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Systematic paleontology of some rare deep-sea benthic foraminiferafrom the Bay of Bengal

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Abstract

Studies on the taxonomy of deep-sea foraminifera from the Bay of Bengal are relatively limited compared to other environments such as the littoral zone and continental shelf. The present study reports the systematic paleontology of some rarely recorded benthic foraminiferal species identified from a 6.18 m long deep-sea retrieved from the Bay of Bengal at a water depth of 2,591 m. Most of the taxa reported here are illustrated by SEM photographs and their ecology, distribution and bathymetry were discussed based on previous literature. To our knowledge, *Martinottiella omnia* Saidova 1975 is recorded for the first time from Indian waters.

Keywords: Bathymetry, Bay of Bengal, Benthic foraminifera, Deep-sea Taxonomy.

Introduction

Deep sea foraminifers have always evoked considerable interest among micropaleontologists for their diverse applications, particularly in inferring paleoclimatic, paleoceanographic and paleoenvironmental changes in the recent to geological past. A variety of environmental and sedimentological factors have been proposed to explain the distribution of deep-sea benthic foraminifera, ranging from bottom water mass properties such as temperature, salinity, dissolved oxygen content, carbonate ion concentration, availability of food, and organic matter influx to the sea floor.

Modern deep sea foraminiferal assemblages include many fragile monothalamous (single-chambered) forms and komokiaceans (a superfamily of protist currently placed within the foraminifera) with soft test walls. These groups are poorly known and most of the hundreds of morphospecies recognized in deep-sea samples are undescribed. The relative abundance of robust and fragile taxa varies with water depth and food supply. Calcareous and other hard-shelled species tend to predominate in relatively eutrophic areas, particularly on continental margins,but decrease as a proportion of the 'entire' live fauna (i.e. including soft-shelled species) with increasing water depth, even above the carbonate compensation depth. Most of the species on which the foraminiferal proxies used in palaeoceanography are based live in these bathyal regions (Gooday *et al*. 2008).

Deep sea foraminiferal studies in India

Studies on recent foraminifers in the Indian region were initiated by Chapman (1895) who reported 274 species from the *Investigator* collections made off the Laccadives, in the Arabian Sea. Later, a monograph of foraminifers from the Arabian Sea was published by Hofker (1930). According to Rai and Srinivasan (1994), who made an attempt to understand the Pleistocene bottom water history in response to paleoclimatic changes in the northern Indian Ocean using quantitative analyses of deep-sea benthic foraminifera at two DSDPsites, *Uvigerina proboscidea* was the most dominant species during the Pleistocene at both sites. The study stated that the lower depth range for the occurrence of *Bulimina aculeata* in the Indian Ocean is 2,300 m, similar to that of many other areas.

Naidu and Malmgren (1995) discussed the possibility of whether benthic foraminiferal records represent a productivity index in OMZ areas. Thestudy reported that benthic foraminifer accumulation rates (BFAR) and benthic to planktic foraminifer ratios (B/P) did not record surface-water productivity signal in the intense upwelling and OMZ along the Oman Margin. Also, speculated that dissolved oxygen concentrations might instead be controlling the benthic foraminifer abundance.

Benthic foraminifera were quantified by den Dulk *et al*. (2000) in two sediment cores from a topographic high (Murray Ridge) in the northern Arabian Sea. One core was from a station within the present-day OMZ, while the other was from a station below the OMZ. The study suggested that percentages of miliolids could be used for rapid reconstruction of periods of increased ventilation in the northern Arabian Sea and is a promising proxy for tracing changes in bottom and pore water oxygenation. However, they opined that the benthic foraminiferal accumulation rates cannot be used as a proxy for surface water productivity under the prevalence of severe dysoxia.

Chowdhury *et al*. (2003) studied the composition, content and distribution of planktic foraminifera from 65 samples taken by piston and gravity cores from the continental shelf and slope areas of the northern Bay of Bengal and the middle Bengal Fan. Nearly 26 taxa were identified and observed that *Globoquadrina conglomerata* and *Globorotaloides hexagona*, known to have disappeared from the Atlantic Ocean 50,000 to 100,000 years ago, were present in the sediments from the outer shelf and slope areas. Downcore distributionindicated that only 4 to 5 species, namely, *Globigerinoides quadrilobatus*, *Gs. ruber*, *Gs. sacculifer*, *Globigernella aequilateralis* and *Neogloboquadrina dutertrei*, constituted 65 to 90% of the total planktic foraminiferal composition. Moreover, the specific prevalence of *Globigerina bulloides* in the inner shelf, *Orbulina universa* in the slope and in the fan, and *Globorotalia (Menardella) menardii* in the outer shelf and beyond was noted.

A total of 128 surface sediment samples (76 grab and 52 core top samples) were analyzed for benthic foraminiferal contents from the region off Goa in the eastern Arabian Sea up to a water depth of 3,300 m and identified 195 species from the samples(Mazumder *et al*., 2003). Species belonging to *Bolivina*, *Cassidulina*, *Lernella*, *Uvigerina* and *Eponides* were found to be the most abundant within the depth zone of 150 to 1,500 m, a zone considered to be the OMZ for the Arabian Sea. A comparison of benthic foraminiferal species abundance in the OMZ of Arabian Sea with other parts of the world oceans revealed that *Bulimina marginata*, reported to be present in considerable numbers within the OMZ in other regions of the world oceans, accounted for only about 2% of the total benthic foraminiferal population in this region. On the contrary, *Bulimina costata* constituted >15% of the total populations, confirming the characteristic nature of the OMZ in the eastern Arabian Sea.

Ammolagena clavata (Jones and Parker 1860), an agglutinated benthic foraminiferal species, was reported for the first time from sediments of the Arabian Sea (Nigam *et al*. 2004). The occurrence of this species in the depth range of 1,650-2,050 m, is comparable with the depth range of 684-2,503 m in the Pacific Ocean and 553-4,500 m in the Atlantic regions. Although earlier reports had indicated its presence as attached specimens, either on large quartz grains or on some other larger benthic foraminiferal species, they found this taxon to be attached to tests of the planktic foraminifer, *G. menardii.*

Heinz and Hemleben (2006) investigated the response of deep-sea benthic foraminifera to the north-east monsoon in the western and southern regions of the Arabian Sea, and obtained contrasting results. The study attributed steady, increased foraminiferal numbers between March and the beginning of May, deepening of the foraminiferal living horizon, variable diversity and rapid variations between dominant foraminiferal communities to enhanced organic carbon fluxes during and after the monsoon in the western Arabian Sea. In the southern Arabian Sea, however, they did not find any significant influence of the monsoon on benthic foraminifera.

Bharti and Singh (2013) studied a 30,000-year record of benthic foraminiferal assemblages in a sediment core retrieved from the base of the OMZ off Goa (eastern Arabian Sea) at a water depth of 1,230 m. During the course of this study, they discovered a new species, *Bulimina arabiensis*, which dominated the benthic foraminiferalassemblage in the fine size fraction (63-125µm). The study opined that the morphological characteristics of this species suggested its preference for infaunal microhabitat and low-oxygen concentrations of bottom water.

A detailed investigation of downcore Holocene foraminifera and their assemblages was undertaken by Rao *et al*. (2013) to comprehend the ecology of the Bay of Bengal and compare it with that of the South China and Sulu Seas, at the same depth (2,004 m) for all the three water bodies. Based on temperature and dissolved oxygen profiles, benthic foraminiferal abundance, and species diversity values, the study inferred that the Bay of Bengal is much better ventilated than either the South China or the Sulu Sea. The study also reported that the planktic/benthic (P/B) ratios were extremely low when compared with those reported elsewhere in the world. The absolute dominance of benthic foraminiferal species over their planktic counterparts was attributed to the effect of fragmentation and dissolution of the latter, as they are relatively more susceptible to this process. The study added that the very low *P/B* values were also indicative of water depth below the lysocline in this part of the Bay of Bengal.

Rao and Kamatchi (2014) reported *Globigerina helicina* (d'Orbigny), a planktic foraminifer, for the first time from deep-sea sediments from the Bay of Bengal. The study used two short cores retrieved from water depths of 2,004 m and 3,042 m, respectively, and observed the presence of this rare species only in the latter, suggesting its comparatively deeper abyssal habitat.

Manasa *et al*. (2016) documented recent benthic foraminiferal distribution from the continental shelf region of the north-western Bay of Bengal. Based on the external morphology, they categorized benthic foraminifera into rounded symmetrical (RSBF) and angular asymmetrical benthic forms (AABF), and compared the relative abundance of each group with the ambient physico-chemical conditions, including dissolved oxygen, organic matter, salinity and temperature, and reported that the RSBF were abundant in comparatively warm and well oxygenated waters of low salinity, suggesting a preference for high energy environment. However, the AABF dominated relatively cold, hypersaline deeper waters with low dissolved oxygen, indicating a low energy environment. The study concluded that the factors associated with freshwater influx affect the distribution of benthic foraminiferal morpho-groups in the north-western part of the Bay of Bengal.

Materials and Methods

A 6.18 m long core was retrieved and provided by the National Institute of Oceanography (NIOT) at a water depth of 2,591 m (11° 56' 23" N latitude; and 80° 30' 44" E.) The location of the drilling site in the Bay of Bengal, off Pondicherry, is shown in (Fig. 1). Although the core was sub-sampled at 5-cm intervals, the number ofsub-samples totaled only 115 as few segments of the core were missing. Only a part of each sub-sample was utilized for foraminiferal studies; in all, 166 foraminiferal species (153 benthic and 13 planktic) belonging to 97 genera, 46 families, 23 superfamilies, and 6 suborders were identified and recorded. The present study reports the systematic paleontology of eight benthic foraminiferal species that have been rarely recorded across the world from different oceans, with remarks regarding their taxonomy, ecology and bathymetry. Most of them are illustrated by scanning electron microscope photographs.

Systematic Paleontology

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Herouard, 1896
Superfamily TEXTULARIACEA Ehrenberg, 1838
Family EGGERELLIDAE Cushman, 1937
Subfamily EGGERELLINAE Cushman, 1937
Genus MARTINOTTIELLA Cushman, 1933
Martinottiella omnia Saidova, 1975 Pl. 1;
Fig. A

Original citation: *Martinottiella omnia* SAIDOVA, 1975, p. 114, pl. 33, figs. 3, 4.
Martinottiella omnia SAIDOVA - Hayward *et al*., 2010, p. 145, pl. 6, figs. 4, 5.
Martinottiella omnia SAIDOVA - Lorz *et al*., 2012, p. 34.

Remarks:Limited studies reported the presence of *Martinottiella omnia.* The only record other than Saidova's (1975) is from off New Zealand (Hayward *et al*. 2010) who found it to be sporadic in occurrence with a geographic distribution ranging between 34° and 51° S. Its bathymetric range was reported as outer shelf to mid abyssal (150-4,000 m). Lorz *et al*. (2012) presented a review of deep-sea benthic biodiversity associated with trench, canyon and abyssal habitats below 1,500 m depth in New Zealand, and reported a bathymetric range for *M. omnia* as 2,390 to 3,452 m. From the descriptions and illustrations given by Hayward *et al*. (2010), *M. omnia* can be distinguished from *M. communis* by its relatively coarser agglutination and longer neck. To our knowledge, this is the first record of *M. omnia* from Indian waters. Bathymetry: Middle neritic to abyssal.

Suborder MILIOLINA Delage and Herouard, 1896
Superfamily MILIOLACEA Ehrenberg, 1839
Family SPIROLOCULINIDAE Wiesner, 1920
Genus SPIROLOCULINA d'Orbigny, 1826
Spiroloculina elegantissima Said, 1949 Pl. 1;
Fig. B

Original citation: *Spiroloculina elegantissima* SAID, 1949, p. 15, pl. 1, fig. 41.
Spirophthalmidium cf. *S. elegantissima* (SAID) - Hottinger *et al*., 1993, p. 44, pl. 24, figs. 5-10.
Spiroloculina elegantissima SAID - Rana, 2009, p. 54, pl. 5, figs. 6a-c. *Spiroloculina elegantissima* SAID - Debenay, 2012, pp. 133, 269.
Spiroloculina elegantissima SAID - Panchang and Nigam, 2014, p. 128, pl. 6, figs. 14a, b.

Remarks: Populations of foraminifera were investigated by Coulbourn and Resig (1975) in regard to the suitability of the various species as indicators of sand transport in Kahana Bay, Oahu, Hawaii. Of the 53 species recorded by the authours, *Spiroloculina elegantissima* was found to be rare (<1%) in very fine channel sands, beach and fine nearshore sands and reef flat sands. Hottinger *et al*. (1993) reported the same species as *Spirophthalmidium* cf. *elegantissimum* (Said) and remarked, "Neither Said (1949) nor Graham and Militante (1959) described in detail the initial stages of *Spiroloculina elegantissima* which is believed to be actually a *Spirophthalmidium.* No specimens with rounded periphery have been found in our material. However, Badawi *et al*. (2005) reported*S. elegantissima* species as *Spirophthalmidium* cf. *elegantissimum* (p. 19, table 1). Debenay (2012) described and illustrated this taxon as *Spiroloculina elegantissima* from a shallow water depth of 10 m off New Caledonia in the south-west Pacific Ocean. *S. elegantissima* species was observed to be quite rare (1%) among the benthic foraminifers identified by Rositasari (2011, p. 105, tab. 1) from the Jakarta Bay. Panchang and Nigam (2014) carried out benthic ecological mapping of the Ayeyarwady delta shelf off Myanmar using foraminiferal assemblages and recorded this species as *Spiroloculina elegantissima* (p. 128; pl. 6; figs. 14a, b). *S. elegantissima* species seems to have been very rarely recorded from the Bay of Bengal.
Bathymetry: Inner shelf to abyssal.

Suborder LAGENINA Delage and Herouar d, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family LAGENIDAE Reuss, 1862

Genus LAGENA Walker and Jacob, 1798, In: Kanmacher, 1798

Lagena gibbera Buchner, 1940 Pl. 1;

Fig. C

Original citation: *Lagena gibbera* BUCHNER, 1940, p. 423, pl. 3, figs. 48-50.
Lagena gibbera BUCHNER - Jones, 1994, p. 63, pl. 57, figs. 8, 9, ?10. *Lagena gibbera* BUCHNER - Sgarrella *et al*., 1997, p. 218. *Geminiella gibbera* (BUCHNER) - Popescu, 1998, p. 73, pl. 27, figs. 7, 8. *Lagena gibbera* BUCHNER - Lanzafame *et al*., 1999, p. 75, tab. 1.
Lagena gibbera BUCHNER - Szarek, 2001, p. 118, appendices A; p. 238, appendix B.1; p. 263, appendix B4b; p. 270, appendix B4c.
Geminiella gibbera (BUCHNER) - Popescu and Crihan, 2004, p. 412, pl. 5, figs. 14-17.
Lagena gibbera BUCHNER - Szarek *et al*., 2007, p. 169, tab. A1. *Lagena gibbera* BUCHNER - Panchang and Nigam, 2014, pl. 19, fig. 2.

Remarks: There seem to be few records for *Lagena gibbera* species. *L. gibbera* was designated as the type of species for the genus *Geminiella* (Popescu, 1998). Lanzafame *et al*. (1999) reported it from the lower Pleistocene in Sicily and observed it to constitute <3% of the foraminiferal fauna. The biodiversity and biogeography of recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea were studied by Szarek (2001) and reported a bathymetry of middle bathyal for *L. gibbera*. Popescu and Crihan (2004) remarked *L. gibbera* is based on the description of the species *L. aspera* Reuss described by Brady (1884, p. 457, pl. 57, figs. 8, 9) and of the species *Lagena* sp. aff. *laevis* Montagu (Brady, 1884, p. 455, pl. 56, fig. 14)". Bathymetry: Middle bathyal.

Family ELLIPSOLAGENIDAE A. Silvestri, 1923

Subfamily ELLIPSOLAGENINAE A. Silvestri, 1923

Genus FISSURINA Reuss, 1850

Fissurina staphyllearia Schwager, 1866

Plate 1; Fig. D

Original citation: *Fissurina staphyllearia* SCHWAGER, 1866, p. 209, pl. 5, fig. 24. *Lagena staphyllearia* (SCHWAGER) - Brady, 1884, p. 474, pl. 59, figs. 8-11. *Lagena staphyllearia* (SCHWAGER) - Egger, 1893, p. 331, pl. 10, figs. 50, 51, 99. *Lagena staphyllearia* (SCHWAGER) - Chapman, 1895, p. 29. *Lagena staphyllearia* (SCHWAGER) - Flint, 1897 (1899), p. 307, pl. 54, fig. 1. *Lagena staphyllearia* (SCHWAGER) - Millett, 1901, p. 619, pl. 14, fig. 2. *Lagena staphyllearia* (SCHWAGER) - Chapman, 1910, p. 410. *Lagena staphyllearia* (SCHWAGER) - Sidebottom, 1912, p. 403, pl. 17, figs. 19-24. *Lagena staphyllearia* (SCHWAGER) - Cushman, 1913, p. 31, pl. 17, fig. 3. *Lagena staphyllearia* (SCHWAGER) - Pearcey, 1914, p. 1019; 1920, p. 162. *Lagena staphyllearia* (SCHWAGER) - Heron-Allen and Earland, 1922, p. 154. *Entosolenia staphyllearia* (SCHWAGER) - Cushman, 1929, p. 96, pl. 13, fig. 40. *Lagena staphyllearia* (SCHWAGER) - Heron-Allen and Earland, 1932, p. 377. *Entosolenia staphyllearia* (SCHWAGER) - Cushman, 1933, pl. 27, fig. 19. *Lagena staphyllearia* (SCHWAGER) - Cushman, 1934, p. 120, pl. 14, fig. 5. *Entosolenia staphyllearia* (SCHWAGER) - Hadley, 1934, p. 17, pl. 2, figs. 10, 11. *Fissurina staphyllearia* SCHWAGER - Cushman, 1939, p. 152, pl. 10(6), fig. 10. *Lagena staphyllearia* (SCHWAGER) - Matthes, 1939, p. 88, pl. 8, fig. 143.
Lagena staphyllearia (SCHWAGER) - Buchner, 1940, p. 523, pl. 24, figs. 507-521; pl. 25, fig. 522.
Entosolenia staphyllearia (SCHWAGER) - Cushman, 1940, pl. 27, fig. 19. *Entosolenia staphyllearia*

(SCHWAGER) - Leroy, 1941, p. 80, pl. 1, fig. 32. *Entosolenia staphyllearia* (SCHWAGER) - Cushman and Stainforth, 1945, pl. 7, figs. 2, 3. *Parafissurina staphyllearia* (SCHWAGER) - Ward, 1984, p. 61, pl. 9, fig. 11.

Parafissurina staphyllearia (SCHWAGER) - Sgarrella and Moncharmont-Zei, 1993, p. 205, pl. 13, fig. 12. *Fissurina staphyllearia* SCHWAGER - Jones, 1994, pp. 67, 68, pl. 59, figs. 8-11. *Parafissurina staphyllearia* (SCHWAGER) - Kaminski *et al*., 2002, p. 193; p. 200, appendix 2. *Parafissurina staphyllearia* (SCHWAGER) - Aksu, 2005, p. 47, pl. 2, fig. 2.

Parafissurina staphyllearia (SCHWAGER) - Meric *et al*., 2009, pl. 3, fig. 2.
Fissurina staphyllearia SCHWAGER - Enge *et al*., 2012, p. 91, pl. 3, fig. 7.
Parafissurina staphyllearia (SCHWAGER) - Kaminski, 2012, p. 763, appendix 1.

Remarks: The types for *Lagena staphylleria*species came from the Upper Pliocene of car Nicobar (Schwager, 1866). Brady (1884) remarked, "The compressed *Lagena* with symmetrically arranged basal spines may be assigned to *L. staphyllearia*. The pointed processes of recent specimens are usually placed at regular intervals on the median line, as shown in Figs. 8-10. Occasionally a deviation from the typical condition is encountered in the form of double spines, of which Fig. 11 is an example. In the North and South Atlantic *L. staphyllearia* has only been observed at great depths, namely at four Stations, ranging from 2200 to 2750 fathoms; but in the Southern Ocean and the South Pacific it occurs also from time to time in shallow water near the coast-line". It was found to be "very rare" in the samples from the Arabian Sea (Chapman, 1895); later the author(1910) recorded *L. staphyllearia* from four stations at water depths ranging from 1,200 to 2,300 fathoms (2,195 to 4,206 m). Cushman (1913) observed that both "three-and five-spined specimens" occurred in his material from the North Pacific, but they did not show the range of variation described by Sidebottom (1912). Cushman and Stainforth (1945) remarked, "Various spinose forms have been referred to Schwager's species. The above references are all apparently to the same form. The base may have, in the median plane, two to five short spines which are broad and flattened at the base and rapidly tapering to a point". According to Parr (1950), *Fissurina staphyllearia* (Schwager) differs from *F. kerguelenensis* (Parr) in having a thicker, more inflated test, lacking a keeled periphery, and in possessing a narrower and more produced apertural end. , Lorz *et al*. (2012) reviewedthe deep sea benthic biodiversity associated with trench, canyon and abyssal habitats below 1,500 m depth in New Zealand watersgave a rather wide bathymetric range of 100 to 2,250 m for *Fissurina staphyllearia*. Bathymetry: Middle neritic to abyssal.

Genus PALLIOLATELLA Patterson and Richardson, 1987
Palliolatella bradyiformis McCulloch, 1977
Pl. 1; Figs. E, F

Original citation: *Lagenosolenia bradyiformis* McCULLOCH, 1977, p. 54, pl. 61, fig. 14.
Palliolatella bradyiformis (McCULLOCH) - Hayward *et al*., 2010, p. 165, pl. 11, figs. 20, 21. *Palliolatella bradyiformis* (McCULLOCH) - Panchang and Nigam, 2014, pl. 21, figs. 14a-c.

Remarks: The types for this species, initially named as *Lagenosolenia bradyiformis* came from the Pacific Ocean (McCulloch 1977). Hayward *et al*. (2010) recorded it as *Palliolatella bradyiformis* from off the Great Barrier Island, New Zealand, at a water depth of 68 m. Though they did not give its bathymetric range, they opined it to be a Recent taxon. According to McCulloch, 1977 and Hayward, 2010, one of the distinguishing features of *L. bradyiformis* species is the presence of three sharp peripheral keels surrounding the whole test, with the strongest on the periphery; the longest keel extends up to enclose a short apertural neck. *L. bradyiformis* species was found to occur off the northern shelf of New Caledonia at a water depth of 600 m (Debenay 2012). Bathymetry: Inner neritic to abyssal.

Suborder ROTALIINA Delage and and Herouard, 1896
Superfamily BULIMINACEA Jones, 1875, In: Griffith and Henfrey, 1875

Family SIPHOGENERINOIDIDAE Saidova, 1981 Subfamily SIPHOGENERINOIDINAE Saidova, 1981

Genus SIPHOGENERINA Schlumberger, 1882, In: Milne-Edwards, 1882

Siphogenerina dimorpha (Parker and Jones, 1865) Pl. 1; Fig. G

Original citation: *Uvigerina (Sagrina) dimorpha* PARKER and JONES, 1865, p. 420, pl. 18, fig. 18.
Sagrina dimorpha (PARKER and JONES) - Brady, 1884, p. 582, pl. 76, figs. 1-3; 1887, p. 915.
Sagrina dimorpha (PARKER and JONES) - Brady, Parker and Jones, 1888, p. 225, pl. 45, fig. 6.
Siphogenerina dimorpha (PARKER and JONES) - Egger, 1893, p. 317, pl. 9, fig. 30.
Sagrina dimorpha (PARKER and JONES) - Goes, 1894, p. 52, pl. 9, figs. 510, 511.
Sagraina dimorpha (PARKER and JONES) - Bagg, 1908, v. 34, p. 152.
Siphogenerina dimorpha (PARKER and JONES) - Cushman, 1913, p. 106, pl. 45, figs. 3, 4.
Sagrina dimorpha (PARKER and JONES) - Heron-Allen and Earland, 1916, p. 266, pl. 42, figs. 17, 18; 1922, p.186.
Siphogenerina dimorpha (PARKER and JONES) - Cushman, 1921, p. 279, pl. 56, fig. 8; 1923, p. 175, pl. 42, figs. 16-18; 1926, p. 13, pl. 3, fig. 5.
Siphogenerina dimorpha (PARKER and JONES) - Heron-Allen and Earland, 1932, p. 398, pl. 12, fig. 44. *Rectobolivina dimorpha* (PARKER and JONES) - Leroy, 1964, p. F34, pl. 3, figs. 3, 4.
Siphogenerina dimorpha (PARKER and JONES) - Jones, 1994, pl. 76, figs. 1-3.

Siphogenerina dimorpha (PARKER and JONES) - Hayward and Grenfell, 1999, p. 86, appendix 1; p. 88, appendix2.
Siphogenerina dimorpha (PARKER and JONES) - Hayward *et al*., 2010, p. 202, pl. 20, figs. 31, 32.
Siphogenerina dimorpha (PARKER and JONES) - Spezzaferri *et al*., 2014, p. 43, tab. 3.4.
Remarks: The types for *Siphogenerina dimorpha* species came from the Abrohlos Bank, off Brazil (Parker and Jones 1865); later, Brady *et al*. (1888) also illustrated this species as *Sagrina dimorpha* (from the type area) and stated that they obtained "A couple of good specimens from 260 fathoms". Cushman (1913) recorded this species from the North Pacific Ocean and stated, "S *dimorpha*species is more widely distributed than others of the genus, both in depth and area. It is characteristic in its appearance and can easily be distinguished". While describing and illustrating this species from the Falkland Islands and adjacent seas, Heron-Allen and Earland (1932) remarked that it, "shewed extraordinary variation in length, ranging from the short type of Parker and Jones with only three final chambers, to a very long individual with no less than nine chambers in the linear series, which was 0-95 mm. long, and 0-20 mm. at the maximum breadth". Chapman and Parr (1937) recorded this species from a sounding off the east coast of Tasmania at 1,300 fathoms (~2,377 m) and stated that their specimen did not have the sutural crenellations figured by Brady, but still retained it as *S. dimorpha* as Brady himself had stated that this feature was not always present. According to them, this species "ranges from Norwegian seas to the Southern Ocean". Hofker (1978) recorded this species as *Rectobolivina dimorpha* (Parker and Jones) at water depths ranging between 513 m and 857 m in the eastern part of the Indonesian Archipelago. Later, the same author (1980) reported its occurrence on the Saba Bank at two stations where the water depths were 850 and 890 m, respectively. In both the Auckland and Campbell Island groups, off New Zealand, Hayward *et al*. (2007) recorded this species at depths shallower than 80 m. According to Sen Gupta *et al*. (2009), *S. dimorpha* is a cosmopolitan species that occurs in a wide water depth range of 14 to 3,292 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico. There are scattered records off the east coast of the main islands of New Zealand (35°-49° S) at mid- to lower bathyal depths of 500-1,200 m

(Hayward *et al*. 2001; Hayward *et al*. 2010).

Bathymetry: Inner shelf to abyssal.

Siphogenerina striata (Schwager, 1866)

Original citation: *Dimorphina striata* SCHWAGER, 1866, v. 2, p. 251, pl. 7, fig. 99.
Sagrina striata SCHWAGER, 1877, v. 8, p. 25, fig. 35.
Siphogenerina (Sagrina) striata (SCHWAGER) - Egger?, 1893, p. 316, pl. 9, figs. 32, 34, 35, 64, 65. *Sagrina striata* SCHWAGER - Brady, 1884, p. 584, pl. 75, figs. 25, 26. *Sagrina striata* SCHWAGER - Millett, 1903, p. 272.
Siphogenerina (Sagrina) striata (SCHWAGER) - Cushman, 1913, p. 107, pl. 47, figs. 4, 5.
Siphogenerina striata (SCHWAGER) - Cushman, 1921, p. 280, pl. 56, fig. 5. *Siphogenerina striata* (SCHWAGER) - Barker, 1960, p. 158, pl. 75, fig. 26. *Siphogenerina striata* (SCHWAGER) - Hayward *et al*., 1997, p. 26, fig. 3C. *Siphogenerina striata* (SCHWAGER) - Schroder-Adams *et al*., 2008, p. 56, fig. 8B-9. *Siphogenerina striata* (SCHWAGER) - Hengstum and Scott, 2011, p. 227, figs. 13.17, 13.18. *Siphogenerina striata* (SCHWAGER) - Fajemila, 2016, p. 157, pl. 30, figs. 11, 12.

Remarks: Cushman (1921) examined foraminifera from the Philippine and adjacent seas and, while observing *S. raphanus*species to be common at some stations, remarked "The species seems to be different from either form of *S. raphanus*, the costae being less independent of the chambers than in *S. raphanus* and the sutures marking well defined limits even in the costae. The neck is invariably short or wanting, no lip being present". According to Hayward *et al*. (1997), "One of the more common subtidal species in the near-normal salinity parts of the upper Waitemata Harbour is *S. striata.* No specimens of this distinctive species have been discovered in previous studies of approximately 400 faunal samples from shallow water environments around New Zealand. Reconnaissance studies show it to be widespread, with a relative abundance of 3-10% for at least another 10 km down the Waitemata Harbour, including samples around Auckland's commercial wharf area. *S. striata* is a common species in shallow water in a number of other countries. Its presence in New Zealand's busiest shipping harbour may be as a result of accidental introduction". Hengstum and Scott (2011) observed an increase in the relative abundance of some coastal and shelf taxa, such as *S. striata* (maximum of 9%) in an anchialine cave assemblage living in saline ground water of the Green Bay Cave System, Bermuda.

Bathymetry: Inner shelf to abyssal.

Superfamily STILOSTOMELLACEA Finlay, 1947
Family STILOSTOMELLIDAE Finlay, 1947
Genus SIPHONODOSARIA A. Silvestri, 1924
Siphonodosaria insecta (Schwager, 1866) Pl. 1;
Figs. H, I

Original citation: *Nodosaria insecta* SCHWAGER, 1866, v. 2, p. 224, text-figs. 53, 54.
Nodosaria insecta SCHWAGER - Leroy, 1964, p. F24, pl. 15, fig. 14. *Stilostomella insecta* (SCHWAGER) - Srinivasan and Sharma, 1980, p. 35, pl. 6, figs. 11-14. *Siphonodosaria insecta* (SCHWAGER) - Boersma, 1986, p. 1031, pl. 16, figs. 5, 6. *Stilostomella insecta* (SCHWAGER) - Boersma, 1990, pl. 3, fig. 4.
Siphonodosaria insecta (SCHWAGER) - Hayward and Kawagata, 2005, p. 172, tab. 1, p. 173, pl. 1, figs. 20, 21.
Siphonodosaria insecta (SCHWAGER) - O'Neill *et al*., 2007, p. 1085, tab. 2. *Siphonodosaria insecta* (SCHWAGER) - Hayward *et al*., 2012, p. 171, pl. 17, figs. 24-29.

Remarks: LeRoy (1964), who recorded this species as *Nodosaria insecta*, found it to be very rare in the Shinzato (Miocene or Pliocene) and Yonabaru (Pliocene) assemblages of southern Okinawa. In the eastern Pacific Ocean, this species is found in the lower middle bathyal zone (Ingle 1980). Boersma (1986) studied the biostratigraphy and biogeography of Tertiary bathyal benthic foraminifers from the Tasman Sea, Coral Sea and on the Chatham Rise and remarked, "This is a common species in the Tasman Sea. It occurs along with *Stilostomella lepidula*, with transitional forms. The species is identical with Paleogene, smooth siphonodosarids, one of which is called *S. nuttalli* (Cushman and Jarvis). Although *S. nuttalli* is more curvilinear than typical *S. insecta*, the species are essentially identical, and Schwager's name takes precedence". According to Bornmalm (1997), who opined that *S. insecta* is one among the several intraspecific variants of *S. lepidula*, "The intraspecific variation of *S. lepidula* is great with regard to the amount of alignment of the spines and the degree of spinosity. As a result of this *S. lepidula* has been referred to by many different names, specific as well as generic. I agree with Hermelin (1989) that several of the variants of this species should probably be regarded as junior synonyms of *S. lepidula*". According to Hermelin (1989), these variants include *Siphonodosaria recta* (Palmer and Bermudez 1936), *Siphonodosaria paucistriata* (Galloway and Morrey 1929), *Siphonodosaria ketienziensis* (Ishizaki 1943), and *Siphonodosaria helenae* (Samoilova 1947). Hayward and Kawagata (2005) listed *Siphonodosaria insecta* as one of the 18 species illustrated by Brady (1884) that became extinct ~600,000 years ago during the mid-Pleistocene Climatic Transition (e.g., Weinholz and Lutze 1989; Schonfeld 1996; Hayward 2001, 2002; Kawagata *et al*. 2005). According to Hayward *et al*. (2012), *S. insecta* "differs from *S. pomuligera* by the larger test with an initial globular chamber thesame size as later chambers or bigger, and by the lack of a well developed collar on the middle of the apertural neck". Moreover, they stated that the genus "*Siphonodosaria* is distinguished from *Stilostomella* (Finlay 1947, declared *Siphonodosaria* to be a junior synonym of *Stilostomella)* by the very different apertural features - the long neck with a collar and phialine lip with a long bifid or T-shaped tooth in the former but not the latter". Its bathymetric range is from 2,000 to 4,000 m. Bathymetry: Upper to middle abyssal.

Conclusions

Deep-sea benthic foraminifera are extremely useful in understanding various aspects of paleoceanography and paleoclimate, their taxonomy and ecology are equally important, just as understanding of basic sciences is so vital in the development of engineering and technology. The results reported here is an attempt to throw light principally on the systematic paleontology of some rare taxa from the deeper regions of the Bay of Bengal, with a note on their bathymetric ranges.

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PLATE – I

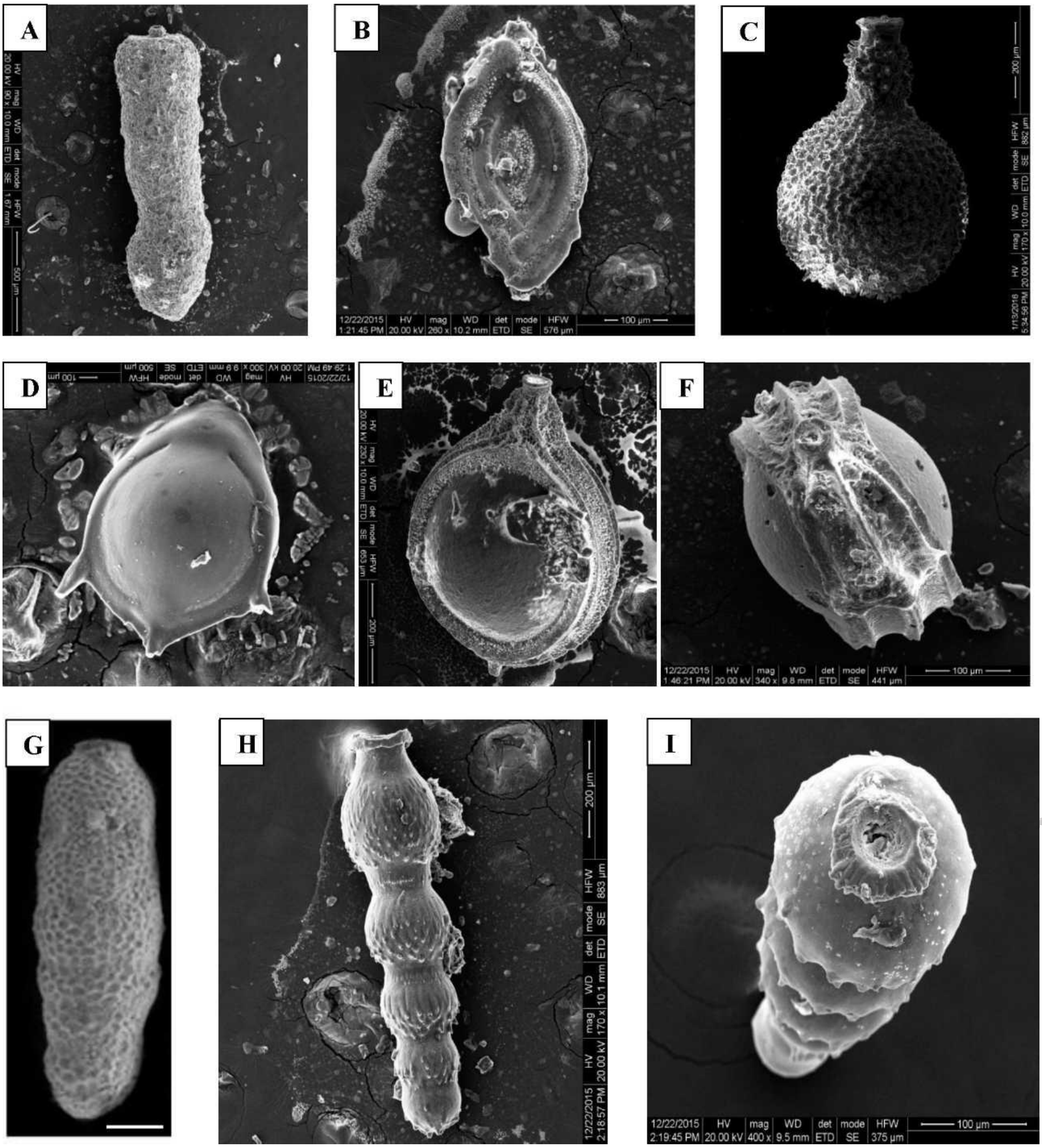

Fig. 1 - **A:** *Martinottiella omnia,* side view, x90; **B:** *Spiroloculina elegantissima,* side view, x260; **C:** *Lagena gibbera,* side view, x170; **D:** *Fissurina staphyllearia,* side view, x300; **E:** *Palliolatella bradyiformis,* side view, x230; **F:** *P. bradyiformis,* apertural view, x340; **G:** *Siphogenerina dimorpha,* side view, x210; **H:** *Siphonodosaria insecta,* side view, x170; **I:** *S. insecta,* apertural view, x400.