* sp., dominant and restricted occurrence of *Viviparus* cf. *V. bengalensis* (MAZ I).
- ii) First occurrence and significant occurrence of *Ostrea* sp. and *Cyclina* sp. (MAZ II).
- iii) Dominant occurrence of *Natica rodatzii*, first occurrence and subdominance of *Turritella* sp., consistent occurrence of *Barbatia* cf. *B. kayalensis* (MAZ III).
- iv) First occurrence and dominance of *Arca* sp., subdominance of *Astarte* sp. and restricted occurrence of *Terebra* sp. (MAZ IV).

## ENVIRONMENT AND AGE OF THE MOLLUSCAN ASSEMBLAGE ZONES

Most of the molluscan remains appear to be autochthonous or parautochthonous, since most of delicate features such as protoconchs, outer lips and ribs are preserved. Some even show partial growth series with early juvenile individuals.

Habitat of the present faunule ranges from brackish water mixed fresh water to nearshore shallow marine environment at different levels of the stratigraphic succession. Based on the bathymetry of extant molluscan genera (Squires, 1984) the present faunule is suggested to have inhabited in the transition zone (in 10-45 m depth of present-day seas). *Barbatia* and *Turritella* are the common forms inhabiting this zone (Squires, 1984). The deposits containing *Arca* and *Astarte* extend to somewhat deeper regions. The occurrence of *Ostrea* in the assemblage may indicate a tidal flat environment. Jackson (1970) suggested that neotropical lucinoids (in the present faunule represented by *Lucina* cf. *L. orbicularis*) are dominant in nearshore areas. The brachiopod *Lingula* usually occurs between tide marks or in shallow water not exceeding 31 metres (Shipley and Reed, 1959). The occurrence of *Viviparus* and *Planorbis* associated

with brackish *Natica* is indicative of a continental marginal area of deposition.

The molluscan assemblage suggests a tropical to subtropical climate (Jackson, 1970; Hertlein and Grant, 1972; Squires, 1984). But the abundance of *Natica* (in MAZ III) indicates the presence of cool water and suggests the possible occurrence of upwelling cool water (Preston, 1915).

The taxa identified in the present study have long stratigraphical ranges and most of them are still surviving. The age of the molluscan assemblages is constrained by the identification of planktic foraminiferal zones (PFZ I and PFZ II) from the same bore core sediments (Bera *et al.*, 1995). Palynostratigraphic zones (Bera, 1995) recovered from the same sediments are also considered for environment analysis (fig. 2a) of the Molluscan zones.

The oldest MAZ I *Viviparus* cf. *V. bengalensis* - *Natica* sp. is a fresh water assemblage with few brackish water taxa, viz., *Natica* sp., and indicates a back swamp environment. This molluscan zone reflects identical depositional environment as the palynostratigraphic environment zone Bn. PEZ II *Graminidites media* - *Margocolporites oligobrochatus* - *Meyeripollis naharkotensis* - *Dicopolopollis elegans* - *Pediastrum boryanum*. On the basis of palynostratigraphy, the age of MAZ I is considered as Oligocene (Burdwan Formation).

Molluscan assemblage MAZ II *Ostrea* sp. - *Cyclina* sp. of tidal mud flat environment is recovered from the sediments of Planktic microforaminiferal zone PFZ I *Globorotalia opima opima* *Globigerinoides quadrilobatus primordius* of Early Miocene age. Bn. PEZ III *Veryhachium magnum* - *Tricolpites reticulatus* - *Palaeosantalaceapites minutus* - *Pinuspollenites* sp. *Polypodiisporites usmensis* of the same age records a transgressional phase of deposition.

The subsequent molluscan zone MAZ III *Natica rodatzii* - *Turritella* sp. - *Barbatia* cf. *B. kayalensis* reveals comparatively more marine influence and compares well with the environment inferred from palynoassemblage study in Bn. PEZ IV *Palmaepollenites keralensis* - *Araliaceipollenites reticulatus* - *Pterospermella* sp. - *Palaeocirrenalia elegans* - *Callimothallus pertusus*.

MAZ IV *Arca* sp. - *Astarte* sp. - *Terebra* sp. with representatives of shallow marine forms viz., *Arca* sp. *Astarte* sp. is recorded as the youngest zone. Bn. PEZ V *Polysphaeridium granulosum* - *Operculodinium* sp. cf. *O. centroporum* - *Cleistosphaeridium cephalum* - *Cordosphaeridium fibrospinosum* - *Zonocostites indicus* of the corresponding sediment is distinguished for remarkable marine representation. Both MAZ III and MAZ IV correspond well with PFZ II *Globigerina angustiumbilitata* - *Globigerina scitula* and are assigned to Late Early Miocene - Pleistocene age.

The molluscan assemblages of MAZ III and IV are closely comparable to the Miocene molluscan assemblages of Quilon, Kerala (Dey, 1962). The taxa of MAZ II show close resemblance to *Ostrea* rich Miocene molluscan assemblages of Baripada, Orissa (Eames, 1936, Sarma, 1957; Mohanti, M. 1966; Bhalla and Dev, 1975).

Mathur (1988) suggested that the Miocene Indopacific and Mediterranean mollusc faunas underwent independent evolution. Dey (1962) while discussing the molluscan assemblage from Quilon bed of Kerala, identified two Indopacific members viz., *Lucina orbicularis* and *Gouldia minima* and suggested a sudden but temporary invasion of Indopacific fauna into the Mediterranean during the Miocene. The occurrence of *Lucina* cf. *L. orbicularis* from MAZ III of Bengal Basin is noteworthy in this connection.

The molluscan assemblages recovered indicate a distinct change in facies of deposition (fig. 2a) from brackish water-mixed fresh water condition (MAZ I) through tidal flat condition (MAZ II) to shallow marine environment (MAZ III and MAZ IV) during Oligocene to Pleistocene in the western Bengal Basin.

## ACKNOWLEDGEMENTS

The authors are grateful to Sri S.K. Bandopadhyay, Ex-Director, Geological Survey of India for kindly providing the core samples and necessary information. Grateful acknowledgements are due to Prof. J.S. Pignatti for critically going through the manuscript and for valuable suggestions.

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**EXPLANATION OF PLATES****Plate I**

The graph units indicate scale; one small unit = 1 mm.

1. *Anadara* sp. (PGD-8/MR37)
2. *Nuculana* sp. (PGD-6/MR83)
3. *Barbatia* cf. *B. kayalensis* (PGD-5/MR6)
4. *Planorbis* sp. (PGD-8/MR4)
5. *Viviparus* cf. *V. bengalensis* (PGD-8/MR2)
6. *Lucina* cf. *L. orbicularis* (PGD-6/MR52)
7. *Astarte* sp. (PGD-6/MR16)
8. *Cyclina* sp. (PGD-6/MR5)
9. *Clanculus* sp. (PGD-6/MR107)
10. *Arca* sp. (PGD-6/MR139)
11. *Natica* sp. (PGD-8/MR35)

**Plate II**

The graph units indicate scale; one small unit = 1 mm.

1. *Natica rodatzki* (PGD-4/MR58)
2. *Turricula* sp. (PGD-4/MR23)
3. *Ficus* sp. (PGD-6/MR23)
4. *Glans* (*Centrocardita*) sp. (PGD-5/MR4)
5. *Tellina* sp. (PGD-9/MR2)
6. *Lingula* sp. (PGD-6/MR110)
7. *Ostrea* sp. (PGD-8/MR16)
8. *Terebra* sp. (PGD-6/MR118)
9. *Marginella* sp. (PGD-5/MR15)

**Plate III**

The graph units indicate scale; one small unit = 1 mm.

1. *Sipho* sp. (PGD-4/MR1)
2. *Cultellus* sp. (PGD-6/MR58)
3. *Lunatia* sp. (PGD-6/MR103)
4. *Lunatia* sp. (PGD-6/MR103)
5. *Natica* sp. (PGD-6/MR30)
6. *Ostrea* sp. (PGD-9/MR12)
7. *Ostrea* sp. (PGD-9/MR12)
8. *Solen* sp. (PGD-9/MR23)
9. *Turritella* sp. (PGD-6/MR41)

