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Article

A study on the vertical distribution of marsh foraminifera from the Sunderbans, India

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ABSTRACT

The Sunderban delta is the largest delta in the world, fed by the Ganga and the Brahmaputra rivers. Geologically, the area results from extensive fluvio-marine deposits of these two mighty rivers at the junction of the terrestrial and the marine realms. Foraminifer, a marine protozoan, is abundantly found in the epipelagic and benthic regions of most marine environments. These unicellular organisms are excellent tools for studying palaeoecology, biostratigraphy, and palaeoenvironments. Two short cores have been studied from the Sunderban regions. A total of seventeen different species have been identified, including both calcareous and agglutinated forms. The dominant taxa are *Ammonia tepida*, *Cribroelphdium poeynum*, *Haplophragmoides wilberti* and *Quinqueloculina seminulum*. The studied area has low diversity assemblages with a dominance of calcareous forms. Epifaunal forms decrease in number as we move down the core sections.

INTRODUCTION

Foraminifera are unicellular protists with a perforated chalky shell through which thin protrusions of the protoplasm extends. They are mostly marine and form thick ocean floor sediments when they die. Their ability to be extremely sensitive toward subtle environmental changes makes them perfect proxies for environmental monitoring. Foraminifera, as a group, exhibit broad ecological tolerance to salinity, depths, and temperatures of the ambient waters. Typical marsh foraminiferal assemblages help in identifying ancient tidal beds. During the last few decades, environmental change in estuarine and coastal areas has increased, and foraminiferal assemblages in many places of the world have markedly changed (Yanko et al. 1999). Some works of foraminifera from the east coast of India comprises of Dey et al. 2012, Ghosh et al. 2014, Sen and Bhadury 2016, Tripathi et al. 2018 and Das et al. 2019. Recent foraminiferal assemblages from different environments contribute to gathering knowledge on the microhabitats of the group and also help in understanding the controlling biotic and abiotic factors for its growth and survival in the environment. Two short cores have been studied, one from Bally island (20 cm long) and another from Jharkhali island (10 cm long) from the Sunderban region. Taxonomical studies were done, along with some statistical analyses presented in this paper.

STUDY AREA

Bally island is an island of the Sunderban delta complex, located on the continental shelf of the Bay of Bengal, near about 100 km south of Kolkata. The GPS location of the core collected from this island is N 22° 08′ 29″ and E 88° 47′ 30″ (**Fig. 1**). Gosaba is one of the main deltaic islands in the Sunderban region, bounded by river Bidya in the west and rivers Gomar and Raimangal in the east. Bally island is located at Gosaba CD block in the Canning sub-division under South 24 Parganas district in West Bengal. Jharkhali is another island in the Sunderbans and the GPS location of the core collected from Jharkhali is N 22° 01′ 09″ and E 88° 44′ 22″. Jharkhali is in CD block in the Canning subdivision of the South 24 Parganas in West Bengal. Geologically, the Sunderbans result from extensive fluvio-marine deposits of the Ganges and the Bay of Bengal

(Mandal et al. 2009).

The deltaic morphology of these two islands is controlled mainly by rivers Matla and Bidyadhari (Mukhopadhyay et al. 2006). The silt brought down by the rivers Brahmaputra and Ganga from the Himalayas along with their network of tributaries deposited and formed the entire landmass of the area (Banerjee et al. 2012). Interaction between marine and freshwater in these regions plays an important role in the formation of the islands interspersed with numerous tidal creeks (Das et al. 2015). The Sunderbans host a wide range of flora, dominated by mangroves like *Avicennia* spp., *Aegialites* spp., *Bruguiera* spp., *Phoenix paludosa* and *Excoecaria agallocha*. The Sunderbans National Park reserves a variety of faunal assemblage. The Royal Bengal tigers occupy the dense forest areas. Fishing cats, leopard cats, macaques, marsh crocodiles, Indian grey mongoose are few representatives of the animal community. Black capped kingfishers, water hens, coots, pariah kites, marsh harriers, swamp partridges, cotton teals, seagulls are some of the common birds found from these regions. Mangrove ecosystems also supports smaller faunal assemblages like bivalves, gastropods, crabs, starfishes, skipping frogs, common toads and fishes.

Figure 1: Location map of the study area

MATERIALS AND METHODOLOGY

Two short core samples have been collected, one each from Bally Island and Jharkhali Island (**Fig.2**). A 20 cm long hollow tube (having a diameter of 5 cm) was pushed into the sediment with the help of a wooden hammer. Sediments around the tube were removed with the help of a trowel and the tube was removed by closing one end so that the sediments remain in position. After that, a solid wooden stand with a slightly less diameter than the hollow tube was pushed in slowly from one side of the tube. Sediment coming out from the other side of the tube was sliced after every 1 cm with the help of a trowel and collected in separate small boxes. Rose Bengal solution (2 grams Rose Bengal powder mixed uniformly in 1 litre ethanol) was added to the samples in order to distinguish live foraminifera from dead foraminifera.

Samples were processed in the "Foraminiferal Applications" laboratory in Calcutta University. A 63-micron brass sieve was used for samples processing. Sediment samples were placed directly on top of the sieve and washed off very gently with the help of running water. A fine and gentle spray of tap water was played upon the material and the sieve was shaken simultaneously to eradicate all the finer particles. The residue remaining back on top of the sieve comprised of the fine sand fraction which includes the size range of most foraminifera. The resulting clean sediments were oven dried at less than 50° C to avoid breakage of the fragile foraminiferal tests. The dried samples were stored in zip locks pouches. One gram of each sample was used for further studies.

Dried sediments were studied under the microscope on a micro-palaeontological tray. Foraminifera were picked with the help of a water moistened sable brush (000). The picked foraminifera were placed in 12-chambered slides. Foraminiferal identification and illustrations were done with a stereo zoom microscope (Magnüs MS24) in the Department of Geology, University of Calcutta; followed by a Scanning Electron Microscope (ZEISS EVO 18) in the Department of Geological Sciences, Jadavpur University. The foraminifera are housed in the "Foraminiferal Applications" laboratory, Department of Geology, University of Calcutta.

Core Number	Location Name	GPS co-ordinate	Core length
Core 1	Jharkhali Island	N 22° 01′ 09″ E 88° 44′ 22″	10 cm
Core 2	Bally Island	N 22° 08′ 29″ E 88° 47′ 30″	20 cm

Table 1: Core location details in Sunderbans marshes

Figure 2: Field photograph of sample collection from Jharkhali

RESULTS AND DISCUSSIONS

The foraminiferal assemblages comprises of both calcareous and agglutinated tests. A total of seventeen species have been identified. The calcareous forms that have been identified are *Ammonia tepida*, *Ammonia beccarii*, *Ammonia parkinsoniana*, *Cribroelphidium poeynum*, *Cribroelphidium decipiens*, *Haynesina germanica*, *Haynesina depressula*, *Quinqueloculina seminulum*, *Cocoarota madrasensis*, *Asterorotalia trispinosa*, *Bolivina advena*, *Brizalina singhi* and *Nonion commune*; whereas the agglutinated forms comprises of *Trochammina inflata*, *Haplophragmoides canariensis*, *Haplophragmoides wilberti* and *Miliammina fusca*. A new agglutinated foraminifera have been identified from this region, namely; *Srinivasania sundarbanensis* (Kaushik et al. 2021).

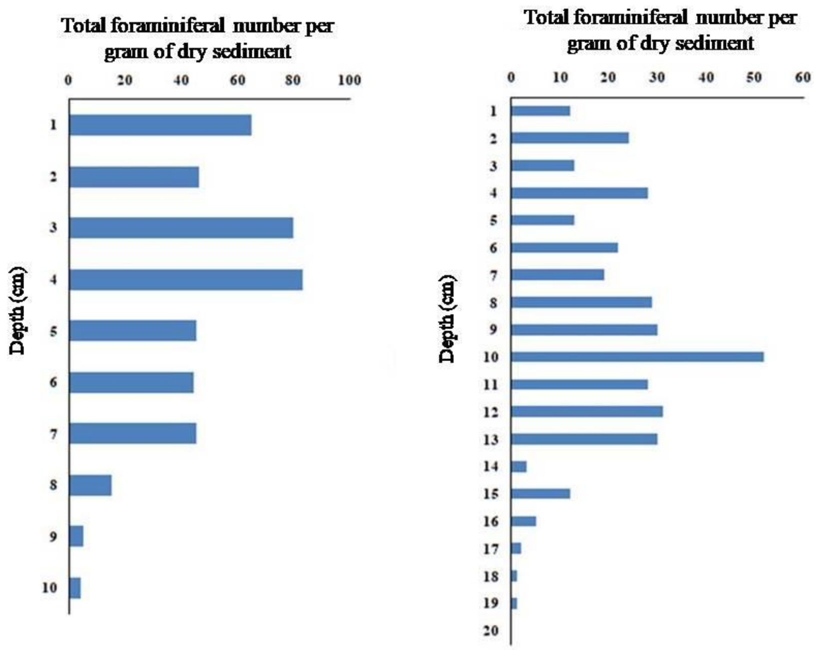

Figure 3: Variation of Total Foraminiferal Number (live + dead) with depth in Core 1 (on the left) and Core 2 (on the right)

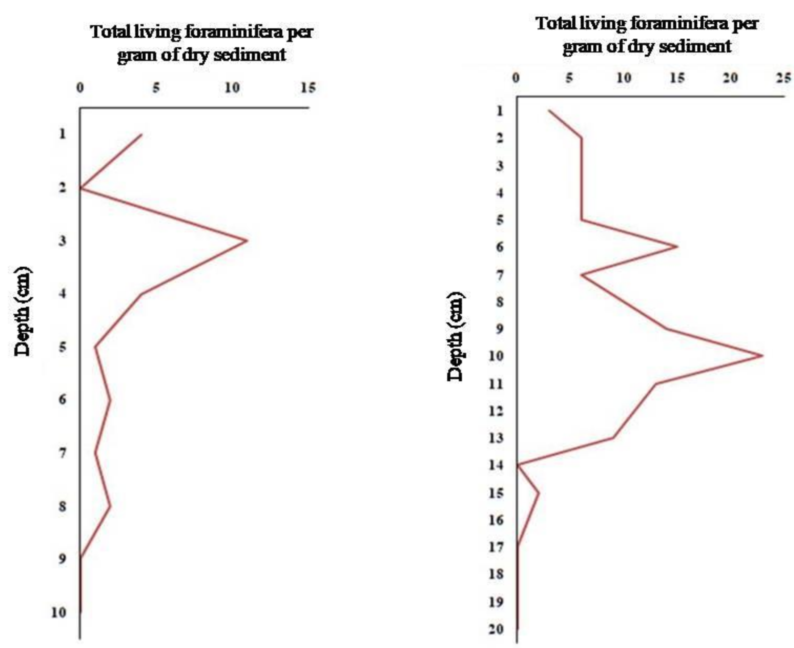

Figure 4: Variation of living foraminifera with depth in Core 1 (on the left) and Core 2 (on the right)

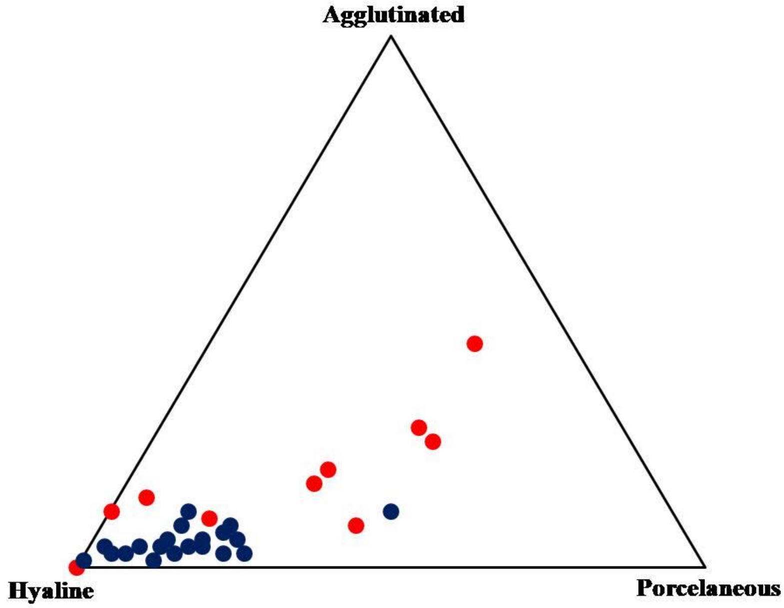

Figure 5: Ternary plot showing wall structures of foraminifera from the cores (red represents Core 1 and blue represents Core 2)

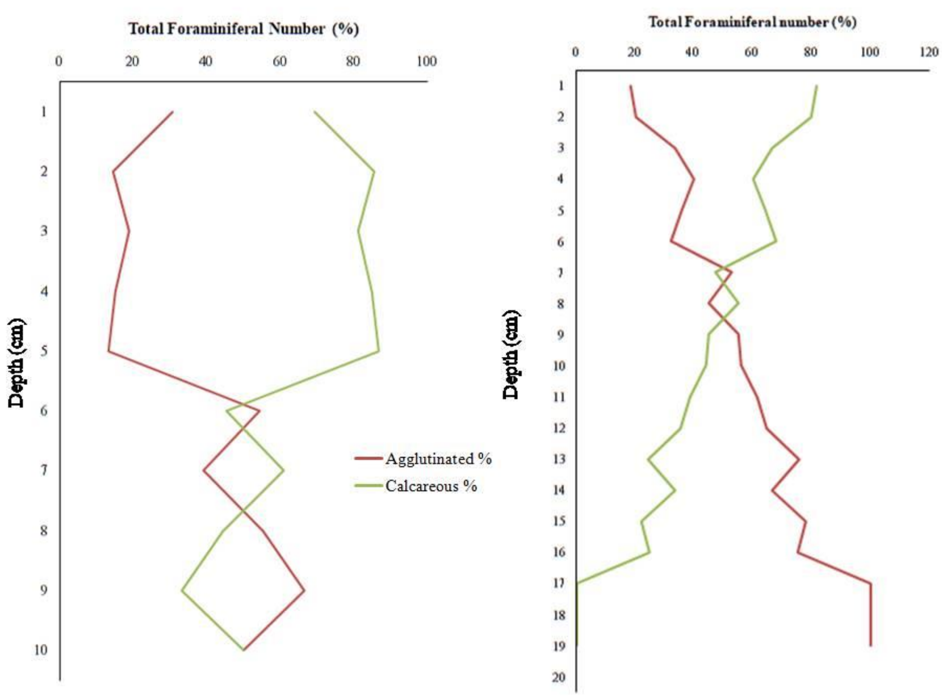

Figure 6: Variation of agglutinated and calcareous tests with depth

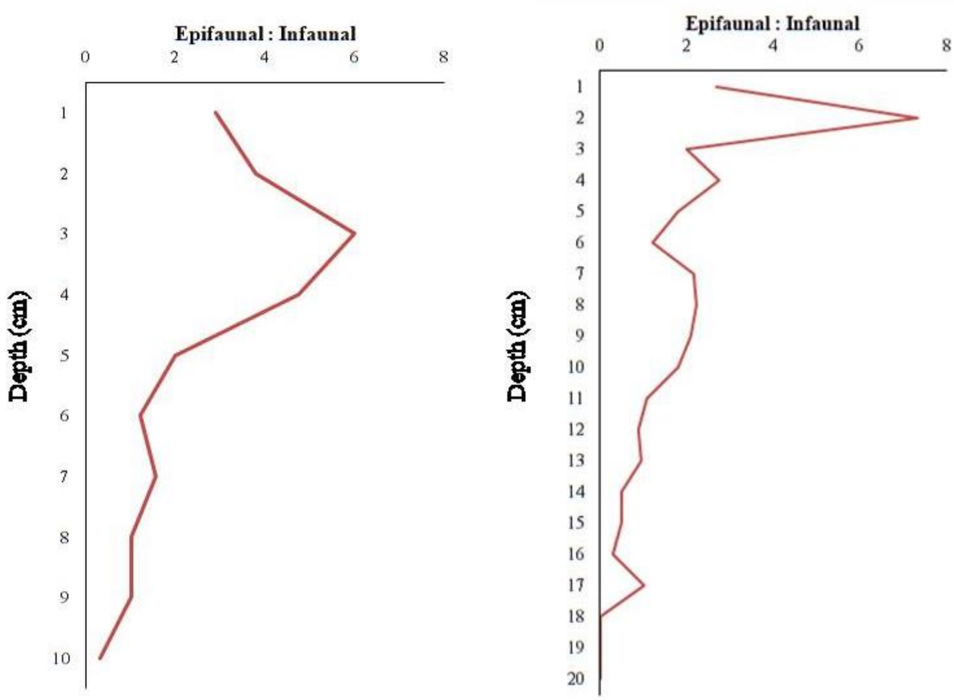

Figure 7: Variation of epifaunal and infaunal forms tests with depth

Variation of Total Foraminiferal Number with depth shows (**Fig. 3**) that there are surface and subsurface maxima present in both the cores. Core 1 shows subsurface maximum at 4 cm whereas Core 2 shows subsurface maximum at 10 cm. A similar trend is observed in the variation of living foraminifera down the cores (**Fig. 4**). Core 1 shows a subsurface maximum of living foraminifera at 3 cm whereas Core 2 shows a subsurface maximum of live foraminifera at 10 cm. This indicates that the nutrient content and dissolved oxygen amounts were favourable at the deeper depths for the survival of foraminifera (Alve and Murray 1994).

Murray's ternary plot shows the assemblages to lie mostly near to the calcareous hyaline region for both the cores (**Fig. 5**). Few depths in Core 1 show significant porcelaneous and agglutinated populations but Core 2 has very little abundance of these forms. The abundance of hyaline tests in the study area can be attributed to salinity conditions (30 to 35 ppm). Figure 6 shows the variation of agglutinated and calcareous forms with depth. It is observable that calcareous forms dominate the upper half of the cores whereas agglutinated forms dominate the lower part. **Figure 7** shows the variation of epifaunal and infaunal forms with depth. As expected, epifaunal forms are mostly present at the upper half of the cores whereas the lower part is occupied by infaunal forms (Sengupta 1993; 1999; 2002). The Shannon-Wiener diversity index was calculated for these assemblages using the PAST software. The values range between 0 to 1, thus indicating a low diversity.

In the present study, the generic classification of Foraminiferida as proposed by Loeblich and Tappan (1988) has been followed. The taxa were identified using the works of Barker (1960), Wells (1985), Kathal (2002), Nomura et al. (2002), Bhalla et al. (2007), Khare et al. (2007), Ghosh (2012), Dey et al. (2012), Ghosh et al. (2014), Das et al. (2019) and Dutta et al. (2021). All the identified species have been illustrated in the Plates.

Serial Number	Genus	Species	Occurrence depths
1	*Ammonia* Brünnich 1772	*Ammonia beccarii* Linnaeus, 1758 (Plate A, Figures 11 and 12)	Found mostly in the top 7 centimetres of the core sections
2	*Ammonia* Brünnich 1772	*Ammonia parkinsoniana*d' Orbigny, 1839 (Plate A, Figures 9 and 10)	Pervasive throughout the vertical sections
3	*Ammonia* Brünnich 1772	*Ammonia tepida* Cushman 1926 (Plate A, Figures 7 and 8)	Found throughout the core sections
4	*Asterorotalia* Hofker 1950	*Asterorotaliatrispinosa* – *Rotaliatrispinosa*Thalmann 1933	Found mostly in the top 10 centimetres of the core

		(Plate B, Figures 6 and 7)	sections
5	*Bolivina* d' Orbigny 1839	*Bolivinaadvena* Cushman, 1925 (Plate B, Figure 8)	Restricted in the bottom 5 centimetres of the core sections
6	*Brizalina* Costa 1856	*Brizalinasinghi* Singh, Jauhari and Vimal, 1976 (Plate B, Figure 10)	Restricted in the bottom 4 centimetres of the core sections
7	*Cocoarota* Loeblich and Tappan 1986	*Cocoarotamadrasensis* Rao and Revets, 2001(Plate B, Figure 5)	Found mostly in the top 8 centimetres of the core sections
8	*Cribroelphidium* Cushman and Brönnimann 1948	*Cribroelphidiumdecipiens* Costa, 1856 (Plate B, Figure 2)	Found mostly in the top 4 centimetres of the core sections
9	*Cribroelphidium* Cushman and Brönnimann 1948	*Cribroelphidium poeynum* – *Polystomella poeynum* d' Orbigny 1839 (Plate B, Figure 1)	Ubiquitous throughout the vertical sections
10	*Haplophragmoides* Cushman 1920	*Haplophragmoideswilberti* Andersen 1953 (Plate A, Figure 2)	Pervasive throughout the core sections
11	*Haplophragmoides* Cushman 1920	*Haplophragmoidescanariensis* d' Orbigny, 1839 (Plate A, Figure 1)	Found throughout the core sections
12	*Haynesina* Banner and Culver 1978	*Haynesina depressula* Walker and Jacob 1798 (Plate B, Figure 3)	Ubiquitous throughout the vertical sections
13	*Haynesina* Banner and Culver 1978	*Haynesina germanica* Ehrenberg 1840 (Plate B, Figure 4)	Found all throughout the vertical sections
14	*Miliammina* Heron-Allen and Earland 1930	*Miliammina fusca* – *Quinqueloculina fusca* Brady 1870 (Plate A, Figure 5)	Restricted in the bottom 10 centimetres of the core sections
15	*Nonion* Montfort 1808	*Nonion commune* d' Orbigny 1846 (Plate B, Figure 9)	Found mostly in the top 4 centimetres of the core sections
16	*Quinqueloculina* d' Orbigny 1826	*Quinqueloculina seminulum* Cushman 1944 (Plate A, Figure 6)	Restricted in the bottom half of the core sections
17	*Trochammina* Parker and Jones 1859	*Trochammina inflata* Montagu 1808 (Plate A, Figures 3 and 4)	Found all throughout the vertical sections

Table 2: Depth distribution of the species in the core sections

CONCLUSIONS

1. Seventeen foraminiferal species have been identified belonging to families Miliolids, Elphidids and Rotalids.
2. *Ammonia tepida* is the most abundant species amongst all the identified species, in both the cores. It is indicative of a low energy environment with high clay content.
3. Both the cores show more abundance of agglutinated species at the bottom and calcareous species on the top; which might be indicative of a change in environmental conditions.
4. The overall assemblage has mostly calcareous hyaline tests, with low occurrence of agglutinated and porcelaneous tests.
5. Both the cores show a downcore maximum in both the Total Foraminiferal Number and the Total living foraminiferal number, which might be attributed to nutrients and dissolved oxygen availability.
6. Low diversity of foraminifera recorded in this region indicates a stressed environment.

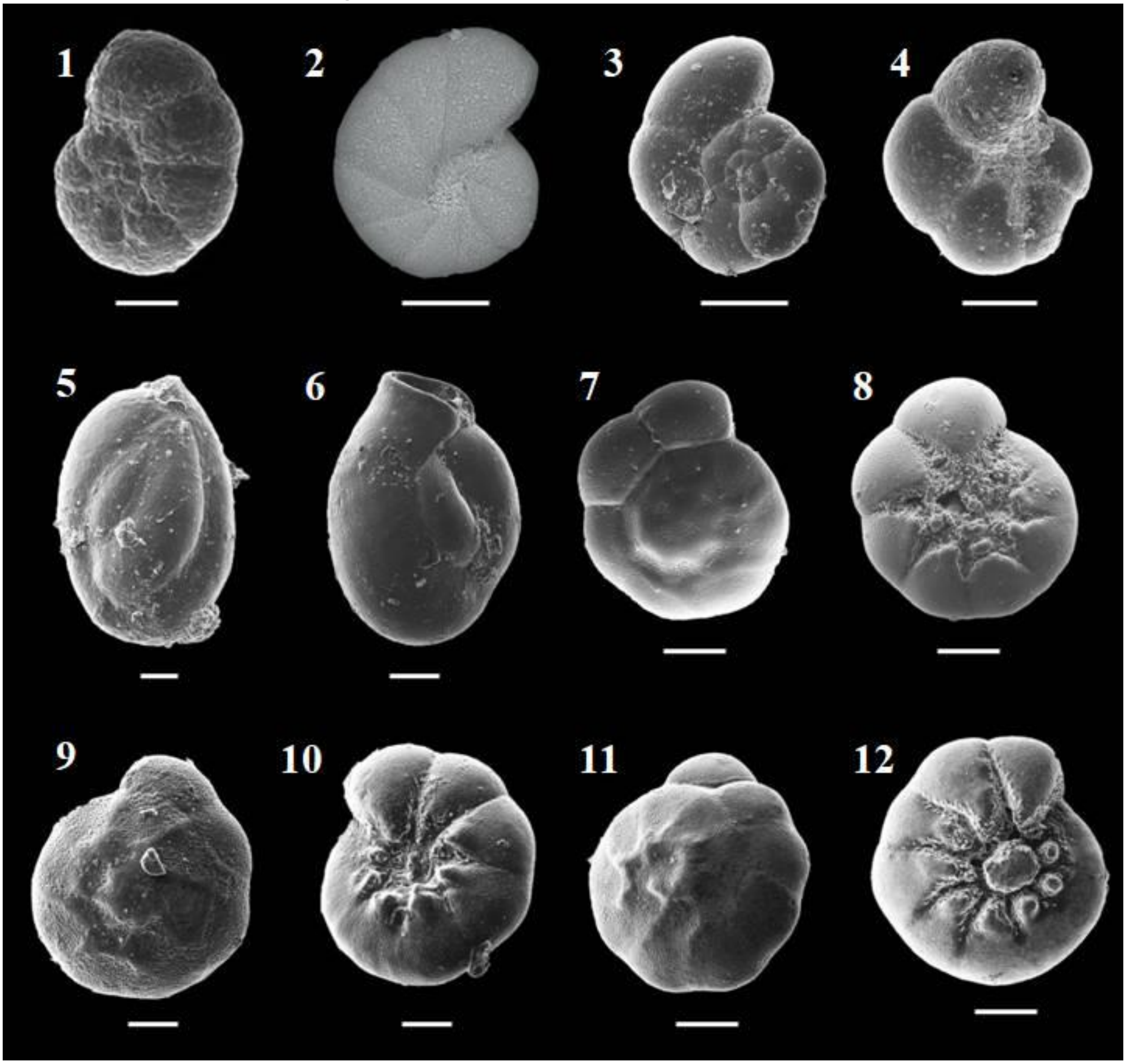

Plate A : 1 – *Haplophragmoides canariensis* (U); 2 – *Haplophragmoides wilberti* (U); 3 – *Trochammina inflata* (S); 4 – *Trochammina inflata* (U); 5 – *Miliammina fusca* (Si); 6 – *Quinqueloculina seminulum* (Si); 7 – *Ammonia tepida* (S); 8 – *Ammonia tepida* (U); 9 – *Ammonia parkinsoniana* (S); 10 – *Ammonia parkinsoniana* (U); 11 – *Ammonia beccarii* (S); 12 – *Ammonia beccarii* (U)
Legends: U – Umbilical view; S – Spiral view, Si – Side view.
All scale bars represent 100 µm.

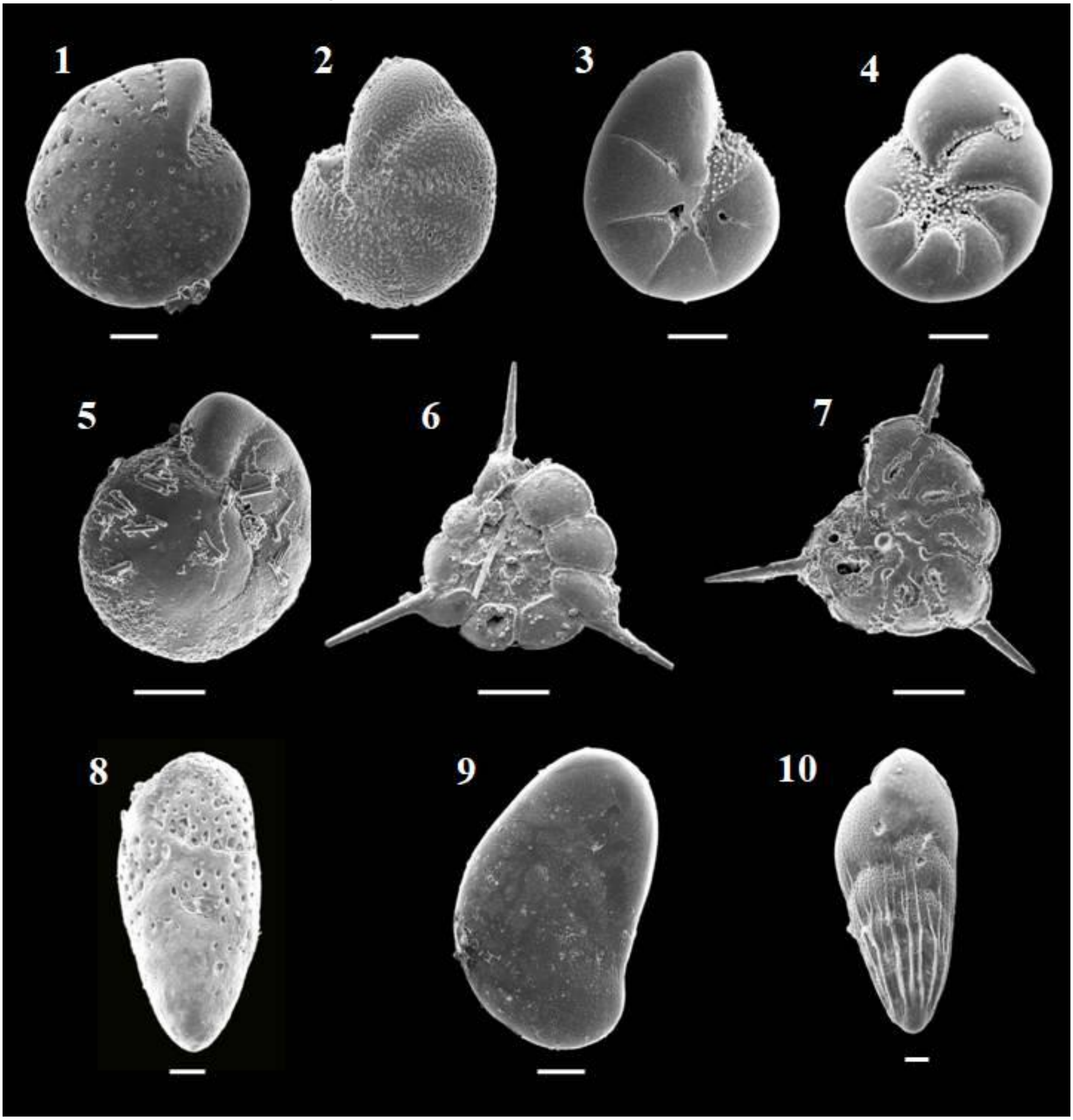

Plate B : 1 – *Cribroelphidium poeynum* (U); 2 – *Cribroelphidium decipiens* (U); 3 – *Haynesina depressula* (U); 4 – *Haynesina germanica* (U); 5 – *Cocoarota madrasensis* (U); 6 – *Asterorotalia trispinosa* (S); 7 – *Asterorotalia trispinosa* (U); 8 – *Bolivina advena* (Si); 9 – *Nonion commune* (U); 10 – *Brizalina singhi* (Si)
Legends: U – Umbilical view; S – Spiral view, Si – Side view.
All scale bars represent 100 µm.

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