Chapter IV

Systematic Paleontology

4.1 Classification

The widely utilised classification proposed by Loeblich and Tappan (1987) has been followed in the present study. A species has been regarded as the sum-total of specimens sharing all test characters, with such measurable, countable, or otherwise observable, variation in size and shape of some elements or of proportions between the latter in different ontogenic stages, which fits a pattern of normal distribution and whereby these specimens are separable from other similar groupings regarded as distinct species (Hottinger et al., 1993).

In a relatively few cases, subspecies have been recognised, that is assemblages of specimens differing from the typical species in a minor, but recognisable modification of a test character, like ornamentation, chamber inflation, etc., especially if there is overlap between the subspecies and if they occur both together and separately in different samples. The identification of the species recorded in this study is based on comparison with the Catalogue of Foraminifera by Ellis and Messina (1940 onwards), innumerable publications from several parts of the world and in the country (especially provided by Dr. Rajiv Nigam, National Institute of Oceanography) and specimens reposited in the Departments of Geology and Applied Geology, University of Madras, Madras 600 025, India.

The list of synonymies has been restricted to original citations and descriptions have been given only for those species that have been kept under open nomenclature; remarks, however, have been presented for almost all the species, although it is impossible to include those given by all earlier workers. As far as possible, the Indian occurrences for all the established and recognised species, from the east as well as west coasts have been included, albeit limited by the amount of literature available.

All objectively observable and defined test characters and features and their stable combination in (usually) more than one species have been regarded as of generic rank. A strict view of characters regarded as generic has been taken here, leading to the use of the valid genera proposed over the years and enumerated by Loeblich and Tappan (1987). In cases where generic revision has taken place, the new nomenclature has been adopted. In the case of Spirillina ssp., the Superfamily SPIRILLINACEA has been included (based on the classification proposed by Loeblich and Tappan, 1964) as their latest (1987) classification does not provide Superfamily status for this group of species.

In the five sub-samples of Core-1, retrieved from a water depth of 2,004 m, 92 foraminiferal species belonging to 62 genera, 39 families, 26 superfamilies and 7 suborders have been identified and recorded. Among these, 22 are arenaceous, agglutinated taxa (suborder TEXTULARIINA), 2 belong to the suborder SPIRILLININA, 6 are calcareous, porcelainous, imperforate forms (suborder MILIOLINA), 13 are calcareous, hyaline species (suborder LAGENINA), 1 is a hyaline, perforate, optically radiate, aragonitic species (suborder ROBERTININA), 16 are calcareous, planktic species (suborder GLOBIGERININA), and 32 are calcareous, perforate species of the suborder ROTALININA. In the longer 30-cm core (Core-2), 226 species have been identified, of which 206 are benthic and 20 are planktic species (Figs. 4.1–4.4).

From the two cores, a consolidated list of 250 foraminiferal species belonging to 140 genera, 66 families, 33 superfamilies and 8 suborders have been identified and recorded. Among these, 41 are arenaceous, agglutinated taxa (suborder TEXTULARIINA), 1 each belong to the
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suborders SPIRILLININA and INVOLUTININA, 15 are calcareous, porcelaneous, imperforate forms (suborder MILIOLINA), 68 are calcareous, hyaline species (suborder LAGENINA), 4 is a hyaline, perforate, optically radiate, aragonitic species (suborder ROBERTININA), 22 are calcareous, planktic species (suborder GLOBIGERININA), and 98 are calcareous, perforate species of the suborder ROTALIINA (Figs. 4.5–4.8).

All the species and varieties have been duly indexed and deposited in the Department of Applied Geology, University of Madras, Madras 600 025, India, with the labels PK–AG–001 to 250.

4.2 Brief Systematics and Remarks

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily ASTRORHIZACEA Brady, 1881
Family ASTRORHIZIDAE Brady, 1881
Subfamily ASTRORHIZINAE Brady, 1881
Genus ASTRORHIZA Sandahl, 1858

Astrorhiza granulosa (Brady, 1879)
Pl. 1; Fig. 1

Original citation: Marsipella granulosa BRADY, 1879, pp. 86–87, pl. 3, figs. 8, 9.
Remarks: Flint (1899) recorded this species from the North Atlantic at water depth ranging from 1,655 to 1,781 fathoms (~3,027 to 3,257 m). This species has been reported from shallower depth of 465 m by Mallon (2011) off the Peruvian continental margin, who observed the tests to be not well solidified and have a tendency to break even when touched carefully with the brush. According to Gooday and Smart (2000), Astrorhiza granulosa has a test structure that is two-layered, with a thin, friable, outer layer, and a more strongly cemented inner layer. They were the first to clearly describe or illustrate its structure, despite the fact that A. granulosa, has been known for well over a century. This might be the first record of this species from Indian waters.
Repository: PK–AG–001

Genus PELOSINA Brady, 1879
Pelosina cylindrica Brady, 1884
Pl. 1; Fig. 2

Original citation: Pelosina cylindrica BRADY, 1884, v. 9, p. 236, pl. 26, figs. 1–6.
Remarks: The type species for genus Pelosina is Pelosina variabilis Brady, 1879. Chapman (1905) found the occurrence of Pelosina cylindrica at a depth of only 110 fathoms (~201 m) rather interesting as it had been recorded as “an essentially deep-water form” in the Challenger dredgings; the least depth at which it was found was 620 fathoms (~1,134 m). The Gazelle expedition, however, obtained this species from a lesser depth range of 82 to 86 m. This is considered to be a cosmopolitan species (Loeblich and Tappan, 1987). This species does seem to have a wider depth range than realized as Debenay (2012) recorded it from the northern shelf off New Caledonia in the south-west Pacific at a depth of 300 m. It is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat and, in the north-eastern part of the Gulf of Mexico, has a water depth range of 1,335 to 2,160 m (Sen Gupta et al., 2009b).
Repository: PK–AG–002
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*Pelosina rotundata* Brady, 1879
Pl. 1; Fig. 3

**Original citation:** *Pelosina rotundata* BRADY, 1879, v. 19, p. 31, pl. 3, figs. 4, 5.

**Remarks:** According to Millett (1899), *Pelosina rotundata* is “essentially a deep water species”. This species has been reported from the Atlantic as well as Pacific oceans in water depth range of 570 to 2,500 m, and in the Ingolf Strait at 2,258 m. The *Challenger* dredged this species at Station 246, at a depth of 2,050 fathoms (~3,749 m) in the middle of the North Pacific (Barker, 1960). This could well be the first record for this species from Indian waters.

**Repository:** PK–AG–003

**Family BATHYSIPHONIDAE** Avnimelech, 1952

**Genus BATHYSIPHON** M. Sars, 1872

*Bathysiphon filiformis* M. Sars, 1872

**Original citation:** *Bathysiphon filiformis* M. SARS, 1872, p. 251.

**Remarks:** Gooday *et al.* (1992) recorded the occurrence of *Bathysiphon filiformis* at bathyal depths ranging between 588 and 930 m on the North Carolina continental slope, and opined that abundances of this species could be related to large inputs of organic material from various sources. Box cores, bottom photographs, and direct submersible observations indicated that *B. filiformis* tubes project above the sediment in an arcuate curve with only the lower 1 cm or so buried. They also observed that the voluminous, dense, granular protoplasm of this species contains biogenic particles, especially diatoms. The frequent abundance of this species is indicative of high nutrient flux of shelf-derived organic matter to the sea floor (Kaminski *et al*., 2005; Kender *et al*., 2008). According to Grunert *et al.* (2013), the conditions at the basin floor can be primarily inferred from the occurrence of *B. filiformis*. This suspension-feeding species is most abundant in eutrophic bathyal areas along the continental shelf where bottom-currents advect large amounts of nutrients (Gooday *et al*., 1997). It has been frequently reported from turbiditic environments and submarine canyons (Miller, 1988, 2005; Koho *et al*., 2007; De Leo *et al*., 2010). There they show highest abundances in the upper canyon terraces close to the continental margin during episodes of reduced turbidity currents and minor mass-flow deposition (Koho *et al*., 2007; De Leo *et al*., 2010). Episodically increased abundances of *B. filiformis* (1,450 m, 1,410–1,402 m) might thus reflect phases of benthic recolonization in-between turbidite deposition (Miller, 1988). Its generally low abundance suggests an upper bathyal environment (Jones and Charnock, 1985) that agrees well with estimated water depths of 500 m for coeval turbiditic deposits (Wagner, 1998). Murray (2014) classified this species as clinging, semi-infaunal.

**Repository:** PK–AG–004

**Family RHABDAMMINIDAE** Brady, 1884

**Subfamily RHABDAMMININAE** Brady, 1884

**Genus MARSIPELLA** Norman, 1878

*Marsipella elongata* Norman, 1878

**Original citation:** *Marsipella elongata* NORMAN, 1878, ser. 5, v. 1, pp. 265–284.

**Remarks:** According to the original description, the wall is of coarse sand grains interspersed “here and there with a sponge spicule” but the mouth opening is formed by a ‘faggot’ (bundle) of sponge spicules. However, Brady (1884) found exceptional individuals made up of coarse grains...
throughout; similar individuals occur in Carpenter's Lightning material in the British Museum, which also include wholly spicular and specimens built of the tests of other foraminifera (Haynes, 1973). *Marsiella elongata* is a benthic species with a bathyal and/or abyssal habitat that been reported from the Caribbean Sea, Atlantic, Pacific and Southern oceans; it occurs in a depth range of 903 to 2,125 m in the north-eastern part of the Gulf of Mexico (Sen Gupta et al., 2009b).

Repository: PK–AG–005

Genus RHABDAMMINA M. Sars, 1869
Rhabdammina abyssorum M. Sars, 1869
Pl. 1; Fig. 5

Original citation: *Rhabdammina abyssorum* SARS, 1869, p. 248.

Remarks: Cushman (1918, p. 60,) raised this branched variety to specific rank, although Carpenter’s original note was not accompanied by any figure. The name *abyssorum* M. Sars was a *nomen nudum*, and the species was first figured as *Rhabdammina abyssorum* Sars by Carpenter (1881, text-figs. 321c, d). For this reason, Cushman and others attributed the species to Carpenter; Sherborn, however, attributed it to M. Sars, which was followed by Barker (1960) and in this study. A wide depth range has been observed by earlier workers ranging from 50 m to >2,500 m (Sgarella and Monchramont Zei, 1993; Barker, 1960). According to Smith (1973, p. 12), this species generally occurs as fragments of extremely coarse-grained tubes that are sometimes branched. Similar observations have been made in this study. According to Gooday and Smart (2000), “the well-known species *Rhabdammina abyssorum* differs from *R. parabyssorum* only in having a much simpler, unlayered wall structure”. According to Sen Gupta et al. (2009b), it is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat and has a water depth range of 165 to 3,488 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico.

Repository: PK–AG–006

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884
Genus LAGENAMMINA Rhumbler, 1911
Lagenammina ampullacea (Brady, 1881)
Pl. 1; Fig. 6

Original citation: *Reophax ampullacea* BRADY, 1881, p. 49.

Remarks: *Reophax ampullacea* was referred by Rhumbler (1903 (1904), p. 248) to *Protonina* Williamson (1858), as did Brady since he regarded *Protonina* as in part synonymous with *Reophax* Montfort (1808), and included *P. fusiformis* Williamson, later made the type of *Protonina* in that genus. *Protonina* was retained by Rhumbler, Cushman, Galloway and later workers, but was later placed in the synonymy of *Reophax* by Loeblich and Tappan (1955). However, after a look at the notes written by Brady (1881) on reticularian rhizopods, he erected a new species in the name of *Reophax ampullacea* and opined that it “is monothalamous and compressed”. It bears very much the same relation to *R. difflugiformis* that *Lagena marginata* bears to *L. globosa*. The illustrations in Barker (1960; figs. 6a, b) are of the specimen recovered from the sediment dredged at Challenger Station 1491, at a depth of 120 fathoms (~219 m) from off the Kerguelen Islands, South Pacific. The present study indicates a wide water depth range for this species: outermost shelf to abyssal.

Repository: PK–AG–007
**Lagenammina difflugiformis** (Brady, 1879)

Pl. 1; Fig. 7

**Original citation:** Reophax difflugiformis BRADY, 1879, ser. 19, p. 51, pl. 4, figs. 3a, b.

**Remarks:** This species was referred to the genus *Proteonina* Williamson 1858 by Brady, but was placed in the synonymy of *Reophax* by Loeblich and Tappan (1955). After considerable confusion about whether it belonged to the a recent species of the fresh water Thecamoebid genus *Difflugia*, derived by contamination of the material by river water (Saunders, 1954), it was decided that this could not be applied to the closely similar forms recorded by Cushman from depths of 299 m and 2,175 fathoms (~3,978 m) in the North Pacific, nor to the specimens obtained by Collins (1968) from 600 m. Collins (*op cit*), therefore, concluded that it was a case of isomorphism between *Difflugia* and the marine foraminiferal genus *Proteonina* (now *Lagenammina*). There seems to a very wide water depth range for this species, as it has been recorded from the inner shelf of the Bay of Bengal as well (Rajeshwara Rao, 1998). It is a benthic, cosmopolitan species and, in the north-eastern and north-western parts of the Gulf of Mexico, has a considerable wide water depth range of 2 to 3,515 m (Sen Gupta *et al*., 2009b).

**Repository:** PK–AG–008

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**Genus SACCAMMINA** Carpenter, 1869

*Saccammina socialis* Brady, 1884

Pl. 1; Fig. 8

**Original citation:** Saccammina socialis BRADY, 1884, v. 9, p. 255, pl. 18, figs. 18, 19.

**Remarks:** Brady recorded *Saccammina socialis* from the Challenger Station no. 246 at a depth of 2,050 fathoms (~3,750 m) in the middle of the North Pacific. He described it as possessing “several independent arenaceous chambers, individually spherical or sub-spherical in shape and of nearly even size”, but rarely more than 6 to 8 in number. Cushman (1910), however, did not find any specimens of *Saccammina socialis* in all the North Pacific material he examined. This species has been reported from abyssal depths in the north-east Pacific Ocean by Enge *et al.* (2012) at a depth of 3,953 m. In the present study, no specimens were observed at 2,004 m, but some were recovered at 3,042 m. *Saccammina socialis* is a benthic species with a bathyal and/or abyssal habitat, and has a water depth range of 819 to 1,564 m in the north-eastern and north-western parts of the Gulf of Mexico (Sen Gupta *et al*., 2009b). It has also been reported from the Atlantic, Arctic, Pacific and Southern oceans.

**Repository:** PK–AG–009

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*Saccammina sphaerica* Brady, 1871

Pl. 1; Fig. 9

**Original citation:** Saccammina sphaerica BRADY, 1871, ser. 4, v. 7, pp. 177–184.

**Remarks:** The types for this species came from Hardangerfjord, Norway. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged from the North Atlantic deep water (figs. 11, 13), from Hardanger Fiord, Norway, at depth ranging from 400 to 500 fathoms (~732 to 914 m; fig. 15), and at Challenger Station 149D, Kerguelen Islands, South Pacific, in the depth range of 20 to 60 fathoms (~37 to 110 m; fig. 17). Its presence in the study area at 2,004 m suggests that *Saccammina sphaerica* has a broad water depth range: inner shelf (Brady, 1871; Rajeshwara Rao, 1998); middle shelf (Debenay and Basov, 1993; Sgarrella and Moncharmont Zoë, 1993); and abyssal (Jones and Sen Gupta, 1995). According to Sen Gupta *et al*.,
al. (2009b), it is a benthic, cosmopolitan species with a depth range of 110 to 3,850 m in the entire Gulf of Mexico.

**Repository: PK–AG–010**

Superfamily HIPPOCREPINACEA Rhumbler, 1895
Family HIPPOCREPINIDAE Rhumbler, 1895
Subfamily HYPERAMMININAE Eimer and Fickert, 1899
Genus HYPERAMMINA Brady, 1878
Hyperammina cylindrica Parr, 1950
Pl. 1; Fig. 10

**Original citation:** Hyperammina cylindrica PARR, 1950, pp. 274, 288, fig. 10, tab. 2.

**Remarks:** Brady referred this species to Hyperammina elongata, but Parr placed it in H. cylindrica (1950, p. 254), and the same was followed by Barker (1960) and in this study. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged off Cumbræae, North Atlantic, in a depth range of 60 to 65 fathoms (~110 to 119 m; fig. 4), and at Challenger Station 323, South Atlantic, at a depth of 1,900 fathoms (~3,475 m; fig. 7). Complete specimens were not recovered from off Chennai; only broken tubular fragments were obtained. A similar wide depth range was observed for this species in the Laptev Sea by Lukina (2001), who recorded it between 243 and 3,171 m. Hyperammina cylindrica is a benthic species with a bathyal and/or abyssal habitat and restricted to the north-western part of the Gulf of Mexico in a water depth range of 1,373 to 3,292 m (Sen Gupta et al., 2009b). There are records of this species from the Atlantic, Pacific and Southern oceans as well. This could well be the first record for this species from Indian waters.

**Repository: PK–AG–011**

Hyperammina friabilis Brady, 1884
Pl. 1; Fig. 11

**Original citation:** Hyperammina friabilis BRADY, 1884, v. 9, p. 258, pl. 23, figs. 1–3, 5, 6.

**Remarks:** According to Hofker (1972), typical specimens of Hyperammina friabilis were not found in the Ingolf samples. Very typical specimens, however, occurred abundantly in the sample off Frederiksted, St. Croix, Caribbean Sea, at a water depth of 800 m. Wollenburg (1992) recorded this species at a depth of 573 m on the upper continental slope north off Kvitceya (Svalbard), Nansen Basin, Arctic Ocean. According to Sen Gupta et al. (2009b), H. friabilis is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat and, in the north-eastern and north-western parts of the Gulf of Mexico, has a water depth range of 358 to 3,550 m. This could also be the first record for this species from Indian waters.

**Repository: PK–AG–012**

Ammodiscus incertus (d’Orbigny, 1839)
Pl. 1; Fig. 12

**Original citation:** Ammodiscus incertus D’ORBIGNY, 1839, p. 49, pl. 6, figs. 16, 17.
Remarks: The type species for this taxon came from Cuba and Martinique (d’Orbigny, 1839). Parr (1950) recorded this species and observed that the surface of this species is smooth and highly polished, no sand grains being visible; he added that the Tasmanian specimens were reddish while the Antarctic ones were yellowish. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 24, West Indies, at a depth of 390 fathoms (~713 m; figs. 1, 3). Barker (op. cit.) reported Ammodiscus incertus as *Involutina anguillae* based on the placement of such agglutinated forms as *anguillae* in genus *Involutina* by Loeblich and Tappan (1954). Loeblich and Tappan (1987), however, transferred this species to genus *Ammodiscus* under the name of *A. incertus*. This species has also been reported from much shallower waters: coastal lagoons (Yassini and Jones, 1995) and inner shelf (Rajeshwara Rao, 1998). According to Kaminski *et al.* (1988), this epifaunal species (Corliss, 1985) is found to live mainly in the flocculent surface layer of sediment of the Panama Basin in the easternmost equatorial Pacific Ocean.

Repository: PK–AG–013

**Subfamily AMMOVERTELLININAE** Saidova, 1981

**Genus GLOMOSPIRA** Rzehak, 1885

*Glomospira gordialis* (Jones and Parker, 1860)

*Glomospira gordialis* (Jones and Parker, 1860)  
Pl. 1; Figs. 13, 13a

Original citation: *Trochammina squamata* JONES and PARKER var. *gordialis* JONES and PARKER, 1860, v. 16, p. 304, pl. 1, fig. 12; Parker and Jones, 1865, v. 155, p. 408, pl. 15, fig. 32.

Remarks: The undivided tubular second chamber that is planispiral or irregular in the early stage, but constantly shifts planes later, is a characteristic feature of this species (Cushman, 1948). Smith (1973) found *Glomospira gordialis* to be present, often abundantly, in the sediment samples collected just south of the Aleutian Trench off southern Alaska. According to Kuhnt and Kaminski (1989), this species is one of the ammodiscids that are opportunistic taxa able to take advantage of empty ecological niches. In their study on benthic foraminifera from a recent, shallow-water hydrothermal environment in the Aeolian Arc (Tyrhhenian Sea), Panieri et al. (2005) opined that the presence of abundant *G. gordialis* is indicative of low pH conditions resulting from acidic hydrothermal emissions that could lead to the dissolution of calcium carbonate tests. According to Patterson and McKillop (1991), *Glomospira gordialis* has been reported from relatively shallow, brackish estuarine environments in Nova Scotia (Scott *et al.*, 1980) with salinities similar to the brackish values recorded at the Lake Winnipegosis area locality. This benthic, cosmopolitan species has been from the entire Gulf of Mexico in a massive water depth range of 0 to 3,700 m (Sen Gupta *et al.*, 2009b).

Repository: PK–AG–014

*Glomospira irregularis* (Grzybowski, 1898)

*Glomospira irregularis* (Grzybowski, 1898)  
Pl. 1; Fig. 14

Original citation: *Ammodiscus irregularis* GRZYBOWSKI, 1898, p. 285, pl. 11, figs. 2, 3.

Remarks: Charnock and Jones (1990) retained the name *Glomospira irregularis* over *G. demarginatus* despite the latter having priority by page, because according to current I.C.Z.N. rules, this is not a means of establishing seniority. According to Valchev (2004), “there are no data about the holotype. Geroch, Verdenius (1983) refigured the original Grzybowski's images. The species was first described from the Eocene of Polish Carpathians (Krosno area). The species is known from the Upper Cretaceous of Italy, Spain, the Upper Cretaceous and Paleocene of the Alps, Carpathians, Caucasus, the Paleocene of Trinidad, the Lower and Middle Eocene of deep sea
holes of Norwegian and Greenland Seas”. Glomospira irregularis has also been recorded from mangroves in Bermuda (Javaux, 1999). Valchev (2006) classified this species under the streptospiral and heteromorphous morphogroup. Sen Gupta et al. (2009a) recorded its occurrence in the Mississippi Canyon (1,067 to 1,081 m), Farnella Canyon (2,918 m), Green Canyon (245 m and 569 m), Garden Banks (640 m), and De Soto Canyon (1,848 m), all in the Gulf of Mexico.

Repository: PK–AG–015

Subfamily USBEKISTANIINAE Vyalov, 1968
Genus USBEKISTANIA Suleymanov, 1960
Usbekistania charoides (Jones and Parker, 1860)

Original citation: Trochamminia squamata JONES AND PARKER var. charoides JONES and PARKER, 1860, v. 16, p. 304.
Remarks: Brady referred this species to Ammodiscus, while Rhumbler (1909) and Cushman (1918) referred it to Glomospira Rzehak 1888. Earlier, Rhumbler (1895) had referred this and the preceding species to his genus Gordiammina, a synonym of Glomospira. Jones stated that this species was referred to Usbekistania by Charnock and Jones (1990) and commented: “It has recently been lectotypified by Berggren and Kaminski (1990). It is also, by synonymy with the originally designated Glomospirella (Usbekistania) mubarakensis Suleymanov 1960, the type species of Usbekistania Suleymanov 1960. Usbekistania differs from the irregularly coiled Glomospira in being strictly streptospiral, that is in being characterized by regular changes in the axis of coiling.” Unlike other species, this taxon was recorded by Brady (Barker, 1960) at depths ranging between 1,865 m and 3,475 m, perhaps indicative of the deep-water preference of this species. This species is mostly restricted to mid-abyssal depths or greater (>3,000 m) with just a few sporadic occurrences up into mid-bathyal depths. This is one of the species that are not useful in paleobathymetric assessments because they are highly susceptible to taphonomic loss with shallow burial. This benthic, cosmopolitan species has been recorded from the entire Gulf of Mexico in a massive water depth range of 0 to 3,850 m (Sen Gupta et al., 2009b).
Repository: PK–AG–016

Superfamily HORMOSINACEA Haeckel, 1894
Family HORMOSINIDAE Haeckel, 1894
Subfamily REOPHACINAE Cushman, 1910
Genus HORMOSINELLA Shchedrina, 1969
Hormosinella distans (Brady, 1881)
Pl. 1; Fig. 15

Original citation: Lituola (Reophax) distans BRADY, 1881, p. 50 (no figure given); – Brady, 1884, p. 296, pl. 31, figs. 18–22.
Remarks: According to Schröder (1988), the majority of the species of Reophax show a tendency to disintegrate rapidly after burial; exceptions include H. distans, and the occurrence of this species at a water depth of 4,499 m was unusual. Kuhnt (1990) distinguished specimens from the Contessa Highway section from Recent ones based on the smaller test, finer agglutination and variable chamber shape. Kaminski and Gradstein (2005) illustrated a specimen from the Upper Campanian of Bottacone as Hormosinella distans (Brady, 1881). According to Kaminski et al. (2011), Hormosinella distans differs from H. fusiformis in having less elongated chambers and possessing a less fragile test. Mikhailovich (2004) observed this species to occur at depths not less than 621 m, and opined that this taxon, normally found at the upper part of the shelf, was found...
also on the deeper shelf parts and in the upper sub-zone of the bathyal zone. This might be due to the abruptness of the shelf and its significant extension, and also to the comparative uniformity of environments with a small drop of temperatures and relative homogeneity of all other hydrologic parameters. Mallon (2011) found this taxon to be rare and recorded only four stained specimens at one station off Ecuador at 2,092 m water depth. According to Sen Gupta et al. (2009b), *H. distans* is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat and has been recorded from the entire Gulf of Mexico in a water depth range of 280 to 3,515 m.

**Repository:** PK–AG–017

*Hormosinella guttifera* (Brady, 1881)

**Pl. 1; Fig. 16**

**Original citation:** *Lituola (Reophax) guttifera* BRADY, 1881, v. 21, p. 49; 1884, pl. 31, figs. 10–15.

**Remarks:** The figures illustrated by Brady (Barker, 1960) are of specimens obtained from the sediment dredged at Challenger Station 323, at a depth of 1,900 fathoms (~3,475 m; figs. 1–3) in the South Atlantic. Collins (1968) observed this species to occur in the Great Barrier Reef region, and opined that it is a widely distributed taxon in both hemispheres. Vilk (1969) observed that specimens recovered from Hazen Strait and Hecla and Griper bays of the Canadian Arctic were very fragile, and commonly the chambers were broken apart. This species was found to be rare in localities shallower than 160 m, but very common at the deep stations. According to Sgarrella and Moncharmont Zei (1993), who reported this species as *Reophax guttifer*, it occurs in the Mediterranean Sea in circa-littoral and epibathyal muds in the Gulf of Salerno (from 198 m onward) and Gulf of Policastro (>96 m), but has been “poorly recorded” in the Gulf of Naples in a depth range of 132 to 490 m. According to Murray (2006), *Hormosinella guttifera* is one of the species that “regularly appears as dominant or subsidiary (>10%)” in the Atlantic Ocean. Enge et al. (2011) observed that this species was one among those showed higher 13C excess within the sediment than at the sediment surface, as its carbon uptake was between 1 and 5 µg C m⁻².

According to Sen Gupta et al. (2009b), this benthic, cosmopolitan species has a wide water depth range of 79 to 2,280 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico.

**Repository:** PK–AG–018

**Genus REOPHAX de Montfort, 1808**

*Reophax dentaliniformis* (Brady, 1881)

**Pl. 1; Fig. 17**

**Original citation:** *Reophax dentaliniformis* BRADY, 1881, p. 49.

**Remarks:** Röttgardt (1952) regarded this species as “marine brackish”; interestingly, this species was recorded by Boltovskoy and Wright (1976) from the deep basin colder brackish waters of the large, relatively land-locked Baltic Sea. Kaminski (1988) observed that *Reophax dentaliniformis* clearly prefers, though not confined to, an infaunal habitat (Kuhnt et al., 2000) in the Panama Basin at a water depth of 3,912 m. According to Murray (2014), this species is capable of dwelling in areas that are intermittently affected by strong bottom currents which cause scour, formation of ripples etc, at the high energy benthic boundary layer experiment (Hebble) site that was established on the continental rise off Nova Scotia where the water depth is 4,815–4,820 m. Although its fossilization potential is extremely low, *R. dentaliniformis* is an opportunistic species with high re-colonization potential (Kaminski, 1985). The only shallower water record is perhaps that of Albani and Geyskes (1969), who recorded it at 350 m on the north-western part of the Australian continental shelf. *Reophax dentaliniformis* (in association with *R. bilocularis*) has
also been observed to dominate an assemblage beneath the intense oxygen minimum zone off Oman (Hermelin, 1992). According to Sen Gupta et al. (2009b), this benthic, cosmopolitan species has an extremely wide water depth range of 19 to 3,431 m in the entire Gulf of Mexico.

Repository: PK–AG–019

Reophax nodulosa Brady, 1879

Original citation: *Reophax nodulosa* BRADY, 1879, v. 19, p. 52, pl. 4, figs. 7, 8.

Remarks: According to Smith (1973), “this species is generally large and robust. It shows a great deal of variation in chamber shape as shown in Brady’s (1884) illustrations”. Todd and Low (1980), who studied foraminifera from the Kara and Greenland seas, observed the occurrence of *Reophax nodulosus* in the much shallower Kara Sea samples (water depth range of 82 to 640 m); the species was, however, not recorded in the deeper water Greenland Sea samples collected from the slope, basin and rise (2,195 to 3,340 m). In the surface sediments associated with hydrocarbon seeps in the Gulf of Mexico, *R. nodulosus* was found to be associated with *Thioploca*, a filamentous bacterium, with relatively much higher populations in Atwater Canyon (1,930 m) than Green Canyon (700 m) (Sen Gupta et al., 2009a). According to Sen Gupta et al. (2009b), this benthic, cosmopolitan species has a very wide water depth range of 15 to 3,250 m in the north-eastern, north-western and south-eastern parts of the Gulf of Mexico.

Repository: PK–AG–020

Reophax scorpiurus de Montfort, 1808

Original citation: *Reophax scorpiurus* DE MONTFORT, 1808, v. 1, p. 331, text-fig. 130.

Remarks: The types of this species came from the beaches of the Adriatic Sea. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged off the Hebrides, West Scotland, North Atlantic (fig. 12), at Challenger Station 323, South Atlantic, at a depth of 1,900 fathoms (~3,475 m; figs. 14), at Challenger Station 260A, Honolulu reef, Pacific Ocean, at a depth of 40 fathoms (~73 m; fig. 15), and at Challenger Station 185, Torres Strait, Pacific Ocean, at a depth of 155 fathoms (~283 m; figs. 16, 17). A characteristic feature of this species is its initial arcuate portion with a tendency to straighten out in the later stages. Commenting on this species, Hatta and Ujjie (1992) remarked, “This species is characterized in having a wall so coarsely agglutinated that the intercameral sutures are indistinct”. *Reophax scorpiurus* is the type species of the genus *Reophax* and has been reported by many authors from variable water depths, ranging from neritic to bathyal environments. There is, however, some taxonomic confusion, partly because its type specimen was lost and not re-examined by modern methods. According to Sen Gupta et al. (2009b), this benthic, cosmopolitan species has a very wide water depth range of 11 to 3,488 m in the entire Gulf of Mexico.

Repository: PK–AG–021

Genus SUBREOPHAX Saidova, 1975

Subreophax aduncus (Brady, 1882)

Citation: *Reophax aduncus* BRADY, 1882, v. 11, p. 715.

Remarks: Saidova (1975) erected the genus *Subreophax* with *Reophax aduncus* Brady as the type species, and remarked, “The syntypes illustrated by Brady (1884) are preserved in the Brady Collection in slides ZF 2256–2259. The lectotype, designated herein, is from Porcupine Station
28 (1,215 fathoms; 2,222 m), and is the specimen illustrated by Brady (1884, pl. 31, fig. 23) and it is preserved in slide ZF 2256. Brady also recorded this species as *Reophax aduncus* from Challenger Station 323, South Atlantic, (1,900 fathoms; ~3,475 m), and at Challenger Station 160, in the South Pacific (2,600 fathoms; ~4,755 m). Hada (1957) erected a new species, *Reophax paucus*, but opined that “the new species somewhat resembles *R. aduncus* Brady in shape and arrangement of chambers, but it is easily distinguished from the latter by a minute size of the test and a small number of chambers”. According to Frenzel (2001), this species was one among the fifteen Recent species recorded from the open Baltic Sea in a salinity range of about 9 to 15‰. This benthic, cosmopolitan species with a bathyal and/or abyssal habitat has a water depth range of 305 to 2,432 m in the north-eastern, north-western and south-eastern parts of the Gulf of Mexico (Sen Gupta et al., 2009b).

**Repository:** PK–AG–022

Subfamilii HORMOSININAE Haeckel, 1894

Genus HORMOSINA, Brady, 1879

*Hormosina globulifera* Brady, 1879

**Original citation:** *Hormosina globulifera* BRADY, 1879, ser. 19, p. 60, pl. 4, figs. 4, 5; 1884, pp. 326–327, pl. 39, figs. 1–6.

**Remarks:** The figures of *Hormosina globulifera* illustrated by Barker (1960) are of specimens recovered from the sediment dredged at three locations: Challenger Station 246 in the North Atlantic (2,050 fathoms; ~3,749 m; figs. 1, 2, 5), Porcupine Station, off north-west Ireland (630 fathoms; ~1,152 m; figs. 3, 4) and Challenger Station 218, north of Papua, Pacific Ocean (1,070 fathoms; ~1,957 m; fig. 6). Cushman (1920) defined this species as characteristic of the North Atlantic deep-water with greatest development around 2,500 to 3,500 m. It was also reported by Pflum and Freirichs (1976) in the deep-water of the Gulf of Mexico from 2,178 to 6,972 feet (~664 to 2,125 m). According to Sgarrella and Moncharmont Zei (1993), *Hormosina globulifera* occurs at depths ranging from 320 to 742 m in the Gulf of Naples, Italy. The lectotype is the five-chambered specimen illustrated by Brady (1884, pl. 39, fig. 4) and is preserved in the centre of slide ZF 1584. The two-chambered specimen originally illustrated by Brady (1879, pl. 4, fig. 5), is preserved in slide ZF 1582. Three additional unfigured paralecotypes are also present in the slide (Kaminski and Cetean, 2011). According to Sen Gupta et al. (2009b), *H. globulifera* is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat, and has been recorded from the entire Gulf of Mexico in a depth range of 305 to 3,850 m.

**Repository:** PK–AG–023

*Hormosina pilulifera* (Brady, 1884)

**Original citation:** *Reophax pilulifera* BRADY, 1884, v. 9, p. 292, pl. 30, figs. 18–20.

**Remarks:** It is interesting to note that Smith (1973) wrote, “This species is very distinctive and somewhat similar to *Hormosina globulifera* Brady (1884, p. 53), but it has a coarsely arenaceous wall”. According to Valchev (2004), who reported this species as *Reophax pilulifera*, the “species is known from the Paleocene to Recent deposits. It was established in the Paleogene flysh deposits in the Carpathians, deep sea holes in the Labrador and North Seas, the Eocene of Ukraine, the Oligocene of Hungary. Nowadays, it lives in the high latitudes of the Atlantic and Pacific”. *Hormosina pilulifera* is a benthic species that is bathyal and/or abyssal, and cosmopolitan. In the north-eastern and north-western parts of the Gulf of Mexico, it has a water depth range of 384 to 3,515 m (Sen Gupta et al., 2009b). Mallon (2011) observed the occurrence of this species (as
Reophax pilulifer) at two stations off Peru and Ecuador at 1,004 and 2,092 m water depth, respectively, but noted that it was rare.

Repository: PK–AG–024

Superfamily LITUOLACEA de Blainville, 1827
Family HAPLOPHRAGMOIDIDAE Maync, 1952
Genus CRIBROSTOMOIDES Cushman, 1910

Cribrostomoides subglobosum (Cushman, 1910)

Original citation: Haplophragmoides subglobosum CUSHMAN, 1910, p. 105, figs. 162–164.
Remarks: The figures illustrated by Barker (1960) are of specimens recovered from the sediments dredged at Challenger Station 300, north of Juan Fernandez, at a depth of 1,375 fathoms (~2,515 m; fig. 7), and at Challenger Station 24, West Indies, at a depth of 390 fathoms (~713 m; figs. 8, 10). Brady referred Alveolophragmium subglobosum to Haplophragmium latidorsatum (Bornemann), while Cushman referred the figures to Haplophragmoides subglobosum (G. O. Sars) in 1910 (p. 105). Höglund (1947, p. 144) placed subglobosum in his new genus Labrospira. However, Loeblich and Tappan (1953) showed that Labrospira is a synonym of Alveolophragmium Tschedrina, 1936. Vilks (1969) observed this species to occur only at depths >200 m and that it was common in the deep waters. This species was recorded in a water depth range of 1,100 to 2,005 m on the continental margin of south-western Norway by Mackensen et al. (1985). At a station (water depth of 1,243 m) on the Voring-Plateau in the Norwegian Sea, Graf and Linke (1992) observed Cribrostomoides subglobosum to be very abundant (up to 24,000 rose-Bengal stained individuals per m²); it was also important in terms of biomass. They also noted that freshly sampled tests of this species had extremely low ATP: AMP ratios, comparable only to the lowest ratios found in the Antarctic sediments.

Repository: PK–AG–025

Genus VELERONINOIDES Saidova, 1981

Veleroninoides wiesneri (Parr, 1950)

Original citation: Labrospira wiesneri PARR, 1950, p. 272, pl. 4, figs. 25, 26.
Remarks: Hayward et al. (2001) gave a water depth range of 1,320 to 3,650 m for this species off New Zealand. In their study on Recent foraminifera from marine and/or glacio-marine sediment samples collected at water depths of up to 75 m in Goulden Cove (Admiralty Bay) on King George Island, West Antarctica, Gazdzicki and Majewski (2003) observed this species (reported as Labrospira wiesneri Parr) at 20, 35 and 75 m water depths. Larkin (2006) observed that the Pakistan margin specimens resembled Trochammina trullissata of Brady (1884, pl. 40, figs. 14, 15), synonymous with Veleroninoides wiesneri according to Jones (1994). Brady’s specimens came from 437 m in the Indian Ocean off Antarctica. The Pakistan margin specimens are 310–520 µm long. This infaunal (Gooday, 1990) species was present only at 300 m. According to Sen Gupta et al. (2009b), Veleroninoides wiesneri is a benthic, cosmopolitan species that has been recorded from the entire Gulf of Mexico at water depths ranging from 28 to 3,850 m. It was recorded in the Deep Green Canyon (562–696 m), Garden Banks (640 m), South of Mississippi Canyon (~1,000 m), Mississippi Canyon (620 m, 1,067–1,081 m), De Soto Canyon (1,850 m), and Alaminos Canyon (2,218–2,227 m) (Sen Gupta et al., 2009a). Live foraminiferal faunas (rose Bengal-stained) from the northern Arabian Sea were examined by Cauille et al. (2013), who observed V. wiesneri to be abundant only in the 63–125 µm fraction. These observations indicate that this species has a very wide water depth range.
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Repository: PK–AG–026

Family LITUOLIDAE de Blainville, 1827
Subfamily AMMOMARGINULININAE Podobina, 1978
Genus ERATIDUS Saidova, 1975

Eratidus foliaceus (Brady, 1881)
Pl. 1; Fig. 20

Original citation: Haplophragmium foliaceum BRADY, 1881, v. 21, p. 50; 1883, v. 9, p. 304, pl. 33, figs. 20–25.
Remarks: The figures illustrated by Barker (1960) are of specimens recovered from the sediment dredged at Challenger Station 323 in the South Atlantic at a depth of 1,900 fathoms (~3,475 m). Brady referred this species to Haplophragmium, while Cushman (1920, p. 64) referred it to Ammolobaculites. It was figured by Cushman in 1933 as Ammomarginulina (pl. 10, figs. 6a, b). According to Schröder (1988), Eratidus foliaceus is one of the agglutinated forms that have greater preservation potential. Murray and Alve (2011) opined this species to be infaunal, correlating with higher total organic carbon (TOC) but tolerating temperature of 1.8–7.9° C in the Gulf of Guinea (Timm, 1992) and generally associated with sea floor organic flux range of 0.2–20 g m² yr⁻¹ (Altenbach et al., 1999). Enge et al. (2012) studied the diversity and microhabitats of living benthic foraminifera in the abyssal north-east Pacific Ocean and observed individuals of Eratidus foliaceus in replicate cores collected at the same site at a water depth of 3,953 m, but always in the top 3 cm. According to Murray (2014), this species was observed to occur in association with Uvigerina peregrina in the uppermost centimeter of a sample collected beneath the Congo Plume and on the Congo Fan.

Repository: PK–AG–027

Superfamily HAPLOPHRAGMIACEA Eimer and Fickert, 1899
Family AMMOSPHAEROIDINIDAE Cushman, 1927
Subfamily AMMOSPHAEROIDININAE Cushman, 1927
Genus ADERCOTRYMA Loeblich and Tappan, 1952

Adercotryma glomeratum (Brady, 1878)

Original citation: Lituola glomerata BRADY, 1878, ser. 5, v. 1, p. 433, pl. 20, figs. 1a–c.
Remarks: The figures of Adercotryma glomeratum illustrated by Barker (1960) are of specimens recovered from samples dredged at Challenger Station 149I, Kerguelen Islands, South Pacific, at a depth of 120 fathoms (~220 m; figs. 15–18). Brady referred this species to Haplophragmium, while Cushman and later workers referred it to Haplophragmoides. Loeblich and Tappan (1952, p. 141) made it the genotype of their new genus Adercotryma. In the Mediterranean region, A. glomeratum is generally poorly represented, while in the Gulf of Naples, the distribution range of A. glomeratum is between 22 and 600 m (Sgarrella and Moncharmont Zei, 1993). Bernhard and Alve (1996) demonstrated experimentally that this species is capable of surviving more than three weeks of anoxia. This infaunal-epifaunal species exhibits negative correlation with TOC but tolerates a wide range of temperature 1.8°–16.6° C in the Gulf of Guinea (Timm, 1992). However, in the Arctic Ocean, it favors temperatures of 1.8°–3.0° C (Williamson et al., 1984). According to Gooday (1988), A. glomeratum inhabits the phytodetritus layer and sediment, moving up and down in sediment seasonally. According to Hayward et al. (2001), this agglutinated species is susceptible to partial taphonomic loss during shallow burial (>0.5 m) at 1,300–4,500 m water depth. They also observed that it is one of the taxa that are mostly restricted to mid-abyssal depths or greater (>3,000 m) with just a few sporadic occurrences up.
into mid-bathyal depths. Recently, Nathan et al. (2014) compared the datasets of Phleger (1952) and Parker (1952) with their own 2006 dataset on benthic foraminifera of the western Gulf of Maine, and found increased abundance as well as landward migration of *A. glomeratum*. They also opined it to be one of the diagnostic species of the delta front at water depth > 70 m.

**Repository:** PK–AG–028

**Genus CYSTAMMINA Neumayr, 1889**

*Cystammina pauciloculata* (Brady, 1879)

*Pl. 1; Fig. 21*

**Original citation:** *Trochammina pauciloculata* BRADY, 1879, p. 58, pl. 5, figs. 13, 14.

**Remarks:** Hofker (1978) recorded the occurrence of this species in the eastern part of the Indonesian Archipelago at a water depth of 2,484 m, where the temperature was 1.8° C, and believed that the low temperatures (<3° C) influenced the distribution of such benthic foraminifers as *Cystammina pauciloculata*. It is a shallow infaunal species (Kuhnt et al., 2000) that tolerates dysoxia (Schönfeld, 1997), and is generally associated with sea floor organic flux range of 1–9 g m² yr⁻¹ (Altenbach et al., 1999). Living individuals of this species were more or less consistently observed by Kuhnt et al. (2000) within the uppermost 1–4 cm of the sediment samples collected from abyssal oligotrophic sites in the Sargasso Sea, continental rise directly beneath the Gulf Stream, and from underneath the zone of cold core rings south of the Gulf Stream. Heinz et al. (2004) examined benthic foraminifera assemblages at Great Meteor Seamount and recorded this species at the deep stations with water depths of 4,096 m and 3,100 m, but only in the uppermost one cm of the samples retrieved by a multi-corer; however, they observed more specimens in the 63–125 µm fraction than in the >125 µm fraction. Sen Gupta et al. (2009a) studied the taxonomy and ecology of bathyal foraminiferal communities in northern Gulf of Mexico and recorded *C. pauciloculata* from the Deep Green, Alaminos and Farnella canyons at water depths of 562–696 m, 2,218–2,227 m and 2,918 m, respectively. This could well be the first record for this species from Indian waters.

**Repository:** PK–AG–029

**Superfamily LOFTUSIACEA Brady, 1884**

**Family CYCLAMMINIDAE Marie, 1941**

**Subfamily CYCLAMMININAE Marie, 1941**

**Genus CYCLAMMINA Brady, 1879**

*Cyclammina cancellata* Brady, 1879

*Original citation:* *Cyclammina cancellata* BRADY, 1879, v. 19, p. 62.

**Remarks:** Brady (1884) recorded this species from the North Pacific, east of Japan, at water depths of 3,400 m and 5,300 m. According to Theyer (1969), *Cyclammina cancellata* Brady shows marked variations of diameter and thickness in Holocene sediments from depths of 500 m to more than 3,500 m in the Peru-Chile Trench area. The mean diameter increases consistently to a maximum of 5 mm at 2,000 m. Fluctuations between 4 and 5 mm follow from 2,000 to 3,500 m, and a decreasing trend characterizes deeper samples. The mean thickness increases steadily downward to about 3,500 m where a slight decrease sets in. Using mean diameter, thickness, and a ratio between both, populations of this study can be characterized as to depth zones. Thus, small and relatively thick forms appear at about 500 m; larger and proportionally thinner forms live deeper than 1,000 m; large but relatively thick specimens characterize depths of about 2,000 to 3,500 m; and somewhat smaller and thicker ones are typical for depths below 3,500 m. Temperature may be the principal factor affecting size, because it increases markedly to about...
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2,000 m, which coincides with the greatest size change in the populations. *Cyclammina cancellata* was quite common on the continental slope, in the water depth range of 1,661 to 2,070 m, but was the most abundant (38% of the foraminiferan fauna) species on the continental slope (water depth of 3,580 m) off Prince Olav Coast, Antarctica (Gupta, 1983). A wide depth range of 524–4,545 m and temperature range of 1.5°–7.7° C was observed by Hofker (1978) for this species in the eastern part of the Indonesian Archipelago. Later, he (1980) recorded *C. cancellata* at water depths ranging between 560 m and 980 m, optimum depth range being 700–980 m, on the deeper parts of the slope of the Saba Bank. An almost similar depth observation was made by Cameron (1995), but he observed it to be rare off the Kaikoura Peninsula, New Zealand, in samples collected in a depth range of 500–1,035 m. According to Sen Gupta *et al.* (2009b), *C. cancellata* is a benthic species with a bathyal and/or abyssal habitat with a depth range of 398–2,538 m in the in the north-eastern, north-western and south-western parts of the Gulf of Mexico.

Repository: PK–AG–030

*Cyclammina pusilla* Brady, 1884

Original citation: *Cyclammina pusilla* BRADY, 1881, p. 53 (type description); illustrated in BRADY, 1884, pp. 353–354, pl. 37, figs. 20–23.

Remarks: Brady (1884) illustrated specimens collected from Challenger Station 323 at a depth of 1,900 fathoms (~3,475 m). A depth-distribution chart for significant species of the Pacific-Antarctic Basin was provided by Theyer (1970), wherein he stated that this species marks the 3,500 m to 4,500 m depth zone, although the graph he provided shows a total depth range of 3,000 m to >5,000 m. Hess *et al.* (2000) used volcanic ash particles that constituted a sub-adult test of *Cyclammina pusilla* that was alive at the time of collection (rose Bengal-stained) and had constructed its last three chambers out of volcanic ash particles to estimate its growth rate. On the Sunda Shelf, in the south-western South China Sea, Szarek (2001) recorded this species at a water depth of 978 m and opined it to be a middle bathyal species. According to Sen Gupta *et al.* (2009b), *C. pusilla* is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat; they recorded this species at 1,067 m water depth in the north-western part of the Gulf of Mexico. This could well be the first record for this species from Indian waters.

Repository: PK–AG–031

*Cyclammina trullissata* (Brady, 1879)

Original citation: *Trochammina trullissata* BRADY, 1879, v. 19, no. 73, p. 56, pl. 5, figs. 10a, b.

Remarks: This species was referred by Brady (1879) to *Trochammina trullissata* and by Cushman to *Cyclammina bradyi* (1910, p. 113). However, Parker (1952, p. 400) pointed out that Brady’s original figures were identical to those illustrated by Barker (1960, p. 82, pl. 40, figs. 13a, b) and, therefore, the name *trullissata* must be retained for this form. Brady’s (op cit.) illustrations were those of specimens obtained from a water depth of 390 fathoms (~713 m), off the West Indies. According to Smith (1973), who examined the foraminifers from the North Pacific Ocean, *Cyclammina trullissata* is widely distributed between latitudes 30° and 55° N, but rare. It is a benthic, cosmopolitan species with a bathyal and/or abyssal habitat and, in the north-eastern and north-western parts of the Gulf of Mexico, has been recorded in the water depth range of 819–1,827 m (Sen Gupta *et al.*, 2009). According to Mallon (2011), *Cyclammina trullissata* resembles *C. cancellata* but is smaller in size, and has less chambers. It was observed to be very rare, at 1,004
water depth off the Peruvian continental margin. This could well be the first record for this species from Indian waters.

Repository: PK–AG–032

Superfamily TROCHAMMINACEA Schwager, 1877
Family TROCHAMMINIDAE Schwager, 1877
Subfamily TROCHAMMININAE Schwager, 1877
Genus AMMOGLOBIGERINA Eimer and Fickert, 1899
Ammoglobigerina globigeriniformis (Parker and Jones, 1865)
Pl. 2; Figs. 3, 3a

Original citation: Lituola nautiloidea (LAMARCK) var. globigeriniformis PARKER AND JONES, 1865, v. 155, p. 407, pl. 15, figs. 46, 47; pl. 17, figs. 96–98.

Remarks: The figures illustrated by Barker (1960) are of specimens recovered from sediments dredged at Challenger Station 323, in the South Atlantic, at a depth of 1,900 fathoms (~3,475 m; fig. 10) and Challenger Station 78, south-east of Azores, Atlantic Ocean, at a depth of 1,000 fathoms (~1,829 m; fig. 11). Brady referred this species to Haplophragmium, but Ammoglobigerina was proposed for this species by Eimer and Fickert (1899, p. 704), with A. globigeriniformis regarded as the same as Globigerina bulloides Williamson non d’Orbigny (apparently an error, however). Cushman placed Ammoglobigerina in the synonymy of Trochammina, Galloway (1933) retained it as a valid genus, while Glassner placed it under Trochammina as a sub-genus. Ammoglobigerina globigeriniformis has been widely and continuously reported for well over a century (Loeblich and Tappan, 1987, p. 120). This species was reported as Trochammina globigeriniformis by Hofker (1978) from a water depth range of 432 to 4,951 m and a temperature range of 1.8° to 8.0° C in the eastern part of the Indonesian Archipelago. Kaminski (1987) recorded live individuals of this species (also as T. globigeriniformis) in the 0–2 and 5–10 cm segments of a spade core from the Panama Basin, and opined that it is one of the taxa that displayed good dispersal capabilities with high fossilization potential. According to Panieri et al. (2005), who studied benthic foraminifera from a shallow-water hydrothermal environment in the Aeolian Arc, Tyrrhenian Sea, this species constituted an assemblage suggestive of low pH conditions resulting from acidic hydrothermal emissions, leading to the dissolution of calcium carbonate tests; this was later corroborated by Hart et al. (2011). Ammoglobigerina globigeriniformis was observed to be common, occurring as small individuals, off Peru and Ecuador, at water depths between 207 and 2,092 m (Mallon, 2011). This species was observed to occur primarily in the 0 to 0.5 cm of the sediment samples collected from the Portuguese margin in the north-east Atlantic (Phipps, 2012) at depths ranging between 282 and 4,987 m.

Repository: PK–AG–033

Superfamily ATAXOPHRAGMIIACEA Schwager, 1877
Family GLOBOTEXTULARIIDAE Cushman, 1927
Subfamily GLOBOTEXTULARIIINAE Cushman, 1927
Genus VERNEUILINULLA Saidova, 1975
Verneuilinulla propinqua (Brady, 1884)

Original citation: Verneuilina propinqua BRADY, 1884 (part), p. 387, pl. 47, figs. 8–12 (not figs. 13, 14).

Remarks: Flint (1899) recorded and illustrated this species as Verneuilina propinqua (pp. 285–286; pl. 31, fig. 2) and remarked that it is “very similar in form to V. pygmaea, but is larger, coarser, rougher, less symmetrical, and in color a reddish brown. The aperture is without the raised lip.
seen in the other species”. He was able to obtain specimens from four stations in the North Atlantic, one in the South Atlantic, and two in the Gulf of Mexico at water depths ranging from 730 to 2,226 fathoms (~1,335 to 4,071 m). The figures illustrated by Barker (1960) are of specimens of this species recovered from sediment samples dredged at Challenger Station 98, off Africa, Atlantic Ocean, at a depth of 1,750 fathoms (~3,200 m; figs. 8, 9, 12) and Challenger Station 246, North Pacific Ocean, at a depth of 2,050 fathoms (~3,749 m; fig. 10). This species was referred by Brady to *Verneuilina*, but was transferred by Cushman to *Eggerella* in 1937 (p. 53). According to Szarek (2001), who studied the biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea, *Verneuilina propinqua* is an upper bathyal to lower bathyal species. *Verneuilinulla propinqua* is a benthic species with a bathyal and/or abyssal habitat has a water depth range of 369 to 1,692 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico (Sen Gupta *et al.*, 2009b). Specimens of this species (reported as *Verneuilina propinqua*) were found by Mallon (2011) at two stations off Peru on 11°S and water depths of 302 m and 823 m, respectively. Caulle *et al.* (2013) examined the relationship between bottom-water oxygenation and live foraminiferal faunas (rose Bengal-stained) from the northern Arabian Sea, and observed the occurrence of *V. propinqua* both in the core of the OMZ, at depths of 885 m and 1,013 m, where oxygen and nitrate penetration are very shallow (~0.1 cm and ~1.3 cm, respectively), and also in the lower part of the OMZ (1,172 to 1,379 m), where the oxygen and nitrate penetration depths increase to 0.6 cm and 3.5 cm depth, respectively.

Repository: PK–AG–034

Superfamily TEXTULARIACEA Ehrenberg, 1838
Family EGGERELLIDAE Cushman, 1937
Subfamily EGGERELLINAE Cushman, 1937
Genus EGGERELLA Cushman, 1935
*Eggerella bradyi* (Cushman, 1911)

Original citation: *Verneuilina bradyi* CUSHMAN, 1911, v. 71, no. 2, p. 54, p. 87.
Remarks: The figures illustrated by Barker (1960) are of specimens recovered from sediment samples dredged at Challenger Station 296, South Pacific, at a depth of 1,825 fathoms (~3,338 m; figs. 4, 5); at Challenger Station 23, West Indies, at a depth of 450 fathoms (~823 m; fig. 6); and at Challenger Station 296B, South Pacific (fig. 7). Brady referred this species to *Verneuilina pygmaea* (Egger), while Cushman (1911, p. 54) referred these figures to *Verneuilina bradyi* and, in 1933 (p. 33), transferred the species to *Eggerella*. The test of *E. bradyi* is composed of calcareous pieces cemented together, which gives the surface a smooth and polished finish (Hermelin, 1989), but some specimens are smooth with a dull luster (Corliss, 1979). Mead (1985) recorded a regular increase in the relative abundance of this species at depths ranging between 1,493 m and 3,122 m in the south-east Atlantic. Nomura (1991) reported *E. bradyi* from lower bathyal depths at the Broken Ridge and Ninety East Ridge in the Indian Ocean, while Gupta (1994) found *E. bradyi* from lower bathyal (1,623 m) to lower abyssal (5,082 m) depths. This infaunal (Zhang *et al.*, 2007) species is found to be associated with degraded organic matter (Gupta, 1997), and has very high abundance in deeper water especially below 3,500 m in the South China Sea (Jian and Wang, 1997). Gupta and Thomas (2003) opined that this species prefers an environment that is cool and carbonate-corrosive, with variable organic flux and high oxygenation. According to Sen Gupta *et al.* (2009b), this species is a benthic, cosmopolitan with a wide water depth range of 99 to 3,850 m in the entire Gulf of Mexico. *Eggerella bradyi* has wide geographic distribution and it has been reported from the all bathyal and abyssal depths of the world’s oceans (Singh *et al.*, 2014).

Repository: PK–AG–035
Genus **EGGERELLOIDES** Haynes, 1973

*Eggerelloides scaber* (Williamson, 1858)

**Original citation:** *Bulimina scabra* WILLIAMSON, 1858, p. 65, pl. 5, figs. 136, 137.

**Remarks:** The original diagnosis of Williamson (1858) was based on material which included specimens from Dublin Bay as well as the Shetlands. In particular, he noted the obtuse shape and tumid distal end, the roughly agglutinated test with its organic cement, and the “involuted” aperture. Höglund (1947) characterized it as a shallow-water form in the Gullmarfjord, Sweden, occurring with thousands of specimens in each core sample at 15–20 m depth. He rarely recorded it deeper than 60 m. However, in the Skagerrak, he found unstained individuals down to 204 m. The figures illustrated by Barker (1960) are of specimens recovered from the sediments dredged from the Clyde, Scotland (fig. 15), and Challenger Station 354A, off Spain, East Atlantic, at a depth of 11 fathoms (~20 m; figs. 16, 17). Brady referred this species to *Verneuilina polystropha* (Reuss), while Cushman referred it to *Verneuilina scabra* (1922, p. 55), but later he transferred it to *Eggerrella* (1937, p. 50). Haynes (1973) remarked, “Our specimens are identical with specimens examined in the Williamson collection at the British Museum. The form of the aperture disposed Williamson to place this species with *Bulimina* and it was in fact called *B. arenacea* on the plate explanation. The difficulties experienced by later authors in this regard have led to it being successively placed in *Textularia*, *Verneuilina* and *Eggerrella*. However, as our plates show, the apertural characters which are remarkably like those of *Bulimina* exclude it from these generic groups.” *Eggerella scabra* is widespread all around the Mediterranean and has been reported as more frequent on infra-littoral fine sand, sandy-muddy bottoms with vegetation, and in the upper circa-littoral zone (Sgarrella and Moncharmont Zeit, 1993). In the Kattegat, the *E. scaber* assemblage typically occurs at 14–35 m water depth (Conradsen et al., 1994). *Eggerelloides scaber* lives epiphytically on seagrass (Debenay, 2000) and is possibly related to the presence of *Zostera* in the lower part of the Guadiana Estuary (Chicharo et al., 2001); it has also been found to be abundant close to areas colonized by *Zostera noltii* in the Array River in France (Redois and Debenay, 1996). According to Mendes et al. (2004), this shallow marine species occurs in highest percentages in water depths shallower than 30 m with a maximum percentage value of 12.59% between 10 m and 13 m water depth in sediment samples dominated by sand and silt. *Eggerelloides scaber* builds a wall of up to 0.5 mm large particles, which are embedded in a fine-grained agglutinated matrix. The matrix particles were bound by a thin film of organic substance where they were in contact with each other (Murray, 1973; Bender, 1989). EDX element mapping revealed that the fine-grained matrix was uniformly rich in Ca and Mg (Schönfeld et al., 2013). According to Melis and Covelli (2013), *E. scaber* is a continental shelf species that lives in microhabitats with different oxygenation conditions (e.g., Jorissen et al., 1992; Donnici and Serandrei Barbero, 2002; Duijnstee et al., 2004); it is also able to colonize the seaward part of estuaries and lagoons (Albani and Serandrei Barbero, 1990; Murray, 2006). These data suggest that this species has a very wide water depth range with both dissolved oxygen and salinity tolerance over a wide range.

**Repository:** PK–AG–036

Genus **KARRERULINA** Finlay, 1940

*Karrerulina apicularis* (Cushman, 1911)

Pl. 2; Fig. 4

**Original citation:** *Gaudryina apicularis* CUSHMAN, 1911, v. 71, pt. 2, p. 69, figs. 110a, b.

**Remarks:** The type species for genus *Karrerulina* is *Gaudryina apicularis* Cushman, 1911, which is synonymous with *Gaudryina conversa* Grzybowski, 1901. According to Charnock and Jones (1990,
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p. 195), “This genus differs from *Karreriella* in the late semi-uniserial development in which the aperture migrates into the terminal position. It may also differ in wall structure”. The consistent presence of *K. apicularis* is indicative of shale or mud rich facies (Pope and Smith, 1948), apparently associated with channel overbank or levee deposits (Green *et al.*, 2000). According to Kuhnt *et al.* (2000), an unbiased identification of living specimens of this deep infaunal species with the rose Bengal staining method is almost impossible. None of the 67 stained specimens of this species showed a clear cytoplasm body in the last chambers. Staining was generally restricted to the earlier chambers and the stained material was identified as an organic meshwork filling most of the extremely small cavities of the massive and thick agglutinated test. Biodiversity and biogeographical investigations of Recent benthic foraminiferal assemblages on the Sunda Shelf in south-western South China Sea by Szarek (2001) revealed it to be an outer shelf to lower bathyal species. *Karrerulina apicularis* dominates (12%) the agglutinated assemblage at 2,475 m water depth in the Northeast Atlantic Deep Water (NEADW) mass of the Portuguese Margin where the temperature and salinity are 3.2° C and 35.0‰, respectively (Phipps, 2012). This is a benthic, cosmopolitan species that occurs throughout the Gulf of Mexico in a very wide water depth range of 15 to 3,850 m (Sen Gupta *et al.*, 2009b). In the deepest parts of the Andaman Sea, which is marginally more saline but significantly warmer than the Indian Ocean, this species occurs at depths greater than 2,000 m (Murray, 2014), where dissolution is active (Frerichs, 1970). This species is common in the agglutinant *Glomospira* biofacies on the lower slope, rise and Sigsbee Plain in the Gulf of Mexico, but “rare as shallow as upper slope” (Poag, 2015).

Repository: PK–AG–037

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus TEXTULARIA Defrance, 1824
*Textularia pala* Czjzek, 1848
Pl. 2; Figs. 5, 5a

Original citation: *Textularia pala* Czjzek, 1848, p. 148, pl. 13, figs. 25–27.
Remarks: According to Ferraro and Molisso (2000), this species occurs in the upper circa-littoral zone on the submerged volcanic banks, Banco di Penta Palumbo and Banco di Miseno in the north-western sector of the Gulf of Naples, and prefers a fine-grained substrate. Panieri (2006) investigated the foraminiferal response to an active methane seep environment in the Adriatic Sea, and found it occur in both non-seep and seep samples with maximum densities of 131.0 and 115.9, respectively. Living specimens were, however, found only in the former. Among the live fauna on the Mallorca Shelf in the western Mediterranean Sea, the coarser-grained samples from shallower water depths (40–94 m) mainly consist of various miliolids and such agglutinated species as *Textularia pala* (Milker, 2010). According to Milker and Schmiedl (2012), the wall of this species is finely agglutinated, and is clearly distinguishable from other *Textularia* species described by him by its smoother test surface and its finer arenaceous wall.

Repository: PK–AG–038

Subfamily SIPHOTEXTULARIINAE Loeblich and Tappan, 1985
Genus SIPHOTEXTULARIA Finlay, 1939
*Siphotextularia concava* (Karrer, 1868)

Original citation: *Plecanium concavum* KARRER, 1868, v. 1, pt. 1, p. 129, pl. 1, fig. 3.
Remarks: Very few specimens that closely resembled *Siphotextularia concava*, described from the Miocene of Hungary, were obtained by Cushman *et al.* (1954). According to Barker (1960), Brady
referred this species to *Textularia* but opined that the apertural characters were those of *Siphotextularia* Finlay, 1939 (p. 510), and rightly so. Hofker (1978) recorded this species off the Lododa Islands, north of Doi, at a water depth of 576 m (7.7° C) in the eastern part of the Indonesian Archipelago. Benthic foraminiferal assemblages were investigated in two cores recovered from the eastern depression of the Marmara Sea at 1,200 m water depth by Alavi (1988), who observed agglutinated foraminifera to be either rare or absent; *Siphotextularia concava* was one of the only seven agglutinates recognized. This species was recorded from circa-littoral and bathyal muds (Sgarella and Moncharmont Zei, 1993) and down to 631 m in the eastern Mediterranean by Parker (1958). According to Sen Gupta et al. (2009b), this benthic species is found in the north-eastern and south-eastern parts of the Gulf of Mexico in a water depth range of 4 to 110 m; it has also been recorded from the Caribbean Sea, Atlantic and Pacific oceans.

Repository: PK–AG–039

*Siphotextularia flintii* (Cushman, 1911)

Pl. 1; Fig. 22

Original citation: *Textularia flintii* CUSHMAN, 1911, Bull. 71, no. 2, p. 21, figs. 36 a, b.

Remarks: Cushman (1911) recorded this species as *Textularia flintii*, while Cole (1981) found this species (also as *T. flintii*) to occur off north-east Newfoundland and remarked, “This large, robust species is rare, but distinctive. It is found from 2,560 to 2,938 m”. According to Boltovskoy and Wright (1976), this is one of the agglutinated species that contain small pores penetrating the inner chamber wall but not the outer. In their review of deep-sea benthic biodiversity associated with trench, canyon and abyssal habitats below 1,500 m depth in New Zealand waters, Lörz et al. (2012) recorded this species at water depths ranging between 1,130 and 4,160 m. According to Milker and Schmiedl (2012), the wall is finely agglutinated, and test of *Siphotextularia flintii* is more inflated when compared to that of *S. concava*.

Repository: PK–AG–040

*Siphotextularia rolshauseni* Phleger and Parker, 1951

Pl. 2; Fig. 6

Original citation: *Siphotextularia rolshauseni* PHLEGER and PARKER, 1951, v. 46, no. 2, p. 4, pl. 1, figs. 23, 24

Remarks: The types for this species came from the Gulf of Mexico. Phleger and Parker (1951) opined that *Siphotextularia rolshauseni* differed from Cushman’s holotype of *Textularia catenata* only in size and, as Corliss (1979) had stated that a difference in size is not a valid specific taxonomic character, Hermelin (1989) remarked that *S. rolshauseni* should be regarded as a junior synonym of *S. catenata*. While presenting taxonomic notes on the bathyal zone benthic foraminiferal species off north-east Newfoundland, Cole (1981) recorded this species in a depth range of 2,560 to 3,000 m and remarked, “A small, coarsely agglutinated species differing from *Textularia* in its apertural neck”. Pflum and Frerichs (1976) found that this species had its upper depth limits in the lower middle bathyal zone and ranged into abyssal water depths in the Gulf of Mexico. In the Indian Ocean, Corliss (1979) reported this species from the lower bathyal zone at 2,500 to 4,600 m. Boltovskoy (1978) recorded this species from lower bathyal (1,253 m) to lower abyssal (3,010 m) depths at the Ninety East Ridge in the northern India Ocean, while Jian et al. (1999) found this species at 1,556 m depth in the South China Sea. According to Nees and Struck (1994), *S. rolshauseni* is a characteristic indicator species for low organic carbon flux rates during the Last Glacial Maximum (LGM) in the Norwegian Greenland Sea. This species is one of the resilient agglutinated, deep-sea taxa that survive taphonomic loss during shallow burial (>0.5 m) at 1,300–
4,500 m water depth and is of potential value in paleobathymetry studies (Hayward et al., 2001).

According to Sen Gupta et al. (2009c), Siboctectularia rolhsaeeni differs from S. affinis in being smaller with a more inflated shell, sutures at right angles to the central axis, chambers that do not overlap, and a smaller aperture. Mancin et al. (2015) have recently observed that this species is quite selective in picking grains for constructing its test; it exclusively picked discoidal coccoliths of the species Coccolithus pelagius. The coccoliths are embedded into a very fine-grained matrix and arranged in an orderly way, with the proximal shields oriented towards the outside to form a very regular test surface. This feature has, however, not been observed in the present study.

Repository: PK–AG–041

Suborder INVOLUTININA Hohenegger and Piller, 1977
Family PLANISPIRILLINIDAE Piller, 1978
Genus PLANISPIRILLINA Bermúdez, 1952
Planispirillina denticulogranulata (Chapman, 1907)

Original citation: Planispirillina denticulogranulata CHAPMAN, 1907, v. 133, pl. 10, figs. 6a–c.
Remarks: This species was originally described and illustrated by Chapman (1907) from Victoria, Australia. Hayward (1982) recorded Planispirillina denticulogranulata for the first time in nearshore sediments of Little Barrier Island, northern New Zealand, and remarked it is, “A highly ornamented species with pustules on one side and short radiating transverse costae on the other”. He also observed this species to occur in other New Zealand Recent samples from the Cavalli Islands, Rangaunu Bay, Leigh and Fouveaux Strait.

Repository: PK–AG–042

Suborder SPIRILLININA Hohenegger and Piller, 1975
Family SPIRILLINIDAE Reuss and Fritsch, 1861
Genus SPIRILLINA Ehrenberg, 1843
Spirillina limbata Brady, 1884

Original citation: Spirillina limbata BRADY, 1884, p. 632, pl. 85, figs. 18–21.
Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 145, Prince Edward Island, South Pacific, at a depth of 50 to 150 fathoms (~91 to 274 m; fig. 18), and at Challenger Station 120, off Pernambuco, Atlantic Ocean at a depth of 675 fathoms (~1,234 m; figs. 19, 20). In the Mediterranean region, Spirillina limbata has been observed to be rare, and has been reported only by Blanc-Vernet (1969). Sgarrella and Moncharmont Zei (1993) recorded this species in one of their Gulf of Naples samples from a water depth of 600 m. This species was observed to be rare in the inlet channels of coastal lagoons, inter-tidal zone and sheltered oceanic embayments off the south-east coast of Australia (Yassini and Jones, 1995). While S. limbata was recorded from the eastern Aegean Sea, it was not observed to occur in the Marmara Sea (Oflaz, 2006). According to Milker (2010), who recorded this species from the western Mediterranean shelf, “The specimens shown in Jones (1994) differ from that shown in Cimerman and Langer (1991) by more numerous coils”, and opined that his specimens resembled those shown in Cimerman and Langer (op cit.). Meriç et al. (2014) reported this species at a shallow depth of only 10 m at Pyramid Rock along the South African coastline.

Repository: PK–AG–043
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Suborder MILIOLINA Delage and Hérouard, 1896
Superfamily CORNUSPIRACEA Schultze, 1854
Family CORNUSPIRIDAE Schultze, 1854
Subfamily CORNUSPIRINAE Schultze, 1854
Genus CORNUSPIRA Schultze, 1854
C. involvens (Reuss, 1850)

Original citation: Operculina involvens REUSS, 1850, v. 1, p. 370, pl. 46, fig. 20.
Remarks: Flint (1899, p. 303, pl. 48, fig. 2) recorded C. involvens from the Caribbean Sea, Straits of Yucatan, and coast of Georgia at water depths between 276 and 463 fathoms (~505 to 847 m). This species is widely distributed. It is common in the shallow waters of the tropics and reaches a large size in the warm waters of the Indo-Pacific region, as, for example, in the Philippines. Elsewhere it seems to be of small size (Cushman, 1920). According to Cushman (1922), the specimens recorded from the Byram Marl were very small measuring 0.4 mm, but some obtained from the Spring Marl measured up to 2 mm in diameter. While presenting taxonomic notes on benthic foraminifera from the bathyal zone off north-east Newfoundland, Cole (1981) recorded a depth range of 1,000 to 2,743 m for C. involvens, and found it to be most common at 1,590 m. Hayward et al. (1999) found the Cornuspira association, main taxon being C. involvens, to be confined to mud beneath the mangrove forest. Although it is a normal salinity inner shelf species (Hayward et al., 1999), it may often be swept into the marsh where it survives but does not reproduce. Small, transparent tests of this species are commonly found transported by the incoming tide into the marsh, and they attributed its light test weight to allow it to be in suspension for longer periods of time. In the Laptev Sea, Lukina (2001) observed Cornuspira involvens to be a part of the deep-water complex in the open part of the sea, ranging in depth between 40 m and 984 m. Cornuspira involvens differs from Spirillina vivipara by having growth lines and opaque and milky-white porcelaneous appearance under reflected light microscope. It is also common and very abundant relative to Spirillina vivipara in the Gulf of İskenderun (Oflaz, 2006). According to Carman (2007), C. involvens was the most common species attached to the colony surfaces of the invasive ascidian, Didemnum sp. A, that first appeared in New England bays and harbors in the early 1990s, and in the waters around Cape Cod in 1993. This species is a benthic, cosmopolitan species that has a very wide water depth range of 1 to 1,426 m (Sen Gupta et al., 2009b) in the north-eastern, south-eastern and south-western parts of the Gulf of Mexico. According to Alyazichi et al. (2014), C. involvens is known as a pollution-resistant and opportunistic species existing in estuary environments contaminated with trace metals (Frontalini and Coccioni, 2008; Romano et al., 2009; Armynot du Châtelet et al., 2011; Foster et al., 2012).

Repository: PK–AG–044

Family OPHTHALMIDIIDAE Wiesner, 1920
Genus SPIROPTHALMIDIUM Cushman, 1927
S. acutimargo (Brady, 1884)
Pl. 2; Fig. 9

Original citation: Spiroloculina acutimargo BRADY, 1884, v. 9, p. 154, pl. 10, fig. 13 (not figs. 14, 15).
Remarks: Cushman (1927) misspelt the name of the genus as Spirothalmidium which was later corrected by Paalzow (1932, p. 99). Haman (1971) recorded this species as Opthalmidium acutimargo (Brady) from the Tremadoc Bay, North Wales, U.K., as did Hermelin and Scott (1985) from the central North Atlantic. This species has been reported from the Mediterranean Sea by Cimerman and Langer (1991). Debenay and Basov (1993) listed it as Spirothalmidium acutimargo.
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among the Recent foraminifera distributed on the West African continental shelf and slope; later, Schmiedl et al. (1997) recorded its occurrence from the eastern South Atlantic Ocean. On the Sunda Shelf, in the south-western South China Sea, this species occurs in a water depth range that is upper bathyal to middle bathyal (Szarek, 2001). According to Kuhnt et al. (2007), *S. acutimargo* has an affinity to oligotrophic to mesotrophic conditions and high oxygen concentrations.

Repository: PK–AG–045

Superfamily MILIOLACEA Ehrenberg, 1839
Family SPIROLOCULINIDAE Wiesner, 1920
Genus SPIROLOCULINA d’Orbigny, 1826
*Spiroloculina tenuiseptata* Brady, 1884

Original citation: *Spiroloculina tenuiseptata* BRADY, 1884, p. 153, pl. 10, figs. 5, 6.
Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 191A, Kii Islands, Japan, at a depth of 580 fathoms (~1,061 m; fig. 5), and at Challenger Station 174B, off Fiji, Pacific Ocean, at a depth of 610 fathoms (1,116 m; fig. 6). According to Quilty (1974), who studied Tasmanian Tertiary foraminifera, “this species is distinct from *S. depressa* d’Orbigny in having an elliptical aperture without tooth, rather than having a round to square aperture with tooth, and from *S. canaliculata* d’Orbigny in having depressed sutures and chambers with convex sides”. In the Mediterranean region, *Spiroloculina tenuiseptata* is widespread, and has been generally reported from circa-littoral muddy bottoms and the upper bathyal zone. Sgarrella and Moncharmont Zei (1993) observed this species to occur in the depth range of 20 to 600 m in the Gulf of Naples, Italy, and to be more frequent between 57 and 432 m. On the Sunda Shelf, in the south-western China Sea, *S. tenuiseptata* has been recorded from a water depth of 404 m (Szarek, 2001). This species has a relative abundance of >1% in the infra-littoral, upper and lower circa-littoral zones in the Gulf of İskenderun, eastern Mediterranean Sea (Oflaz, 2006). According to Kaminski (2012), this species is an oxic indicator, epifaunal and associated with bottom waters that are high in dissolved oxygen (>2 mL/L O₂).

Repository: PK–AG–046

Family HAUERINIDAE Schwager, 1876
Subfamily HAUERININAE Schwager, 1876
Genus QUINQUELOCULINA d’Orbigny, 1826
*Quinqueloculina aspera* d’Orbigny, 1826

Original citation: *Quinqueloculina aspera* D’ORBIGNY, 1826, sera 1, v. 7, p. 301.
Remarks: Quilty (1974) obtained three well preserved specimens of this species from Fossil Bluff formation (early Miocene) in which the species was very rare. Off the Karaburun Peninsula, Meriç et al. (2012) found this species to be scattered in a water depth range of 10 to 100 m, with maximum numbers at 60 m.

Repository: PK–AG–047

*Quinqueloculina lamarkiana* d’Orbigny, 1839

Original citation: *Quinqueloculina lamarkiana* D’ ORBIGNY, 1839, p. 189, pt. 11, figs. 14, 15.
Remarks: *Quinqueloculina lamarkiana* was originally recorded from the shallow waters off Cuba and Jamaica by d’Orbigny (1839). This species has been reported from several localities
worldwide and is a cosmopolitan species. This species exhibited a remarkably uniform percentage distribution nearly throughout the three traverses in the Gulf of Mexico (Bandy, 1954), with rather marked percentage increase of this form on the topographic highs in shallow water. Vella (1957) observed that this species is represented by large, typical specimens in the Nukumaruan (Lower Pleistocene) of east Wairarapa and in Tertiary beds elsewhere in New Zealand. The figures illustrated by him are of specimens from Wairarapa and include a fully grown individual with a small dental trough, and a younger one with a dental septum expanded at the outer edge, but lacking a definite trough. He also observed that no typical specimens were found in Cook Strait, but small tests with simple tooth and rather rounded peripheral angles were referred to *Q. cf. lamarckiana*. The figures illustrated by Brady (Barker, 1960) are of the specimens recovered from the sediment dredged at Challenger Station 346, South Atlantic, at a depth of 2,350 fathoms (~4,298 m; figs. 7a–c). Brady referred *Q. lamarckiana* to *Miliolina venusta* Karrer, while Wiesner (1923, p. 67) referred it to *Q. lamarckiana* d’Orbigny. According to Hatta and Uijie (1992), this species usually showed a single angle at the test-periphery in their material from the coral seas off Japan, although their figured specimen has the weakly doubled angles. This variation has been found in many reports. Yassini and Jones (1995) observed *Q. lamarckiana* to occur in inlet channels of coastal lagoons and inter-tidal zone of the inner shelf off the south-east coast of Australia. This species has been recorded from nearshore areas, lagoons, and forereef-inner and outer shelf, in a water depth range of 1 to 60 m (Javaux and Scott, 2003). *Quinqueloculina lamarckiana* is one of the two most abundant species, when present, and one of the most common taxa in the inter-reef areas of the extreme south of the State of Bahia (between Corumbau and Nova Viçosa), occurring in >97% of the samples (Araújo and Machado, 2008). It was observed by them to be abundant in mixed sand and mud, whether carbonate or mixed carbonate and siliciclastic. According to Sen Gupta et al. (2009b), this benthic, cosmopolitan species is distributed all over the Gulf of Mexico at water depths of 0 to 274 m; in the Laptev Sea, it has been recorded from a water depth of 984 m (Lukina, 2001). In general, it can be concluded that *Q. lamarckiana* has a very wide range not only with regard to water depth but also to ecological settings.

**Repository:** PK–AG–048

*Quinqueloculina seminula* (Linnaeus, 1758)

**Original citation:** Serpula seminulum LINNE, 1758, p.786, pl.2, figs.1a–c.

**Remarks:** The types for this species came from the shore sands of Rimini, Italy. It is a cosmopolitan species with countless records from both cold and shallow, warm waters world over. Murray (1968a) recorded it from the Christchurch Harbour, off the south coast of Cornwall at depths of 14 to 42 m, in the Bristol Channel, at depths of 66 to 91 m, and in the English Channel, south of the Lizard, at depths ranging between 84 and 95 m (1970). He (1971) opined that *Quinqueloculina seminula* is a stenohaline, marine, inner shelf species. Haynes (1973) reported it from the Cardigan Bay, British Isles, and stated, "There is apparently continuous variation from this species through to *Q. lata* which is oblong in outline and oval in section and in the other direction to *Q. dunkerquiana* which is short with angled chambers. Failure to distinguish between these forms has led to considerable confusion in the literature." This species was reported from the Mediterranean Sea by Cimerman and Langer (1991). It has also been reported from the inlet channels of coastal lagoons, open estuaries, and the inter-tidal zone of the inner shelf off the south-east coast of Australia (Yassini and Jones, 1995). In their studies on the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, Hayward et al. (2001) gave a water depth range of 90 to 4,440 m for this species. According to Wang and
Chappell (2001), *Q. seminula* can live in hypo- to hypersaline waters and comprises a monospecific fauna in supra-littoral hypersaline environments. Debenay *et al.* (2009) identified 51 species at 10 stations from 8 shrimp ponds of 3 shrimp farms in New Caledonia, and observed *Ammonia tepida* and *Quinqueloculina seminula* to dominate the assemblages. Their high reproduction rates led to increasing numbers of living specimens and accumulations of empty tests during the first ten weeks. In his study on benthic foraminifera from the Peruvian and Ecuadorian continental margin, Mallon (2011) found this species in a water depth range between 697 and 2,092 m. According to Kaminski (2012), this species is an indicator of dissolved oxygen levels in bottom water of >2 mL/L. In experiments in the northern Adriatic Sea that induced anoxia at 24 m water depth, Langlet *et al.* (2013) observed *Q. seminula* to be sensitive to anoxia but showed a clear standing stock increase during the first month of the experiment, which they interpreted as its opportunistic response to increasing organic matter availability due to the degradation of the dead macrofaunal organisms.

Repository: PK–AG–049

Subfamily MILIOLINELLINAE Vella, 1957
Genus PSEUDOTRILOCULINA Cherif, 1970
*Pseudotriloculina rotunda* (Schlumberger, 1893)

Original citation: *Triloculina rotunda* SCHLUMBERGER, 1893, p. 64, pl. 1, figs. 48–50, figs. 11, 12 (in text).

Remarks: A study of guilds among epiphytal foraminifera on fibrous substrates in Nevis, West Indies, by Wilson (2007) revealed that greatest numbers of this species were associated with *Penicillus capitatus* capitulae, followed by *Halimeda opuntia*, and *Syringodium filiforme* rhizomes in Mosquito Bay. In the Long Haul Bay, however, it was associated more with *Penicillus capitatus* capitulae rather than *Thalassia* rhizomes. Accordingly, this species was categorized under Morphotype D (upright, permanently motile). According to Sen Gupta *et al.* (2009b), this species (reported as *Triloculina rotunda*) is a benthic, cosmopolitan species that occurs in a water depth range of 0 to 110 m in the north-eastern, north-western and south-eastern parts of the Gulf of Mexico. Meriç *et al.* (2012) observed this species to occur in a water depth range of 10 to 80 m in the Karaburun Peninsula. This species is common in the lagoons of South Gilla (Sardinia, Italy) and Orbetello (Tuscany, Italy) (Foresi *et al.*, 2006), where it can achieve a high degree of morphological variability within the population in relation to the confinement of the lagoon (Melis and Covelli, 2013). Musco (2011) examined the applicability of benthic foraminifera as bioindicators in the Sicilian Channel, and observed this “epifaunal, free of clinging, herbivore, detritivore” species (reported as *T. rotunda*) to have high positive correlation with As and Cd and other heavy metals, except for Cu and Hg, and significant positive correlation with sand. According to Nardelli *et al.* (2013), who attempted to understand the biological response of *Pseudotriloculina rotunda* to experimental chronic exposure at several Zn concentrations, increasing concentrations led to increasing delay or to complete cessation of construction of new chambers, with negative consequences on its growth rate.

Repository: PK–AG–050

Genus PYRGO Defrance, 1824
*Pyrgo lucernula* (Schwager, 1866)
Pl. 2; Figs. 10, 10a

Remarks: Todd and Low (1968) found *Pyrgo lucernula* to be well represented in their material by typical and fairly common specimens in the Pamplona samples and two fjordland samples. They observed that it is characterized by its circular and protruding apertural neck (Cushman et al., 1954), and that it could be distinguished from a closely similar species, *Pyrgo murrhina* (Schwager), by its outline being slightly elongate rather than circular and by having a rounded rather than a sharp periphery. Srinivasan and Sharma (1980) made the distinction between *Triloculina lucernula* and *Pyrgo lucernula*, which were both named as *Biloculina lucernula* by Schwager. *Triloculina lucernula* resembles *Pyrgo lucernula* in the front view but the apertural view reveals a third chamber. In his taxonomic notes on bathyal benthic foraminifera off north-east Newfoundland, Cole (1981) observed this species to occur in a water depth range of 1,400 to 3,000 m, but most commonly between 2,918 and 3,000 m. Bhaumik and Gupta (2005) investigated deep-sea benthic foraminifera from a gas hydrate-rich zone in the north-west Atlantic and remarked, “The genus *Pyrgo*, comprising such species as *P. lucernula* and *P. murrhina*, is a good indicator of well-oxygenated environment. Almost complete absence of *P. lucernula* in the gas hydrate zone suggests that this species cannot tolerate low-oxygen stressful environment”. According to Sen Gupta et al. (2009b), this benthic, cosmopolitan species is distributed over the entire Gulf of Mexico in a wide water depth range of 10 to 3,488 m. This species has also been recorded from much shallower depths (~43 and 52 m) associated with medium sand in the Serasan Islands of Riau Islands (Natsir and Subkhan, 2012). At the deepest and best ventilated sites (1,970 and 2,470 m depth), in the northern Arabian Sea, *Pyrgo lucernula* is one of the best represented miliolid taxa. Its absence from the core and lower part of the OMZ, and exclusive presence in fair numbers below the OMZ clearly suggests its intolerance to dysoxia (Caulle et al., 2013, 2014).

Repository: PK–AG–051

*Pyrgo murrhina* (Schwager, 1866)

**Original citation:** *Biloculina murrhina* SCHWAGER, 1866, p. 203, pl. 4, figs. 15a–c.

**Remarks:** *Pyrgo murrhina* is found in the lower middle bathyal zone of the eastern North Pacific (Bandy and Arnal, 1957) with a known stratigraphic range from middle Miocene through Holocene. Hofker (1980) recorded *Pyrgo murrhina* at water depths ranging of 125 m, 235 m and 620 m on the northern, north-western and western slopes of the Saba Bank, where the bottom water temperature ranged between 7.5° C and 16° C. Its deepest occurrence was at 850 m (water temperature of 6° C) associated with muddy sand and pteropods. This species inhabits the recent well-ventilated lower bathyal and abyssal areas of the eastern Mediterranean Sea and is obviously adapted to a range of oligotrophic to mesotrophic environments (Mullineaux and Lohmann, 1981; De Rijk et al., 1999; Geslin et al., 2004). According to Gupta and Thomas (2003), *P. murrhina* is an indicator of a cool, strongly pulsed organic flux, high oxygenation, and high seasonality environment. Murgese and De Deecker (2005) opined that it prefers a cold (<3° C) and well-oxygenated (>3.5 mL/L) environment, with low carbon flux to the sea floor (<3 g C m⁻² year⁻¹). This is a benthic, cosmopolitan species with a very wide water depth range of 19 to 3,700 m in the entire Gulf of Mexico (Sen Gupta et al., 2009b). Mallon (2011) observed this species to occur only at the deep stations in water depths between 918 and 2,092 m off Peru and Ecuador. At the deepest and best ventilated sites (1,970 and 2,470 m depth), in the northern Arabian Sea, *Pyrgo murrhina* is one of the best represented miliolid taxa. Its absence from the core and lower part of the OMZ, and exclusive presence in fair numbers below the OMZ clearly suggests its intolerance to dysoxia (Caulle et al., 2013, 2014). Along the Australian coast of the Timor Sea, *P. murrhina* became the dominant species in the Miliolacea assemblage (e.g., 67% of the total counts) below 2,500 m; its tests were not found above 500 m (Sadekov et al., 2014). These observations are generally consistent with previous studies (Corliss and Honjo, 1981;
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Haynes, 1981; Murgese and De Deckker, 2005; Murray, 2006), which suggest that the distribution of this benthic foraminifer is controlled by bottom water oxygen levels and the organic matter content of sediments.

Repository: PK–AG–052

Pyrgo sarsi (Schlumberger, 1891)

Original citation: Biloculina sarsi SCHLUMBERGER, 1891, v. 4, p. 553, figs. 55–59, text-figs. 10–12.
Remarks: Pyrgo sarsi is a benthic, cosmopolitan species that has a water depth range of 110 to 1,322 m in the north-eastern, north-western and south-eastern parts of the Gulf of Mexico (Sen Gupta et al., 2009b). This species is one of the miliolids associated with cold-water coral ecosystems off the Norwegian margin, but is only abundant at 2,098 m (Margreth, 2010). Debenay (2012) recorded this species on the northern shelf off New Caledonia at a water depth of 600 m. Pyrgo sarsi tests were found in almost every sample over a depth range of 131–2,530 m along the Australian coast of the Timor Sea. Although the absolute abundance of P. sarsi decreased with increasing depth, it made up >50% of the total population of Miliolacea species counted between 400 m and 2,500 m (Sadekov et al., 2014). According to them, Pyrgo spp. (P. sarsi + P. murrhina) offer the most potential as proxy for paleoreconstruction, as Mg/Ca values of these two Pyrgo species strongly correlate with bottom water temperatures and carbonate ion saturation.

Repository: PK–AG–053

Pyrgo serrata (Bailey, 1861)

Original citation: Biloculina serrata BAILEY, 1861, v. 7, no. 3, p. 350, pl. 8, fig. f.
Remarks: The specimen illustrated by Brady (Barker, 1960) was recovered from the sediment dredged at Challenger Station 168, off New Zealand, South Pacific, at a depth of 1,100 fathoms (~2,012 m; fig. 3). Brady referred this species to Biloculina depressa d'Orbigny var. serrata. The name serrata had been used previously by Bailey (1862, p. 350) for the same species, according to Cushman (1929, p. 73). Pyrgo serrata was recorded by Hofker (1978) off the Nenoesa Islands, in the eastern part of the Indonesian Archipelago at a water depth of 524 m. Off north-east Newfoundland, Cole (1981) observed that this bathyal species was the most commonly found from 1,400 to 3,210 m water depth, with greater concentration between 1,462 and 1,600 m. Yassini and Jones (1995) observed this species to be distributed on the outer shelf and continental slope off the south-east coast of Australia. Pyrgo lucernula and Pyrgo serrata are both deep-water miliolids, occurring below 3,692 m in the Bass Canyon (Smith and Gallagher, 2003), the latter capable of tolerating reduced oxygenated conditions. According to Sen Gupta et al. (2009b), this cosmopolitan species is distributed in a water depth range of 181 to 997 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico.

Repository: PK–AG–054

Genus TRILOCULINA d'Orbigny, 1826

Triloculina tricarinata d'Orbigny, 1826

Original citation: Triloculina tricarinata D'ORBIGNY, 1826, v. 7, p. 299, no. 6, modeles no. 94.
Remarks: Triloculina tricarinata is a cosmopolitan species. The figures illustrated by Brady (Barker, 1960) are of the specimens recovered from the sediment dredged at Shell Cove, Port Jackson, Australia. This species was referred by Brady to Miliolina, while d'Orbigny referred it to
**Repository:** PK–AG–055

**Subfamily SIGMOILINITINAE Luczkowska, 1974**

**Genus SPIROSIGMOILINA Parr, 1942**

*Spirosigmoilina pusilla* (Earland, 1934)

**Original citation:** *Spiroloculina pusilla* EARLAND 1934, p. 47, pl. 1, figs. 3, 4.

**Remarks:** The figures illustrated by Brady (Barker, 1960) are of a specimen recovered from the sediment dredged at Challenger Station 332, in the South Atlantic Ocean, at a depth of 2,200 fathoms (~4,023 m). *Spirophthalmidium pusillum* was referred by Brady to *Spiroloculina tennis* (Czjzek), while Earland (1934, p. 47) referred it to *S. pusilla* nov. Later, Cushman and Todd (1944, p. 76) transferred it to *Spirophthalmidium* Cushman 1927, which genus was shown by Macfadyen (1939, p. 164) to be synonymous with *Ophthalmidium* Zwingli and Kubler, 1870. Wood and Barnard subsequently (1946, p. 84) reinstated *Spirophthalmidium* Cushman, and was used by Barker (1960). But Loeblich and Tappan (1964) considered *Spirophthalmidium* to be a junior synonym of *Ophthalmidium*, and Corliss (1979) used the same in his taxonomic studies of deep-sea benthonic foraminifera from the south-east Indian Ocean. He (*op cit.*) observed that this species was found at only 23% of the stations with frequency values ranging from 1–3%, and occurred between 2,500 and 4,600 m water depths. Smith (1973) recorded this species as *Ophthalmidium pusillum* (Earland) in her studies on the foraminifers from the North Pacific Ocean, but observed it to be rare. According to Hermelin and Scott (1985), this is a fairly uncommon species in the central North Atlantic Ocean, found between 540 and 2,760 m, and more frequent at depths...
<2,410 m. *Spirosigmoilina pusilla* was listed by Szarek (2001) among the Recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea with a water depth range of inner shelf to upper bathyal. According to Mikhalevich (2004), this species (reported as *Spiroloculina pusilla*) occurs at shallow depths on the Antarctic shelf, although it occurs in other oceans only in the bathyal and abyssal zones and in regions of upwelling. She attributed this to the very low temperature range (−1°C to −1.9°C) of the Antarctic waters. According to Hayward *et al.* (2010), this species has bathymetric distribution of lower bathyal-mid abyssal (1,000 to 4,000 m), off New Zealand, with a depth range of 1,130 to 3,540 m east of the nation (Hayward *et al.*, 2001).

**Repository:** PK–AG–056

*Spirosigmoilina tenuis* (Cžjžek, 1848)

Pl. 2; Fig. 11

**Original citation:** *Quinqueloculina tenuis* CŽJŽEK, 1848, p.149, pl.13, figs.31–34.

**Remarks:** Todd and Bronnimann (1957) recorded this species from the eastern Gulf of Paria, Trinidad, as *Sigmoilina tenuis*. This species has also been reported from the Mediterranean Sea by Cimerman and Langer (1991). Debenay and Basov (1993) listed it among the several Recent foraminiferal taxa distributed on the continental shelf and slope off West Africa. Debenay and Redois (1997) recorded it from the northern continental shelf of Senegal. After examining the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, Hayward *et al.* (2001) gave a water depth range of 750 to 1,840 m for *Spirosigmoilina tenuis*. According to Sen Gupta *et al.* (2009b), this species (reported as *Sigmoilinita tenuis*) is a cosmopolitan species that is distributed over the entire Gulf of Mexico in a very wide water depth range of 1 to 3,237 m. The fossil and extant records suggest that the abundance of this oxyphilic species is controlled rather by food supply and oxygen conditions than water depth and, at the same time, is adapted to high organic matter flux (Grunert *et al.*, 2012).

**Repository:** PK–AG–057

**Subfamily SIGMOILOPSINAE Vella, 1957**

**Genus SIGMOILOPSIS Finlay, 1947**

*Sigmoilopsis schlumbergeri* (Silvestri, 1904)

Pl. 2; Fig. 12

**Original citation:** *Sigmoilina schlumbergeri* SILVESTRI, 1904, v. 22, p. 267, pl. 7, figs. 12–14; p. 481, text-fig. 6; p. 482, text-fig. 7.

**Remarks:** The specimens illustrated by Brady (Barker, 1960) were recovered from the sediments dredged at Porcupine Station 23, west of Ireland, Atlantic Ocean, at a depth of 630 fathoms (~1,152 m; figs. 1, 2), Challenger Station 120, off Pernambuco, Atlantic Ocean, at a depth of 675 fathoms (~1,234 m; fig. 3), and at Porcupine Station 37, off Ireland, Atlantic Ocean at a depth of 2,435 fathoms (~4,453 m). This species was referred by Brady to *Planispirina celata* (Costa), and by Silvestri to *Sigmoilopsis schlumbergeri* (1904, p. 267). Finlay (1947, p. 270) erected the genus *Sigmoilopsis* with *S. schlumbergeri* (Silvestri) as the genotype. Collins (1968) remarked, “Records of this species are mostly from the Atlantic, though Brady states that the form recorded by him is found in all the great oceans, and it is recorded by Le Roy from the Late Tertiary of Sibeoeret Island, off Sumatra”. Cimerman and Langer (1991) recorded this species from the Mediterranean Sea as *S. schlumbergeri*. In the Mediterranean region, this quite widespread species has been reported in the muddy circa-littoral and bathyal bottoms. It occurs down to 1,000 m in the north-
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western Mediterranean (Bizon and Bizon, 1984), and to 1,016 m in the eastern Mediterranean (Parker, 1958). In his taxonomic notes on the bathyal zone benthic foraminifers off north-east Newfoundland, Cole (1981) observed it to be a fairly common species ranging 1,800 to 3,210 m, usually more common from 2,560 to 3,000 m. Hermelin and Scott (1985) obtained single specimens of this species at different depths in the central North Atlantic Ocean. It has also been reported in the Adriatic Sea, mostly on muddy bottoms rich in organic matter in the depth range of 60 to 100 m (Jorissen, 1987), and has high fossilization potential (Schröder, 1988). In the Gulf of Naples, *S. schlumbergeri* occurs from 16 m depth downwards, and becomes frequent deeper than 60 m (Sgarrella and Moncharmont Zei, 1993). Its optimum occurs in the depth range of 60 to 450 m. According to Yassini and Jones (1995), this species occurs in open estuaries, and on the inner and middle shelf off the south-eastern coast of Australia. Hayward et al. (2001) studied the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, and gave a water depth range of 750–2,700 m for this species. This cosmopolitan miliolid is distributed all over the Gulf of Mexico in a very wide water depth range of 1 to 3,515 m (Sen Gupta et al., 2009b); it has also been recorded from a mangrove ecosystem of Qeshm Island in the Persian Gulf by Sohrabi-Mollaeyousefy et al. (2006). *Sigmoilopsis ottangensis* is an endemic species of the Burdigalian Central Paratethys (Wenger, 1987; Cicha et al., 1998) and often compared to the extant *S. schlumbergeri* from the Adriatic Sea (Grunert et al., 2012). According to Mancin et al. (2015), the test wall of this miliolid species typically has two distinct portions: an inner calcareous layer secreted by the foraminifer and an outer and thicker agglutinated portion. Within the agglutinated portion, the grains are never selected in function of size and shape, thus resulting in a heterogeneous arrangement.

Repository: PK–AG–058

Suborder LAGENINA Delage and Hérouard, 1896
Superfamily NODOSARIACEA Ehrenberg, 1838
Family CHRYSALOGONIIDAE Mikhalevich, 1993
Genus SCALLOPOSTOMA Hayward and Kawagata, 2012

*Scallopostoma ovicula* (d’Orbigny, 1826)

Original citation: *Nodosaria ovicula* D’ORBIGNY, 1826, v. 7, p. 252.
Remarks: There seems to be lot of confusion regarding this species. The genus *Neugeborina* was erected by Popescu in 1998 with the type species as *Nodosaria longiscata* d’Orbigny, 1846. According to Popescu and Crihan (2000), this genus “differs from other Nodosariidae by the cylindrical shape of the chambers and the characteristic shape of the sutures. It differs from *Orthomorphina* by their elongated cylindrical shape of the chambers, the long apertural neck and the lack of apertural lip”. They also opined that the species *Orthomorphina filipescei* Popescu, *Nodosaria gyanta* Mallory, *Nodosaria irregularis* d’Orbigny, and *Dentalina boueana* d’Orbigny belong to this genus, as well as the species described by Neugeboren (1851) from Lăpugiu de Sus as *Nodosaria gracilis*, *N. clavaiformis*, *N. bronniana* (suspected as a synonym of *N. irregularis*), *N. excis* and *N. nodifera* (suspected as a synonym of *N. longiscata*). Interestingly, the WoRMS database lists the following species as synonyms of *Nodosaria (Nodosaire) ovicula*: *Dentalina boueana* d’Orbigny, 1846; *D. farimen* (Silvestri, 1872); *D. trichostoma* Reuss, 1850; *Neugeborea ovicula* (d’Orbigny, 1826); *Nodosaria (Dentalina) lorneiana* d’Orbigny, 1840; *N. bielziana* Neugeboren, 1852; *N. bronniana* Neugeboren, 1852; *N. czjzekiana* Neugeboren, 1852; *N. elongata* d’Orbigny, 1902; *N. evalidi* Reuss, 1851; *N. farimen* Silvestri, 1872; *N. gracili* Neugeboren, 1852; *N. haidingeriana* Neugeboren, 1852; and *N. irregularis* d’Orbigny, 1846. This species has also been reported and illustrated as *Laevidentalina lorneiana* (d’Orbigny) by Ashkenazi-Polivoda (2012, p. 96, pl. 2, fig. 3) in a case
study from the high productivity sequence in the Late Cretaceous southern Tethyan upwelling system, Negev, Israel. On the basis of test shape and the nature of test coiling (i.e., chamber addition), Valchev and Stojanova (2014) categorized *N. ewaldi* under the tapered and cylindrical morpho-group (T/C), which is represented by forms with round, oval or triangular cross-section, and parallel or sub-parallel sides (Valchev, 2006).

Repository: PK–AG–059

**Family NODOSARIIDAE Ehrenberg, 1838**

**Subfamily NODOSARIINAE Ehrenberg, 1838**

**Genus DENTALINA Risso, 1826**

*Dentalina ittai* Loeblich and Tappan, 1953

Pl. 2; Fig. 13

Original citation: *Dentalina ittai* LOEBLICH and TAPPAN, 1953, v. 121, no. 7, p. 56, pl. 10, figs. 10–12.

Remarks: Matoba (1970) recorded this species from the Matsushima Bay, Miyagi Prefecture, north-east Japan. *Dentalina ittai* had a ranked frequency value of 3.6 in Chaleur Bay, Gulf of St. Lawrence (Scafer and Cole, 1978). In his studies on the benthic foraminifera from the bathyal zone off north-east Newfoundland, Cole (1981) observed this species to be “rare on the slope”. Korsun and Hald (1998) reported this species as *Dentalina ittai* Loeblich and Tappan from off Novaya Zemlya tidewater glaciers in the Russian Arctic. According to Kuzmin *et al.* (2004), this species is characteristic of sub-tropical water masses.

Repository: PK–AG–060

**Genus LAEVIDENTALINA Loeblich and Tappan, 1986**

*Laevidentalina advena* (Cushman, 1923)

Pl. 2; Fig. 14

Original citation: *Nodosaria advena* CUSHMAN, 1923, p. 79, pl. 14, fig. 12.

Remarks: According to Sen Gupta *et al.* (2009b), *Laevidentalina advena* is a benthic species has a bathyal and/or abyssal habitat with a water depth range of 305 to 1,335 m in the north-eastern and south-eastern parts of the Gulf of Mexico; it has been recorded from the Caribbean Sea, Atlantic and Pacific oceans as well. This species was recorded at a water depth of 600 m on the northern shelf of New Caledonia in the south-western Pacific (Debenay, 2012).

Repository: PK–AG–061

*Laevidentalina communis* (d'Obigny, 1826)

Original citation: *Nodosaria (Dentalina) communis* D'ORBIGNY, 1826, ser. 1, v. 7, p. 254, modeles no. 32.

Remarks: The types for this species came from the Adriatic Sea. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the material dredged at Challenger Station 174A, off Fiji, Pacific Ocean, at a depth of 255 fathoms (~466 m; figs. 21, 22). Brady (1884) referred this species to *Nodosaria*. In the Mediterranean region, *Laevidentalina communis* has been reported mostly from bathyal muds (Blanc-Vernet, 1969; Moncharmont Zei *et al.*, 1981; Sgarrella and Barra, 1985; Sgarrella *et al.*, 1985). It occurs scattered, also from circa-littoral muds in the Gulf of Salerno and Gulf of Policastro. Culver and Buzas (1983) reported this species as *Dentalina communis* from the Gulf of Mexico, as did Ward and Webb (1986) from the Ross Island, Antarctica. Later, Loeblich and Tappan (1987) suggested that the genus *Dentalina* should be
restricted to those species that have longitudinal costate surface. Although subsequent workers have reported forms with smooth surface under *Dentalina* (Galluzzo *et al*., 1990, from the Grenada Basin, Caribbean Sea; Khare, 1992, from off Karwar, Arabian Sea), the suggestions given by Loeblich and Tappan (1987) have been followed, and the species has been reported as *Laevidentalina communis* (d’Orbigny) in the present study. In the Gulf of Naples, the occurrence of this species is scattered and has been recorded deeper than 130 m (Sgarrella and Moncharmont Zei, 1993). *Dentalina communis* differs from *Dentalina leguminiformis* in the presence of oblique instead of straight sutures (*op cit*). Yassini and Jones (1995) recorded this species as *Laevidentalina communis* and observed it to occur on the middle and outer shelf off the south-east coast of Australia. Lundquist *et al.* (1997), however, reported its occurrence as *Dentalina communis* from the Wilmington and South Heyes submarine canyons, U. S. Atlantic continental slope. On the basis of test shape and the nature of test coiling (i.e., chamber addition), Valchev (2006) categorized *N. ewaldi* under the tapered and cylindrical morpho-group (T/C), which is represented by forms with round, oval or triangular cross-section, and parallel or sub-parallel sides. This species was recorded at a water depth of 600 m on the northern shelf of New Caledonia in the south-western Pacific (Debenay, 2012).

Repository: PK–AG–062

Laevindentalina *inflexa* (Reuss, 1866)

*Original citation*: *Nodosaria inflexa* REUSS, 1866, p. 131, pl. 2, fig. 1.

*Remarks*: Hofker (1978) recorded this species as *Nodosaria inflexa* off the Nenoesa Islands in the eastern part of the Indonesian Archipelago, at a water depth of 524 m. According to him, Brady, Cushman and others described and illustrated only incomplete tests which lacked the initial part. He also stated that the only figure of a complete test known to him was one that had been given by Asano (1956, fig. 36), but even that did not show the costae, as it was too small. Hayward *et al.* (2001) recorded this species as *Laevindentalina inflexa* in a water depth range of 210 to 230 m east of New Zealand. According to Szarek (2001), who examined the biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in south-western South China Sea, *L. inflexa* is an outer shelf to lower bathyal species. This species has also been recorded from a shallow water depth range of 5 to 20 m in the Bay of Prony, off New Caledonia, in the south-western Pacific (Debenay, 2012); it is considered to be a suboxic indicator species (Kaminski, 2012).

Repository: PK–AG–063

Laevindentalina *inornata* (d’Orbigny, 1846)

*Original citation*: *Dentalina inornata* D’ORBIGNY, 1846, v. 44, pl. 1, pp. 50, 51.

*Remarks*: Pozaryska (1977) examined Upper Eocene foraminifera of East Poland and recorded this species as *Dentalina inornata*; she obtained a few, well preserved specimens that corresponded well with the holotype illustrated by d’Orbigny (1846). Living specimens of *Dentalina inornata* were recorded by Heinz *et al.* (2004) at only two stations on the Great Meteor Seamount, a large guyot located south of the Azores in the Atlantic Ocean, at 323 m and 3,015 m water depths, but they observed it to be very rare. Grunert *et al.* (2010) investigated 13 samples from different levels in the Upper Eocene Pucking section, and observed this species to occur rarely or as single specimens; it is also considered to be a suboxic indicator species (Kaminski, 2012).

Repository: PK–AG–064
Original citation: _Nodosaria subsoluta_ CUSHMAN, 1923, p. 74, pl. 13, fig. 1.

Remarks: This species was referred by Brady to _Nodosaria soluta_ (Reuss) and by Cushman (1923) to _Nodosaria subsoluta_. Later, Cushman and McCulloch (1950) placed this species under the genus _Dentalina_. The figures illustrated by Barker (1960) are of the specimens dredged from Challenger Station 24, off the West Indies, at a water depth of 390 fathoms (~713 m), and from Porcupine Station 23, north-west of Ireland, at a depth of 630 fathoms (~1,152 m). In his studies on the foraminifera of the shelf of Surinama and the Guyanas, Hofker (1983) reported this species as _Nodosaria subsoluta_ at two stations, one at a water depth of 121 m, associated with mud and shells, and the other at 940 m, in association with soft mud. According to Ofplaz (2006), _Laevidentalina (Dentalina) subsoluta_ is differentiated from _L. inflexa_ by possessing more globular chambers and by the lack of a neck. _Laevidentalina subsoluta_ was recorded by Debenay (2012) from the northern shelf off New Caledonia at a water depth of 600 m. This benthic species (as _Dentalina subsoluta_) with a bathyal and/or abyssal habitat is distributed in the north-eastern and north-western parts of the Gulf of Mexico in a water depth range of 518 to 1,335 m (Sen Gupta _et al._, 2009b); it has also been recorded from the Caribbean Sea, Atlantic and Pacific oceans. Hayward _et al._ (2012) classified deep-sea uniserial, elongate, benthic foraminifera into two informal groups: Extinction and Die-back groups. The former includes all the families, genera and species that became extinct (or almost extinct) during the last global extinction (LGE) in the deep sea, while the latter includes a smaller number of elongate benthic foraminifera that declined in abundance and geographic range during the LGE, but did not become extinct. _Laevidentalina communis, L. inflexa_ and _L. subsoluta_ all belong to the latter group (Mancin _et al._, 2013).

Repository: PK–AG–065

Genus MUCRONINA Ehrenberg, 1839

_Mucronina compressa_ Costa, 1855

Original citation: _Frondicularia compressa_ COSTA, 1855, p. 372, pl. 3, fig. 2.

Remarks: According to Hayward _et al._ (2012), this common and distinctive species has most commonly been recorded under the following species names: _Plectofrondicularia advena, P. foliacea, or P. inaequalis_. They classified deep-sea uniserial, elongate, benthic foraminifera into two informal groups: Extinction and Die-back groups. The former includes all the families, genera and species that became extinct (or almost extinct) during the last global extinction (LGE) in the deep sea, while the latter includes a smaller number of elongate benthic foraminifera that declined in abundance and geographic range during the LGE, but did not become extinct. _Mucronina compressa_ belongs to the former group (Mancin _et al._, 2013).

Repository: PK–AG–066

Genus NODOSARIA Lamarck, 1812

_Nodosaria radicula_ (Linnaeus, 1758)

Pl. 3; Fig. 4

Original citation: _Nautilus radicula_ LINNAEUS, 1758, p. 711, pl. 1, figs. 5a–c.

Remarks: According to Plummer (1926), who examined the foraminifera of the Midway Formation in Texas, “The Midway form of this species appears to be very typical. Both megalospheric and microspheric forms are found together in numerous samples, the former being more abundant. The megalospheric forms are characterized by the broad, blunt initial
proloculum succeeded by chambers increasing only slightly in diameter till three or four have been formed, and from this point the test is evenly developed. The microspheric form is sharply pointed at its proximal extremity, the first three or four short and unconstricted chambers comprising the acute angle, from which point the growth is identical with that of the megalospheric form”. *Nodosaria radicula* is a cosmopolitan species with a stratigraphic range from Jurassic through Holocene (Loeblich and Tappan, 1988), with wide geographic distribution around the world (Anan, 2009). On the basis of test shape and the nature of test coiling (i.e., chamber addition), Valchev (2006) categorized *N. radicula* under the tapered and cylindrical morpho-group (T/C), which is represented by forms with round, oval or triangular cross-section, and parallel or sub-parallel sides.

**Repository:** PK–AG–067

Genus *GLANDULONODOSARIA* Silvestri, 1900

*Glandulonodosaria ambiguca* (Neugeboren, 1856)

Pl. 3; Fig. 5

**Original citation:** *Nodosaria ambiguca* NEUGEBOREN, 1856, p. 71, pl. 1, figs. 13–16.

**Remarks:** The types for this species came from the Middle Miocene in Romania. A. Silvestri (1900) erected a new genus *Glandulonodosaria* with *Nodosaria ambiguca* as the type species. LeRoy (1964) studied smaller foraminifera from the Late Tertiary of southern Okinawa, recorded this species as *Rectoglandulina ambiguca* (Neugeboren), and observed it to be rare only in the Miocene Yonabaru Member of the Shimajiri Formation. According to Hayward et al. (2009), *Glandulonodosaria ambiguca* is one of the more common Quaternary Extinction Group species with its time of highest occurrence as 0.9 Ma. Previous classification schemes (e.g., Cushman, 1948; Loeblich and Tappan, 1964, 1987) synonymized *Glandulonodosaria* with *Nodosaria* Lamarck, 1812, but the former is distinguished from the latter by its simple rounded aperture without a neck or radial grooves (not present in the type species = *Nodosaria ambiguca*), compared with the necked radial aperture in the type species of *Nodosaria* (*Nautilus radicula* Linnaeus, 1758). Stainforth (1952) proposed a new genus *Orthomorphina* and transferred 11 known species to this genus, including *Nodosaria ambiguca* Neugeboren, 1856 without noticing that this species was designated as the type species of *Glandulonodosaria* Silvestri, 1900. Therefore, Hayward et al. (2012) re-assigned species with a simple round aperture and lacking an everted lip or apiculate neck, to the genus *Glandulonodosaria*, and gave a water depth range of upper bathyal–middle abyssal (400–4,000 m). This could well be the first record for this species from Indian waters.

**Repository:** PK–AG–068

Genus *PSEUDONODOSARIA* Boomgaard, 1949

*Pseudonodosaria rotundata* (Reuss, 1850)

**Original citation:** *Glandulina rotundata* REUSS, 1850, v. 1, p. 366, pl. 46, fig. 2.

**Remarks:** Bag (1898) studied the Cretaceous foraminifera of New Jersey and remarked (p. 43), “This is not an uncommon form in the limes and at Vincentown. Our specimens agree very closely with those figured by Professor Reuss”. He gave a stratigraphic range of Cretaceous to Recent for this species. According to Risdal (1964), this species (recorded as *Glandulina rotundata*) is found in the Oslofjord at depths of 100 and 200 m. Late Quaternary foraminifera from Denmark and Norway were investigated by Knudsen (1971), who observed the occurrence of a few specimens of this species (as *Glandulina rotundata*) in the Older Yoldiad Clay at Hirtshals. According to Cole (1981), who studied benthic foraminifera from the bathyal zone off north-east
Newfoundland, *Pseudonodosaria rotundata* was “a rare species, found randomly from 800 to 3,000 m”.

**Repository:** PK–AG–069

*Pseudonodosaria torrida* (Cushman, 1923)

**Original citation:** *Nodosaria (Glandulina) laevigata* D'ORBIGNY var. *torrida* CUSHMAN, 1923, p. 65, pl. 12, fig. 10.

**Remarks:** The specimens figured by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 24, off the West Indies, at a water depth of 390 fathoms (~713 m). This species was referred by Brady to *Nodosaria (Glandulina) laevigata* (d'Orbigny), but Cushman noted that the early chambers in *Glandulina* are biserial and placed this genus in the family Polymorphinidae. He also (1923, p. 65) remarked that Brady's figured specimens were his *Nodosaria (Glandulina) laevigata* var. *torrida*. Since *laevigata* is a true *Glandulina* and this form appears to be nodosarian, it would belong to the genus *Pseudoglandulina* of Cushman, and, therefore, Barker (1960) placed it in *Rectoglandulina*. Hofker (1983) recorded this species as *Glandulina torrida* from the continental shelf of Surinam and the Guyanas at a water depth of 940 m, associated with soft mud. According to Sen Gupta *et al.* (2009b), *Pseudonodosaria torrida* is distributed in the north-eastern, north-western and south-eastern parts of the Gulf of Mexico in a water depth range of 95 to 1,067 m; it has also been recorded from the Caribbean Sea and the Atlantic Ocean.

**Repository:** PK–AG–070

Genus *PYRAMIDULINA* Fornasini, 1894

*Pyramidulina catesbyi* (d'Orbigny, 1839)

**Original citation:** *Nodosaria catesbyi* D'ORBIGNY, 1839, p.16, pl.1, figs.8–10.

**Remarks:** Hofker (1983) recorded this species (as *Amphicoryna catesbyi*) on the continental shelf of Surinam and the Guyanas at water depths ranging from 35 to 64 m. Hottinger *et al.* (1993) recorded this species from the Gulf of Aqaba, Red Sea, and remarked, "Two types occur: one with 6 to 7 prominent, straight, longitudinal costae extending continuously from the base of the first chamber, which usually possesses a short, central, hollow pseudospine, to the apertural lip; and the second type with additional longitudinal costae which in part may start on the second chamber only. Furthermore, the longitudinal costae meet the phialine lip in a tangential manner and not perpendicularly like in the first type". *Pyramidulina catesbyi* occurs frequently in the Gulf of Iskenderun and in the infra-littoral and upper cerca-littoral zones at water depths ranging from 20 to 76 m, and is one of the 27 alien species observed along the Turkish coastline in the Mediterranean Sea (Meriç *et al.*, 2008). According to Sen Gupta *et al.* (2009b), this species (as *Nodosaria catesbyi*) occurs in the north-eastern and south-eastern parts of the Gulf of Mexico at a water depth of 46 m. Investigations by Meriç *et al.* (2010) on benthic foraminiferal fauna in Pamucak Cove, north-west Kuşadası, Turkey, revealed a foraminiferal assemblage that was typically Mediterranean, except for some alien species such as *P. catesbyi*. It has also been recorded at shallower depths of 5 to 20 m in the coastal bays of New Caledonia in the south-western Pacific Ocean.

**Repository:** PK–AG–071

*Pyramidulina comatula* (Cushman, 1923)

**Original citation:** *Nodosaria comatula* CUSHMAN, 1923, no. 104, pt. 4, p. 83, pl. 14, fig. 5.
Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 33, off Bermuda, Atlantic Ocean, at a depth of 435 fathoms (~796 m; figs. 1, 2, 4, 5) and Challenger Station 23, West Indies, at a depth of 450 fathoms (~823 m; fig. 3). *Pseudonodosaria comatula* was referred by Brady to *Nodosaria comata* (Batsch), but by Cushman to (1923, p. 83) *N. comatula*. This was later transferred to *Pseudoglandulina* Cushman, a genus later suppressed by Loeblich and Tappan, and in part replaced by *Rectoglandulina* (1955, pp. 2, 4). On the Saba Bank, *Pseudonodosaria comatula* (Cushman) was recorded in a water depth range of 280 to 730 m by Hofker (1980). Later, he (1983) observed it to occur on the continental shelf of Surinam and the Guyanas at water depths of 121 m, associated with mud and shells, and at 240 m in association with heavy clay. Sgarrella and Moncharmont Zei (1993) recorded this species from the Gulf of Naples at a depth of 438 m. According to Sen Gupta *et al.* (2009b), who recorded this species as *Pseudoglandulina comatula*, this is a cosmopolitan species that is distributed in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a water depth range of 47 to 950 m. It has been reported under the same name from the Setúbal Canyon axis, Portuguese margin at a water depth of 969 m (Phipps, 2012).

Repository: PK–AG–072

**Family VAGINULINIDAE** Reuss, 1860

**Subfamily LENTICULININAE** Chapman, Parr and Collins, 1934

**Genus LENTICULINA** Lamarck, 1804

*Lenticulina callifera* (Stache, 1864)

Pl. 3; Fig. 6

*Original citation:* Cristellaria callifera STACHE, 1864, p. 236, pl. 23, fig. 15.

*Remarks:* Hornibrook (1971) recorded this species as Robulus calliferus (Stache) and gave a New Zealand stratigraphic range of late Eocene to early Miocene (Runangan to Otaian stages). Leckie and Webb (1990) reported (p. 1111) and illustrated this species as *Lenticulina callifera* (p. 1139, pl. 20, figs. 11, 12) from the Deep Sea Drilling Project (DSDP) Site 270, in the Ross Sea, Antarctica. According to Li *et al.* (1996), who published a preliminary report on southern Australian endemic and semi-endemic foraminifera, *L. callifera* is listed in the latter group. This could well be the first record for this species from Indian waters.

Repository: PK–AG–073

*Lenticulina convergens* (Bornemann, 1855)

Pl. 3; Fig. 7

*Original citation:* Cristellaria callifera STACHE, 1864, p. 236, pl. 23, fig. 15.

*Remarks:* Hornibrook (1971) recorded this species as Robulus calliferus (Stache) and gave a New Zealand stratigraphic range of late Eocene to early Miocene (Runangan to Otaian stages). Leckie and Webb (1990) reported (p. 1111) and illustrated this species as *Lenticulina callifera* (p. 1139, pl. 20, figs. 11, 12) from the Deep Sea Drilling Project (DSDP) Site 270, in the Ross Sea, Antarctica. According to Li *et al.* (1996), who published a preliminary report on southern Australian endemic and semi-endemic foraminifera, *L. callifera* is listed in the latter group. This could well be the first record for this species from Indian waters.

Repository: PK–AG–073

*Lenticulina convergens* BORNEMANN, 1855

Pl. 3; Fig. 7

*Original citation:* Cristellaria callifera STACHE, 1864, p. 236, pl. 23, fig. 15.

*Remarks:* Hornibrook (1971) recorded this species as Robulus calliferus (Stache) and gave a New Zealand stratigraphic range of late Eocene to early Miocene (Runangan to Otaian stages). Leckie and Webb (1990) reported (p. 1111) and illustrated this species as *Lenticulina callifera* (p. 1139, pl. 20, figs. 11, 12) from the Deep Sea Drilling Project (DSDP) Site 270, in the Ross Sea, Antarctica. According to Li *et al.* (1996), who published a preliminary report on southern Australian endemic and semi-endemic foraminifera, *L. callifera* is listed in the latter group. This could well be the first record for this species from Indian waters.

Repository: PK–AG–073

Repository: PK–AG–072
Lenticulina cultrata (Montfort, 1808)

Original citation: Robulus cultratus MONTFORD, 1808, v. 1, p. 215, fig. on p. 214.
Remarks: In the south-eastern part of the Indonesian Archipelago, Hofker (1978) reported this species from a water depth of 1,374 m where the bottom water temperature was 3.6°C. Later, he (1983) recorded this species at two stations on continental shelf of Surinam and the Guyanas at water depths of 85.5 m and 120 m, associated with sandy mud and coarse sand/mud, respectively. Hayward et al. (2001) gave a water depth range of 90 to 720 m for this species east of New Zealand. In the Campos Basin, south-eastern Brazilian margin, Lenticulina cultrata is part of a Bolivina spp. assemblage that occurs preferentially at the deeper stations sampled, characterized in general by muddy sediments, relatively higher organic carbon content, and total phosphate values measured in the water varying between 1.09 and 2.3 μmol kg⁻¹ (De Mello e Sousa et al., 2006). Spezzaferri and Tamburini (2007) gave a water depth range of 50 to 4,500 m for this epifaunal, suboxic indicator species (Kaminski, 2012). According to Sen Gupta et al. (2009b), this species is distributed in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a water depth range of 99 to 1,644 m; it has also been recorded from the Caribbean, Atlantic, Pacific and Southern oceans. Lenticulina cultrata has been recorded at a water depth of 600 m on the northern shelf of New Caledonia, south-western Pacific (Debenay, 2012).
Repository: PK–AG–075

Lenticulina limbosa (Reuss, 1863)

Original citation: Robulina limbosa REUSS, 1863, v. 48, pt. 1, p. 55, pl. 6, figs. 69a, b.
Remarks: The types for this species came from the Oligocene formations of the Vienna Basin. According to Albani and Geyskes (1969), this species was the most abundant of the genus and occurred along all three traverses on a part of the north-western Australian continental shelf. Hofker (1978) recorded the presence of Lenticulina limbosa at one station in Moro Gulf the eastern part of the Indonesian Archipelago at a water depth of 513 m and bottom water temperature of 7°C. Hatta and Ujiie (1992) recorded this species from the coral seas between Ishigaki and Iriomote Islands of the Southern Ryukyu Island Arc in the north-western Pacific Ocean. Its occurrence in the middle and outer shelf regions off the south-east coast of Australia was reported by Yassini and Jones (1995). A water depth range of 210 to 750 m was given for this species by Hayward et al. (2001) in their studies on depth distribution of Recent deep-sea benthic foraminifera east of New Zealand. In the Bass Canyon, a temperate submarine canyon in Gippsland, Australia, Smith and Gallagher (2003) observed Lenticulina limbosa to be rare at middle shelf to upper slope depths. This species has been recorded at a water depth of 600 m on the northern shelf of New Caledonia, south-western Pacific (Debenay, 2012).
Repository: PK–AG–076

Lenticulina macrodisca (Reuss, 1863)

Original citation: Cristellaria macrodisca REUSS, 1863, p. 78, pl. 9, figs. 5a, b.
Remarks: This species was originally described from the Lower Cretaceous, upper Hils and middle Gault of northern Germany. Tappan (1962) examined foraminifera from the Arctic Slope of Alaska and observed this species to occur in the Grandstand, Topagoruk and Fortress Mountain formations. She stated, “The most notable characteristic is the extremely large
proloculus which is generally visible at the center of the test”. In his studies on the foraminifera of the South Indian Cretaceous, Gowda (1964) recorded Lenticulina macrodisca from the Upper Albian-Cenomanian Cullygoody Limestone and the Upper Cenomanian Odhium Clay. Webb (1973) referred two generations of a small Lenticulina to this species. According to him, the microspheric form resembles L. (L.) cultrata (Montfort) of Hillebrandt (1962). Slightly uncoiled variants resembling Lenticulina (Astartoid) gibba (d’Orbigny) are also placed with L. (L.) macrodisca. The species was quite common in the Paleocene samples examined by Webb (1973) from Wangaolao and Dunedin, New Zealand, and he observed that many tests had been bored. Dalby (1997) recorded this species from the Late Albian-Cenomanian and Albian samples of the Haida Formation in the Queen Charlotte Islands, British Columbia, Canada, and remarked, “The specimens were two basic sizes. The larger ones were 0.8 to 1.2 mm in diameter, and the smaller ones 0.2 to 0.35 mm in diameter. There was no gradual spectrum of sizes, one might consider these two distinct species, but as specimens of both sizes were always found together, they probably represent alternation of generations”, actually echoing Webb’s (op cit.) observations.

Repository: PK–AG–077

Lenticulina pliocaena (Silvestri, 1898)
Pl. 3; Fig. 10

Original citation: Polymorphina pliocaena SILVESTRI, 1898, pl. 4, figs. 3a–c.
Remarks: According to Sen Gupta et al. (2009a), who reported Lenticulina pliocaena for the first time from the Gulf of Mexico, the test is characterized by two prominent longitudinal ribs running from basal spine to apertural end; sometimes a third is present. Among the eight canyons in the gulf, it was present in four: Shallow Green Canyon at 245 m, Deep Green Canyon at 562 to 696 m, Garden Banks at 640 m, and South of Mississippi Canyon at ~1,000 m. Mallon (2011), who studied benthic foraminifera of the Peruvian and Ecuadorian margin, observed L. pliocaena to be very rare, occurring at only one station, off Ecuador, at 207 m water depth. This could well be the first record for this species from Indian waters.

Repository: PK–AG–078

Lenticulina submamilligera (Cushman, 1917)
Pl. 3; Fig. 9, 9a

Remarks: This species was referred by Brady (1884) to Cristellaria mamilligera Karrer and by Cushman (1917) to C. submamilligera. According to Cushman (1921), the type specimen (U.S.N.M. No. 9127) came from the Albatross Station D5388 at a water depth of 226 fathoms (~413 m), between Burias and Luzon, where it was abundant. He stated, “The species is a very common one in the Philippine Archipelago, being found also in the China Sea, but not recorded in the areas to the south”, and remarked, “The species differs from C. mamilligera Karrer in the keel, which is entire and not regularly denticulate; the ornamentation, which consists of raised ridges with bosses and not of a series of knobs”. The figures illustrated by Brady (Barker, 1960) are of specimens obtained from material dredged at Challenger Station 174C, off Fiji in the Pacific Ocean, at a water depth of 210 fathoms (~384 m). In the eastern part of the Indonesian Archipelago, Hofker (1978) recorded this species as Lenticulina submamilligera at 216 m water depth off the Pisang Islands, and at 432 m off Lifamatola. Later, he (1980) observed the occurrence of this species on the eastern slope of the Saba Bank at a water depth of 340 m, associated with clayey sand substrate and bottom water temperature of 12°C. According to Szarek (2001), the bathymetric range for this species is inner shelf to upper bathyal on the Sunda
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Genus NEOLENTICULINA McCulloch, 1977

Neolenticulina peregrina (Schwager, 1866)

Original citation: Cristellaria peregrina SCHWAGER, 1866, p. 245, pl. 7, fig. 8.

Remarks: Brady referred this species to Cristellaria variabilis Reuss (1850, p. 369), but was transferred by Cushman (1923) to C. peregrina. It is possible that Cristellaria variabilis is a senior synonym of C. peregrina (Popescu and Crihan, 2000). According to Sen Gupta et al. (2009b), this cosmopolitan species is distributed all over the Gulf of Mexico in a very wide water depth range of 8 to 3,017 m. Kaminski (2012) made an attempt to calibrate benthic foraminiferal oxygen index in the Marmara Sea and classified this species (as Lenticulina peregrina) as a suboxic indicator. According to Milker and Schmiedl (2012), this species was observed to be extremely rare in the Oran Bight and the south-west shelf of Mallorca in the western Mediterranean Sea.

Repository: PK–AG–079

Subfamily MARGINULININAE Wedekind, 1937

Genus AMPHICORYNA Schlumberger, 1881

Amphicoryna hirsuta (d’Orbigny, 1826)

Original citation: Nodosaria hirsuta D’ORBIGNY, 1826, p. 252, no. 7.

Remarks: According to Hofker (1978), who recorded this species at water depths of 432 m (off Lifamatola), 513 m in the Moro Gulf, and at 587 m in the eastern part of the Indonesian Archipelago, “The genus Amphicoryna is found in rather deep to very deep water, and has no cosmopolitan species. A. scalaris (Batsch) is found in the Mediterranean Sea and in the Atlantic, possibly also in the Philippines (Brady); A. intercellularis (Brady) is found in the Caribbean region; A. sublineata, A. substriatula and A. hirsuta are known from the Pacific”. Amphicoryna proxima, A. hirsuta and Nodosaria calomorpha have been already reported as the ‘survivor group’ during the so-called ‘Stilostomella extinction’ event (Kawagata et al., 2006). According to Sen Gupta et al. (2009b), this species is distributed all over the Gulf of Mexico in a wide water depth range of 19 to 1,020 m, and has also been recorded from the Atlantic and Pacific oceans. Bhaumik et al. (2011) recorded Amphicoryna hirsuta among elongated benthic foraminifera in 9 out of 15 core top samples from the Indian Ocean, but observed it to be rare in abundance.

Repository: PK–AG–081

Amphicoryna hirsuta (d’Orbigny) forma sublineata (Brady, 1884)

Original citation: Nodosaria hispida D’ORBIGNY, 1826 forma sublineata BRADY, 1884, p. 508, pl. 63, figs. 19–22.

Remarks: This species was referred by Brady to Nodosaria hispida var. sublineata and by Parr (1950) to Amphicoryna. However, Barker (1960) did not observe any material confirming the Amphicoryna characters noted by Parr and opined that this species may belong in Orthomorphina and that the generic name should be Amphicoryna. Hofker (1978) recorded this species as Amphicoryna sublineata from the eastern part of the Indonesian Archipelago at water depths ranging from 378 m (Timor...
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Sea, east of Roti) to 4,048 m (Banda Sea, south of Ambelau). Szarek (2001) studied the biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea and gave an inner shelf to upper bathyal water depth range for this species. He observed that specimens from the South China Sea were much smaller, transparent and more fragile in comparison to forms in the Challenger Collection. According to Sen Gupta et al. (2009b), who recorded this species as Amphicoryna subtitlea, it has a very wide water depth range of 45 to 3,400 m in the north-eastern and north-western parts of the Gulf of Mexico. It has also been recorded from the Atlantic and Indian oceans. In their analysis of benthic foraminiferal assemblages of a drill core from the lower Guadalquivir Basin (northern Gulf of Cádiz, south-west Spain) for reconstructing the paleoenvironmental evolution in the vicinity of the Betic seaways during the Messinian, Pérez-Asensio et al. (2012) reported this species (as A. subtitlea) to be shallow infaunal.

Repository: PK–AG–082

Amphicoryna scalaris (Batsch, 1791)

Pl. 3; Fig. 11

Original citation: Nautilus (Orthocera) scalaris BATSCH, 1791, p. 91, pl. 2, figs. 4a, b.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the dredged material at Porcupine Station 10, west of Ireland in the North Atlantic, and at Challenger Station 209, off the Philippines in the Pacific, at a water depth of 95–100 fathoms (~174 to 183 m). This species was referred by Brady to Nodosaria and, according to Barker (1960), if congeneric with N. scalaris var. separans Brady, would be placed in Lagenonodosaria Silvestri, of which separans is the type. Parr (1950), however, placed Lagenonodosaria in the synonymy of Amphicoryne. This was based on Silvestri (1902, p. 50), who had shown that Amphicoryne falx (Jones and Parker), the genotype of Amphicoryne Schlumberger, was the microspheric form of Nodosaria scalaris (Batsch). Hofker (1932, p. 115) had also placed Amphicoryne falx in synonymy with scalaris but placed this species in Marginulina, with var. separans Brady in synonymy. Parker (1958) and Todd and Low (1967) referred this species to the genus Lagenonodosaria. Hofker (1932) and Buchner (1940) suggested that it must be regarded as the megalospheric form of the species Amphicoryna scalaris. Knudsen (1971) studied Late Quaternary foraminifera from Vendsyssel, Denmark and Sandnes, Norway and recorded a few specimens of A. scalaris in the Late Glacial Zirfaea layers and in the Older Yoldia Clay of Vendsyssel. Amphicoryna scalaris and Rosalina globularis are not known for their preferences or tolerances for stressed and/or eutrophic environments (Mojtahid et al., 2006), though the former, A. scalaris, is considered to be a suboxic indicator species (Kamniski, 2012) that prefers an inner shelf to upper bathyal water depth range (Szarek, 2001). In their studies on the response of benthic foraminifera and ostracoda to heavy metal pollution in Gulf of Izmir, Eastern Aegean Sea, Bergin et al. (2006) observed this species to among the most abundant taxa in the most polluted inner Bay. They also noted that A. scalaris had significant correlation with Cr, Cu, Ni and Mn. According to Sen Gupta et al. (2009b), this species is distributed in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a water depth range of 19 to 414 m. Debenay (2012) recorded this shallow infaunal species (Pérez-Asensio et al., 2012) at 600 m water depth on the northern shelf off New Caledonia in the south-western Pacific.

Repository: PK–AG–083

Genus ASTACOLUS de Montfort, 1808

Astacolus insolitus (Schwager, 1866)

Pl. 3; Figs. 12, 12a

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Original citation: Cristellaria insolita, SCHWAGER, 1866, p. 242, pl. 6, fig. 85.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the dredged material at Challenger Station 192, off the Ki Islands in the Pacific Ocean, at a water depth of 129 fathoms (~236 m). Astacolus insolitus was initially referred by Brady to Cristellaria crepidula (Fichtel and Moll, 1798) and by Galloway and Heminway (1941, p. 334) to Astacolus insolitus (Schwager). In their studies on depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, Hayward et al. (2001) recorded this species at a depth of 170 m. Later, Hayward (2002) listed this species under the calcareous, elongate, uniserial Survivor Group of benthic foraminifera present in late Pliocene and Pleistocene sections of studied sites and/or in modern sediments in six DSDP and ODP sites around New Zealand, in the southwest Pacific Ocean. According to Meriç et al. (2008), A. insolitus is an alien but established species (Çinar et al., 2005; wrongly spelt as insolithus) along the Aegean and south-western coasts of Turkey, and was poorly recorded from only two localities in the infra-littoral zone, in the Gulf of Edremit at a water depth of 29 m, and in the Gulf of Gokova at 34.5 m.

Repository: PK–AG–084

Genus MARGINULINA d'Orbigny, 1826
Marginulina obesa Cushman, 1923

Original citation: Marginulina glabra D’ORBIGNY, 1826 var. obesa CUSHMAN, 1923, p. 128, pl. 37, fig. 1.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens retrieved from the dredged material at Challenger Station 246 in the North Pacific Ocean, at a depth of 2,050 fathoms (~3,749 m). This species was referred by Brady to M. glabra d’Orbigny. Cushman (1923, p. 128) noted that Brady's North Atlantic specimens of M. glabra might prove to be his M. glabra var. obesa, while Parr referred these figures to M. obesa Cushman. In his studies on the biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in the southwestern South China Sea, Szarek (2001) recorded this species as M. obesa at outer shelf to lower bathyal depths. According to Sen Gupta et al. (2009b), who reported this species as Marginulina glabra obesa Cushman, 1923, this cosmopolitan species is distributed in the north-eastern, north-western, and south-western parts of the Gulf of Mexico, in a wide water depth range of 80 to 1,067 m. Debenay (2012) recorded this species at much shallower depth of 40 m in the southern lagoon of New Caledonia in the south-western Pacific Ocean.

Repository: PK–AG–085

Genus VAGINULINOPSIS Silvestri, 1904
Vaginulinopsis sublegumen Parr, 1950

Original citation: Vaginulinopsis sublegumen PARR, 1950 p. 325, pl. 11, fig. 18.

Remarks: This species was referred by Brady to Vaginulina legumen (Linnaeus) but Parr (1950, p. 325) established it as a new species under the name Vaginulinopsis sublegumen. In his studies on the bathyal zone benthic foraminiferal species off north-east Newfoundland, Cole (1981) reported this species as Vaginulinopsis sublegumen and observed it to be rare but large in size, up to 5 mm long, and distributed in a water depth range of 1,200 to 2,600 m. Szarek (2001) reported this species as Vaginulinopsis sublegumen at inner shelf to upper bathyal depths on the Sunda Shelf in the south-western South China Sea. According to Çinar et al. (2005), Astacolus sublegumen (= V. sublegumen) is one of the invasive (Zenetos et al., 2005) alien, established, Lessepsian species off
the coasts of Turkey in a water depth range of 51 to 100 m, preferring soft substrate and having its origin from the Indo-Pacific and/or Red Sea. Meriç et al. (2008) observed that *A. sublegumen* is an alien species along the Aegean and south-western coasts of Turkey, and was poorly recorded from only two localities in the infra-littoral zone, in the Gulf of Edremit at a water depth of 29 m, and the Gulf of Gokova at 34.5 m. According to Sen Gupta et al. (2009b), this cosmopolitan species with a bathyal and/or abyssal habitat is distributed in a water depth range of 613 to 1,067 m in the north-eastern and north-western parts of the Gulf of Mexico. This species was recorded by Debenay (2012) as *V. subelegans* at a water depth of 600 m on the northern shelf off New Caledonia in the south-west Pacific Ocean.

Repository: PK–AG–086

Subfamily VAGINULININAE Reuss, 1860
Genus VAGINULINA d’Orbigny, 1826
*Vaginulina subelegans* Parr, 1950
Pl. 3; Fig. 13

**Original citation:** *Vaginulina subelegans* PARR, 1950, v. 5, pt. 6, p. 326, pl. 11, figs. 20a, b.

**Remarks:** This species was referred by Brady to *Vaginulina legumen* d’Orbigny, while Cushman (1933) referred similar specimens to *V. elegans* d’Orbigny, which Parr (1950) regarded as *V. subelegans*. Parr (*op cit*), however, did not refer to Brady’s figures and this probably prompted Barker (1960) to add a question mark to Brady’s illustrations. These were of specimens obtained from the material dredged at Challenger Station 279C, off Tahiti in the Pacific Ocean, from a water depth of 620 fathoms (~1,134 m). In his studies on the biodiversity and biogeography of recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea, Szarek (2001) recorded this species as *Vaginulina subelegans* at outer shelf to middle bathyal depths.

Repository: PK–AG–087

Family LAGENIDAE Reuss, 1862
Genus HYALINONETRION Patterson and Richardson, 1987
*Hyalinonetrion elongata* (Ehrenberg, 1844)
Pl. 3; Figs. 14, 14a

**Original citation:** *Miliolina elongata* EHRENBERG, 1844, p. 274; type-fig. not given.

**Remarks:** The type locality for this species is in Kurdistan, Iran. Finger et al. (1990) recorded and illustrated this species (p. 11, pl. 1, fig. 53) among the calcareous microfossils in the Lower to Middle Miocene Lower Monterey Formation in the Graves Creek area, Central California. It has also been recorded by Yassini and Jones (1995) from open estuaries, sheltered oceanic embayments, middle and outer shelf, off south-east Australia. Lundquist et al. (1997) reported it as *Lagena elongata* from the Wilmington and South Heyes submarine canyons, U.S. Atlantic continental slope, as had been done earlier by Debenay and Basov (1993) from the West African continental shelf and slope. Debenay (2012) recorded and illustrated this species as *Hyalinonetrion elongata* from the coastal bays of New Caledonia in the south-western Pacific Ocean at a very shallow depth of 10 m.

Repository: PK–AG–088

Genus LAGENA Walker and Jacob, 1798
*Lagena apiculata* (Reuss, 1850)
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Original citation: *Oolina apiculata* REUSS, 1850, v. 4, p. 22, pl. 1, fig. 1.

Remarks: The type specimen of this species, as described by Reuss, has a short basal spine. Brady (1884) stated that “*Lagena apiculata* is an entosolenian variety, only differing from *Lagena globosa* in having a pointed instead of a rounded base. Like the allied form it is cosmopolitan, and has been found at every depth from the littoral zone down to 2,750 fathoms. It is also one of the commonest of fossil *Lagena*, occurring in microzoic rocks of almost every age as far back as the Liassic”. Bagg (1912) examined Pliocene and Pleistocene foraminifera from Southern California, and remarked, “This form is very similar to *Lagena gracillima* except that the body is less bulbous and more attenuate, with a short taper at each extremity”. Mello (1969), who studied the foraminifera and stratigraphy of the Upper Part of the Cretaceous Pierre Shale in Dakota, remarked, “One of the Pierre specimens has such a spine and appears to be identical to Reuss’ figured specimen. The other Pierre specimens from the same, as well as different, samples lack a basal spine but in other respects are similar to the specimen bearing the basal spine. A small suite of specimens labelled *Lagena apiculata* (Reuss) from the Lizard Springs Marl, Trinidad, (Cushman Colln. 46656), includes several specimens lacking basal spines which are closely similar in form to the majority of the Pierre specimens, though slightly larger”.

Repository: PK–AG–089

*Lagena aspera* Reuss, 1861
Pl. 3; Fig. 15

Original citation: *Lagena aspera* REUSS, 1861, v. 44, no. 1, p. 305, pl. 11, fig. 5.

Remarks: In their studies on Recent foraminifera from the Atlantic Coast of South America, Cushman and Parker (1931) observed *Lagena aspera* to be rare at Port William, Falklands. Cushman and Stainforth (1945) recorded this species from the Cipero Marl Formation of Trinidad, British West Indies, and stated, “Large specimens of this species, very similar to those figured by Nuttall from Trinidad, occur in Zones II and III. The species seems to occur in the present oceans. The surface is a peculiar one with its short spines, and there is a well developed neck and a phialine lip with radiating ridges on the outer surface. Bermudez recorded it from the Eocene of Cuba”. In his studies on smaller foraminifera from the Late Tertiary of Southern Okinawa, LeRoy (1964) observed *Lagena aspera* to occur rarely in the Yonabaru Formation. Only two specimens of this species were found in the Late glacial *Zirfaea* layers at Skee Mollebæk, Vendsyssel, among the Late Quaternary foraminifera from Vendsyssel, Denmark and Sandnes, Norway (Knudsen, 1971). Quilty (1974) examined Tertiary Tasmanian foraminifera and, while reporting *L. aspera*, remarked, “The species recorded here seems to be identical with one figured by Brady (1884, pl. 57, fig. 11) and Barker (1960) as *L. aspera*. It seems close to *L. aspera* var. *spinifera* Chapman, in that it has a spherical test with short neck. However, no spines are evident”.

Repository: PK–AG–090

*Lagena flatulenta* Loeblich and Tappan, 1953
Pl. 3; Fig. 16

Original citation: *Lagena flatulenta* LOEBLICH and TAPPAN, 1953, v. 121, no. 7, p. 60, pl. 11, figs. 9, 10.

Remarks: In their studies on foraminifera from the Kara and Greenland Seas, Todd and Low (1980) remarked that *Lagena flatulenta* differs from *L. hispidula* in having a wall surface that is smooth and hyaline instead of finely hispid. Patterson and Richardson (1988) erected eight new genera of unilocular foraminifera and stated that, “*Pygmaeoseistron* differs from *Lagena* by lacking costae, and from *Procerolagena* and *Hyalinometrion* in being globular rather than fusiform. Based on
a search of the literature, *L. flatulenta* Loeblich and Tappan, *L. laevis* (Montagu) var. *nebulosa* Cushman, *L. parri* Loeblich and Tappan, *L. adhaea* Jennings, and *L. vulgaris* Williamson, are herein transferred to *Pygmaeoseistron*. A decade later, Patterson *et al.* (1998) recorded this species (p. 8, pl. 29, fig. 3) in their atlas of common benthic foraminiferal species from the Quaternary shelf environments of western Canada.

Repository: PK–AG–091

*Lagena hispidula* Cushman, 1913

Original citation: *Lagena hispidula* CUSHMAN, 1913, p. 14, pl. 5, figs. 2, 3.

Remarks: *Lagena hispidula* was originally described by Cushman (1913) based on the types from deep sea samples between Yokohama and Guam in the North Pacific and the species has been found subsequently in deep sea sediments in the South and North Atlantic Ocean. Later, this species was made the type species for the genus *Pygmaeoseistron* erected by Patterson and Richardson (1987), and was followed by some later workers, although several continued to report it as *L. Hispidula* (e.g., Yassini and Jones, 1995). The specimens figured by Brady (1884) came from the material dredged at Challenger Station 160 in the Southern Ocean at a depth of 2,600 fathoms (~4,755 m), and from Challenger Station 332 in the South Atlantic at a depth of 2,200 fathoms (~4,023 m). This species was first recorded as *L. hispidula* by Vilks *et al.* (1979), who studied the Holocene marine environment on the Beaufort Shelf in the Arctic Basin. According to Todd and Low (1980), “This cosmopolitan species differs from *L. laevis* in that the greatest diameter is midway of the chamber rather than toward the base and the body of the test does not merge into the long slender neck. From the Arctic species, *L. flatulenta* Loeblich and Tappan, it differs in its wall surface being finely hispid instead of smooth hyaline”. Cole (1981) studied bathyal zone benthic foraminifera from off north-east Newfoundland and gave a water depth range of 1,000 to 3,210 m, with a slightly higher concentration from 3,000 to 3,210 m. According to Bornmalm (1997), *Lagena hispidula* differs from *Lagena hispida* Reuss, 1863 in that it has a smooth flask-shaped body with a long slender neck rather than a rounded short-necked body with coarser spines. Szarek (2001) gave a water depth range of outer shelf to lower bathyal for this species on the Sunda Shelf in the south-western South China Sea. In their contributions to the knowledge of the calcareous unicameral foraminifera from the Middle Miocene of Romania, Popesu and Crihan (2004) stated, “This is the only genus of Lagenidae without aboral opening. This is the simplest test building within the monothalamous foraminifera. A similar species was described by Cushman (1913, p. 14) as *Lagena hispidula*, which in our opinion, can be included in the variability of the Reuss’ species, and is a junior synonym”. According to Sen Gupta *et al.* (2009b), this species has a very wide water depth range of 22 to 1,314 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico; it has also been recorded from the Caribbean, Atlantic and Pacific oceans. Mallon (2011) observed *L. hispidula* to occur at three stations off Peru in water depths between 995 and 1,004 m, but found it to be rare.

Repository: PK–AG–092

*Lagena perlucida* (Montagu, 1803)

Pl. 3; Fig. 17

Original citation: *Vermiculum perlucidum* MONTAGU, 1803, p. 525, pl. 14, fig. 3.

Remarks: Cushman and McCulloch (1950, pl. 46) figured two specimens, figures 1 and 2, as *Lagena perlucida*. According to Feyling-Hansen (1964), similar figures are scattered through the literature of Foraminifera, quite constantly referred to *Lagena perlucida* (Montagu). They have very little in common with Montagu's original description of *Vermiculum perlucidum* (1803, p. 525) or
his drawing of the same (pl. 14, fig. 3), which shows a globose Lagena with few (probably only 6) equidistant longitudinal costae extending over the whole inflated part of the test, from the basal knob to the base of the apertural neck. Murray (1971) did not observe any living forms of this species off the British Isles, and opined that though the type figure shows a small boss, it is doubtful whether it really existed, as claimed by Williamson (1848). Haynes (1973) reported this species from the Cardigan Bay, British Isles. In the eastern part of the Indonesian Archipelago, Hofker (1978) recorded Lagena perlucida at a water depth of 587 m (6.4° C BWT) south of Makassar, and at 2,693 m (3° C BWT) west of Benteng. Lundquist et al. (1997) reported it, albeit tentatively, from the Wilmington and South Heyes submarine canyons, U.S. Atlantic continental slope. Szarek (2001) recorded this species at outer shelf to uppermost bathyal depths on the Sunda Shelf in the south-western South China Sea. In the context of the paleoclimatic interpretation of the Pleistocene to sub-Recent Holocene of the British Isles, comparatively warm water conditions were inferred by Jones and Whittaker (2010) based on the occurrence of such cool-temperate species as Lagena perlucida. According to Nabavi et al. (2014), who studied the distribution, diversity and abundance of benthic foraminifera of the north-western Persian Gulf, L. perlucida is a rare species in the region.

Repository: PK–AG–093

Lagena quinquelatera Brady, 1881

Pl. 3; Fig. 18

Original citation: Lagena quinquelatera BRADY, 1881, v. 21, p. 60; 1884, v. 9, p. 454, pl. lxi, figs. 15, 16.

Remarks: Brady (1881) erected a new species under the name of Lagena quinquelatera, which he considered as a five-sided modification of L. lævis with sharp or carinate angles, the surface being unornamented or very faintly striate. The figures illustrated by Brady (1884) were of specimens obtained from the material dredged at Challenger Station 276 in the South Pacific at a water depth of 2,350 fathoms (~4,298 m), and at a much shallower depth of 50 to 150 fathoms (~91 to 274 m) at Challenger Station 145, off Prince Edward Island in the South Pacific. This species was referred by Brady (1884) to Lagena but opined by Barker (1960) to probably belong to Fissurina. In his investigations on the foraminifera of the Scottish National Antarctic Expedition, Pearcey (1914) observed Lagena quinquelatera to be rare at one station where the water depth was 1,946 fathoms. This could very well be the first report of this typical species from Indian waters.

Repository: PK–AG–094

Lagena radiata (Seguenza, 1862)

Original citation: Fissurina radiata SEGUENZA, 1862, p. 70, pl. 2, figs. 42, 43. (fide Ellis and Messina).

Remarks: This species was referred by Brady to L. lagenoides (Williamson) and by Cushman (1911, p. 40) to L. sublagenoides. Buchner (1940, p. 450) placed L. sublagenoides Cushman in the synonymy of L. radiata (Seguenza) referring to Brady (fig. 14 only), following Silvestri (1902, p. 145). Barker (1960), however, referred it to Fissurina radiata Seguenza and the specimens figured by Brady (1884) are from material dredged at Challenger Station 185, in the Torres Strait, Pacific Ocean, at a water depth of 155 fathoms (~283 m), and from Challenger Station 85, off the Canaries in the Atlantic Ocean, at 1,125 fathoms (~2,057 m). Popescu and Crihan (2004) recorded this species as Lagnea radiata (Seguenza, 1862) from the middle Miocene beds of Romania. According to Sen Gupta et al. (2009b), who recorded it as Fissurina radiata (Seguenza), this species has a bathyal
and/or abyssal habitat in the north-eastern and north-western parts of the Gulf of Mexico at water depths ranging between 347 and 1,204 m.

Repository: PK–AG–095

**Lagena striata** (d'Orbigny, 1839)

Pl. 3; Figs. 19, 19a

**Original citation:** *Oolina striata* D'ORBIGNY, 1839, v. 5, pt. 5, p. 21, pl. 5, fig. 12.

**Remarks:** *Lagena striata* (d'Orbigny) was described from the Falkland Isles (1839), the type locality being Islas Malvinas. The ornamentation in the form of numerous, distinct costae running almost to the entire length of the test is characteristic of this species. The specimens figured by Brady (1884) came from the material dredged at Challenger Station 217A, off Papua in the Pacific Ocean, at a water depth of 37 fathoms (~68 m), and from Challenge Station 232, south of Japan, in the North Pacific Ocean, at a depth of 345 fathoms (~631 m). Though Brady (*op cit.*) included his figures 19 and 28 under *L. striata*, Barker (1960) doubted the authenticity of it; Buchner (1940), however, included only figures 22 and 24 under this species. According to Todd and Low (1968), who studied Recent foraminifera from the Gulf of Alaska, “Our specimens, occurring rarely on the searidge and at Kasaan Bay, are typical of this species as described from off the Falklands. It has been widely reported from both cold and warm waters, and specimens show great variability in shape and strength of costae. Our specimens, however, are quite uniform. They are 0.20–0.25 mm in diameter; the slender neck arises abruptly from the body of the test; the costae are very fine, delicate, evenly spaced, and there are more than 50 around the circumference of the test. The neck is also ornamented by a few oblique costae spiralling around it”. Hofker (1978) recorded this species at a single station in the Moro Gulf in the eastern part of the Indonesian Archipelago, at a water depth of 513 m (7° C BWT). Szarek (2001) gave a water depth range of Inner shelf to upper bathyal for *Lagena striata* on the Sunda Shelf in the south-western South China Sea, while Lukina (2001) recorded it in a depth range of 243 to 3,171 m in the Laptev Sea. In the Gulf of Mexico, this species is distributed in a wide water depth range of 22 to 1,360 m (Sen Gupta *et al.*, 2009b). According to Forster (2013), the species that are marked with numerous strong longitudinal costae comprise *Lagena striata* (d'Orbigny, 1839), *Lagena semistriata* (Williamson, 1848), *Lagena sulcata* (Walker and Jacob, 1798) and taxa similar to *Oolina borealis* Loeblich and Tappan, 1954 and *Lagena laevicostata* Cushman and Gray, 1946. According to Pezelj *et al.* (2013), who studied paleoenvironmental dynamics in the southern Pannonian Basin during initial Middle Miocene marine flooding, *Lagena striata* is an epifaunal/shallow infaunal (Pérez-Asensio *et al.*, 2012) species that indicates suboxic conditions (Kaminski, 2012) and is characteristic of sub-tropical water masses (Kuzmin *et al.*, 2004).

Repository: PK–AG–096

**Lagena sulcata** (Walker and Jacob, 1798)

Pl. 4; Fig. 8, 8a

**Original citation:** *Serpula sulcata* WALKER and JACOB, 1798, p. 634, pl. 14, fig. 5.

**Remarks:** According to Allen and Todd (1900), who studied the fauna of the Salcombe Estuary, *Lagena sulcata* was common in the channel to the west of Salstone and in the sand between Ferry House and Millbay, with a few specimens from the north-east end of Salcombe Harbour, and from mud between Ferry House and Millbay. Bagg (1905) stated that this species is known from every latitude at depths of from a few down to 2,750 fathoms (~5,029 m), though the species is normally present in shallow waters. The specimens figured by Brady (1884) are of those retrieved from the material dredged at contrasting water depths (Barker, 1960): at Challenger Station...
149D, off the Kerguelen Islands in the South Pacific at 20 to 60 fathoms (~37 to 110 m) and at Challenger Station 271, also in the South Pacific, at 2,425 fathoms (~4,435 m). Bagg (1912) described the test surface of *Lagena sulcata* as “invariably ornamented with sulcations, above which run parallel costae the entire length of the shell. When these lines are broken the variety is known as *Lagena sulcata var. interrupta* Williamson. The number of sulcations is variable, but there are fewer costae than in *L. striata* (d’Orbigny)”. Pearcey (1914) opined that this species was one of the most abundant and most generally distributed of all the members of the genus, and that it had been “recorded in every latitude, from Baffin’s Bay in the north to Heard Island in the Southern Ocean. Its bathymetrical range extends from the littoral zone to a depth of 2,750 fathoms” (~5,029 m). In his study on bathyal zone benthic foraminifera from off north-east Newfoundland, Cole (1981) observed *L. sulcata* to be rare in a water depth range of 1,200 to 2,600 m. Patterson and Richardson (1988) stated that “A great number of different species of *Lagena* have been incorrectly referred to *Lagena sulcata*. In order to avoid confusion, they illustrated a hypotype from the Pliocene of Bologna, Italy. In their studies on the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, Hayward et al. (2001) presented a water depth range of 850 to 3,650 m for *L. sulcata*. According to Sen Gupta et al. (2009b), this species occurs in the north-eastern, north-western and south-western parts of the Gulf of Mexico in depth range of 47 to 933 m, with records from the Caribbean Sea, Atlantic, Pacific and Southern oceans as well. Mallon (2011) recorded only one specimen of this species, off the Peruvian margin, at a water depth of 1,923 m and stated, “The globular chamber with its strong longitudinal costae is readily to distinguish from other species”. According to Nabavi et al. (2014), who studied the distribution, diversity and abundance of benthic foraminifers, *L. sulcata* is very rare in the north-western part of the Persian Gulf.

Repository: PK–AG–097

*Lagena tokiokai* Uchio, 1962

Pl. 4; Figs. 1, 1a

Original citation: *Lagena pliocenica tokiokai* nsubsp. UCHIO, 1962, p. 387, pl. 18, figs. 10a, b.

Remarks: The holotype of this species came from Station 24, off the River Shinano, Niigata-ken, Japan, at a water depth of 39 m. Uchio (1962) erected this new subspecies and stated that it differed from *Lagena pliocenica* “in that the main portion of the test of *L. pliocenica* is roughly triangular or semi-circular in side view and thus the greatest width near the base, while that of *L. pliocenica tokiokai* is somewhat pyriform, and widest about the middle of it”. Obviously, it has been shifted from a sub-specific status to full species status, but there do not seem to be many known records for this species. This might well be the first record of this rare species from Indian waters.

Repository: PK–AG–098

Genus PROCEROLAGENA Puri, 1954

*Procerolagena gracilis* (Williamson, 1848)

Pl. 4; Figs. 9, 9a

Original citation: *Lagena gracilis* WILLIAMSON, 1848, p. 13, pl. 1, fig. 5.

Remarks: *Lagena gracilis* Williamson is the type species of the genus *Procerolagena* established by Puri (1954), and Jones (1994) designated a lectotype for this species. According to Bagg (1905), “this finely costate or striated *Lagena* is much longer than *Lagena sulcata*, and is further distinguished by the presence of a small spine at the distal end. It is of world-wide distribution at the present day, and is usually found in shallow waters, but it is known in many instances to
occur as deep as 2,775 fathoms (~5,075 m) in the South Atlantic Ocean. Its geological range is from Cretaceous to Recent”. The illustrations by Brady (1884) that are presented in Barker (1960) are of specimens from material dredged at as many as 6 stations: Challenger Station 276, north of Tahiti, Pacific, at water depth of 2,350 fathoms (~4,298 m); Challenger Station 160, in the Southern Ocean at 2,600 fathoms (~4,755 m); Challenger Station 283 in the South Pacific at 2,075 fathoms (~3,795 m); Challenger Station 306, off the west coast of Patagonia, in the eastern Pacific at 345 fathoms (~631 m); and Challenger Station 192, off the Ki Islands in the Pacific at 129 fathoms (~236 m). Hožker (1978) recorded this species as *Lagena gracilis* at 522 m water depth, south of Sarmata, and at 378 m in the Timor Sea, south of Roti, in the eastern part of the Indonesian Archipelago. This species is distributed in a water depth range of 108 to 934 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico (Sen Gupta et al., 2009b) with records from the Caribbean Sea, Atlantic, Pacific and Southern oceans as well. According to Majewski (2010), *Procerolagena gracilis* has been recorded from both Arctic and Antarctic seas. Debenay (2012) described and illustrated forms resembling *P. gracilis* as *Procerolagena cf. P. gracilis* from the northern shelf of New Caledonia in the south-western Pacific Ocean at a water depth of 600 m. According to Nabavi et al. (2014), who studied the distribution, diversity and abundance of benthic foraminifera, this species is rare to very rare in the north-western part of the Persian Gulf.

Repository: PK–AG–099

Family POLYMORPHINIDAE d’Orbigny, 1839
Subfamily POLYMORPHININAE d’Orbigny, 1839
Genus PYRULINA d’Orbigny, 1839

*Pyrulina angusta* (Egger, 1857)

*Original citation:* *Polymorphina (Globulina) angusta* EGGER, 1857, p. 290, pl. 13, figs. 13–15.

*Remarks:* The specimens figured by Brady (1884) and reproduced by Barker (1960) are of specimens obtained from the material dredged at Challenger Station 332 in the South Atlantic at a water depth of 2,200 fathoms (~4,023 m), Challenger Station 346, also in the South Atlantic at 2,350 fathoms (~4,298 m), and Challenger Station 300, north of Juan Fernandez, at 1,375 fathoms (~2,515 m). This species was referred by Brady (1884) to *Polymorphina*, but Barker (op cit) placed it under *Pyrulina*. According to Pearcey (1914), “It is a widely distributed species, and has been found in the North and South Atlantic and the North and South Pacific, but is for the most part a deep-sea form, with a range of depth in these oceans of 1,000 to 2,400 fathoms, although it has been collected on several occasions in shallow water. *Pyrulina angusta* constituted 2% of the benthic foraminifers in the Pliocene Cameron Inlet Formation on Flinders Island, Bass Strait (Quilty, 1985). Szarek (2001) observed this species to be distributed in the full bathymetric range on the Sunda Shelf in the south-western South China Sea, while Debenay (2012) reported it at a shallow depth of 40 m from the south-western lagoon of New Caledonia in the south-western Pacific. According to Sen Gupta et al. (2009b), this cosmopolitan species has a bathyal and/or abyssal habitat in the north-eastern and north-western parts of the Gulf of Mexico in a water depth range of 1,827 to 3,515 m.

Repository: PK–AG–100

Family ELLIPSOLAGENIDAE A. Silvestri, 1923
Subfamily OOLININAE Loeblich and Tappan, 1961
Genus CUSHMANINA R. W. Jones, 1984

*Cushmanina feildeniana* (Brady, 1878)

Pl. 4; Figs. 5, 5a
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Original citation: *Lagena feildeniana* BRADY, 1878, v. 5, no. 1, p. 434, pl. 20, fig. 4.

Remarks: Brady’s (1884) illustrations provided by Barker (1960) are of specimens obtained from the material dredged at Challenger Station 241 in the North Pacific at a water depth of 2,300 fathoms (~4,206 m), and at Challenger Station 332 in the South Atlantic at 2,200 fathoms (~4,023 m). Pearcy (1914) recorded this species as *Lagena feildeniana* and remarked, “This beautiful striato-punctate variety was found (rare) at Stations 447, 459, and 467. It is by no means a common species; it has been collected from as far north as 79° N, in 80 fathoms; and in the Southern Ocean to the west of Marion (Prince Edward) Island, in 1,570 fathoms; and in comparatively shallow water in the Pacific Ocean”. Barker (*op cit.*) opined that it might be an *Oolina* but retained it under *Lagena* as Brady had not mentioned or described the presence of an entosolenian tube. Knudsen (1973) examined the foraminifera of the Lundergård Clay of Vendsyssel, Denmark, and recorded a few specimens of *L. feildeniana* in the borings. Hermelin (1989) studied Pliocene benthic foraminifera from the Ontong-Java Plateau in the western equatorial Pacific Ocean and observed it (also as *L. feildeniana*) to be very rare.

Repository: PK–AG–101

Genus EXSCULPTINA Patterson and Richardson, 1987

*Exsculptina exsculpta* (Brady, 1881)

Pl. 4; Fig. 2

Original citation: *Lagena exsculpta* BRADY 1881, p. 61, pl. 58, fig. 1, pl. 61, fig. 5.

Remarks: Brady (1881) recorded this species as *Lagena exsculpta* and his figure is of the specimen obtained from the material dredged at Challenger Station 168, north-east of New Zealand, at a water depth of 1,100 fathoms (~2,012 m). Chapman and Parr (1937) also recorded this species as *L. exsculpta* and observed it to be very rare at 930 fathoms (~1,701 m) between 60° and 70° S in the Southern Ocean. However, Parr (1950) referred it to the genus *Fissurina* as did Barker (1960). Much later, Patterson and Richardson (1987) erected a new genus *Exsculptina* with *Lagena sidebotom* Earland, 1934 as its type species and remarked, “*Exsculptina* differs from other genera of the Oolininae in possessing incised rather than raised surface sculpture”. Based on a thorough literature review, they transferred *L. pliocenica* Cushman and Gray, *L. pliocenica* Cushman and Gray var. *discrepans* Cushman and Gray, *L. semilineata* Wright, *L. semilineata* Wright var. *spinigera* Earland, *Exsculptina spinigera* (Earland), and *L. exsculpta* Brady to this new genus *Exsculptina*. This is a cosmopolitan species (Jones, 1994). Hayward *et al.* (2010) recorded this species as *Exsculptina exsculpta* (p. 160, pl. 10, figs. 16, 17) from deep waters of the Campbell Plateau slopes, off New Zealand, and gave its stratigraphic range as Recent.

Repository: PK–AG–102

Genus FAVULINA Patterson and Richardson, 1987

*Favulina squamosa* (Montagu, 1803)

Original citation: *Vermiculum squamosum* MONTAGU, 1803, p. 526, pl. 14, fig. 2.

Remarks: Patterson and Richardson (1987) erected a new genus *Favulina* with *Entosolenia squamosa* (Montagu) var. *hexagona* Williamson, 1848 as its type species. They opined that *Favulina* differs from *Oolina* in having a reticulate outer surface and, based on a literature search, they transferred *Lagena hexagona* (Williamson) *aperture* Balakhatmatova, *L. hexagona* (Williamson) *apicostata* ten Dam and Reinhold, *Oolina melo* d’Orbigny, *O. lineatopunctata* (Heron-Allen and Earland), and *O. squamosa* (Montagu) to genus *Favulina*. Barrick *et al.* (1989) recorded this species as *Favulina squamosa* in their studies on the benthic foraminiferal fauna from a Late Pleistocene marine
terrace deposit near Goleta, California. On the Sunda Shelf, in the south-western part of the South China Sea, Szarek (2001) recorded this species from the inner shelf to uppermost bathyal depths. According to Sen Gupta et al. (2009b), who recorded this species as *Oolina aquamosa*, it is found only in the south-eastern part of the Gulf of Mexico at 110 m water depth, but has been reported from the Caribbean Sea, Atlantic and Pacific oceans, too. Margreth (2010) observed this species among the benthic foraminifers associated with the cold-water coral reefs that are settled on post-glacial structures on the Norwegian shelf and on the upper continental slope.

Repository: PK–AG–103

Genus *Oolina* d’Orbigny, 1839

*Oolina globosa* (Montagu, 1803)


Remarks: The illustrations provided by Barker (1960) are of Brady’s specimens obtained from the material dredged at variable depths: Challenger Station 224 in the North Pacific at 1,850 fathoms (~3,383 m); Challenger Station 162, in the Bass Strait, Pacific Ocean, at 38 to 40 fathoms (~69.5 to 73 m); and Challenger Station 300 in the North Pacific at 1,375 fathoms (~2,515 m). This species was referred by Brady to *Lagena*, but Parr (1950) preferred to place it under the genus *Oolina*. According to Brady (1884), “In the living condition *Lagena globosa* is a cosmopolitan species, frequenting every latitude and almost every depth of water at which calcareous Foraminifera have been found”. Jones (1900) stated, “*Lagena globosa* is one of the commonest varieties of the genus. On all parts of the British coast it may be met with in dredged and littoral sands. At the Hunde Islands it has been found in material dredged at from thirty to seventy fathoms”. He also wondered about the occurrence of equally large individuals of this variety at very great depths (1,080 fathoms = ~1,975 m) in the tropical Atlantic Ocean. Chapman and Parr (1937) examined typical specimens of this widely distributed but very rare species (as *Lagena globosa*) in the Southern Ocean at depths varying between 125 and 1,940 fathoms (~229 to 3,548 m) and remarked, “The delicate, transparent test shows the tenuous inner, tube to perfection”. Cushman et al. (1954) studied Recent foraminifera from the Marshall Islands and found only single specimens of this species from the Bikini and Rongelap atolls and Eniwetok Lagoon. A few specimens of *Oolina globosa* were observed to occur in the Late Glacial *Zirfaea* layers (Late Quaternary) at Skeen Møllebæk and Blødegrøft in Vendsyssel, Denmark (Knudsen, 1971). Voorhuyzen (1973) recorded this species as *Lagena globosa* and observed it to be rare in the Upper Pliocene sands of Luchthal and Kallo as well as in the oldest marine Pleistocene sands of Merksem. He also noted that his specimens possessed very fine striae, which were absent in the typical *globosa*. This species was recorded by Korsakova (2009) as *Oolina globosa* in the Late Pleistocene marine units (Ponoi beds, Strel'na beds and Leningrad horizon) from the Kola Peninsula. Quilty and Seymour (2010) reported a single specimen of *Oolina globosa* from an early Miocene silicified limestone from Temma, north-western Tasmania, and opined that it was identifiable as it had been preserved as a fully silicified test.

Repository: PK–AG–104

*Oolina seminiformis* Albani and Yassini, 1989

Original citation: *Oolina seminiformis* ALBANI and YASSINI, 1989, p. 389, figs. 4H, I.

Remarks: *Oolina seminiformis* was described and illustrated as a new species by Albani and Yassini (1989) based on the types that came from the Bass Strait. They described the test as being
“compressed, elongate, seed-like, with rounded ends”. The test wall is smooth and finely perforated, and the aperture is radiate and provided with a very short entosolenian tube. There do not seem to be many reports of this species across the world. This could well be the first record of this species from Indian waters.

**Repository:** PK–AG–105

**Oolina seminuda** (Brady, 1884)

Pl. 4; Fig. 7

**Original citation:** *Lagena seminuda* BRADY, 1884, pp. 446, 472, pl. 58, figs. 34 a, b.

**Remarks:** In his monograph on the foraminifers of the Crag, Jones (1900) stated, “The striking characteristic of *Lagena seminuda* is its truncate oral end, and this feature is very constant. Of the many specimens found in the Coralline Crag, not one shows any approach to a produced neck”. On referring to the tables at the end of the Challenger Report, he found that the specimens were obtained from the temperate zone at depths ranging from 1,375 to 2,350 fathoms (~2,515 to 4,298 m). The figures provided by Barker (1960) are, however, of a specimen obtained from the material dredged at the Challenger Station 302 in the South Pacific at a depth of 1,450 fathoms (~2,652 m). Although Brady referred this species to *Lagena seminuda*, Buchner (1940) referred it to *Lagena foveolata* (Seguenza) which was not “too convincing” as far as Barker was concerned; probably that is why he preferred to place it under *Oolina* but with an element of doubt. Quinterno (1994) recorded this species as *Oolina seminuda* from the top one centimeter of a gravity core retrieved from the Escanaba Trough, Gorda Ridge, in the north-east Pacific Ocean.

**Repository:** PK–AG–106

**Subfamily ELLIPSOLAGENINAE** A. Silvestri, 1923

Genus **Fissurina** Reuss, 1850

**Fissurina aff. F. alveolata** (Brady, 1884)

**Original citation:** *Lagena alveolata* BRADY, 1884, p. 487, pl. 60, figs. 30, 32.

**Remarks:** The figures reproduced by Barker (1960) are of specimens obtained from the material dredged at Challenger Station 64 in the North Atlantic at a depth of 2,750 fathoms (~5,029 m) and Challenger Station 332 in the South Atlantic at 2,200 fathoms (~4,023 m). Although Brady (1884) referred this species to *Lagena*, Barker *(op cit.*) preferred to place it under the genus *Fissurina*. Pflum (1966) used Parr’s classification of the lagenids and recorded this species as *Fissurina alveolata* from the eastern Ross Sea, Antarctica, as did Todd (1966) from the Miocene deposits of Guam. According to Cole (1981), this species was not common, but present in a water depth range of 2,560 to 3,000 m off north-east Newfoundland. This species was recorded by Hofker (1978) as *Lagena alveolata* at a water depth of 3,358 m, north-west of Damar, in the eastern part of the Indonesian Archipelago. Webb and Strong (1998) listed *Fissurina alveolata* among the Quaternary foraminifers in glacial sediments recovered from the Cape Rogers Project (CRP)-1 drillhole on Roberts Ridge, south-western Ross Sea, Antarctica; later, they (2000) also recorded it from CRP-2. An attempt was made by Hooper and Jones (2007) to classify the benthic foraminiferal species from the mid-Atlantic Ridge into habitat groups; they classified *F. alveolata* under Group V (bathyal and abyssal restricted species).

**Repository:** PK–AG–107

**Fissurina annectens** (Burrows and Holland, 1895)
Original citation: *Lagena annectens* BURROWS and HOLLAND, 1895, pt. 2, p. 203, pl. 7, figs. 11a, b.

**Remarks:** *Fissurina annectens* was described from the early Pliocene of England. The figure illustrated by Brady (Barker, 1960) is of the specimen recovered from the material dredged at Challenger Station 149D, Kerguelen Islands, South Pacific, in a depth range of 20 to 60 fathoms (~36.5 to 110 m; fig. 15). Brady referred this species to *Lagena quadriostulata* Reuss, while Burrows and Holland (1895) referred it to *Lagena annectens*. Millett (1901, p. 495) referred this figure to *Lagena fasciata* (Egger), with *L. quadriostulata* Reuss, in synonymy and no mention of *annectens*. Silvestri (1902, p. 143) referred it to *Lagena quadriostulata* var. *sexcostulata*, again without any mention of *annectens*. In the Mediterranean, *Fissurina annectens* has been reported by Buchner (1940) at 60 m depth in front of the Mazzara (Sicily), and near Ponza (Tyrrhenian Sea) at 80 m depth, and from the Gulf of Taranto at 143 m and 910 m water depths (Moncharmont Zei et al., 1981). In the Gulf of Naples, Buchner (1940) reported it in the depth range of 40 to 900 m, while Sgarrella and Moncharmont Zei (1993) observed this species to be poorly recorded in the depth range of 20 to 780 m. Hofker (1978) recorded this species south-west of New Guinea, at a water depth of 2,106 m, in the eastern part of the Indonesian Archipelago. Off north-east Newfoundland, Cole (1981) observed this species to be rare at water depths ranging between 1,800 and 2,800 m. According to Hemleben (1989), the ornamentation in *F. annectens* in the form of two narrow curved bands, parallel with the margins and flush with the surface on each face of the test, is due to structural differences in the test and can be distinctly seen under the light-microscope, and less distinctly in SEM. In their studies on the depth distribution of deep-sea benthic foraminifera off New Zealand, Hayward et al. (2001) reported forms resembling this species (as *Fissurina aff. F. annectens*) at a depth of 1,240 m. Lukina (2001) observed this species among the 24 taxa that were found within the water depth limits of 243 to 3,171 m in the Laptev Sea, actually at 1,658 m. Mallon (2011) observed this species to be rare at water depth ranging 697 and 1,105 m water depth off Peru and stated, “This species resembles *Fissurina submarginata* (Boomgaart) but differs from it by the ovate shape, whereas *F. submarginata* has a cyclic shape. Furthermore this species is not always carinate”.

Repository: PK–AG–108

*Fissurina clathrata* (Brady, 1884)

Pl. 4; Figs. 6, 6a

Original citation: *Lagena clathrata* BRADY, 1884, v. 9, pt. 2, p. 485, pl. 60, fig. 4.

**Remarks:** *Fissurina clathrata* was described from the Holocene of the central Pacific (Hermelin, 1989). The figure illustrated by Brady (Barker, 1960) is of the specimen recovered from the sediment dredged at Challenger Station 191, Arrou Islands, or Station 191A, Ki Islands, Central Pacific Ocean, at a depth of either 800 fathoms (~1,463 m; fig. 4) or 580 fathoms (~1,061 m; fig. 4). This species was referred by Brady to *Lagena*, but was transferred by Parr (1950, p. 310) to *Fissurina*. *Fissurina clathrata* has been regarded by some authors (e.g., Seguenza) as a variety of *Lagena orbignyana* (Bornmalm, 1997). Heron-Allen and Earland (1922, p. 165) noted that this species (reported as *Lagena clathrata*) was one of the most characteristic New Zealand Foraminifera. Chapman and Parr (1937) recorded this species as *Lagena clathrata* and observed it to be very rare at 1,940 m associated with grey-colored *Globigerina oozes*, and at 1,180 m with pale green mud with spicules, and rare at 1,320 m with green terrigenous mud and spicules in the Southern Ocean. In the Mediterranean region, this species was reported by Buchner (1940) from the Tyrrhenian Sea at 80 m water depth (near Ponza), and along the Sicily coast at 60 m depth (Milazzo), at 450 m depth (Messina Straits) and at 820 m (Mondello). It has also been reported from the Gulf of Taranto at 628 m water depth (Moncharmont Zei et al., 1981). *Fissurina clathrata*
was observed to be poorly recorded in the depth range of 30 to 705 m in the Gulf of Naples by Sgarrella and Moncharmont Zei (1993). Yassini and Jones (1995) observed this species to occur on the outer shelf and continental slope off the south-east coast of Australia. *Fissurina clathrata* was recorded by Hayward *et al.* (1999) around North, South and Chatham Islands, and observed this species is widespread in low numbers in sheltered to exposed, fully marine, inner- and mid-shelf depths, and outer parts of harbours and deep inlets. In their studies on the depth distribution of deep-sea benthic foraminifera from off the east of New Zealand, Hayward *et al.* (2001) gave a water depth range of 390 to 1,080 m for this species.

**Repository:** PK–AG–109

*Fissurina cucullata* Silvestri, 1902

Pl. 5; Fig. 1

**Original citation:** *Fissurina cucullata* SILVESTRI, 1902, v. 19, p. 146, figs. 23–25.

**Remarks:** The figures presented by Barker (1960) are of specimens obtained from the material dredged at Challenger Station 296, south-west of Juan Fernandez, in the east Pacific, at a water depth of 1,825 fathoms (~3,338 m). This species was referred by Brady to *Lagena orbignyana* (Seguenza) but Silvestri compared to his own *Fissurina cucullata*, Barker *(op cit.)* opined that it was, indeed, very close to the latter. This species was recorded by Quilty (1974) from the Tertiary formations of Tasmania and gave a stratigraphic range of Late Oligocene to Early Miocene. Seibold (1975) recorded this species from off Cochin and observed it to be as rare as the other species of this genus. She remarked, "The specimens closely resemble the form which Brady 1884 illustrates under the name *Lagena orbignyana* and which Barker 1960 with some reservations has put to *Fissurina cucullata". Debenay and Basov (1993), in their synthesis of the distribution of Recent foraminifera distributed on the West African continental shelf and slope, listed *F. cucullata*. McDougall (1993, p. 60) recorded this species among the Eocene benthic foraminiferal assemblages of the Palo Alto 7-1/2’ Quadrangle, California. In their studies on the impact of climatic changes on the benthic foraminiferal fauna in the Ionian Sea during the last 330,000 years, Schmiedl and Hemleben (1998) observed *F. cucullata* to be rare.

**Repository:** PK–AG–110

*Fissurina eburnea* (Buchner, 1940)

Pl. 5; Fig. 2

**Original citation:** *Lagena eburnea* BUCHNER, 1940, p. 458, pl. 9, figs. 146, 147.

**Remarks:** Buchner (1940) reported this species at 250 m in the Gulf of Naples, Italy, while Sgarrella and Moncharmont Zei (1993) observed this species to be poorly recorded in the depth range of 208 to 685 m, and illustrated it using SEM photography of a specimen collected at a depth of 585 m. Plio-Pleistocene foraminiferal assemblages of the Monte Mario site in Rome, Italy, were studied by di Bella (2010, pl. 3, fig. 18), who reported and illustrated *Fissurina eburnea*, as did Margreth (2010, p. 108, pl. 16, figs. 2a–c) from benthic foraminifera associated with cold-water coral ecosystems. In a study of benthic foraminifera in the Sicilian Channel, Musco (2011) recorded 1,728 individuals/28.6 cm³ volume of *F. eburnea* from a single station in the Sciacca–Pantelleria transect; interestingly, not a single specimen was found at any of the other 16 stations in the channel.

**Repository:** PK–AG–111

81
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Ph.D. Thesis

_**Fissurina fimbriata** (Brady, 1881)

Pl. 5; Fig. 3

**Original citation:** _Lagena fimbriata_ BRADY, 1881, v. 21, p. 61 (fide Ellis and Messina, 1940 _et seq._); BRADY, 1884 (part), v. 9, pl. 60, fig. 26 (not figs. 27, 28).

**Remarks:** _Fissurina fimbriata_ was first described from the Holocene of the Pacific Ocean. The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at Challenger Station 271 in the South Pacific at 2,425 fathoms (~4,435 m), Challenger Station 276, north of Tahiti, in the Pacific Ocean at 2,350 fathoms (~4,298 m), and Challenger Station 191A, off the Ki Islands, Pacific, at 580 fathoms (~1,061 m). Although Brady (1881) referred it to _Lagena_, Parr transferred it to the genus _Fissurina_, and has been retained as such till date. Cushman and Stainforth (1945) recorded this species as _Entosolenia fimbriata_ (Brady) from the Cipero Marl Formation in Trinidad, Wst Indies, and remarked, “So many different forms have been recorded under this name that no attempt is made here to give references. It is interesting to note that the only fossil records are from the late Tertiary of the Indo-Pacific regions. Our figured specimen seems to be very similar to one of Brady’s type figures in the _Challenger_ Report (Pl. 60, fig. 26). Specimens referable to this species occur in all three zones of the Cipero and show some variation”. Cole (1981) examined bathyal zone benthic foraminifera from off north-east Newfoundland, and observed _Fissurina fimbriata_ to be rare at water depths ranging between 2,000 and 2,400 m. A checklist of Recent New Zealand foraminifera was presented by Hayward _et al._ (2012), which included _F. fimbriata_, but they listed it under species that could not be confirmed at that point of time.

**Repository:** PK–AG–112

_**Fissurina kerguelenensis** Parr, 1950

Pl. 5; Figs. 4, 4a

**Original citation:** _Fissurina kerguelenensis_ PARR, 1950, ser. B, v. 5, no. 6, p. 305, pl. 8, figs. 7a, b.

**Remarks:** _Fissurina kerguelenensis_ was first described from the Holocene off Kerguelen Island, South Pacific. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 151, Heard Island, South Pacific, at a depth of 75 fathoms (~137 m; fig. 8), Challenger Station 149D, Kerguelen Islands, in a depth range of 20 to 60 fathoms (~37 to 110 m; figs. 9, 10), and at Challenger Station 160, Southern Ocean, at a depth of 2,600 fathoms (~4,755 m; fig. 11). This species was referred by Brady to _Lagena staphyllearia_ (Schwager), later followed by Buchner (1940), while others (e.g., Parisi, 1981; Moncharmont Zei _et al._, 1981) reported it as _Fissurina staphyllearia_ Schwager, or as _Parafissurina staphyllearia_ (Sgarrella and Moncharmont Zei, 1993). Parr (1950, p. 305), however, referred it to _Fissurina kerguelenensis_, the species name which was later retained by Barker (1960). The specimens of the present study area do not possess a crescentic aperture characteristic of genus _Parafissurina_; instead they are slit-like as in typical _Fissurina_. They are, therefore, placed under _Fissurina kerguelenensis_ Parr. Brady’s figures illustrated in Barker (1960) show forms with two, three and five spines, while one specimen exhibits three pairs of spines; all the specimens obtained in the study area, however, exhibit three spines only. According to Pfum (1966), who studied the distribution of foraminifera in the eastern Ross Sea, Antarctica, “this species is widespread throughout both the Arctic and Antarctic. Green and Wagner both reported it from the Arctic. Parr and McKnight both reported it from the Antarctic. It was represented in cores from the western Ross Sea and Amundsen Sea in the present study”. In the central North Atlantic Ocean, _F. kerguelenensis_ is found at all depths but never abundant (Hermelin and Scott, 1985). In their studies on the foraminifera from the Kara and Greenland seas, Todd and Low (1980) found this species as
single or rare specimens at one or a few stations in Kara Sea, east of Franz Josef Land. Cole (1981) observed this species to be common, but never abundant, off north-east Newfoundland, at water depths ranging between 1,200 and 3,210 m. While examining Pliocene benthic foraminifera from the Ontong-Java Plateau in the western equatorial Pacific Ocean, Hermelin (1989) remarked, “Most specimens of *Fissurina kerguelenensis* have three symmetrically arranged spines but there are others which have more and irregularly arranged spines. In this study I have placed all of these forms within *F. kerguelenensis*”. Bornmalm (1997) studied the taxonomy and paleoecology of Late Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, but observed this species to be “very rare with few occurrences at both investigated sites”. According to Sen Gupta *et al.* (2009c), who recorded this species as *Parafissurina kerguelenensis*, Parr (1950) had stated that his *Fissurina kerguelenensis* differed from *F. staphyllearia* Schwager, as the latter had a thicker, more inflated test, lacked a keeled periphery, and had a narrower and more produced apertural end. He had also observed one specimen in which the sides of the aperture were of different heights and had noted that in the absence of other specimens, this species would have been placed in *Parafissurina*.

**Repository:** PK–AG–113

*Fissurina lucida* (Williamson, 1848)

**Original citation:** *Entosolenia marginata* (MONTAGU) var. *lucida* WILLIAMSON, 1848, v. 1, p. 17, pl. 2, fig. 17.

**Remarks:** Some difficulty has been caused in the interpretation of *Fissurina lucida* because the illustrations in Williamson’s Monograph of 1858 show specimens different in a number of respects from the type described in 1848. In particular, fig. 22 of 1858 shows a pear-shaped form with rather flat base and fig. 23 an elongate form with marked spine. These figures were repeated by Cushman (1923) but Haynes (1973) believed they should have been left out of the synonymy. Specimens described by Balkwill and Millett (1884) from Galway resemble fig. 22. Williamson mentioned a “carina” in his description which appears to refer to the clear peripheral band. As shown by the stereoscanner photograph (pl. 14; fig. 1) in Haynes (1973), this can resemble a keel. The margin is in fact rounded. It is of interest that Heron-Allen and Earland illustrated a double specimen joined base to mouth, which they described as “due to budding”. It is possible that the slight peduncle in many specimens indicates this former attachment. Todd and Low (1968) found this species to be more common in the Gulf of Alaska than in south-eastern Alaska and stated, “This is a relatively large species for this genus. They are surrounded by a narrow keel on the periphery, and the flattened faces are somewhat translucent with broad opaque band just within the periphery making a horseshoe pattern on the face of the test”. A few specimens of *Fissurina lucida* were recorded by Knudsen (1971) from the Late Quaternary Older Yoldia Clay and in the Late Glacial Yoldia Clay of Vendsyssel, Denmark. Hayward and Grace (1981) recorded this species at shallow water depth ranging from 15 to 20 m, associated with a fine- to medium-grained sandy substrate off the Cuvier Island, north-east New Zealand. Hayward (1993) listed *Fissurina lucida* among the estuarine foraminifera of Helena Bay, Northland, New Zealand, while Yassini and Jones (1995), observed it to inhabit the inlet channels of coastal lagoons and open estuaries. In the New Zealand region, it is widespread in low numbers in sheltered to exposed, fully marine, inner- and mid-shelf depths, and outer parts of harbours, around Chatham, Auckland and Campbell Islands (Hayward *et al.*, 1999). *Fissurina lucida* is an indigenous species in the Holocene estuarine and marine stages in the Corgo do Porto rivulet of the Mira River in south-west Portugal (Alday *et al.*, 2006). Horton and Murray (2007) recorded its ephemeral occurrence between May and August in the Cowpen Marsh, Tees Estuary, United Kingdom. According to Sen Gupta *et al.* (2009b), *F. lucida* is a cosmopolitan species that is distributed all
over the Gulf of Mexico in a water depth range of 11 to 966 m. Papaspyrou et al. (2013) have reported this species from the inter-tidal muddy sediments in the Bay of Cádiz, south-west Spain. The available data suggests a very wide water depth range for this species.

Repository: PK–AG–114

Fissurina marginata (Montagu, 1803)

Pl. 5; Fig. 6

Original citation: Vermeleum marginatum MONTAGU, 1803, p. 524.
Remarks: Hooper (1968) examined benthic foraminiferal depth assemblages of the continental shelf off eastern Canada, and noted that Fissurina marginata was part of an assemblage in a water depth range of 56 to 74 m. A few specimens of this species occurred in the Quaternary Sandnes Clay of Norway. In the Vendsysssel of Denmark, rare specimens were found both in the Older Yoldia Clay and in the Late Glacial Yoldia Clay (Knudsen, 1971). Voorthuysen (1973), who studied foraminiferal ecology in the Ria de Arosa, a large inlet of the Atlantic in western Galicia, Spain, observed it to be rare in the Upper Pliocene sands of Luchtbal and Kallo. According to Vilks et al. (1979), who studied the Holocene marine environment on the Canadian continental shelf of the Beaufort Sea, F. marginata is distributed in a water depth range of 33 to 585 m. Hayward and Grace (1981) studied foraminiferal microfauna from off Cuvier Island, north-east New Zealand, and recorded it at shallow water depths ranging between 10 and 30 m, associated with fine- to medium-grained sand with shells. According to Hermelin (1989), Fissurina marginata has incorrectly been accredited to Walker and Boys (1784) by many authors. He opined that as Walker and Boys (1784) had not followed the convention of binomial nomenclature, their specific names should be rejected (ICZN, 1959). He observed F. marginata to occur in many samples throughout the studied Neogene interval of both the Caribbean and eastern equatorial Pacific Ocean sites, but in relatively low abundances. In their preliminary report on the benthic foraminifera from the mid-Atlantic Ridge, Hooper and Jones (2007) categorized this species under a group that is adapted to cool and cold shallower waters, but attributed its occurrence to the prevalence of similar conditions at increased depth. Horton and Murray (2007) recorded its ephemeral occurrence between May and August in the Cowpen Marsh, Tees Estuary, United Kingdom. According to Sen Gupta et al. (2009b), Fissurina marginata is distributed in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a water depth range of 14 to 1,361 m with records from the Caribbean Sea, Atlantic, Pacific, Arctic and Southern oceans as well.

Repository: PK–AG–115

Fissurina orbignyana Seguenza, 1862

Pl. 5; Fig. 5

Original citation: Fissurina orbignyana SEGUENZA, 1862, p. 66, pl. 2, figs. 24, 26.
Remarks: The types for this species came from the Upper Miocene marl at Rometta, Messina District, Sicily. The illustration reproduced by Barker (1960) is of Brady’s specimen obtained from the material dredged at the Challenger Station 271 in the South Pacific at 2,425 fathoms (~4,435 m). Although Brady (1884) referred this species to Lagena, Seguenza placed it under the genus Fissurina. Chapman and Parr (1937) recorded this species as Lagena orbignyana and stated, “Typical specimens are found in the Aurora dredgings from the Antarctic and from stations off Tasmania”. His own Terra Nova specimens were universally distributed, but rare to very rare at depths ranging between 710 and 2,400 fathoms (~1,299 to 4,389 m), mostly associated with Globigerina oozes and spicules. Pflum (1966) recorded two forms of this species as Lagena
orbignyana Form A and Form B in the Amundsen Sea, Antarctica, at water depths of 1,765 m and 2,685 m, respectively. In their preliminary account of the distribution of Recent foraminifera on a part of the northern-western part of the Australian continental shelf, Albani and Geyyskes (1969) recorded this species as F. orbignyana at two stations at 95 m and 350 m. This species was recognized by Hofker (1978) as Fissurina orbignyana, at two stations, one south of Makasar, at 587 m, and the other, west of Benteng, at 2,693 m, in the eastern part of the Indonesian Archipelago. Later, he (1983) reported it from the continental shelf the surf inam and the Guayas at 132 m (common), associated with muddy sand, and at 940 m (rare), with soft muddy substrate. Montaggioni and Véne-Peyré (1993) opined F. orbignyana to be a tropical to temperate, Indo-Pacific species, present on the inner platform areas having depths of less than 30 m on the central Great Barrier Reef shelf, north-eastern Australia. According to Szarek (2001), who studied biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea, the habitat for Fissurina orbignyana is middle bathyal. Sousa et al. (2006) recorded this species from surface sediment samples of the Campos Basin, south-eastern Brazilian continental margin, and observed its distribution in the water depth range of 750 to 1,950 m, with its greatest abundance at 1,950 m. According to Sen Gupta et al. (2009b), this species is distributed in the north-western, south-eastern and south-western parts of the Gulf of Mexico in a wide water depth range of 16 to 1,695 m, with records from the Atlantic, Pacific and Southern oceans as well. In a study of benthic foraminifera in the Sicilian Channel, Musco (2011) recorded 1,188 individuals/28.6 cm$^3$ volume of F. orbignyana from a single station in the Sciacca–Pantelleria transect; at all other stations, this species was either absent or poorly represented.

Repository: PK–AG–116

Fissurina semimarginata (Reuss, 1870)

Original citation: Lagena marginata WILLIAMSON var. semimarginata REUSS, 1870a, p. 468; 1870b, pl. 4, figs. 4–6, 10–12.

Remarks: The illustrations provided by Barker (1960) are of Brady’s specimens obtained from the material dredged at Challenger Station 145, off the Prince Edward Islands, in the South Pacific at 50 to 150 fathoms (~91 to 274 m), and at Challenger Station 332 in the South Atlantic at 2,200 fathoms (~4,023 m). Brady (1884) referred this species to Lagena marginata (Walker and Boys) var. semimarginata Reuss, but was later raised to specific rank by Loeblich and Tappan (1953, p. 78) as Fissurina semimarginata (Reuss). According to Vilks et al. (1979), who studied the Holocene marine environment on the Canadian continental shelf of the Beaufort Sea, this species occurs at an average depth of 38 to 40 m. Mackensen et al. (1985) studied the distribution of living foraminifera on the continental slope and rise off south-west Norway and observed F. semimarginata to occur in only the dead assemblages in a water depth range of 1,600 to 2,683 m. In their preliminary report on the benthic foraminifera from the mid-Atlantic Ridge, Hooper and Jones (2007) categorized this species under a group that is adapted to cool and cold shallower waters, but attributed its occurrence to the prevalence of similar conditions at increased depth. In her studies on benthic foraminifers associated with cold-water coral reef ecosystems, Marcher (2010) recorded this species as Palliolatella semimarginata (Reuss). In his studies on the impact of organic supplies on the density, biodiversity and composition of benthic foraminifera of the Portuguese margin, Phipps (2012) observed F. semimarginata to be rare in the top 0 to 0.5 cm of two cores retrieved at 1,039 m and 1,374 m, but at 5 to 6 cm in a third core retrieved in deeper water at 2,475 m. Kelmo and Hallock (2013) examined the responses of foraminiferal assemblages to ENSO climate patterns on bank reefs of northern Bahia, Brazil and, based on
similarity percentages analysis, estimated the average dissimilarity between non-ENSO and ENSO years in the case of F. semimarginata to be 0.20.

Repository: PK–AG–117

Genus LAGENOSOLENIA McCulloch, 1977
Lagenosolenia favosa (Brady, 1884)
Pl. 5; Fig. 7

Original citation: Lagena formosa SCHWAGER var. favosa BRADY, 1884, p. 480, pl. 60, fig. 21.
Remarks: The figure reproduced by Barker (1960) is of Brady’s specimen obtained from the material dredged at Challenger Station 224 in the North Pacific at a water depth of 1,850 fathoms (~3,383 m). It was referred by Brady to Lagena, as a new species under the name Lagena Formosa var. favosa, who stated, “This is a mere sub-varietal form, differing from the type in having two or three rows of reticulated ornament between the body of the test and the peripheral wing. It is comparatively rare, but occurs in company with allied forms at a few localities, notably at Station 224, in the western part of the North Pacific, 1,850 fathoms”. Barker (op cit), however, preferred to name it as Fissurina formosa (Schwager) var. favosa Brady. Wonders and Van der Zwaan (1979) recorded this species as Fissurina formosa (Schwager) var. favosa Brady among the single-chambered forms in Section Potamidha 1. According to Debenay (2012), who presented an illustrative guide to 1,000 species of foraminifera from off New Caledonia in the south-western Pacific, Lagenosolenia favosa was recorded from the northern shelf at a water depth of 600 m.
Repository: PK–AG–118

Genus PALLIOLATELLA Patterson and Richardson, 1987
Palliolatella bradii (Silvestri, 1902)
Pl. 5; Fig. 8

Original citation: Fissurina bradii SILVESTRI, 1902, v. 19, p. 147.
Remarks: The figure reproduced by Barker (1960) is of the specimen obtained from the material dredged at Challenger Station 300, north of Juan Fernandez, in the eastern Pacific at a depth of 50 to 150 fathoms (~91 to 274 m). Brady referred this species to Lagena orbignyana (Seguenza) while Silvestri (1902, p. 147) referred it to F. bradii. Cushman (1923, p. 41), however, referred it to a new species L. orbignyana var. caribaea and, in 1945, Cushman and Stainforth transferred this form to Entosolenia flintiana (Cushman) var. caribaea (Cushman). Cole (1981) studied bathyal zone benthic foraminifers off north-east Newfoundland and observed Fissurina bradii to be rare and present only at 1,590 m. Szarek (2001) also recorded this species as F. bradii and gave a bathymetric range of outer shelf to middle bathyal for it. Phipps (2012) examined live benthic foraminifera in eight cores collected along a depth transect ranging 282–4,987 m on the Portuguese margin, but observed this species (reported as Fissurina bradyi) in only one core (1.0 to 1.5 cm in the 63–150 µm fraction) retrieved at a water depth of 490 m on the eutrophic upper-slope.
Repository: PK–AG–119

Palliolatella fasciata (Egger, 1857)
Pl. 5; Fig. 9

Original citation: Oolina fasciata EGGER, 1857, p. 270, pl. 5, figs. 12–15.
Remarks: The figure reproduced by Barker (1960) is that of Brady’s specimen obtained from the material dredged at Challenger Station 149D, off the Kerguelen Islands, in the South Pacific at 20
to 60 fathoms (~36.5 to 110 m). This species was referred by Brady (1884) to *Lagena quadricostulata* Reuss, and by Burrows and Holland to *L. annectens*. Millett (1901, p. 495) referred this figure to *L. fasciata* (Egger), with *L. quadricostulata* Reuss, in synonymy and no mention of *annectens*. Silvestri (1902, p. 143), however, referred it to *L. quadricostulata var. sexcostulata*, again without any mention of *annectens*. Heron-Allen and Earland (1922) recorded this species as *Lagena fasciata* and observed it to be more widely distributed than *L. annectens* and “much more abundant”. They stated that the species had been recorded by them as a Recent British form, and also opined that “it has no doubt been included in the numerous records of *L. quadricostulata*, Reuss”. This view was later supported by Feyling-Hanssen (1964), who studied foraminifera in Late Quaternary deposits from the Oslofjord area, recorded forms resembling the species as *Fissurina cf. F. fasciata* and observed it to be very rare. Knudsen (1971) examined Late Quaternary foraminifers from Vendsyssel, Denmark and Sandnes, Norway, and found a solitary specimen of *F. fasciata* in a sample from Rise Jæren, and a few specimens in the Older Yoldia Clay of Vendsyssel. This species was also found to be rare in the samples collected during the Port Philip survey between 1957 and 1963, particularly in the Lonsdale Bight, Bass Strait and the Lower Bay (Collins, 1974). A checklist of Recent New Zealand foraminifera was presented by Hayward *et al.* (2012), which included *F. fasciata*, but they listed it under species that could not be confirmed at that point of time.

**Repository:** PK–AG–120

**Subfamily PARAFISSURININAE R. W. Jones, 1984**

**Genus PARAFISSURINA Parr, 1947**

*Parafissurina botelliformis* (Brady, 1881)

Pl. 5; Fig. 10

**Original citation:** *Lagena botelliformis* BRADY, 1881, p. 60; 1884, p. 454, pl. 56, fig. 6.

**Remarks:** Brady referred this species to *Lagena botelliformis* while describing specimens from off the Cape Verde Islands, at a depth of 11 fathoms (~20 m). Sidebottom (1906) recorded this species as *Lagena botelliformis* off the Island of Delos, Grecian Archipelago, and remarked, “The contour of the Delos specimens so closely resembles Brady’s figure in the above reference, with the exception that the orifice is situated at the end of a produced neck, that I think it may be considered a variation of that species, in preference to treating it as a variety of *L. laevis*”. He did not find *L. laevis* in the material examined, but observed *L. botelliformis* to be rare. Specimens of this species were reported by McKnight (1962) as *Entosolenia botelliformis* (Brady) from the Ross and Weddell Seas. He observed it to be most abundant in the Weddell Sea at a depth of 800 m, and gave a water depth range of 164 to 800 m. Hofker (1978) recorded this species as *Oolina botelliformis* at only one station in the Moro Gulf, in the eastern part of the Indonesian Archipelago, at a water depth of 513 m where the BWT was 7° C. The taxonomy and paleoecology of Early Miocene benthic foraminifera of northern New Zealand and the North Tasman Sea were studied by Hayward and Buzas (1979), who observed this species to be rare in the *Cassidulina laevigata* thanatotope D, and extremely rare in the *Globocassidulina subglobosa* thanatotope E assemblages. Webb and Strong (1998) listed *Parafissurina botelliformis* (as *Oolina botelliformis*) among the Quaternary foraminifers in glacial sediments recovered from the Cape Rogers Project (CRP)-1 drillhole on Roberts Ridge, south-western Ross Sea, Antarctica. *Parafissurina botelliformis* was always found as dead specimens by Lobegeier and Sen Gupta (2008) in the Green Canyon (shallow) at 245 m, Green Canyon (deep) at 562 to 696 m, South of Mississippi Canyon at 1,076 m, Alaminos Canyon at 2,218 to 2,227 m; it was, however, absent in the Garden Banks, Mississippi, De Soto and Farnella canyons. According to Sen Gupta *et al.* (2009b), *Parafissurina botelliformis* has a bathyal and/or abyssal habitat in the north-western part of
the Gulf of Mexico in a water depth range of 577 to 1,630 m, with records from the Atlantic, Indian and Southern oceans, too. A checklist of Recent New Zealand foraminifera was presented by Hayward et al. (2012), which included O. botelliformis, but they listed it under species that could not be confirmed at that point of time.

**Repository:** PK–AG–121

*Parafissurina felsinea* (Fornasini, 1894)

_Pl. 5; Fig. 11_

**Original citation:** *Lagena emaciata* REUSS var. *felsinea* FORNASINI, 1902, ser. 5, v. 9, p. 47, fig. 1 (fide Ellis and Messina, 1940 et seq).

**Remarks:** The figure reproduced by Barker (1960) is that of Brady’s specimen obtained from the material dredged at Challenger Station 276, in the South Pacific, at a water depth of 2,350 fathoms (~4,298 m). This species was referred by Brady (1884) to *Lagena apiculata* (Reuss). However, Parr (1947) opined that it should be placed in *Oolina* due to the presence of an entosolenian tube. Earlier, Fornasini (1894) had referred this figure to *Lagena felsinea* in a privately printed note. This species was recorded by Hayward (1979) as *Oolina felsinea* among the Altonian, deep-water, fossil fauna from the Carter Road Quarry section in the eastern Waitakere Ranges, Auckland, New Zealand. He opined that at that time the area was under water depths ranging between 1,000 and 2,000 m. In a preliminary report on benthic foraminifers from the Mid-Atlantic Ridge, Hooper and Jones (2007) also reported it as *O. felsinea* and opined it to be a species restricted to bathyal and abyssal depths. According to Sen Gupta et al. (2009b), this species, recorded by them as *Parafissurina felsinea*, has a bathyal and/or abyssal habitat in the north-western part of the Gulf of Mexico where it is found to occur at a water depth of 2,215 m. Margreth (2010) recorded it as *P. felsinea*, among benthic foraminifers associated with cold-water coral eco-systems, while Phipps (2012) observed it (as *Lagena felsinea*) to be a shallow infaunal species at 2,908 m off the Portuguese margin.

**Repository:** PK–AG–122

*Parafissurina lateralis* (Cushman, 1913)

_Pl. 5; Figs. 12, 12a_

**Original citation:** *Lagena lateralis* CUSHMAN, 1913, p. 9, pl. 1, fig. 1.

**Remarks:** The figure reproduced by Barker (1960) is that of a specimen recovered by Brady from the material dredged at Porcupine Station 67-68, east of the Shetlands, Scotland at a water depth of 64 to 75 fathoms (~117 to 137 m). While Brady referred it to *Lagena apiculata* (Reuss), Cushman (1913) tentatively referred it to *Lagena lateralis*. On the other hand, Chapman and Parr (1937) opined that it was a new species of the genus *Ellipsolagena*. Later, Parr (1947) placed *Ellipsolagena* in the synonymy of *Fissurina*, and referred *L. lateralis* Cushman to *Parafissurina*. In a paleoenvironmental study of Early to Middle Pleistocene foraminifera of the Santa Barbara Formation at Santa Barbara, California, Patterson et al. (1990) recorded this species as *Parafissurina lateralis*. Hayward et al. (2001) studied the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand and gave a water depth of 720 to 3,540 m for this species. While studying the biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea, Szarek (2001) opined that *P. lateralis* is an outer shelf to lower bathyal species. According to Sen Gupta et al. (2009b), this cosmopolitan species has a very wide water depth range of 36 to 3,250 m in the north-eastern, north-western and south-western parts of the Gulf of Mexico. Hayward et al. (2010) presented
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the taxonomy, ecology, distribution and biogeography of Recent deep-water benthic foraminifera off New Zealand, and recorded this species at a water depth of 974 m, off Kahia, while Margreth (2010), observed it to occur among the benthic foraminifers associated with cold-water coral reef ecosystems of the Norwegian margin. *Parafissurina lateralis* was reported by Mallon (2011) off the Peruvian margin, at only one station at a depth of 1,004 m.

Repository: PK-AG-123

Genus PSEUDOSOLENINA R. W. Jones, 1984

*Pseudosolenina wiesneri* (Barker, 1960)

Original citation: *Fissurina wiesneri* BARKER, 1960, p. 124, pl. 59, figs. 23a, b.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 168, north-east of New Zealand, at a depth of 1,100 fathoms (2,012 m; figs. 23a, b). Brady referred this species to *Lagena marginata* (Walker and Boys), but Wiesner (1931, p. 121) referred it to *Lagena marginata var. carinata*. This is a homonym of *Lagena quadrata var. carinata* Chapman, 1909, and of *Fissurina carinata* Reuss, 1863. Hence, Barker (1960) proposed a new name *wiesneri* for this form, which was followed by Yassini and Jones (1995), who observed this species to inhabit the outer shelf and the continental slope off the south-east coast of Australia. This species was recorded by Hofker (1978) from south of Makassar, south-west point Celebes, in the eastern part of the Indonesian Archipelago, at a depth of 587 m, as *Fissurina wiesneri*. Later, he (1980) reported it from south-west Saba Bank, at a water depth of 890 m, associated with sandy clay and pteropods. Hermelin (1989) listed it among the Pliocene benthic foraminifera from the Ontong-Java Plateau in the western equatorial Pacific Ocean and remarked, “*Fissurina wiesneri* is characterized by its very wide keel, almost as wide as the diameter of the central body”. According to Bornmalm (1997), the characteristic feature of this species is the wide keel, which surrounds the test. He observed it to be a rare species with a few occurrences at both Neogene sites in the Caribbean Sea and eastern equatorial Pacific Ocean. Szarek (2001) studied the biodiversity and biogeography of Recent benthic foraminiferal assemblages on the Sunda Shelf in the south-western South China Sea and recorded it as *Pseudosolenina wiesneri* (Barker). *Fissurina wiesneri* has also been reported from much shallower waters, in a depth range of 1 to 10 m on the back reefs in Bermuda, as illustrated by Javaux and Scott (2003). Hayward et al. (2007) studied the biogeography and ecological distribution of shallow-water benthic foraminifera from the Auckland and Campbell Islands, sub-Antarctic south-west Pacific, and reported it as *Pseudosolenia wiesneri* (Barker).

Repository: PK-AG-124

Subfamily SIPHOLAGENINAE Patterson and Richardson, 1987

Genus BIFARILAMINELLA Patterson and Richardson, 1987

*Bifarilaminella advena* (Cushman, 1923)

Pl. 5; Fig. 13

Original citation: *Lagena advena* CUSHMAN, 1923, p. 6, pl. 1, fig. 4.

Remarks: A new genus *Bifarilaminella* was established by Patterson and Richardson (1987) with *Lagena advena* Cushman as its type species. They opined that *Bifarilaminella* differed from *Siphologena* and *Pytime* in having the two walls juxtaposed rather than separated by a network of pillars, and stated that network of anastomosing costae on the outerwall is the diagnostic character of *Bifarilaminella advena*. This species was first described and illustrated by Cushman (1913) as *Lagena striata* (d'Orbigny) var. haidingeri (Czjzek) from off the Galapagos Islands, and later as *Lagena advena* from off the coast of Nicaragua in the Caribbean (Cushman, 1923). The
figures reproduced by Barker (1960) are of specimens obtained from the material dredged at Challenger Station 338 in the South Atlantic at a depth of 1,990 fathoms (~3,639 m) and Challenger Station 346 in the South Atlantic at 2,350 fathoms (~4,298 m). Bornmalm (1997) recorded it as *Lagena advena* and noted that it was a rare species with scattered occurrences at the Caribbean site, and very rare with few occurrences at the eastern equatorial Pacific Ocean site (both Neogene). Hayward *et al.* (2001) presented the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, and observed the occurrence of *Bifarilaminella advena* at a water depth of 3,540 m, while Phipps (2012) recorded it among the benthic foraminifera of the Portuguese margin.

**Repository:** PK–AG–125

**Family GLANDULINIDAE Reuss, 1860**

**Subfamily GLANDULININAE Reuss, 1860**

**Genus GLANDULINA d’Orbigny, 1839**

*Glandulina ovula* d’Orbigny, 1846

*Pl. 5; Fig. 14*

**Original citation:** *Glandulina ovula* D’ORBIGNY 1846, p. 29, pl. 1, figs. 6–7.

**Remarks:** This species was originally described from the Oligocene-Miocene of the Vienna basin by d’Orbigny (1846). Kender *et al.* (2008) obtained only two specimens from two samples at depths of 2,840 m and 2,890 m, respectively, in early to middle Miocene foraminifera from the deep-sea Congo Fan, offshore Angola. They stated that *Glandulina ovula* can be distinguished from *G. laevigata* d’Orbigny by the lack of a pointed base, and in possessing fewer radiating ribs at the aperture. According to Sen Gupta *et al.* (2009b), *G. ovula* is a cosmopolitan species that is distributed all over the Gulf of Mexico in a water depth range of 21 to 1,247 m. *Glandulina ovula* is a deep infaunal species (Fontanier *et al.*, 2002) and is an indicator of suboxic conditions (Pezelj *et al.*, 2013). Valchev *et al.* (2013) recorded this species among the Paleogene hyaline benthic foraminifera from the Republic of Macedonia and stated, “We accept the Papp and Schmidt’s (1985) opinion that *G. laevigata* d’Orbigny is subjective junior synonym of *G. ovula* d’Orbigny”.

**Repository:** PK–AG–126

**Suborder ROBERTININA Loeblich and Tappan, 1984**

**Superfamily CERATOBULIMINACEA Cushman, 1927**

**Family CERATOBULIMINIDAE Cushman, 1927**

**Subfamily CERATOBULIMININAE Cushman, 1927**

**Genus CERATOBULIMINA Toula, 1915**

*Ceratobulimina jonesiana* (Brady, 1881)

*Pl. 6; Figs. 1, 1a*

**Original citation:** *Cassidulina jonesiana* BRADY, 1881, p. 59.

**Remarks:** Brady (1881) erected a new species under the name of *Cassidulina jonesiana*. The figures reproduced by Barker (1960) are of specimens obtained from the material dredged at the Challenger Station 191A, off the Ki Islands in the North Pacific at a depth of 580 fathoms (~1,061 m). This species was referred by Brady to *Bulimina contraria* Reuss, but Chapman and Parr (1937) placed it under *Ceratobulimina pacifica* Cushman and Harris and remarked, “There are two examples of this recently described species, the types of which were from off the Philippines, 494 fathoms. The specimen from off the Ki Islands, figured by Brady as *Bulimina contraria* (Reuss), is undoubtedly identical with the present species”. Jones (1994) regarded *Ceratobulimina pacifica*
Cushman and Harris as a junior synonym of *Cassidulina jonesiana* Brady. Hofker (1978) recorded this species as *C. pacifica* at water depths ranging between 522 and 4,048 m, in the eastern part of the Indonesian Archipelago. Szarek (2001) recorded this species as *Ceratobulimina jonesiana* (Brady, 1881) among the Recent benthic foraminiferal assemblages on the Sunda Shelf in the southwestern South China Sea, and gave a water depth range of middle to lower bathyal. Hayward et al. (2012) also recorded this species as *C. jonesiana* for the first time from New Zealand waters, but they listed it under species that could not be confirmed at that point of time. Fontanier et al. (2014) recorded this species as *C. contraria* from the deep-water Niger Delta (Gulf of Guinea) and opined that it has been described from the continental margin of Gulf of Guinea either as *Ceratobulimina pacifica* Cushman and Harris (Altenbach et al., 2003) or as *Robertinoides chapmani* (Heron-Allen and Earland) (Licari et al., 2003; Licari and Mackensen, 2005). In all cases, it seems that this species thrives in well-ventilated benthic environments (>180 μmol/L) characterized by a moderate to high sedimentary organic content (1.2–3.0% dry weight) and relatively deep oxygen penetration depth (between 2 and 8 cm within sediments) (Licari et al., 2003; Licari and Mackensen, 2005).

Repository: PK–AG–127

Family EPISTOMINIDAE Wedekind, 1937
Subfamily EPISTOMININAE Wedekind, 1937
Genus HOEGGLUNDINA Broizen, 1948

*Hoeglundina elegans* (d'Orbigny, 1826)


Remarks: Smith (1964) studied the ecology of Recent benthic foraminifers from off Central America and observed *Hoeglundina elegans* to occur in a water depth range of 800 to 1,700 m. According to Grossman and Ku (1986), some aragonitic benthic foraminiferal species such as *H. elegans*, secrete their tests in near oxygen isotope equilibrium with the ambient water. Van Morhoven et al. (1986) observed that this species is widespread in recent oceans at depths ranging from 42 to 4,300 m; on the mud platform north of Trinidad, they observed it to occur in a depth range of 50 to 140 m, with the highest frequencies occurring between 70 and 110 m. *Hoeglundina elegans* is thought to be less susceptible to diagenetic overgrowths than many other foraminifers because of its glassy aragonitic test. Cadmium uptake by this species is far less depth dependent than that of calcitic benthic foraminifera. Due to this, a comparison of calcitic and *Hoeglundina* Cd data can be used to verify the assumption that the depth dependence observed for calcitic benthic foraminifera is time invariant (Boyle et al., 1995). Martin (1999) attributed its greater resistance to dissolution, in spite of being aragonitic, to its test structure, which is smoother, thicker, and less porous than those of many calcitic species. *Hoeglundina elegans* is generally considered an oligotrophic taxon (e.g., Lutze and Coulbourn, 1984; Mackensen et al., 1995), living close to the sediment-water interface. Although often considered strictly epifaunal, a closer inspection of the data (e.g., Corliss, 1985; Jorissen et al., 1998) shows that some stained specimens also occur in slightly deeper (top 2 cm) sediment layers, a phenomenon that can be observed in all taxa considered epifaunal (Jorissen et al., 1998). Experimental and field studies by Geslin et al. (2004) clearly showed the preference shown by this species for high oxygen concentrations, and its migration upward or downward into the oxic sediment layers. According to Eberwein (2006), *Hoeglundina elegans* showed high standing stocks on the Cape Ghir-B, and Cape Yubi transects off Morocco at intermediate to great water depths (1,547 to 2,504 m), whereas the dead assemblage occurred at greater water depths (2,035 to 2,504 m). Fontanier et al. (2006) demonstrated that the δ¹³C value of *H. elegans* increases with increasing water depth, and reflects phytodetrital seasonal deposits in the North Atlantic by a decrease of ~0.3% in spring
bloom compared to more oligotrophic periods. According to Rosenthal et al. (2006), who attempted to assess the potential use of both Mg/Ca and Sr/Ca in this aragonitic species for reconstructing seawater temperature, both the Mg/Ca and Sr/Ca ratios in its tests showed a general decrease with increasing water depth. *Hoeglundina elegans* is a cosmopolitan species that is distributed all over the Gulf of Mexico in a water depth range of 36 to 3,632 m (Sen Gupta et al., 2009b). In this species, the wall and septal thicknesses vary with bottom-water oxygen levels of the deep water mass up to 2,000 m, probably to maintain the required rate of osmosis for the intake of dissolved O₂. Below this depth, both parameters show parallel relationship with deviation indicating that oxygenation may play some role in the variation of wall and septal thicknesses (Bhaumik et al., 2014).

**Repository:** PK–AG–128

Superfamily ROBERTINACEA Reuss, 1850  
Family ROBERTINIDAE Reuss, 1850  
Subfamily ROBERTININAE Reuss, 1850  
Genus ROBERTINA d’Orbigny, 1846  
*Robertina translucens* Cushman and Parker, 1936  
Pl. 6; Fig. 2

**Original citation:** *Robertina translucens* CUSHMAN and PARKER, 1936, v. 12, p. 99, pl. 16, figs. 8a, b.  
**Remarks:** The types for this species came from Recent material from 1,000 fathoms (~1,829 m), off south-west Ireland. According to Cushman (1946), *Robertina translucens* occurs “south-westward the eastern coast of the United States, and southward to Brazil”. It differs from *R. arctica* d’Orbigny in possessing fewer but much more rounded chambers, more strongly curved and less oblique aperture, and in the great extension of the chambers toward the base. In the Mediterranean region, *Robertina translucens* has been reported as characteristic from bathyal muds (Blanc-Vernet, 1969). It has been recorded in the deep water assemblages of the Sicily Channel; of the Balearic Basin, where it characterizes the depth range of 2,650 to 2,700 m (Cita and Zocchi, 1978); of the Tyrrhenian Sea, down to 3,588 m (Parisi, 1981); of the eastern Mediterranean, where it is frequent in the depth range of 179 to 1,265 m, and occurs down to 3,241 m (Parker, 1958). According to Cita and Zocchi (1978), this species has a very thin and transparent test, which is composed of aragonite as all the tests of the Robertinidae; this test can very unlikely be displaced without major damage; therefore, if present, *R. translucens* has to be considered as autochthonous. It has been reported from the infra-littoral zone only in the Gulf of Salerno and Gulf of Policastro (Sgarrella and Moncharmont Zei, 1993). In the Gulf of Naples, *R. translucens* is found from 60 m downwards, frequent at depths greater than 90 m. A single specimen was found to occur at 25 m (*op cit*). In their study on the response of modern benthic foraminiferal assemblages to water-mass properties along the southern shelf of the Marmara Sea, Chendes et al. (2004) recorded this species at a water depth of 80 m. According to Kaminski (2012), *Robertina translucens*, an epiphytic species (Abu-Zied et al., 2008), is an indicator of suboxic conditions.  
**Repository:** PK–AG–129

Genus ROBERTINOIDES Höglund, 1947  
*Robertinoides oceanicus* (Cushman and Parker, 1947)

**Original citation:** *Robertina oceanica* CUSHMAN and PARKER, 1947, p. 75, pl. 28, fig. 18.
Remarks: Cushman and Parker’s (1947) holotype came from 75 fathoms (~137 m) water depth off the North Cape of New Zealand. The figure reproduced by Barker (1960) is of Brady’s specimen obtained from the material dredged at the Challenger Station 191A, off the Ki Islands, central Pacific, at a depth of 580 fathoms (~1,061 m). This species was referred by Brady (1884) to Bulimina delivis Reuss but Cushman and Parker (1947, p. 75) referred it to Robertina oceanica. Pflum and Frerichs (1976), who investigated the deep-water foraminifers from the Gulf of Mexico, recorded this species at one station at a water depth of 3,006 feet (~916 m). With the exception of one station in the Gulf of Bone, where it was found at 1,374 m, Hofker (1978) recorded it as Robertinosides oceanicus at water depth ranging mostly between 513 and 615 m in the eastern part of the Indonesian Archipelago. The depth distribution of Recent benthic foraminifera from off east New Zealand was studied by Hayward et al. (2001), who presented a range of 390–720 m for this species. According to Sen Gupta et al. (2009b), R. oceanicusis distributed in the north-eastern and north-western parts of the Gulf of Mexico in a water depth range of 892 to 2,896 m, with records from the Pacific and Indian oceans as well. Hayward et al. (2010) observed it to be rare off the east coast of both islands (32°–45° S), occurring at outer shelf to upper bathyal depths (100–500 m), and gave a stratigraphic range of mid-Eocene to Recent. This species was reported by Mallon (2011) as Robertina oceanica Cushman and Parker off the southern Ecuador margin at a depth of 995 m; it was, however, observed to be very rare. Debenay et al. (2012) recorded this species on the northern shelf of New Caledonia in the south-western Pacific at a water depth of 600 m.

Repository: PK–AG–130

Suborder GLOBIGERININA Delage and Hérouard, 1896
Superfamily GLOBOROTALIACEA Cushman, 1927
Family GLOBOROTALIIDAE Cushman, 1927
Genus GLOBOROTALIA Cushman, 1927
Globorotalia hirsuta (d’Orbigny, 1839)

Original citation: Rotalina hirsuta D’ORBIGNY, 1839, p. 131, pl. 1, figs. 37–39.
Remarks: The type specimens originally came from the Canaries. The figures reproduced by Barker (1960) are of Brady’s specimens from the material dredged at Challenger Station 300, north of Juan Fernandez, in the east Pacific, at a water depth of 1,375 fathoms (~2,515 m) and Challenger Station 33, off Bermuda, in the Atlantic, at 435 fathoms (~796 m). This species was referred by Brady to Pulvinulina canariensis (d’Orbigny) but Cushman (1931, p. 99) referred it to Globorotalia hirsuta (d’Orbigny). Hofker (1978) recorded this species at two stations, one south of Makassar, south-west point Celebes, and the other north of Doi, Lododa Islands, at water depths of 587 m and 576 m, respectively. According to Healy-Williams (1989), changes in the test shape of G. hirsuta are minimal in an area where the thermocline is poorly developed and water temperatures change gradually over a large water depth range (2° over 800 m). Globorotalia hirsuta prefers diatoms as well as dinoflagellates, eukaryotic and thecate algae and muscle tissue (Hemleben et al., 1989). This is a sub-tropical deep-dwelling species, which reproduces semi-annually to annually in winter in the surface waters near Bermuda and has an abundance maximum in March and April (Bé and Hamlin, 1967; Hemleben et al., 1985; Deuser and Ross, 1989). Globorotalia hirsuta lives below the mixed layer, except during gametogenesis (Bé, 1960; Hemleben et al., 1989), when specimens ascend to shallower waters. According to Sen Gupta et al. (2009b), G. hirsuta is distributed over the entire Gulf of Mexico with an overall geographic range of sub-Arctic to south temperate. In the Porcupine Seabight, the deep-dwelling, sub-tropical G. hirsuta showed two successive maxima in late May and mid-June, occurring only as
single individuals in 6 out of 13 core-top samples, but having very high abundance in the sediment trap sample. Whether *G. hirsuta* is a displaced species transported to temperate area by the Gulf Stream, or has successfully settled in the western European waters, needs be determined by monitoring its occurrence over a longer time interval (Harbers *et al.*, 2010). Rebotim *et al.* (2010) observed living *G. hirsuta* down to 1,200 m, as one of the most abundant species, from the north of the Azores Front to the south. Based on the fact that the abundance of *G. scitula* started to decrease and of *G. hirsuta* to increase, they opined that both seemed to be good indicators for the water masses in which they occur, especially in this region.

Repository: PK–AG–131

*Globorotalia inflata* (d'Orbigny, 1839)

**Original citation:** *Globigerina inflata* D'ORBIGNY, 1839, p. 134, pl. 2, figs. 7–9.

**Remarks:** According to Bé (1967), *G. inflata* proliferates between early August and late December in the Antarctic and sub-Antarctic Atlantic and Pacific ocean sectors. *Globorotalia inflata* is one of the most abundant deep-dwelling transitional water species in the South Atlantic (e.g., Bé and Hutson, 1977; Niebler and Gersonde, 1998). Oba (1991) investigated sediment trap samples from the Japan Trench, and estimated the water depth habitat of this species to range from 200 to 600 m. According to Mortyn and Charles (2003), the consistent observation of *G. inflata* as a relatively deep-dwelling species confirms its utility as an indicator of upper thermocline properties. This species is consistently most abundant at sub-surface depths (between 50 and 300 m). During its ontogenetic cycle, *G. inflata* migrates through the upper few hundred meters of the water column (e.g., Lončarić *et al.*, 2005; Wilke *et al.*, 2006; Chiessi *et al.*, 2007), providing great potential of recording past thermocline conditions (Chiessi *et al.*, 2008) as well as the migration of mid-latitude oceanic fronts. Cléroux *et al.* [2007] analyzed plankton tow results from the Atlantic sector of the Southern Ocean and showed that *G. inflata* lives preferentially at the base of the summer thermocline, which is about 100 m deep north of 35° latitude, but calcifies deeper in the main thermocline under warmer conditions. According to Kucera (2007), *G. inflata* is a sub-surface dwelling, facultative species that reproduces on a monthly basis and is resistant to dissolution. Ovechkina (2010) observed *G. inflata* to be very rare on the Thukela Shelf, South Africa, and opined that it differs from other *Globorotalia* species in having sub-globular chambers and in lacking a keel. This species characterizes cool-temperate waters, and is uncommon in the tropical region (Bylinskaya *et al.*, 2002). The data generated by Groeneveld and Chiessi (2011) showed that Mg/Ca from *G. inflata* is a reliable recorder of permanent thermocline temperatures even under considerably different upper water column structures, highlighting its applicability in paleoceanographic studies. They also observed that this species commonly occurs in high amounts from sub-tropical to sub-polar conditions with an apparent calcification depth of 350–400 m in the South Atlantic. According to Chiessi *et al.* (2007), this species is, therefore, relatively less sensitive to seasonal and other short-term variations of the Brazil-Malvinas Confluence (BMC) than surface-dwelling species of foraminifera, and hence they suggested that the oxygen isotopic composition of *G. inflata* is the most reliable indicator for the present position of the BMC, and can be used to derive past migrations of the front. Voight *et al.* (2015) used the stable oxygen isotopic composition (δ¹⁸O) of the deep-dwelling planktic foraminifera *Globorotalia inflata* as a proxy for the position of the Brazil-Malvinas Confluence (BMC). The δ¹⁸O of *G. inflata* depicts a sharp gradient of 2‰ at the BMC with remarkably stable values north and south of it.

Repository: PK–AG–132

*Globorotalia menardii* (d'Orbigny, 1826)

Pl. 6; Figs. 3, 3a

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The controversy over the nomenclatural priority of *G. menardii* versus *G. cultrata* was discussed at length by Banner and Blow (1960), Parker (1962), and Stainforth *et al.* (1975). We support the proposal of Stainforth *et al.* (1975) that the name *menardii* be retained for the Miocene and younger *menardii*-form species, so widely recognized. Beard (1973) opined that the almost inverse relationship between the vertical abundances of two species, *Globorotalia menardii* (warm) and *Globorotalia inflata* (cold), allowed recognition of three major episodes of climatic warming and cooling across the Pleistocene-Holocene boundary in the Gulf of Mexico. *Globorotalia menardii* and *Pulleniatina obliquiloculata* are both warm-water, dissolution-resistant forms (Bé, 1977). The former inhabits the tropical–sub-tropical upper water but is, however, much less abundant in the Pacific. It occurs abundantly between 20° N and 10° S in the Atlantic Ocean, north of the equator in the Indian Ocean, and in isolated areas of the eastern tropical Pacific Ocean (Bé, 1977; Cullen and Prell, 1984). In the Pacific, maximum abundance of *G. menardii* often occurs in places where the SSTs are between 26° and 28° C (Le *et al.*, 1995). Yassini and Jones (1995) observed that it was rare in the middle and outer shelf, and the continental slope, off the south-east Australian coast. According to Broecker *et al.* (1999), the radiocarbon dates for *G. menardii* in the top 15 cm of a core retrieved from the Ceara Rise at a water depth of 4,050 m are considerably younger thereby implying that this species did not enter the Atlantic Ocean until ~6,700 ¹⁴C years ago. Both *Pulleniatina obliquiloculata* and *Globorotalia menardii* grow in greatest abundance along the seasonal thermocline in association with maximum chlorophyll concentration, indicating that they proliferate when the seasonal thermocline is in the photic zone (Ravelo and Fairbanks, 1990; Ravelo *et al.*, 1992). Therefore, these two species can be categorized as subsurface species, and their abundance can be used as proxies indicating shallow thermocline (Ravelo and Fairbanks, 1990; Jian *et al.*, 2001; Huang, 2002). According to Slowey *et al.* (2002), the species *G. menardii* and *G. tumida* repopulated the Caribbean and Gulf of Mexico at about 6,250 and 8,200 yr B.P., respectively, after being very low in abundance or absent during the last glaciations. It was observed by Xu *et al.* (2005) that the relative and absolute abundances of *Globorotalia menardii* were high in inter-glacials and low in glacials and covaried with δ¹⁸O fluctuations over the studied interval in the southern South China Sea. Bhonsale and Saraswat (2012) studied variations in absolute abundance, size and coiling direction ratio of *Globorotalia menardii* during the late Quaternary from three cores, collected along a north-south transect from the north-eastern Indian Ocean. Increased abundance and larger size were observed during the warm inter-glacial period, whereas smaller and fewer *G. menardii* specimens were noted during the cold glacial periods. However, its coiling direction did not show any systematic change in any of the cores. Caley *et al.* (2012) demonstrated that according to earlier assumptions, the presence and reseeding of *G. menardii* in the sub-tropical south-east Atlantic Ocean was driven by inter-ocean exchange south of Africa, and that heat and salt transfer from the Indian Ocean to the Atlantic Ocean (Agulhas leakage) had an important effect on the global thermohaline circulation and climate. According to Regenberg *et al.* (2012), the tests of *G. menardii* and *G. cultrata* can be reliably differentiated by their textures under the microscope. While the encrusted *G. menardii* shows a sugar-like surface and keel, smooth *G. cultrata* is shiny to transparent with a less pronounced keel. They also noted that during November–February, when the north-east
monsoonal winds are active and the mixed layer is expanded, *G. menardii* seems to follow the middle seasonal thermocline towards greater depths.

**Repository:** PK–AG–133

*Globorotalia punctulata* (d’Orbigny, 1826)

**Original citation:** *Globigerina punctulata* D’ORBIGNY, 1826, v. 7, p. 277, no. 8.

**Remarks:** The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 5, in the North Atlantic at a depth of 2,740 fathoms (~5,011 m). These were referred by Brady to *Pulvinulina crassa* (d’Orbigny), but according to Barker (1960), they were the source of endless confusion and contradictions. Galloway and Wissler (1927, p. 41) referred both figures to *Globigerina crassaformis* (Pleistocene, California); White (1928, p. 191) referred fig. 11 to *Globigerina angulata*, and fig. 12 to *G. crassaformis* Galloway and Wissler; Cushman and Stewart (1930, p. 77) referred both figures to *Globorotalia crassula*, ignoring earlier changes; Chapman and Parr (1937, p. 115) referred fig. 12 (not 11) to *Globorotalia pseudocrassa*, stating that the type of *G. crassula* was fig. 11, and they regarded the figures as representing two species; Cushman and Bermudez (1949, p. 43) referred both figures to *Globorotalia (Turborotalia) oceanica*, again without reference to earlier designations. Later, Phleger, Parker and Peirson (1953, p. 20) reviewed the whole question of these two figures in detail and reached the conclusion that both figures represented variations of *Globorotalia punctulata* (d’Orbigny). This problem was also studied, albeit in less detail, by Phleger and Parker (1951, p. 36) who reached the conclusion that Brady’s fig. 11 was *Globorotalia punctulata*. LeRoy (1964) studied the smaller foraminifers from the late Tertiary of Southern Okinawa and observed it to be common in the Shinzato Member of the Shimajiri Formation (Miocene or Pliocene), but was seemingly absent in the Yonabarau Member of the same formation. According to Schwartz (1962), in test morphology, *G. punctulata* is about halfway between *G. truncatulinoides* and *G. hirsuta*. It is plano-convex like *G. truncatulinoides* but without the deep open umbilicus; also the final chamber does not extend outward. It has only four chambers in the final whorl and the outline tends to be squarish rather than rounded. From *G. hirsuta* which it resembles in chamber arrangement, it differs in being highly plano-convex. Also, it has a rougher, beaded surface, especially over the earlier chambers. The periphery is blunt angled, not sharp angled as in *G. hirsuta*, and the outline is squarish, not lobulate as in *G. hirsuta*. In his microfossil analysis from Sailfish No. 1 well of the Magellan Petroleum Australia, Limited, Bandy (1972) recorded *G. punctulata* at 880 to 910 feet (~268 to 277 m), and opined it to belong to the Pliocene lower sublittoral facies. Hofker (1980) recorded *Globorotalia punctulata* at 5 stations at water depths ranging between 420 and 850 m on the Saba Bank. There seems to be a lot of confusion regarding *punctulata* and *punctulicata* while referring to the existing literature, but it seems prudent to include the forms in the present study under *Globorotalia punctulata* (d’Orbigny).

**Repository:** PK–AG–134

*Globorotalia tumida* (Brady, 1877)

Pl. 6; Figs. 4, 4a

**Original citation:** *Pulvinulina tumida* BRADY, 1884, v. 9, p. 692, pl. 103, figs. 4–6.

**Remarks:** The figures of specimens illustrated by Brady (Barker, 1960) are of the specimens recovered from the sediments dredged at Challenger Station 224, North Pacific, at a depth of 1,850 fathoms (~3,383 m), and at Challenger Station 276, north of Tahiti, Pacific Ocean, at a depth of 2,350 fathoms (~4,298 m). *Globorotalia tumida* was referred by Brady to *Pulvinulina*, but Cushman (1927, p. 91) referred it to *Globorotalia* as the genotype. Schmid (1934) considered *G. menardii* and *G. tumida* to a single species with the former being the micorspheric form and latter
the macrospheric form. Phleger et al. (1953) opined that *G. tumida* emerged as an entity in the near Recent based on the fact that the lectotype resembled the modern form very closely. Parker (1962) recorded this species from the Pacific Ocean sediments and observed its occurrence north of 22° S. According to Frerichs (1971), this species was sparsely distributed in the sediments of the Andaman Sea, and never composed as much as 1% of the planktic populations, with a maximum absolute abundance of 5 specimens per gram. Berggren (1973) and Fleisher (1974) considered the first appearance of *G. tumida* at the base of Zone N18 to be a useful criterion for recognition of the Miocene-Pliocene boundary. The characteristic features of this species are its large, tumid test, exceptionally heavy keel, and rapidly opening spire (Kennett and Srinivasan, 1983). *Globorotalia tumida* is a deep dweller that is constrained to the bottom of the photic zone, but is no longer present in the Atlantic Ocean (Billups et al., 1999). Like *Globorotalia menardii*, *G. tumida* is also a prominent Neogene sub-tropical to tropical planktic foraminiferal species. Though both share a distinctive lenticular keeled morphology, *G. tumida* shows greater spiral height and heavier secondary crusting (Brown, 2005). Farmer et al. (2007) estimated the calcification depth for this species as 176 to 273 m, suggesting that this species calcifies below the thermocline; their results corroborated well with the Fairbanks and Wiebe (1980) net tow results. Based on morphological data, smaller size, and low levels of encrusting, Brown (2007) opined that *G. ungulata* is a shallow dwelling juvenile of *G. tumida* and that *G. tumida* is the deeper dwelling adult form of the same species. Moreover, isotopic results show differing depth habitats for the two, and the results are interpreted as indicating ecophenotypic variation within a species.

Repository: PK–AG–135

Genus NEOGLOBOQUADRINA Bandy, Frerichs and Vincent, 1967

*Neogloboquadrina dutertrei* (d'Orbigny, 1839)

*Original citation:* *Globigerina dutertrei* D'ORBIGNY, 1839, v. 8, p. 84, pl. 4, figs. 19–21.

*Remarks:* Parker (1962) recorded this species from the bottom sediments of the Pacific Ocean, as *Globoquadrina dutertrei*, and gave its morphological variations (pl. 7, figs. 1–13; pl. 8, figs. 1–4). According to Tolderlund and Bé (1971), this species is a sub-tropical and tropical species, which is especially abundant in major current systems near continental margins, such as the Gulf Stream and the Equatorial Current off West Africa. Frerichs (1971) observed this species to be abundant in the sediments of the Andaman Sea, constituting as much as 20% of the planktic population, with absolute abundance as large as 8,437 specimens per gram. Kennett and Srinivasan (1983) observed, “Stereoscopic examination of *N. dutertrei* indicates two kinds of surface ultramicrostructure, which are restricted to different longitudinal ranges”. Forms belonging to *N. dutertrei* Group A with a relatively thin wall, high pore concentration, and pitted wall surface with microcrystal are typical of tropical areas; forms belonging to *N. dutertrei* Group B, with the characteristic rosette pattern formed by concentric arrangement of euhedral crystals on each chamber, are typical of cool, sub-tropical areas (op cit.). Thunell et al. (1983) observed that seasonal high abundances of this species are closely linked to shallowing of the thermocline to within the photic zone, which enhances productivity of this species. They (op cit.) opined that during the early part of the Holocene, *N. dutertrei* became a consistent and abundant faunal element throughout the Gulf of Mexico when warmer water masses existed in the gulf and salinities were optimal for this species. According to Kennett et al. (1985), this species “is more generally known to increase in abundance at times of decreased surface-water salinity”. *Neogloboquadrina dutertrei* is the end member of the neogloboquadrinid lineage, and is a significant component of the planktic foraminiferal group in the modern Arabian Sea upwelling area (Be
and Hutson, 1977; Kroon, 1988). Yassini and Jones (1995) observed this thermocline dwelling species (Billups et al., 1999) to inhabit the middle and outer shelf, continental slope and occasionally drift into shallower areas off the south-east coast of Australia. Farmer et al. (2007) estimated a calcification depth near 100 m for N. dutertrei, but with a wide confidence interval of 64 to 169 m. According to Kucera (2007), N. dutertrei is a surface to sub-surface dwelling, facultative species that reproduces on a monthly basis and is resistant to dissolution. It differs from N. incompta in having a bigger and less compact test, and in having more chambers in the final whorl (Ovechkina et al., 2010). Cléroux et al. (2013) observed that both N. dutertrei and G. tumida show a remarkably constant calcification depth independent of oceanographic conditions, the range for the former being 115±25 m.

Repository: PK–AG–136

Family PULLENIATINIDAE Cushman, 1927
Genus PULLENIATINA Cushman, 1927
Pulleniatina obliquiloculata (Parker and Jones, 1865)

Original citation: Pullenia sphaeroides (D’ORBIGNY) var. obliquiloculata PARKER and JONES, 1865, v. 155, p. 368, pl. 19, figs. 4a, b.
Remarks: Parker (1962) recorded this species from the Pacific Ocean sediments and remarked, “The classification of this genus is difficult. The early portion of the tests (also juveniles) is often hispid and apparently globigerine, but the non-spinose living forms appear to be allied to the globorotaliids”. From detailed ultrastructural studies, Burt and Scott (1975) suggested that this species is spinose in the early part of its ontogeny. The type locality for this warm water, dissolution-resistant species is in the North Atlantic, and it displays higher percentages in the Pacific than in the Atlantic or Indian Oceans (Bé, 1977). Ravelo and Fairbanks (1992) found that P. obliquiloculata was most abundant at 60 m, near the base of the seasonal thermocline, agreeing well with the estimate of 50 m for its calcification depth (Farmer et al., 2007). It has been observed to inhabit the middle and outer shelf, and the continental slope, occasionally drifting into shallow waters (Yassini and Jones, 1995). P. obliquiloculata is a species indicating warm water mass and/or deep thermocline conditions in the open ocean environment of the western Pacific (Chen and Prell, 1997). According to Steinke and Chen (2003), the abundances of this species are higher in the northern South China Sea (>10%) (Pflaumann and Jian, 1999); in this sea, this species is thought to reflect conditions within the bottom of the mixed layer and/or in the uppermost part of the thermocline. This species prefers high salinity and is closely associated with the warm and saline currents, such as the Kuroshio Current in the South China Sea (Li et al., 1997; Xu et al., 2005). According to Köster et al. (2001), the isotopic composition of Li in the calcium carbonate tests of P. obliquiloculata is independent of the size of tests and resembles the Li isotopic composition of modern seawater, suggesting that this species may provide a record of Li isotope variations in past oceans. The highest abundance of P. obliquiloculata in the global ocean surface sediments is restricted to a relatively narrow belt between ~10° N and 10° S, broadly coinciding with the equatorial current systems in the Atlantic, Indian and Pacific oceans (Xu et al., 2005). A study by Cléroux et al. (2008) showed that in the North Atlantic, this species lives at the base of the summer thermocline, which is well represented by conditions around 100 m deep in the area where this species is distributed; it is limited to the warm part of the North Atlantic Drift. According to Ovechkin et al. (2010), P. obliquiloculata can easily be identified by its rounded polished (glossy) test, being very compact, with embracing chambers; they, however, observed it to be rare on the Thukela Shelf, South Africa.

Repository: PK–AG–137
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Family CANDEINIDAE Cushman, 1927
Subfamily CANDEININAE Cushman, 1927
Genus CANDEINA d’Orbigny, 1839

Candeina nitida d’Orbigny, 1839

Original citation: Candeina nitida d’Orbigny, 1839, p. 107, pl. 2, figs. 27, 28.

Remarks: D’Orbigny (1839) gave the original description for this species, based on the types recovered from Cuba. The figures illustrated by Brady (Barker, 1960) are of the specimens recovered from the sediments collected from the surface off Philippines, and from the sediments dredged at Challenger Station 338, South Atlantic, at a depth of 1,990 fathoms (~3,639 m), at Challenger Station 280, South Pacific, at a depth of 1,940 fathoms (~3,548 m), and at Challenger Station 120, off Pernambuco, Atlantic Ocean, at a depth of 675 fathoms (~1,234 m). Parker (1962) recorded this species from the bottom sediments of the Pacific Ocean. Candeina nitida was found to be rare in the sediments of the Andaman Sea, and never formed 1% of the planktic population (Frerichs, 1971). Bé and Tolderlund (1971) opined that this species is one of the rarest, seldom exceeding 5% of the foraminiferal population, and that it is more abundant in tropical than sub-tropical waters. They noted that the tests of this species were wrapped in peculiar “cocoon-like” envelopes, and were equally abundant in 0–10 m and 0–300 m tows, thereby probably without any depth habitat preference. This species was observed by Bé and Hutson (1977) at only few stations in equatorial waters between southern India and Sumatra; it also occurs sparsely in equatorial sediments of the southern Arabian Sea, Bay of Bengal and Andaman Sea, as well as in sediments off Tanzania in the central sub-tropical Indian Ocean. Hofker (1978) recorded this species south of Makassar, at a water depth of 587 m, and in the Gulf of Bone, at 1,374 m, in the eastern part of the Indonesian Archipelago. According to Kennett and Srinivasan (1983), Candeina is a monospecific genus and and C. nitida is easily distinguished by its microperforate, trochoid test with sutural supplementary apertures completely surrounding the later chambers. Candeina nitida is very rare in the outer shelf and continental slope off the south-east coast of Australia (Yassini and Jones, 1995).

Repository: PK–AG–138

Family CATAPSYDRACIDAE Bolli, Loeblich and Tappan, 1957
Genus GLOBOQUADRINA Finlay, 1947

Globoquadrina conglomerata (Schwager, 1866)


Remarks: The only figure of this species illustrated by Brady (Barker, 1960) is of a specimen recovered from the material dredged at Challenger Station 155, Antarctic, at a depth of 1,300 fathoms (~2,377 m). Brady referred this species to Globigerina dutertrei, but Cushman (1927) referred it to G. conglomerata and observed that it was the dominant species of the genus in the eastern Pacific Ocean. Parker (1962) recorded this species as Globorquadrina conglomerata (Schwager) from the Pacific Ocean sediments. According to Todd (1964), “Globigerina conglomerata was described from the Neogene (undoubtedly Pliocene) of Kar Nicobar”. This species was observed to be rare in the sediments of the Andaman Sea, constituting as much as 7% of the planktic populations with absolute abundance of 694 specimens per gram (Frerichs, 1971). According to Bé and Hutson (1977), this common tropical species occurs in low frequency (<5%) in the plankton and sediments north of ~20° S, and is associated with boundary currents (Agulhas, Somalı, and West Australian currents) and the North Equatorial Current, where it comprises 10–20% of the fauna. Highest percentages (10–20%) occur in the sediments of the equatorial regions and along the African, Indonesian, and West Australian continental margins (op cit). Globigerina conglomerata occurs in higher percentages in the equatorial region and southern Arabian Sea.
According to Chaisson (1995), who recorded it as *Globoquadrina conglomerata*, it is a non-spinose, deep dwelling herbivore. Chowdhury *et al.* (2003) studied the distribution of planktic foraminifera from the continental shelf and slope areas in the northern Bay of Bengal and observed that *Globoquadrina conglomerata* and *Globorotaloides hexagona*, known to have disappeared from the Atlantic Ocean 50,000 to 100,000 years ago, show their presence mostly in the sediments from the outer shelf and slope areas.

**Original citation:** *Hastigerina digitata* RHUMBLER, 1911, v. 3, pt. 1, pl. 37, figs. 9a, b.

**Remarks:** The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the material dredged at Challenger Station 276, in the South Pacific, at a depth of 2,350 fathoms (~4,298 m), and at Challenger Station 338, in the South Atlantic, at 1,990 fathoms (~3,639 m), from where it was originally described. This species was referred by Brady to *Globigerina* but Galloway (1933, p. 333) referred it to *Hastigerinella*. According to Banner (1965), the availability of the name *Hastigerina digitata* Rhumbler, 1911, was disputed, and an attempt was made to substitute *Hastigerinella eosaniia* Nuttall, 1928, as type species of the genus *Hastigerinella* Cushman, 1927. Banner, however, refuted this and designated a neotype for *Hastigerina digitata* Rhumbler, 1911 = *Hastigerinella digitata* (Rhumbler) Cushman, in accordance with the I.C.Z.N. Bé and Tolderlund (1971) observed that the tests of this sub-surface species were more abundant in the 0 to 300 m than in 0 to 10 m plankton tows in the Atlantic and Indian Oceans. Both *Hastigerina pelagica* and *Hastigerinella digitata* lack symbionts (Hemleben *et al*., 1989), are exclusively carnivorous, and found to feed predominately on copepods (Anderson and Bé, 1976; Hull *et al*., 2011). According to Aurahs (2010), the only two extant species in the family Hastigerinidae reported to build monolamellar shells are the “spinose” *Hastigerina pelagica* and *Hastigerinella digitata* and hence are classified separately in the family. *Hastigerinella digitata* is a rare deep-dwelling form with conspicuous digitate chambers. In situ video surveys in the Monterey Canyon over 12 years revealed that the species occupies a narrow depth horizon of <100 m around a median depth of 300 m, immediately above the core of the regional oxygen minimum zone at a depth of 280–358 m and O$_2$ concentrations of 1.0–1.3 mL L$^{-1}$ (Hull *et al*., 2011).

**Original citation:** *Globigerina bulloides* D’ORBIGNY, 1826, p. 277, modeles nos. 17 (juvenile), 76 (adult).

**Remarks:** The types for this species came from the Adriatic Sea, near Rimini, Italy (d’Orbigny, 1826). The large umbilical aperture is characteristic of this species. Bé (1967) opined that *Globigerina bulloides* is an inhabitant of sub-polar and cold temperate latitudes. Murray (1971) recorded it from off the British Isles. This species was observed to be very abundant in the sediments of the Andaman Sea, and composed as much as 15% of the planktic population, with
absolute abundance as great as 5,017 specimens per gram (Frerichs, 1971). According to Tolderlund and Bé (1971), the highest concentrations of this species are found in sub-polar and transitional waters, and remarked, “Because of its high productivity and its extensive areal distribution, *G. bulloides* is an excellent species for studying both seasonal and latitudinal abundance shifts, particularly in temperate latitudes”. According to Kennett and Srinivasan (1983), this species distribution is centered in temperate areas; relative abundances decrease toward the tropics and the species is rare in equatorial areas. According to Kroon *et al.* (1991), summer upwelling, which is a result of south-western winds, occurs along the coast of Somalia producing distinct foraminiferal assemblages that are dominated by *G. bulloides*. Consequently, variations in the distribution record of *G. bulloides* through time aid in monitoring the upwelling history associated with monsoonal activities. *Globigerina bulloides* is the most abundant species in the Arabian Sea upwelling areas and is commonly used as a proxy for upwelling in paleoceanographic studies (Curry *et al.*, 1992; Prell *et al.*, 1992; Anderson and Prell, 1993; Naidu and Malmgren, 1995; Bylinskaya *et al.* 2002). *Globigerina bulloides* is a macroperforate, spinose, thermocline (Chaisson, 1995), cool to cold water species (Zheng *et al.*, 2005), which is adapted to productive areas of the oceans (Hecht, 1976; Duplessy *et al.*, 1981) as it seems to track phytoplankton blooms (Mortyn and Charles, 2003). The species differs from *G. falconensis* in having a high aperture without a lip. *G. bulloides* has a more hispid and thicker wall than does *Globigerinella cañada*. According to Ovechkina *et al.* (2010), *G. bulloides* is a cosmopolitan species, occurring in waters from equatorial to sub-polar latitudes, but is most abundant in the temperate Atlantic.

**Repository:** PK–AG–141

*Globigerina helicina* d'Orbigny, 1826

Pl. 6; Fig. 7

**Original citation:** *Globigerina helicina* D'ORBIGNY, 1826, v. 7, p. 277, no. 5.

**Remarks:** The type material for this species came from the beach sands of Rimini in Italy (d'Orbigny, 1826). The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the material dredged at Challenger Station 338, in the South Atlantic, at a depth of 1,990 fathoms (~3,639 m) and at Challenger Station 85, off the Canaries, in the Atlantic, at 1,125 fathoms (~2,057 m). According to Barker (1960), “the *Globigerina helicina* of d'Orbigny possesses characters which entitle it to rank as a zoological variety, and whether the forms it includes would not be better treated as examples of monstrous or abnormal development. Nevertheless the peculiar features of the test are tolerably constant. It most resembles an ordinary small Globigerine shell of the 'rubra' type, with the addition of an inflated chamber at two opposite points of its periphery. The superior face is obscurely spiral, and shows two, three, or more apertures; the inferior has four visible segments, two large and oblong, laid side by side, and two small and rounded, one at each end of the test; and the latter have inferior apertures. Of the figures in Soldani's Testaceographia, referred to by d'Orbigny, that marked qq, which gives both the superior and inferior aspects of the shell, is the most characteristic, and leaves nothing to be desired in point of definition. It is interesting to note that examples precisely analogous, from a morphological point of view, to those upon which this variety is founded, occur in other genera of the Globigerinidae, notably in *Pullenia* and *Candeina* (Pl. LXXXIV. fig. 19, and Pl. LXXXII, fig. 19)”. A thorough review of literature shows that *G. helicina* has had only sporadic records since as far back as 1791. According to Weaver (1841), this species was found living in the Adriatic Sea and the Ocean; he observed it to be present as fossil in the white chalk of Cattolica and remarked, “Ehrenberg had referred, with a mark of interrogation, four species of calcareous-shelled Polythalamia to the white chalk of Cattolica, in which they are very extensively
distributed: *Globigerina bulloides*, *Globigerina helicina*, *Rosalina globularis* and *Textularia aciculata*. Dabrio *et al.* (1972) recorded this species and remarked, “We believe that this form can be identified, with certain reserve, with *Globigerina helicina* d’Orbigny, as per Banner and Blow (1960). There is, however, the presence of a lip and relatively more oval chambers”. Todd and Low (1976) found this species to be rare as well, occurring as scattered specimens at various water depths off St. Croix Island in the Caribbean Sea. Perhaps the most recent mention of *G. helicina* is that of Ovechkina *et al.* (2010), who examined planktic foraminiferal assemblages in surface sediments from the Thukela Shelf, off South Africa. This might be the first record of this peculiar species from Indian waters.

**Repository**: PK–AG–143

*Globigerina hexagona* Natland, 1938

**Original citation**: *Globigerina hexagona* NATLAND, 1938, v. 4, no. 5, p. 149, pl. 7, figs. 1a–c.

**Remarks**: This species was originally described from a depth of 884 m off Long Beach, California (Natland, 1938). Parker (1962) reported this species from the Pacific Ocean sediments and remarked, “There is a good deal of variation in the coarseness of the pitted surface, but all gradations are found, often on a single specimen”. Haynes (1973) gave the diagnostic features of this species as follows: “A species of *Globoquadrina* with 4½ to 6 chambers visible on the ventral side, rapid rate of chamber size increase, radial ventral sutures and large polygonal to hexagonal pits”. He identified specimens as *Globoquadrina hexagona* from the Cardigan Bay, British Isles, following the broad interpretation of the species made by Parker (1962) to cover a series of variants from the South Pacific. These ranged from rather loosely coiled, flat forms with six chambers at the periphery and large umbilicus with marked teeth through five-chambered forms, like the holotype (though smaller) to more globular, close-coiled forms with more rapid rate of chamber size increase and small umbilicus. The Pacific Ocean records are: mid-Pacific sea mounts (Hamilton, 1953); equator to 45° N (Bradshaw, 1959); Gulf of California (Bandy, 1961); and the South Pacific, north of 45° (Parker, 1962). According to Bé (1967; 1969), *G. hexagona* is restricted to the Indo-Pacific; this underlines the idea that the North Atlantic variety is distinct. Frerichs (1971) observed this species to be rare in the sediments of the Andaman Sea, never constituting >1% of the planktic populations, with absolute abundance as large as 436 specimens per gram. Kennett and Srinivasan (1983) recorded this species as *Globorotaloides hexagona* (Natland) and observed that this species exhibits a wide range of variation in the inflation and size of chambers, and in apertural characters. It is usually distinguished by its 5 to 6 globular, inflated chambers in the final whorl, which are individually more distinct and less embracing than in *G. variabilis*. *Neogloboquadrina hexagona* is a tropical species and a minor constituent (<5%) in living and fossil assemblages north of 30° S, and its maximum abundances are found in plankton samples of the equatorial region and in surface sediments of the southern Bay of Bengal (Bé and Hutson, 1977). This deep dwelling, non-spinose herbivorous species (Chaisson, 1995) is typically tropical to sub-tropical (Peeters *et al.*, 2004), and has been reported by many workers as *Globoquadrina hexagona* (e.g., Ujić, 1985), *Neogloboquadrina hexagona* (e.g., Wang *et al.*, 1988), *Globorotaloides hexagona* (e.g., Dowsett and Robinson, 2007) or *Globorotaloides hexagonus* (e.g., Kender *et al.*, 2008). Hanagata and Nobuhara (2015) have presented an illustrated guide to Pliocene foraminifera from Miyakojima, Ryukyu Island Arc, and observed this species to be common in the Yonahama and Minebari formations.

**Repository**: PK–AG–143

Genus GLOBIGERINELLA Cushman, 1927
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Globigerinella adamsi (Banner and Blow, 1959)

Original citation: Hastigerina (Bolliella) adamsi Banner and Blow, 1959, v. 2, pt. 1, p. 13, text-figs. 4a–d.

Remarks: This species was originally described by Brady (1884) as Globigerina digitata from 580 fathoms (~1,061 m) off the Kei (Ewab) Islands in the East Indies (Challenger Station 191A). Banner and Blow (1959), however, opined that it appeared to be closely related to Globigerina siphonifera. Parker (1962) observed that the radiate elongation of the chambers is a specific characteristic, as it is in Globigerina digitata. Within a couple of years, Todd (1964) had commented about its records from South Atlantic, the South Pacific, off Bikini, and the Equatorial and west-central Pacific. According to her, “Parker (1958, p. 277) seems to have been the first to recognize that this species (represented by Brady’s pl. 82, figs. 6, 7) is in reality a species of Globigerinella, though she did not name it or even list or illustrate it as Globigerinella”. Saito et al. (1976) gave an elaborate account of the skeletal ultra-microstructure of this species, and the figures have been reproduced by Loeblich and Tappan (1987, pl. 534, figs. 6–8). According to Frerichs (1971), this species was not recorded in counts of a representative split of the samples collected from the Andaman Sea, but was noted in an examination of larger quantities of the planktic populations. Bé and Hutson (1977) recorded this species as Globigerinella adamsi and observed it to be a tropical species encountered in small numbers in the southern Arabian Sea and equatorial waters. According to Hull et al. (2011), there are three living digitate species, Hastigerinella digitata (Rhumbler, 1911), Globigerinella adamsi (Banner and Blow, 1959), and Beella digitata (Brady, 1879); all are generally known from low to mid latitudes worldwide (Bé, 1977; Coxall et al., 2007). Oblique plankton tows and depth-stratified tows indicate that extant digitate species occur primarily in the water column below 200 m in depth (Rhumbler, 1911; Bradshaw, 1959; Bé, 1977) and comprise a rare component of both planktic and fossil assemblages (Prell et al., 1999; Coxall et al., 2007). All these three species are all equipped with a dense spine network believed to represent a functional adaptation for capturing active prey (Hemleben et al., 1989). According to Weiner et al. (2014), Globigerinella adamsi is characterized by its elongated, digitate chambers with pointed tips, very rare, and inhabits mesopelagic waters of the Indo-Pacific low latitude realm (Bé and Tolderlund, 1971).

Repository: PK–AG–144

Globigerinella calida (Parker, 1962)

Original citation: Globigerina calida PARKER, 1962, v. 8, no. 2, p. 221, pl. 1, figs. 9–13, 15.

Remarks: The original description and illustration of this species were given by Parker (1962), the type locality being the central southern Pacific Ocean, at a water depth of 3,120 m. Globigerinella calida was characterized as possessing trochospirally coiled evolute tests with radially elongate chambers, with the final chamber being separated from the earlier ones and being perforated by large, circular pores (Parker, 1962; Saito et al., 1981). Frerichs (1971) recorded this species to be a constant component of both planktic and fossil assemblages (Prell et al., 1999; Coxall et al., 2007). All these three species are all equipped with a dense spine network believed to represent a functional adaptation for capturing active prey (Hemleben et al., 1989). According to Bé et al. (1985), this species predominantly occurs in the water depth range of 50 to 200 m in the Panama Basin, and lives mainly within and below the thermocline (25 to 75 m, or deeper). Globigerinella calida has been recorded in most of the climatic areas from equatorial to temperate, but is never abundant in assemblages (Bylinskaya et al., 2002). Yu et al. (2008) observed that G. calida did not exhibit any clear glacial/inter-glacial pattern in a core retrieved from off the Vietnamese margin, in the
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western South China Sea, while Ovehkina et al. (2010) reported it to be rare on the Thukela Shelf, South Africa. A recent diagnosis for this species by Weiner (2014) is as follows: “Individuals of *Globigerinella calida* possess slightly trochospirally coiled evolute shells with typically five chambers in the last whorl. The last whorl is marked by radially elongated chambers . . . . with rounded tips. The aperture is in an interiomarginal position and cannot be seen from the spiral view. The surface of the shell is marked by round spines”.

**Repository:** PK–AG–145

_**Globigerinella siphonifera** (d’Orbigny, 1839)

**Original citation:** *Globigerina siphonifera* D’ORBIGNY, 1839, v. 83, pl. 4, figs. 15–18.

**Remarks:** The figure illustrated by Brady (Barker, 1960) is of a specimen recovered from the sediment dredged at Challenger Station 224, North Pacific, at a depth of 1,850 fathoms (3,330 m; fig. 19). This species was referred by Brady to *Globigerina*, but by Cushman (1927, p. 87) to *Globigerinella* as the genotype. Bolli, Loeblich and Tappan, however, placed *Globigerinella* Cushman 1927 in synonymy with *Hastigerina* Thomson, 1876 (1875, p. 29). Banner and Blow (1960) considered *G. aequilateralis* (Brady) as a junior synonym of *G. siphonifera* (d’Orbigny), but Kennett and Srinivasan (1983) retained the name *aequilateralis* Parker (1962) following the reasons stated by Todd (1963), and Saito et al. (1976). *Globigerinella aequilateralis* is most frequent in the western Indian Ocean than in the eastern. *Globigerinella siphonifera* is more hispid than *H. pelagica*, and more tightly coiled and planispiral than *Globigerinella calida*. It occurs over wide ranges of surface temperature, salinity and phosphate. In the surface sediments, *G. aequilateralis* is most abundant along the continental margin of Africa, Bay of Bengal and Indonesian Archipelago as well as the Carlsberg, mid-Indian and Madagascar ridges (Belyaeva, 1964). According to Tolderlund and Bé (1971), this species is a common sub-tropical and tropical species, which occurs abundantly in strong current systems, transitional waters and areas of upwelling. Bé et al. (1971) observed *G. aequilateralis* to be common in the northern as well as southern Sargasso Sea. Its increase in abundance in the Antilles Current and Caribbean Sea was indicative of its preference for boundary current conditions. Ujjié (1968) and Ujjié and Nagase (1971) found it to be one of the common species in the transitional-subtropical fauna between north-eastern Australia and latitude 10° S. Zobel (1971) observed that this species is one of the most common species in the Somali Current and the central and southern Arabian Sea. This species *sensu lato* includes a wide morphological range of individuals which varied coiling tightness and spiral angles. It is the one of the most common taxa in tropical and sub-tropical waters. It is especially abundant in such active current systems as the Somali Current, Agulhas Current and Equatorial Counter Current, where it frequently exceeds 20% of the total planktic foraminifera (Bé and Hutson, 1977). Its relative abundance in the sediments is generally lower than in the plankton tows, which may be related to its comparatively high susceptibility to dissolution on the sea floor. Cimerman and Langer (1991) recorded this species as *Globigerinella aequilateralis* (Brady) from the Mediterranean Sea, but Hottinger et al. (1993) reported it as *Globigerinella siphonifera* (d’Orbigny) from the Gulf of Aqaba, Red Sea, and remarked, “Since the different characters which have been described to distinguish the typical *siphonifera* from the sub-species *involuta*, seem to occur in a variable manner throughout the populations observed, no sub-specific differentiation is made for the time being”. They also observed that this species has chrysophycean symbionts. Yassini and Jones (1995) recorded this species as *Hastigerina siphonifera* (d’Orbigny) and observed it to occur in the middle and outer shelf and continental slope regions off the south-east coast of Australia, and that this species “very rarely drifts into shallow areas”. According to Huber et al. (1997), the two physiological types of *Globigerinella siphonifera*, which are distinguished by their possession of two different types of symbionts (Faber et al. 1988, 1989), can also be separated on the genetic level as
well as by different shell ultra-structures. Ovechkina et al. (2010) recorded this species as *Globigerinella siphonifera* and observed it to occur in almost all sediment samples from the Thukela Shelf, South Africa, but in low abundance. According to Rebotin et al. (2010), surface to thermocline dwelling species like *G. ruber*, *G. siphonifera* and *O. universa* seem to reflect conditions of the upper ocean, without significant differences in the north and south of the Azores Front. *Globigerinella siphonifera* is a species that is marked by a high genetic as well as morphologic variability (Weiner, 2014).

Repository: PK–AG–146

Genus GLOBIGERINOIDES Cushman, 1927

*Globigerinoides conglobatus* (Brady, 1879)

Pl. 6; Fig. 9

Original citation: *Globigerina conglobata* BRADY, 1879, v. 19, p. 286; 1884, v. 9, pl. 80, figs. 1-5; pl. 82, fig. 5.

Remarks: One of the figures illustrated by Brady (Barker, 1960) is of a specimen recovered from the sediment dredged at Challenger Station 64, North Atlantic (°), at a depth of 2,750 fathoms (~5,029 m). Brady referred this species to *Globigerina*, while Cushman (1927) referred it to *Globigerinoides*. Relative abundances between 1% and 4% were recorded on such topographic highs as the Carlsberg Ridge, mid-Indian Ridge, African continental margin, and southern Bay of Bengal (Belyaeva, 1964). Frerichs (1971) observed this species to be a constant component of the planktic populations of the Andaman Sea, and constituted as much as 6%, with absolute abundance as large as 455 specimens per gram. *Globigerinoides conglobatus* is a sub-tropical species with a distributional range that includes the transitional and tropical waters. Its highest abundance occurs in the central water masses of the North Pacific and North Atlantic (Bé and Tolderlund, 1971). According to Bé and Hutson (1977), this species is found in tropical and sub-tropical waters. It is encountered most frequently within and south of the South Equatorial Current, where it reaches a frequency between 5 and 20% in relatively warm waters. In the surface sediments, it is widespread but seldom exceeds >4% of the total planktic foraminifera. Kennett and Srinivasan (1983) remarked, “*G. conglobatus* is distinguished by its thick-walled and tightly coiled test. Specimens representing an evolutionary and morphologic transition between *Gs. extremus* and *Gs. conglobatus* resemble *Gs. canimarensis* Bermudez. We concur with Parker (1973) and Stainforth et al. (1975) in treating *Gs. canimarensis* as a synonym of *Gs. conglobatus*. According to Cimerman and Langer (1991), *Globigerinoides conglobatus* lives in the photic zone and has dinoflagellate symbionts, similar to those occurring in *Orbulina universa* and other *Globigerinoides* species. Yassini and Jones (1995) observed this species to be rare in the middle and outer shelf and continental slope off the south-east coast of Australia. *Globigerinoides conglobatus*, a spinose and/or omnivorous thermocline dweller, (Chaisson, 1995), lives in warm waters, within the range of temperatures inhabited by *G. ruber* and there are many specimens showing intermediate morphologies (Serrano et al., 2007). Molecular data also indicate a close phylogenetic relationship between *G. ruber* and *G. conglobatus* (de Vargas et al., 1997). Ovechkina et al. (2010) recorded this species from the Thukela Shelf, South Africa, and stated, “*G. conglobatus* has a larger and more compact test in adults, and more embracing chambers in juveniles, than does *G. ruber*”. The distinct species status of *G. conglobatus* is supported by its divergent morphological features which promoted its classification as a separate morpho-species (André et al., 2014). According to Jonkers and Kučera (2015), such tropical and sub-tropical species as *G. conglobatus* have relatively even flux patterns, with low prominence peaks occurring at any time of the year in their optimum high-temperature range (>25° C).

Repository: PK–AG–147
Globigerinoides ruber (d’Orbigny, 1839)
Pl. 6; Fig. 10

Original citation: Globigerina rubra D’ORBIGNY, 1839, v. 8, p. 82, pl. 4, figs. 12–14.
Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 338, South Atlantic, at a depth of 1,990 fathoms (~3,639 m), at Challenger Station 344, Ascension Island, South Atlantic, at a depth of 420 fathoms (~768 m), and at Challenger Station 346, South Atlantic, at a depth of 2,350 fathoms (~4,298 m). Brady referred this species to Globigerina, while Cushman (1927) referred it to Globigerinoides. Todd (1955, p. 368, footnote) cited Roland W. Brown as being of the opinion that a generic name ending in –oides an adjectival suffix meaning like, takes its gender from the gender of the generic name on which it is based, thus Globigerina is feminine, therefore, the present species becomes Globigerinoides rubra (d’Orbigny). Parker (1962) described several morphological variations of this species from a detailed study of specimens from the Pacific Ocean and remarked, “Whether this group represents subspecies or phenotypic variants is open to question, and no sub-specific designations are given here”. She also opined that the three groups with variations in morphological features might be a consequence of latitudinal variations. The presence of three chambers in the final whorl and the symmetrical placement of the primary and secondary apertures above the suture between the two earlier chambers are the characteristic features of this species. Globigerinoides sacculifer, along with Globigerinoides ruber, is generally the most abundant species in the equatorial regions of the Atlantic, Indian, and Pacific oceans (Bradshaw, 1959; Bé And Tolderlund, 1971), preferring surface water temperatures higher than 24°C. According to Frerichs (1971), G. ruber is very abundant in the sediments of the Andaman Sea, and composed as much as 45% of the planktic populations, with absolute abundance as large as 16,425 specimens per gram. Tolderlund and Bé (1971) opined that G. ruber is the most successful warm-water species in terms of distribution and abundance in the Atlantic Ocean, and that it is the most prolific form in sub-tropical waters and is second only to G. sacculifer in the tropical waters of the Atlantic and Pacific oceans. According to Bé et al. (1971), G. ruber was the dominant species in the southern Sargasso Sea, where it constituted about 51% of the total population. Bé and Hutson (1977) opined that this species occurs mainly in sub-tropical waters north of 15° N and south of 10° S, with salinity greater than 36‰. In the Panama Basin, G. sacculifer and G. ruber were most common in the warm mixed layer above the thermocline in the plankton tow material (Fairbanks et al., 1982). Cimerman and Langer (1991) reported G. ruber from the Mediterranean Sea and remarked, “G. ruber lives in shallow water and has dinoflagellate symbionts giving the protoplasm a reddish colour”. The pink-colored forms have not been found in surface sediments of the Indo-Pacific area (Bé and Hutson, 1977; Saito et al., 1981), where they disappeared at about 120 ka (Thompson et al., 1979). Many specimens in the Indo-Pacific area, which could be considered pink varieties, have an early whorl or two of light pink chambers and gradually become white in later chambers (Saito et al., 1981). This species has been found to inhabit the middle and outer shelf and continental slope, occasionally drifting into shallow areas, off the south-east coast of Australia (Yassini and Jones, 1995). Yamasaki and Oda (2003) observed abundant G. ruber and G. sacculifer in the size fraction of 250–500 µm from July through November in a shallow trap in the East China Sea. In fact, stained G. ruber and G. sacculifer were most common in the surface mixed layer above the thermocline in October at a station, where the surface temperature was 25°C. The temporal variation for the size of G. ruber, which was larger in summer and smaller in winter, was consistent with that of the trap reported by Deuser et al. (1981) in the Sargasso Sea. According to Jonkers and Kučera (2015), such tropical and sub-
tropical species as *G. ruber* have relatively even flux patterns, with low prominence peaks occurring at any time of the year in their optimum high-temperature range (>25°C).

**Repository:** PK–AG–148

*Globigerinoides sacculifer* (Brady, 1877)

Pl. 7; Figs. 1, 1a

**Original citation:** *Globigerina sacculifer* BRADY, 1877, v. 4, no. 12, p. 535; 1884, v. 9, p. 604, pl. 80, figs. 11–17; pl. 81, fig. 2; pl. 82, fig. 4.

**Remarks:** The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 224, North Pacific, at a depth of 1,850 fathoms (~3,383 m), at Challenger Station 24, West Indies, at a depth of 390 fathoms (~713 m), and at Challenger Station 36, North Atlantic (from the surface). This species was referred by Brady to *Globigerina*, but Cushman (1927, p. 173) referred it to *Globigerinoides*. Commenting on this species, Kostanowich (1963) stated, “It includes specimens both with an elongated final chamber and with a globose final chamber”. According to Frerichs (1971), *G. sacculifer* is abundant in the sediments of the Andaman Sea, and composed as much as 39% of the planktic population, with absolute abundance as large as 2,832 specimens per gram. Tolderlund and Bé (1971) recorded this species from the western North Atlantic and remarked, “*Globigerinoides sacculifer* is a surface-dwelling, tropical and sub-tropical species and is the dominant species in the equatorial regions of all oceans. Its occurrence at some stations in the northern Sargasso Sea was attributed to transport by the Gulf Stream system (Bé *et al*., 1971). According to Bé and Hutson (1977), this species is found predominantly between 25° N and 10° S in tropical waters with salinity less than 36.0‰. Hottinger *et al.* (1993) recorded *Globigerinoides sacculifer* from the Gulf of Aqaba, Red Sea, and observed the presence of dinophycean symbionts in this species. Yassini and Jones (1995) reported this species from the middle and outer shelf off the south-east coast of Australia, and observed that it occasionally drifted into shallow areas. Yamasaki and Oda (2003) observed abundant *G. ruber* and *G. sacculifer* in the size fraction of 250–500 µm from July through November in a shallow trap in the East China Sea. In fact, stained *G. ruber* and *G. sacculifer* were most common in the surface mixed layer above the thermocline in October at a station, where the surface temperature was 25°C. According to Ovechkina *et al.* (2010), *G. sacculifer* species differs from *G. triabulus* in the characteristic sac-like shape of the last chamber and in being generally larger. *Globigerinoides sacculifer* constitutes a highly abundant and cosmopolitan plexus of four different morphotypes. Because of the high morphological variability it seemed likely that a comparable amount of genetic diversity might be detected, a sufficiently large enough dataset was available, covering wide areas of the distribution range of the morphospecies. Unexpectedly, André *et al.* (2013) found an extremely reduced genetic variation within the plexus and no correlation between genetic and morphological divergence, suggesting “taxonomical over interpretation”. According to Jonkers and Kučera (2015), such tropical and sub-tropical species as *G. sacculifer* have relatively even flux patterns, with low prominence peaks occurring at any time of the year in their optimum high-temperature range (>25°C).

**Repository:** PK–AG–149

**Genus Sphaeroidinella** Cushman, 1927

*Sphaeroidinella dehiscens* (Parker and Jones, 1865)

**Original citation:** *Sphaeroidina bulloides* D’ORBIGNY var. *dehiscens* PARKER and JONES, 1865, v. 155, p. 369, pl. 19, fig. 5.
Remarks: Originally described from the tropical Atlantic and the Indian Ocean, the lectotype of this species (Banner and Blow, 1960, pl. 7, fig. 3) is from 1,080 fathoms (~1,975 m) in the Equatorial Atlantic. The species is widely recorded in the Pacific and Atlantic Oceans but not in the colder waters. Based on observations of specimens from the Eniwetok deep-sea core samples, it is true that most specimens of *Sphaeridinella debiscens* show open fissures on both dorsal and ventral sides of the test (Todd, 1964). Utilizing the data of Phleger et al. (1953) and Kipp (1976), Emilliani and Ericson (1991) gave the lowest tolerable winter and summer temperatures for *S. debiscens* as 23° and 26°C, respectively. As this species is present mainly in inter-glacial times, they opined that it was an indication that temperature may have dropped below 23°C during glacial times. Based on the δ¹⁸O values from planktic foraminiferal tests of 24 species from the Atlantic Ocean, Niebler et al. (1999) distinguished four depth-related groups with regard to apparent calcification depths, among which *S. debiscens* fell in the group between 0 and 50 m. This is a deep dwelling, tropical, warm water species (Zheng et al., 2005) that is present in the thermocline (Chaisson, 1995); its presence in cores in present-day colder latitudes but absence in the modern fauna in cold waters as off western Iberia corroborates this fact (Salgueiro et al., 2008). Ovechkina et al. (2010) found only three specimens of this species in the samples from the Thukela Shelf, South Africa, and commented that this species demonstrates a very wide variation in the size and shape of the test, and in the development of apertures.

Repository: PK–AG–150

Subfamily ORBULININAE Schultze, 1854

Genus ORBULINA d’Orbigny, 1839

*Orbulina universa* d’Orbigny, 1839

Original citation: *Orbulina universa* D’ORBIGNY, 1839a, v. 8, p. 3, pl. 1, fig. 1; 1839b, p. 123, pl. 1, fig. 1.

Remarks: This species was originally described by d’Orbigny (1839) from the South Pacific. The figures of the specimens illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 246, North Pacific, at a depth of 2,050 fathoms (3,690 m; fig. 8), Challenger Station 78, east of the Azores, Atlantic Ocean, at a depth of 1,000 fathoms (1,800 m; fig. 21), and at Challenger Station 302, west coast of Patagonia, at a depth of 1,450 fathoms (2,610 m; fig. 26); data regarding other figures is doubtful. Le Calvez (1936) suggested externally and internally different tests of *Orbulina universa* depending on its generation and mode of life. Subsequently, Hofker (1959) interpreted *O. universa* as the adult stage of various species of planktic foraminifera. According to Tolderlund and Bé (1971), *Orbulina universa* is a nearly ubiquitous species in transitional, sub-tropical and tropical waters, and its highest frequencies are observed in the surface layers of strong current systems and upwelling regions near continental margins. Bé et al. (1971) recorded this species to be sparse in both northern and southern Sargasso Sea. Haynes (1973) recorded this species from the Cardigan Bay, British Isles, and observed its diagnostic features as follows: “a species of *Orbulina* in which the final chamber completely encloses the trochospiral juvenile”. The large number of records of this species indicates that it is cosmopolitan, but more than one species may be involved, as noted by Parker (1962). Belyaeva (1964) reported highest concentrations along the Carlsberg Ridge and in the north-western Indian Ocean north of 20° S. Detailed work by Bé and Hamlin (1967) in the North Atlantic shows that it is widespread in tropical, sub-tropical and transitional waters, with highest concentrations in the Gulf Stream and in the eastern Atlantic of Spain and Morocco. Study of the variation in water column depth preference among various species of planktic foraminifera was pioneered by Bé and Tolderlund (1971) and furthered by Fairbanks and Wiebe (1980). They observed that *O. universa* was often most abundant in the mixed layer but also
sometimes most abundant in the thermocline (hence its “universal” name). Bé et al. (1973) observed that populations with large tests and highest test porosities occur in tropical areas, and those with lower porosities and which decrease in mean test diameter occur in sub-tropical and sub-Antarctic waters. The test diameter of *O. universa* varies with latitudinal occurrence. Large tests (600–800 µm diameter) occur in tropical–subtropical areas; intermediate-sized tests (450–550 µm) in the Transition Zone, and small tests (<450 µm) in sub-Antarctic waters (op cit). Bé et al. (1973) and Colombo and Cita (1980) observed that the size of Recent *Orbulina universa* decreases with lowering temperature, and the former also noted that the wall tends to become thinner with increase in test size. This suggests a dependence of thickness of test wall on temperature. *Orbulina universa* d’Orbigny is a spinose planktic foraminifer which occurs throughout surface waters of the tropical, sub-tropical and transition zones of the world ocean (Bé and Tolderlund, 1971). This species is unique among planktic foraminifera in that its life cycle is composed of two growth stages. The juvenile stage is a trochospiral form which is enclosed within a terminal spherical chamber in the adult stage (Bé et al., 1973). According to Bé and Hutson (1977), *O. universa* is a common species in southern sub-tropical waters. Its highest frequencies occur near or within the waters of the Transition Zone between latitude 30° and 35° S. It is also widespread and rare in the sediments. At most stations in the Indian Ocean, it constitutes <1% of the total planktic foraminifera. Slightly higher frequencies are found in sediments along the African coast from Kenya to South Africa, and along the south-west branch of the mid-Indian Ridge (Bé and Hutson, 1977). According to Collen and Burgess (1979), dissolution begins with the removal of the external layers of the test by the smoothing of the surface and, subsequently, the accentuation and widening of the sutural pores. This process is strongly related to the distribution of the pores, which constitute weak points. Consequently, finely perforated species such as *Orbulina universa* and *Globigerinoides trilobus* are intensely affected by dissolution. In terms of micro-structural characteristics, *Orbulina universa* presents pore-like apertures scattered across the surface of the last chamber surface, which is densely perforated and commonly presents pores of two different sizes (Bolli and Saunders, 1985; Kennett and Srinivasan, 1983). Hottinger et al. (1993) reported it from the Gulf of Aqaba, Red Sea, and observed dinophycean symbionts in it. The spinose foraminifer *Orbulina universa* is a ubiquitous species in sub-tropical and tropical waters and hosts high numbers of the endosymbiotic dinoflagellate *Gymnodinium bêii* (Spero, 1987). During daytime, the symbionts are light exposed within the host cytoplasm, which is stretched out along the calcite spines. High photosynthetic activities have been measured (Jørgensen et al., 1985; Rink et al., 1998). As already pointed out by various authors (e.g., Parker, 1962), *O. universa* may, in fact, be a polyphyletic form. Yassini and Jones (1995) observed this species to inhabit the middle and outer shelf and the continental slope, often drifting into shallow areas, off the south-east coast of Australia. Using two high-resolution microanalysis techniques, Eiggs et al. (2004) showed that the final chamber of the planktic foraminifera *Orbulina universa* typically comprises between three and six paired, low and high Mg, growth bands. The number and spacing of these bands is consistent with a diurnal origin, modulated by changing pH within the foraminiferal microenvironment due to the day–night, photosynthesis–respiration cycle of algal symbionts. Köhler-Rink and Kühl (2005) measured pronounced variations in CO₂, O₂, and pH at the shell surface of *O. universa* during experimental light/dark cycles. In the light, symbiont photosynthesis rapidly increased the O₂ and pH concentrations and decreased the CO₂ concentration at the shell surface. When the light was switched off, the respiration of the association resulted in increasing CO₂ levels, and rapidly decreasing levels of O₂ and pH. The most striking oddity is a proportion of *O. universa*, which constitutes over 32% of the total Thukela Shelf assemblage. On a smaller scale, *O. universa* is substantially more abundant at sampling sites on the outer Thukela Shelf, away from fresh water influx. This agrees well with the ecological requirements of the species, which prefers cooler
temperatures and normal/elevated salinities, and again, may reflect the direct influence of the Agulhas Current (Ovechkina et al., 2010). According to Rebotim et al. (2010), surface to thermocline dwelling species like *G. ruber*, *G. siphonifera* and *O. universa* seem to reflect conditions of the upper ocean, without significant differences in the north and south of the Azores Front. According to Jonkers and Kučera (2015), such tropical and sub-tropical species as *O. universa* have relatively even flux patterns, with low prominence peaks occurring at any time of the year in their optimum high-temperature range (>25° C).

Repository: PK–AG–151

Family HASTIGERINIDAE Bolli, Loeblich and Tappan, 1957
Genus HASTIGERINA Thomson, 1876
*Hastigerina pelagica* (d’Orbigny, 1839)

Original citation: *Nonionina pelagica* D’ORBIGNY, 1839, v. 5, pt. 5, p. 27, pl. 3, figs. 13, 14.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 338, South Atlantic, at a depth of 1,990 fathoms (~3,639 m). This species was referred by Brady to *H. pelagica* (d’Orbigny), but according to Bolli, Loeblich and Tappan (1957, p. 29) these figures represent *H. murrayi* Thomson, and Barker (1960) referred it to the latter. Banner and Blow (1960) chose the same specimen as the neotype for *Hastigerina pelagica* and lectotype for *H. murrayi*, and thereby removed a cause of disagreement among workers and stabilized the nomenclature of this species. Cimerman and Langer (1991) quoted the same illustrations as those of *H. pelagica*, and the same nomenclature has been followed in the present study. Parker (1962) recorded this species from the bottom sediments of the Pacific Ocean and remarked, “Although this is a common and ubiquitous in the plankton, there are few specimens in the sediments, presumably because of their fragility”. Studies by Bé (1967), Hemleben (1969), and Walker and Vilks (1973) revealed that *H. pelagica* is characterized by spines that are constantly triradiate through their length. This southern sub-tropical species lives in large numbers in the Mozambique–Agulhas Current region and in the Gulf of Aden. It occurs widely in other tropical and sub-tropical regions of the Indian Ocean. *Hastigerina pelagica* is rarely found in the sediments due to the extreme susceptibility of its fragile tests to dissolution. It is found only in a narrow belt from Madagascar eastward and in scattered localities off south-western Australia in the Indian Ocean (Bé and Hutson, 1977). Relatively detailed ecological and life-history observations are available for the tropical, shallow-dwelling *Hastigerina pelagica* (e.g., Anderson and Bé, 1976; Spindler et al., 1979; Loncaric et al., 2005). This is the reason why no surface water *H. pelagica* specimens were reported by Field (2004) off Southern California by 28 depth-stratified plankton net tows across seasons from 2000 to 2002. *Hastigerina pelagica* has been demonstrated to be exclusively carnivorous based on similar feeding experiments and field observations (Anderson et al., 1979; Spindler et al., 1984; Anderson, 1996). Lončarić et al. (2005) hypothesized that the combined life-history characteristics of carnivory and lunar reproduction explain the relative consistent population abundance of *H. pelagica*, as compared to the highly seasonal abundances of other spinose planktic foraminifera. According to Weiner et al. (2012), only limited data exist so far on the genetic variability and phylogeography of the cosmopolitan and broadly vertically occurring *H. pelagica* despite its conspicuous appearance and abundance in the plankton.

Repository: PK–AG–152
Genus BOLIVINA d’Orbigny, 1839

*Bolivina alata* (Seguenza, 1862)

*Original citation:* *Valvulina alata* SEGUENZA, 1862, p. 115, pl. 2, figs. 5a, b.

*Remarks:* The species was described from the Pleistocene of Catania, Sicily, and most of its recorded occurrences as *Bolivina alata* are from the upper Tertiary and Recent sediments of the Mediterranean area. The figures provided by Barker (1960) are of Brady’s specimens obtained from the material dredged at Challenger Station 191, off the Arrou Islands, in the North Pacific at a depth of 800 fathoms (~1,463 m) and at Challenger Station 209, off the Philippines, in the Pacific Ocean at 95 to 100 fathoms (~174 to 183 m). Todd and Low (1967) obtained excellent specimens of *Bolivina alata* in abundance from a depth of 215 fathoms (~393 m) in the Clarence Strait; they did not, however, find it, even rarely, in any other sample studied. They stated that the material appeared fresh with well preserved spinose keel, and that the tops of early chambers were clearly visible through the perforate glassy wall. Hofker (1978) recorded this species at a water depth of 354 m in the Arafoera Sea, in the eastern part of the Indonesian Archipelago. *Bolivina alata* was also described in the Bay of Ajaccio (Corsica, France) as a species dominating the total foraminiferal (dead + living) faunas between 320 and 360 m depth in a canyon system (Bizon and Bizon, 1984). Bolli *et al.* (1994) stated, “*Bolivina alata* differs from *B. pseiformis* and *B. alazanensis* in possessing fewer chambers which are higher and appear slightly inflated. Further, the sharply keeled periphery shows in the basal portion of each chamber a spinose projection turned towards the initial part of the test”. Cameron (1995) recorded this species from bathyal depths of 775 m, 1,030 m and 1,280 m from the Kaikoura Peninsula; on the southern side of the peninsula, live *B. alata* specimens were observed on the shelf below 110 m. De Rijk *et al.* (1999) described high relative frequencies of *B. alata* in the thanatocoenoses from the Alboran Sea and off Algeria (western Mediterranean Sea) without any depth preference along the slope. As this species was (together with *Chilostomella* spp. and *Globobulimina* spp.) abundant in sediments characterized by high organic carbon concentration, they suggested that it would be favored by a high sedimentary carbon supply. Therefore, *B. alata* may be considered as a relevant bio-indicator of organic detritus-enriched sediments. In such settings, it may occupy dysoxic microhabitats as an intermediate infaunal species. Szarek (2001) recorded this species as *Euloxostomum alata* (Seguenza) from the Sunda Shelf in the south-western South China Sea and opined that it differed from *E. pseudobeyrichi* (Gushman) in being broader and having larger and better developed peripheral keel. Kaminski *et al.* (2002) recorded this species as *Brizalina alata* from gravity cores that penetrated Holocene marine sediments in the Marmara Sea, as did Chendeş *et al.* (2004). According to Fontanier *et al.* (2008), perforate taxa characterized by robust planispiral and trochospiral tests (*Hyalinea balthica, Melonis barleeanus, Valvulineria bradyana*) or by flattened tests (*Bolivina alata*) are well preserved and become, therefore, dominant taxa of the dead faunas. They also observed *Bolivina alata* is not found at the sediment-water interface but occupies intermediate infaunal microhabitats in the Bay of Fréjus. According to Sen Gupta *et al.* (2009c), *Bolivina alata* differs from *B. barbata* in having a wider carina which extends along the entire periphery of the final chamber and forms an apertural lip. Hayward *et al.* (2010) studied Recent deep water benthic foraminifera off New Zealand, and gave an outer shelf to lower bathyal (100 to 1,200 m) depth range for this species. It was observed by Mallon (2011) that most specimens of *B. alata*, found at water depths ranging between 207 and 679 m off Peru and Ecuador, were relatively small and had a serrate periphery.

*Repository:* PK–AG–153

*Bolivina oceozela* Vella, 1957

Pl. 7; Figs. 2, 2a

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Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Original citation: *Bolivina cacozela* VELLA, 1957, v. 28, p. 33, pl. 8, figs. 162, 163.

Remarks: Brook *et al.* (1981) studied soft bottom benthic faunal associations of Tutukaka Harbor, Northland, New Zealand, and recorded *B. cacozela* at a shallow water depth of 10 m on muddy and fine sandy substrate, associated with the bivalve genera *Gari*, *Myadora* and *Nucula*. Hayward (1993) observed *Bolivina cacozela* to be rare among the estuarine foraminifers of Helena Bay, Northland, New Zealand. The depth distribution of Recent deep-sea benthic foraminifera east of New Zealand was investigated by Hayward *et al.* (2001), who observed *Bolivina cacozela* to occur in a depth range of 100 to 1,240 m. Hayward *et al.* (2003) examined Recent benthic foraminifera from offshore Taranaki, New Zealand, and gave a wide water depth range of 6 to 850 m for this species. According to Hayward *et al.* (2010), *Bolivina cacozela* can be distinguished from *B. spathulata* by its less carinate periphery and less curved sutures. They observed that it is widespread in low to moderate numbers in sheltered inner shelf to mid bathyal depths (<1,000 m) with rarer occurrences at lower bathyal and abyssal depths. Its greatest relative abundances (5% to 15%) were recorded at mid shelf depths. Interestingly, all the records obtained for this species in this study are from off New Zealand, so it is quite possible that this is the first record of this species from Indian waters.

Repository: PK–AG–154

*Bolivina earlandi* Parr, 1950

Original citation: *Bolivina earlandi* PARR 1950, p. 339, pl. 12, figs. 16a–b.

Remarks: The figures reproduced by Barker (1960) are of specimens of *Bolivina earlandi* obtained from the material dredged at the Challenger Station 151, off Heard Island, in the South Pacific, at a depth of 75 fathoms (~137 m). Brady (1884) referred this species to *B. punctata* d’Orbigny, but Barker (*op cit.*) found no sign of the carinate periphery of *B. punctata* and opined that it probably represented *B. earlandi* Parr (1950, p. 339). According to Albani and Geyskes (1969), this species was rare on the north-western Australian continental shelf; they found very few specimens at two stations at water depths of 75 m and 90 m, respectively. Only two specimens were found by Hofker (1978) in the Moro Gulf at a water depth of 513 m in the eastern part of the Indonesian Archipelago, who mentioned the presence of a “distinct toothplate which is sigmoid at its folded back, with a smooth border of its folded part”. Parr (1950), however, denied the presence of this toothplate, though Chapman and Parr (1937, p. 92) did mention it. Lena (1980) recorded this species as *Virgulina earlandi* (Parr) off the Antarctic Peninsula and observed it to be the second most dominant among the calcareous species, with a sample distribution of 41%. In her study on the microhabitat preferences of benthic foraminifera in South Atlantic Ocean sediments, Schumacher (2001) recorded this species as *Fursenkoina earlandi* (Parr). Szarek (2001) studied the biodiversity and biogeography of Recent benthic foraminiferal assemblages in the south-western South China Sea and gave an inner shelf to upper bathyal water depth range for this species on the Sunda Shelf. According to Sen Gupta *et al.* (2009b), *Bolivina earlandi* has a bathyal and/abyssal habitat in the Gulf of Mexico where it occurs in a water depth range of 692 to 2,238 m in the north-western part of the gulf. Hayward *et al.* (2010) stated that this species occurs scattered off south-east New Zealand (43° to 53° S) at inner shelf to lower bathyal depths of 0 to 2,000 m.

Repository: PK–AG–155

*Bolivina aff. B. hamedii* Yassini and Jones, 1995

Original citation: *Bolivina hamedii* YASSINI and JONES, p. 130, figs. 533, 534.
Remarks: Only one specimen was recovered from the shorter core retrieved from a water depth of 2,004 m in the study area, and it resembles the holotype figured by Yassini and Jones (1995, fig. 533) in shape and spathulate appearance, but differs in the ornamentation. Typical *Bolivina hamedii* Yassini and Jones possesses ornamentation in the form of anastomosing costae and is coarsely perforate; the specimen in my material is ornamented with lobate tubules in the last few chambers on both sides, and the perforations are not visible. It has, therefore, been reported as *Bolivina aff. B. hamedii*.

Repository: PK–AG–156

*Bolivina robusta* Brady, 1881

Original citation: *Bolivina robusta* BRADY, 1881, v. 21, p. 27; 1884, v. 9, p. 421, pl. 53, figs. 7–9.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 191A, off the Ki Islands, in the central Pacific Ocean, at a depth of 580 fathoms (~1,061 m), and at Challenger Station 174B, off Fiji, Pacific Ocean, at a depth of 610 fathoms (~1,116 m). Bagg (1912) reported the occurrence of two specimens of *Bolivina robusta* from the Pliocene of San Pedro, and stated that although this species, so well described by Brady, had been recognized off Norway at shallow depths and in various oceans from the shore line down to 1,900 fathoms (~3,475 m), it had not been recorded as fossil prior to his finding. While reporting this species from the Byram calcareous marl, Cushman (1920) remarked, “There is probably more than one form or variety of this species in recent seas. In spite of other records the typical form of the species occurs mainly in the Indo-Pacific region”. Chapman and Parr (1937) found a solitary specimen in Tasmanian waters and stated that although it was typical in form, the surface was ornamented with some exogenous beading. They remarked, “It is a well known species in the Southern Hemisphere, where it is most characteristic, but is also distributed as far north as Bergen, Norway”. This species was found to be very frequent in the Recent fauna of the Skagerrak, especially at depths between 300 and 500 m (Höglund, 1947). In the Gullmarfjord, with depths not exceeding 120 m, he obtained only one single specimen, indicating its preference for greater water depth. Cushman et al. (1954) recorded typical specimens of this species with distinctive crenulated sutures from the Bikini and Eniwetok atolls of the Marshall Islands, but stated that their specimens did not possess the basal spine. Although Brady described this species from generally less than 1,500 m, Smith (1973) reported one stained specimen of *Bolivina robusta* at a water depth of 5,500 m in a core retrieved from the North Pacific Ocean. Hofker (1978) recorded its occurrence in the Moro Gulf at 513 m, south-west of Pisang Islands at 216 m, north-west point Flores at 857 m, and between Sermata and Babar at 1,625 m in the eastern part of the Indonesian Archipelago. *Bolivina robusta* is tolerant to low-oxygen conditions (Linsley et al., 1985; Miao and Thunell, 1996) and seasonally oxygen-deficient bottom conditions in the glacial southern South China Sea result in its high relative abundance. Tests with flattened, elongated shapes containing abundant pores, such as those of *Bolivina robusta* are associated with infaunal lifestyles and environments characterized by high organic carbon flux (Corliss and Chen, 1988; Corliss and Fois, 1990; Rosoff and Corliss, 1992; Jorissen et al., 1995; Jorissen, 1999; Loubère and Fariduddin, 1999), and/or dysoxic to anoxic conditions on the seafloor or within the seafloor sediments (Kaiho, 1994, 1999; Bernhard and Sen Gupta, 1999). Yassini and Jones (1995) observed this species to occur in inlet channels of coastal lagoons, open estuaries, sheltered oceanic embayments, inner and middle shelf, off the south-east coast of Australia. Szatek (2001) studied the biodiversity and biogeography of Recent benthic foraminiferal assemblages in the south-western South China Sea and gave an outer shelf to middle bathyal water depth range for this species on the Sunda Shelf. According to Hayward et al. (2003), *B. robusta* has a relative abundance of >5% in the New Zealand region in a water depth
range of 300 to 750 m, but east of New Zealand, it occurs in higher numbers at 200 to 650 m (Hayward et al., 2001), with an overall wide water depth range of 18 to 1,545 m. The distribution of B. robusta is limited to intermediate depths (700–2,000 m) and to environments with low dissolved-oxygen concentrations (Murgese, 2003) and a more stratified water column (Murgese and De Deckker, 2007). A few macroscopic specimens of this species were observed by Debenay (2012) on the northern shelf, off New Caledonia, at a water depth of 600 m.

Repository: PK–AG–157

*Bolivina spathulata* (Williamson, 1858)

**Original citation:** *Textularia variabilis* WILLIAMSON var. *spathulata* WILLIAMSON, 1858, v. 76, pl. 6, figs. 164, 165.

**Remarks:** The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Porcupine Station 18, west of Ireland, in the East Atlantic, at a depth of 183 fathoms (~335 m). Brady referred this species to *B. dilatata* Reuss, but Cushman (1937) referred it to *B. spathulata* (Williamson). In the Adriatic Sea, Barmawidjaja et al. (1992) observed some taxa such as *Bolivina spathulata* to occur near the sediment surface in some months (October and December) and at deep infaunal positions in months that were characterized by improved bottom and pore-water oxygenation (February). *Bolivina spathulata* is indicative of high and continuous flux of organic matter to the sea floor (Gupta and Thomas, 1999), an oxygen- and high organic carbon bottom water environment with deep Oxygen Minimum Zone (OMZ) during intense upwelling (Gupta, 1997), extremely stagnant bottom waters (Katz and Thunell, 1984; Van der Zwaan and Gudjonsson, 1986), and relatively large nutrient availability (Drinia et al., 2004). This species is also tolerant to elevated salinity and can adapt itself to different water depths, depending on prevailing environmental conditions, but is most common in upper bathyal environments (Kouwenhoven et al., 2006). *Bolivina spathulata* prefers a shallow to intermediate infaunal microhabitat (e.g., Corliss, 1991; Barmawidjaja et al., 1992; De Stigter et al., 1998). In the modern Mediterranean Sea, *B. spathulata* is part of a species group that commonly occurs in a wide range of mesotrophic to eutrophic settings (e.g., Barmawidjaja et al., 1992; Jorissen et al., 1995; De Stigter et al., 1998; De Rijk et al., 2000; Schmiedl et al., 2000; Mojtahid et al., 2009). Fontanier et al. (2008) observed high abundances of *Bolivina spathulata* and *Bolivina dilatata* in the 63- to 150-mm size fraction of the first centimeter of sediment in the Saint-Tropez Canyon, Bay of Fréjus, reflected a state of ecologic equilibrium present in a passive canyon environment. Both these taxa have been documented as living preferentially in organic-matter enriched sediment from outer-shelf environments under the influence of riverine discharge (Langezaal et al., 2006; Duchemin et al., 2007). According to Sen Gupta et al. (2009b), *B. spathulata* is a cosmopolitan species (Murray, 1991) that is present in a water depth range of 4 to 110 m in the north-eastern and south-eastern parts of the Gulf of Mexico, and is an indicator of dyoxic conditions (Kaminski, 2012). This species is present in moderate to low numbers (up to 5% of foraminifera) at inner shelf to upper bathyal depths (0 to 600 m) around New Zealand, with a few deeper records probably being displaced (Hayward et al., 2010). In the Bay of Prony, New Caledonia, south-western Pacific Ocean, Debenay (2012) observed *Bolivina spathulata* in shallow waters in a depth range of 20 to 40 m.

Repository: PK–AG–158

*Bolivina subaenariensis* Cushman, 1922

**Original citation:** *Bolivina subaenariensis* CUSHMAN, 1922, pt. 3, p. 46, pl. 7, fig. 6.
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Remarks: The types of this species came from near Nantucket off the north-east shore of North America. Cushman (1922) stated that B. subaenariensis var. Mexicana differed from B. subaenariensis in possessing greater number of costae that run nearly to the apertural end of the test, and in the test being more abruptly tapering. Sen Gupta et al. (2009c), however, opined that this difference is rather gradational, and within the natural range of variability for the species and, therefore, they rejected the varietal name. Bolivina subaenariensis differs from B. bastata in its larger size and more distinct keel and costae. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Porcupine Station 17, west of Ireland, in the North Atlantic at a depth of 1,230 fathoms (~2,249 m), and at Porcupine Station 11, west of Ireland, also in the North Atlantic at 1,630 fathoms (~2,981 m). This species was referred by Brady to B. aenariensis (Costa) and by Cushman (1937, p. 156) to a variety of B. subaenariensis Cushman. Sen Gupta et al. (1981) found a small area on the continental slope off Daytona Beach, Florida, where the substrate had high clay-silt, organic carbon and hydrocarbon content, as a consequence of periodic upwelling. In this area, Bolivina subaenariensis, which is generally rare in the western North Atlantic, is a major component of the benthic foraminiferal assemblage, and could be considered as an opportunistic taxon. It is a nitrogen-storing species and is opportunistic with respect to oxygen and may be found in both oxic and oxygen-free environments (e.g., Fontanier et al., 2002; Fontanier, 2003; Hess and Jorissen, 2009). Langezaal et al. (2006) observed a clear seasonal pattern for the dominant species B. subaenariensis, on the outer shelf of the Bay of Biscay. In the >150 µm fraction, this species showed a strong correlation to spring, suggesting that the species has a reproductive response to the arrival of important amounts of phyto-detritus in spring, quickly followed by a period of accelerated growth. This means that B. subaenariensis is an opportunistic species that remains small for a large part of the year, but exhibits a strong response to the input of organic matter in spring. In some active canyon areas where gravity–flows are common, living foraminiferal faunas are mainly composed of early colonizing and opportunistic foraminiferal taxa like Bolivina subaenariensis (Hess et al., 2005; Koho et al., 2007). According to Sen Gupta et al. (2009b), this species is distributed all over the Gulf of Mexico in a very wide water depth range of 2 to 3,292 m; it has been recorded from the Caribbean Sea, Atlantic and Pacific oceans. Foraminifera from the Bay of Biscay were sampled by Geslin et al. (2011) at about 450 m depth in the axis of Cape Breton Canyon. At this station, the sediment consists of silty mud with abundant plant debris and micas (Hess and Jorissen, 2009). The oxygen penetration depth is 5 mm. The exceptionally rich fauna is strongly dominated by Bolivina subaenariensis. Although this species shows a maximum density in the uppermost sediment layer (~3,400 individuals per 72 cm² in the first half cm layer), numerous specimens are found deeper in the sediment in anoxic conditions. According to Piña-Ochoa et al. (2010), B. subaenariensis is a facultative anaerobe with the ability to respire nitrate. Mallon (2011) observed it to be very rare and found it at only one station off Ecuador at 350 m water depth, and remarked, “This species differs from the very similar B. argentea (Cushman) by having somewhat lower chambers and four distinct longitudinal costae whereas B. argentea has just two distinct longitudinal costae at the median part of the test which do not reach the last chambers”.

Repository: PK–AG–159

Genus PSEUDOBRIZALINA Zweig-Strykowski and Reiss, 1976

Pseudobrizalina lobata (Brady, 1881)

Original citation: Bolivina lobata BRADY, 1881, v. 21, p. 58; 1884, v.9, p. 425, pl. 53, figs. 22, 23.

Remarks: The types for this species came from the Admiralty Islands (Brady, 1881). He described this species as, “Test elongate, depressed, digitate; superior extremity obliquely truncate or rounded, inferior obtuse. Segments inflated, especially the later ones, their peripheral margins
sub-angular. Surface of the later chambers more or less granulated. Sutures thickened, deeply sunk. Aperture a long oval slit contracted at the middle; nearly central. Saidova (1975) recorded its occurrence in the equatorial Pacific Ocean at depths between 25 and 284 m. Reiss and Hottinger (1984) noted *S. lobata* to be an exclusively "shallow-water" species in the Gulf of Aqaba. Haig (1993) reported it from the inner neritic sand and mud facies of the Papuan Lagoon, New Guinea, and observed it to have a broad distribution in both the facies throughout the full bathymetric range of the lagoon. He remarked, “The geographic occurrence of *S. lobata* is interesting because Graham and Militante (1959) did not record it among the Mindoro material; and Blakeway (unpublished University of Western Australia thesis, supervised by D. W. Haig) did not recover the species from Coral Bay on the central western Australian coast where many of the other species listed above occur”. Hottinger et al. (1993) recorded this species from the Gulf of Aqaba, Red Sea, as *Sagrillina lobata* (Brady) *lobata* (Brady), and placed specimens similar to it but with polygonal ridges and pseudospines on the chamber shoulders from early stages on in *Sagrillina lobata* sub. sp. A. However, Revets (1996) recognized the genus *Pseudobrizalina* as distinct from *Sagrillina* on the basis of the important differences in apertural and toothplate morphology, and opined that the differences between *S. jugosa* (= *S. guinae*) and *P. lobata* were sufficient to classify them in different sub-families. Hayward et al. (2010) observed that most occurrences of *Pseudobrizalina lobata* were at mid bathyal depths (500 to 1,000 m) with two rare deeper records in the south, which they opined that they may have been displaced. Mallon (2011) observed this species to be rare off Peru and Ecuador and recorded specimens at 115, 207, 1,923 and 2,092 m water depths, while Debenay (2012) recorded this species at shallow depths of 20 m in the south-western lagoon, New Caledonia, in the south-western Pacific Ocean.

**Repository:** PK–AG–160

Superfamily BOLIVINITACEA Cushman, 1927

Family BOLIVINITIDAE Cushman, 1927

Genus ABDITODENTRIX Patterson, 1985

*A. pseudothalmanni* (Bolovskoy and Guissani de Kahn, 1981)

Pl. 7; Fig. 3

**Original citation:** Bolivina *pseudothalmanni* BOLTOVSKOY and GUISSANI De KHAN, 1981, p. 44.

**Remarks:** In their studies on the distribution, biomass and diversity of benthic foraminifera in relation to sediment geochemistry in the Arabian Sea, Kurjewit et al. (2000) recorded this species as Bolivinita *pseudothalmanni*. Hayward et al. (2001) never recorded this species at water depths <90 m around New Zealand, and stated that it has a depth range of 500 to 2,800 m (middle to lower bathyal) with a relative abundance of >10%, but could be observed up to 4,680 m. In modern sediments in the region, *A. pseudothalmanni* is most abundant at depths of 600–3,000 m with lowered oxygen concentrations. It is probably an infaunal opportunist, like the morphologically similar genus *Bolivina*, which flourishes in areas of high food supply and lowered bottom oxygen (Lutze and Coulbourn, 1984; Thomas and Gooday, 1996). Greatly increased relative abundance of the infaunal *A. pseudothalmanni*, together with the decreased abundance of epifaunal trochospiral forms, suggests increased total organic carbon flux and decreased oxygen (Bernhard and Sen Gupta, 1999; Berger et al., 2002). Peak abundances of *A. pseudothalmanni* occur in mid-lower bathyal association, and may be linked to the decreasing oxygen content within the bottom waters as the oxygen minimum zone (OMZ) is approached (Hayward et al., 2006). According to Hayward et al. (2005), mid-Pleistocene faunas exhibited strong glacial-interglacial fluctuations, inferred to be due to higher interglacial nutrient supply and lower oxygen levels, south of the sub-tropical front, beneath Sub-Antarctic Surface Water in the south-west Pacific,
east of New Zealand. The most dramatic faunal change in the south occurred at the end of the mid-Pleistocene transition (MPT) (MIS 15–12), with an acme of *Abditodentrix pseudothalmanni*, possibly reflecting higher carbon flux and lowered bottom oxygen. According to Sen Gupta et al. (2009c), *Abditodentrix* differs from *Bolivinita* in its surface ornamentation. This ornamentation along with the truncate margin distinguishes it from *Bolivina*. *Latibolivina* displays a similar network of reticulations, but it lacks the truncate margin of *Abditodentrix*. Around New Zealand, Hayward et al. (2010) observed this cosmopolitan species to be infaunal with a dominant water depth range of 500 to 3,000 m, but never present at <50 m. They stated that it could be distinguished from species of *Bolivina* by its rectangular cross-section and from *Bolivinita* by its reticulate ornament. Debenay (2012) recorded *Abditodentrix pseudothalmanni* from the northern shelf, off New Caledonia, in the south-western Pacific Ocean, at a depth of 600 m.

Repository: PK–AG–161

Genus BOLIVINITA Cushman, 1927

*Bolivinita quadrilatera* (Schwager, 1866)

Pl. 7; Figs. 4, 4a

Original citation: *Textularia quadrilatera* SCHWAGER, 1866, v. 2, no. 2, p. 253, pl. 7, fig. 103.

Remarks: The types for this species came from the Pliocene of Kar Nicobar in the Indian Ocean. Flint (1899) obtained a few specimens from near Aspinwall in the Isthmus of Panama, at a water depth of 896 fathoms (~1,639 m) and reported it as *Textularia quadrilatera* Schwager. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 164A, off Sydney, Australia, at a depth of 410 fathoms (~750 m), and at Challenger Station 279C, off Tahiti, in the Pacific Ocean, at 620 fathoms (~1,134 m). *Bolivinita quadrilatera* was referred by Brady to *Textularia*, while Cushman (1927, p. 90) referred it to *Bolivinita* as the genotype. Cushman et al. (1954) recorded a few specimens, some as long as 1.15 mm, in three deep-water samples from the Bikini Atoll in the Marshall Islands. This species was reported as *Bolivina quadrilatera* by Hofker (1978) at water depths ranging from 513 to 1,470 m in the eastern part of the Indonesian Archipelago. Yassini and Jones (1995) observed this warm water indicator species (Hanagata and Watanabe, 2001; Hanagata, 2003) to be distributed on the outer shelf and continental slope, off the south-east coast of Australia. According to Revets (1996), the specimens described by him were different from the majority of Recent specimens usually identified as *B. quadrilatera*, as the toothplate anatomy of *B. quadrilatera* as observed in totopotypes was quite different from most of the Recent specimens. He felt, therefore, that the latter may actually belong to *B. pliozea* Finlay, 1939a, known to range into the Recent, thereby implying that the stratigraphic distribution of *B. quadrilatera* is very likely more restricted than hitherto assumed. In the South Australian Margin, *B. quadrilatera* prefers a shallow infaunal habitat, consistent with the pattern observed for this species by Fontanier et al. (2003) in the Bay of Biscay and by Heinz et al. (2005) in methane seeps in the north-east Pacific. Some species, such as *B. quadrilatera*, have significantly deeper upper depth limits in the west off New Zealand (Hayward et al., 2003), and attributed the differences in upper depth limits, at least in part, to the differences in primary productivity and consequently food supply to the seafloor. They gave a water depth range of 498 to 1,825 m for this species. For example, its upper depth limits are 400 m, 250 m, 500 m and 1,750 m off north-east, east central, west and sub-Antarctic New Zealand, respectively (Hayward et al., 2010), with an overall range of upper bathyal to upper abyssal (400 to 3,000 m). Basak et al. (2009) observed that abundance distributions of *B. quadrilatera* differed at the two sampled water depths along the Australian Margin. At a water depth of 2,476 m, *B. quadrilatera* was most abundant at the 0–1 cm sediment interval (18 ind./50 cm³) and abundances declined sharply down core to 2 cm. At 1,634 m water depth, however, it displayed an abundance...
maximum at the surface and at 2–2.5 cm (9 ind./50 cm³). According to Sen Gupta et al. (2009b), this cosmopolitan species has a bathyal and abyssal habitat in the north-eastern part of the Gulf of Mexico, where it occurs at a water depth of 2,092 m.

Repository: PK–AG–162

Superfamily CASSIDULINACEA d’Orbigny, 1839
Family CASSIDULINIDAE d’Orbigny, 1839
Subfamily CASSIDULININAE d’Orbigny, 1839
Genus CASSIDULINA d’Orbigny, 1826
*Cassidulina carinata* Silvestri, 1896

**Original citation:** *Cassidulina laevigata* var. *carinata* SILVESTRI, 1896, p. 104, pl. 2, figs. 10a–c.

**Remarks:** According to Phleger et al. (1953), *Cassidulina carinata* Silvestri has a broader apertural face and tooth and a less compressed test than *C. neocarinata* Thalmann and is more coarsely perforate. They also pointed out that neither the aperture nor the apertural face of *C. carinata* resembles that of *C. laevigata* d’Orbigny, the type specimen of which has a more rounded apertural face and a small aperture. Pfum (1966) observed that the Antarctic specimens, obtained in a water depth range of 210 to 1,134 m, had distinct chambers but did not have the large keel Silvestri’s figures show, but otherwise were closely similar to Silvestri's and Brady's figures. *Cassidulina carinata* was observed to be among the twelve most abundant species in the Taiwawe Bay, Northland, New Zealand, at very shallow depths ranging from 1 to 1.5 m, with a persistence of 0.90 (Reid and Hayward, 1997). This species has a deep infaunal microhabitat (Corliss, 1985; Jorissen et al., 1998), and is often considered as a low oxygen marker (Kaiho, 1991, 1994; Jorissen, 1999). Hayward et al. (1994) recorded *Cassidulina carinata* in a sub-association inside Port Pegasus, Stewart Island, New Zealand, in relatively deep, quieter bottom conditions with fine to very fine sandy substrates in a depth range of 21 to 40 m. In the Mediterranean Sea, both *B. marginata* f. *aculeata* and *C. carinata* require relatively ‘eutrophic’ conditions of >3 g of labile carbon m⁻² y⁻¹ to flourish (De Rijk et al., 2000). The latter can display the behavior of ‘pioneering’ species which can initially colonize a barren substrate in large numbers (Kaminski et al., 2002). According to Morigi et al. (2001), samples above 1,000 m water depth were usually dominated by *C. carinata* or *Bulimina marginata*. In fact, between 500 and 1,000 m, *C. carinata* was dominant in the southern part of their study area, off north-west Africa. They observed it to be dominant in the shallowest area south of 20°N, where the organic flux was very elevated (8 g/m²/year), and bottom water oxygen concentrations fell below 3 mL/L. East of New Zealand, the outershelf–bathyal associations (90–1,250 m), dominated by *Cassidulina carinata* and *Trifarina angulosa*, occur within coarse substrates under well-oxygenated, relatively high energy regimes and sustained food input. The occurrence of the bathyal–upper abyssal associations (230–2,840 m), again dominated by *C. carinata* closely mirrors the distribution of Antarctic Intermediate Water within a region of variable food supply (Hayward et al., 2005; Hayward et al., 2006). Murray (2006) listed *Cassidulina carinata* as one of the species that regularly appears as dominant or subsidiary (>10%) in the Atlantic Ocean. According to Sen Gupta et al. (2009b), this cosmopolitan species is distributed all over the Gulf of Mexico in a wide water depth range of 21 to 3,237 m. In the north-western part of the Indian Ocean (Arabian Sea region), surface primary production has a major maximum during the summer monsoon season and a secondary maximum during winter monsoon season. This results in high organic flux to the seafloor, making the deep-sea one of the most oxygen-deficient regions in the world ocean, with a pronounced OMZ. This region is dominated by benthic foraminifera characteristic of low oxygen and high organic food flux, intermediate to high organic carbon, and warm deep water, such as *Cassidulina carinata* (De and Gupta, 2010; Kaminski, 2012). According to Geslin et al. (2011), *C. carinata* showed a marked preference for the
superficial layer at a sampling site in the Rhône Delta, where the sediment was oxic till 5 mm depth; Pérez-Asensio et al. (2012) also corroborated the shallow infaunal nature of this species. According to Mancin et al. (2013), abundance of this species indicates moderately high and pulsing food supply fluxes, moderately high oxygen content, and mostly terrigenous mud to mixed substrate; Cassidulina carinata can tolerate intermediate to slightly dysoxic conditions, and reflects the presence of typically of strong bottom water currents.

Repository: PK–AG–163

Cassidulina teretis Tappan, 1951


Remarks: Green (1960) studied foraminifers (>63 µm) collected at water depths ranging between 433 and 2,760 m from the continental slope of Ellesmere Island and the Alpha Ridge, and observed that the shelf assemblage was characterized by Cassidulina teretis. In the Alaskan region, Todd and Low (1968) observed Cassidulina teretis in both seafloor and fjordland samples, but never abundantly. They opined that morphologically the species was transitional between C. tortuosa and C. norcrossi. In a study on foraminifera from the Magdalen Shallows in the Gulf of St. Lawrence, Vilks (1968) recorded this species as Islandiella teretis (Tappan) mainly in the central and western parts of the area. It is to be noted that the range of depth over the central part of the Magdalen Shallows was between 40 and 90 m, and within the cold intermediate water layer with small seasonal variations in temperature. Smith (1973) examined the distribution of foraminifera in the North Pacific Ocean and recorded the presence of Cassidulina teretis on the Aleutian Terrace, but not in the Aleutian Trench or Deep-sea plain. Analysis of Recent foraminiferal distribution patterns for the Amerasian Basin and the adjacent continental shelves by Lagoe (1979) revealed three major biofacies, one of them being the Cassidulina teretis biofacies in a water depth ranging between 350 and 900 m, with the water mass properties appearing to play the dominant role in controlling their distribution. According to Cole (1981), who studied benthic foraminifers from off north-east Newfoundland, this is the common Cassidulina species on the slope, ranging in depth from 506 to 3,210 m, and found mostly between 506 and 2,000 m. In the Barents and Kara seas, C. teretis occurs almost exclusively in Bear Island, Franz Victoria, and St. Anna troughs, all areas with Atlantic Water in the sub-surface (e.g., Todd and Low, 1980; Polyaik, 1985; Mackensen and Hald, 1988; Steinsund, 1994). Osterman et al. (1999) identified an intermediate-depth calcareous biofacies between 500 and 1,100 m water depth in the surface sediments of the Arctic Ocean, which contained abundant Cassidulina teretis, presumably indicating the influence of Atlantic-derived water at this depth. This species constituted >20% of the benthic foraminiferal population in the Northwind Ridge samples, while it was more abundant (30–80%) on the Chukchi Plateau, Mendeleev and Lomonosov Ridges. According to Lubinski et al. (2001), C. teretis does not occur in areas where Atlantic Water has been strongly mixed with shelf waters such as in the north-eastern Barents Sea. The distribution of C. teretis in the troughs probably reflects a combination of environmental factors associated with Fram Strait Branch Water (FSBW) including its relatively high phytodetrital deposition, temperature, and salinity. In the Laptev Sea, Lukina (2001) observed this species to occur in a water depth range of 77 to 984 m. Gupta et al. (2003) demonstrated a pattern of persistent variability in the monsoon throughout the Holocene that may be linked with episodic warming/cooling of the North Atlantic by correlating the monsoon record with the Medieval Warm Period along the east Greenland margin as indicated by increased abundance of Cassidulina teretis. According to Bartoli et al. (2005), this species is capable of adapting itself to low nutrient availability, harsher over-all conditions, and perhaps to higher seasonality. Some workers have also reported this species as Cassidulina neoeteretis (e.g., Eberwein, 2006). Margreth (2010) listed this species as C. teretis among
the benthic foraminifers she identified in association with the cold water coral reef ecosystems along the Norwegian margin.

**Repository**: PK–AG–164

Genus **CASSIDULINOIDES** Cushman, 1927  
*Cassidulinoides parkerianus* (Brady, 1881)

**Original citation**: *Cassidulina parkeriana* BRADY, 1881, v. 21, p. 59; 1884, v. 9, p. 432, pl. 54, figs. 11–16.  
**Remarks**: The figures provided by Barker (1960) are of Brady’s specimens obtained from material dredged at Challenger Station 308, west of Patagonia, in the East Pacific Ocean at a depth of 175 fathoms (~320 m), at Challenger Station 305, off the west coast of Patagonia at 120 fathoms (~220 m), at Challenger Station 304, in the Gulf of Penas, Patagonia, East Pacific, at 45 fathoms (~82 m), and at Challenger Station 306, also in the Gulf of Penas, at 345 fathoms (~631 m). This species was referred by Brady (1884) to *Cassidulina* but Thalmann (1932, p. 302) referred it to *Cassidulinoaides*. In the bottom samples in the vicinity of Adelaide, Anvers, and Brabant Islands near the Antarctic Peninsula, Lena (1980) observed *Cassidulinoaides parkerianus* to be the most dominant calcareous species, constituting 7% of the benthic foraminiferal content. According to Leckie and Webb (1990), *C. parkerianus* can be distinguished from *C. bradyi* (Norman) by the slightly more inflated chambers in the former. Gaździcki and Majewski (2003) recorded *Cassidulinoides parkerianus* at all the three stations sampled at Goulden Cove (fjord-like Admiralty Bay), King George Island, West Antarctica, at water depths of 20 m, 35 m and 75 m. In the shallowest parts of the upper Antarctic shelf near the continent, at depths up to 50 m, the fauna is significantly less rich and is usually represented by only 7 to 12 species, one of which is *C. parkerianus* (Mikhalevich, 2004). She stated that its distribution appeared to be circum-Antarctic due to the water temperature uniformity of this harsh area, with the lowest water temperatures (~1°C to ~1.9°C) in the circum-Antarctic current (Antarctic Coastal Current–ACC), and also, perhaps, due to the long period of isolation from other shelf faunas. She considered this species to be Antarctic or Antarctic/sub-Antarctic endemic. According to Rodrigues et al. (2006), a decrease in temperature in 2003/2004 compared to 2002/2003 and a corresponding increase in the silt content of the bottom sediment of the Admiralty Bay favored the abundance of *C. parkerianus* and a few other species. It is now quite well established that the presence of this species indicates the influence of cold water (Concheyro et al., 2007). This species has a bathyal and/or abyssal habitat in the Gulf of Mexico where it is distributed in a water depth range of 745 to 2,975 m in the north-eastern and north-western parts of the gulf (Sen Gupta et al., 2009b). Rodrigues et al. (2010) observed *Cassidulinoaides parkerianus* to be abundant in muddy substrates, particularly between Dufayel Island and the western coves in the Ezcurra Inlet, King George Island, Antarctica, a restricted area located near glaciers with a depth range of 30–55 m.  
**Repository**: PK–AG–165

Genus **EVOLVOCASSIDULINA** Eade, 1967  
*Evolvocassidulina bradyi* (Norman, 1881)

**Pl. 7; Figs. 5, 5a**

**Original citation**: *Cassidulina bradyi* NORMAN, In: Brady, 1881, p. 59; Brady, 1884, pl. 54, figs. 6–9 (not figs. 10a, b).  
**Remarks**: The figures 6–9 reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at Porcupine Station 35, south of Ireland, in the Atlantic Ocean, who (1884) assigned them to *Cassidulina* but to Cushman (1930, p. 58) transferred them to *Cassidulinoides*.  

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Figure 10 (specimen collected from Challenger Station 305, west of Patagonia, in the East Pacific, at a depth of \(~220\) m) was also referred by Brady to \(C.\ bradyi\), but Cushman (1925, p. 37) transferred it to \(Cassidulinoides\), Barker (1960), however, preferred to place it under \(Cassidulinoides orientale\) (Cushman). According to Leckie and Webb (1990), \(Evolvocassidulina\) \(bradyi\) (Norman) can be distinguished from \(Cassidulinoides\) \(parkerianus\) (Brady) by the slightly less inflated chambers in the former. Popescu and Crihan (2005) examined middle Miocene foraminifers from Romania and recorded this species as \(Cassilongina\) \(bradyi\) (Norman, 1922). Kuhnt \(et\ al\). (2007) recorded this shallow infaunal species (e.g., De Stigter \(et\ al\)., 1998; Schmiedl \(et\ al\)., 2000; Licari \(et\ al\)., 2003) that is well adapted to suboxic and occasional anoxic conditions (Sen Gupta and Machain-Castillo, 1993; Bernard and Sen Gupta, 1999) as \(Cassidulinoides\) \(bradyi\). According to Hayward \(et\ al\). (2001), \(Evolvocassidulina\) \(bradyi\) inhabits the outer shelf to lower bathyal depths (100–2,000 m), off New Zealand, but they stated that the one deeper record was possibly displaced.

Repository: PK–AG–166

Genus GLOBOCASSIDULINA Voloshinova, 1960

\[Globocassidulina\ crassa\] (d'Orbigny, 1839)

Pl. 7; Fig. 6

Original citation: \(Cassidulina\ crassa\) D'ORBIGNY, 1839, p. 56, pl. 7, figs. 18–20.

Remarks: The types for this species came from Falkland Islands and off Cape Horn. Brady (1884) illustrated that the test shape in \(Globocassidulina\ crassa\) ranges from sub-globular (usually the smaller forms) to slightly compressed (larger forms), which may be an expression of ontogeny and generation. Holland (1910) recognized this species as the dominant form (83%) in the material supplied to him from a Swedish South Polar Expedition sample (SPE-12). \(Cassidulina\ crassa\), as it was recorded by Pearcey (1914), was observed to be common at a station where the water depth was 56 fathoms (~102 m); he stated that its “distribution is world-wide, from 83° 11' N to as far south as the Antarctic Continent, ranging in depth from comparatively shallow water to the deepest water in mid-ocean”. According to Chapman and Parr (1937), who recorded this species as \(Cassidulina\ crassa\), it was surprisingly rare in the \(Aurora\) dredgings, but in those of the \(Terra Nova\), it was almost universally distributed, increasing in size and abundance towards south. Parker (1958) gave a lower depth limit of 1,000 to 1,300 m for \(Cassidulina\ crassa\) and \(C.\ subglobosa\) in the eastern Mediterranean, but Cita and Zocchi (1978) opined that this should not, perhaps, be extrapolated to the Western Mediterranean bioprovince, where they occur in shallower waters. Recent faunas with low diversity and dominance of \(C.\ crassa\) and \(Elphidiu\) \(excavatum\) were reported from localities near calving glaciers in the fjords of Spitsbergen (Feyling-Hanssen, 1964; Nagy, 1965; Elverhøi \(et\ al\)., 1980). Ward (1984) recorded the presence of \(Globocassidulina\ crassa\) in the shallow water and harbour/enclosed bay assemblages but not in the deep, open water assemblage in McMurdo Sound, Antarctica, and stated that the composition of the assemblages was controlled largely by the calcium carbonate compensation depth (CCD). In the Sicily Channel, as well as in the Thyrrenian Sea, Parisi (1981) reported this species as abundant at about 1,060 m (Sgarrella and Moncharmont Zei, 1993). \(Cassidulina\ crassa\) constituted 84% of the fauna in their split of SPE 12 and was also a dominant form in four samples of the eight Pliocene \(Pecten\) Conglomerate samples examined by Gądzicki and Webb (1996) from Cockburn Island in the Antarctic Peninsula. They also observed that the tests were large and preservation ranged from good to decorticated, and stated that it is a common species in many polar and deep water assemblages. Bornmalm (1997) opined that \(Cassidulina\ crassa\) differs from \(C.\ minuta\) in having a less compressed test, and in the aperture being less elongate than in the latter. According to Hayward \(et\ al\). (2001), who presented the depth distribution ranges of Recent deep-sea benthic foraminifera east of New Zealand, \(Globocassidulina\ crassa\) occurs as deep as 3,170 m. In
the Mediterranean Sea, the distribution of \textit{C. crassa} is associated with oligotrophic and well ventilated conditions (De Rijk \textit{et al.}, 2000), with enhanced flux rates of organic matter (Kuhnt \textit{et al.}, 2007). Suhr and Pond (2006) found evidence from fatty acid analysis for selective feeding on high quality phytodetritus by \textit{Cassidulina crassa} from 55-m water depth in Arthur Harbour, Anvers Island, Antarctica. According to Carson \textit{et al.} (2008), \textit{Globocassidulina crassa} has considerable range in size, and can be distinguished from \textit{G. subglobosa} by its more flatted periphery and slit-like aperture. This species, reported as \textit{C. crassa}, is distributed all over the Gulf of Mexico in a wide water depth range of 27 to 3,850 m (Sen Gupta \textit{et al.}, 2009b). Hayward \textit{et al.} (2010) noted that the cosmopolitan \textit{G. crassa} appeared to be restricted to east and south-east of southern South Island (46° to 56° S), and has a bathyal and abyssal habitat, with greatest relative abundances (10–15%) in the upper bathyal. It has been observed to be epifaunal to shallow infaunal (Pérez-Asensio \textit{et al.}, 2012). According to Musco (2011), who reported it as \textit{Cassidulina crassa}, this is a very widespread species, mostly from circa-littoral and bathyal mud (deeper than 100 m) in the Sicilian Channel. Off New Caledonia in the south-western Pacific Ocean, this species was recorded by Debenay (2012) at depths ranging between 5 and 40 m in the estuaries and bays.

\textbf{Repository:} PK–AG–167

\textit{Globocassidulina subglobosa} (Brady, 1881)

\textit{Pl. 7; Fig. 15}

\textbf{Original citation:} \textit{Cassidulina subglobosa} BRADY, 1881, v. 21, p. 60; 1884, p. 430, pl. 54, figs. 17a–c.

\textbf{Remarks:} The figure illustrated by Brady (Barker, 1960, as \textit{Cassidulina subglobosa}) is of a specimen recovered from the sediment dredged at Challenger Station 120, off Pernambuco, Atlantic Ocean, at a depth of 675 fathoms (~1,234 m). This species exhibits a wide range of test size is related to water depth (Corliss, 1978). Small test sizes are found in water depths generally >3,500 m, with both small and large tests found in water generally <3,500 m. Variation in test size had earlier been noted by Phleger and Parker (1951) in the Gulf of Mexico, and by Phleger, Parker and Peirson (1953) in the Atlantic Ocean. Certain species of \textit{Globocassidulina} exhibit large variation in the shape of the aperture (Kennett, 1967), but no variation has been found in the shape of the aperture of \textit{G. subglobosa}. This species is an important deep-sea form, and is found in the south-east Indian Ocean between 2,500 and 4,600 m (Corliss, 1979), and is associated with the Antarctic Bottom Water (AABW) in the south-west Indian Ocean. From the Mediterranean Sea, Cimerman and Langer (1991) recorded this species as \textit{Globocassidulina subglobosa}. This species is very widespread, frequent from circa-littoral and bathyal muds, and has been reported from the eastern Mediterranean down to 1,016 m (Parker, 1958) and in the deep water assemblages off the Algerian coast (optimum at 1,620 m), in the Sicily Channel, and in the Tvrhenian Sea, where its optimum occurs at about 1,000 m. It is rarer deeper than 2,860 m (Parisii, 1981). Fine and coarse size fraction studies suggested that the \textit{Globocassidulina subglobosa--Oridorsalis umbonatus} association was widespread at abyssal depths (>2,000 m) throughout the south-west Pacific and Southern Ocean in the Miocene, attributed to the influence of relatively warm, saline deep water, largely of low latitude Tethyan origin, at least in the early Miocene (Woodruff and Savin, 1989). In the Gulf of Naples, Italy, this species is abundant from circa-littoral and bathyal muds, with an optimum in the depth range of 80 to 110 m (Sgarrella and Monchamont Zei, 1993). \textit{Globocassidulina subglobosa} is an infaunal cosmopolitan species, associated with phytodetritus (Gooday, 1993; 1994). Fariduddin and Louberé (1997) observed this species associated with the North Atlantic Deep Water (NADW) and categorized it as a low productivity species. This fauna is often found abundant in the sediments receiving lower organic matter in the regions where strong bottom
currents are likely to occur (e.g., Schmiedl et al., 1997; Nees and Struck, 1999; Hayward et al., 2004). Ohkushi et al. (2000) suggested that *Globocassidulina* lives in areas with enhanced, continuous food supply. Schmiedl et al. (1997) concluded that *G. subglobosa* seems to be adapted to environments characterized by enhanced bottom current velocities. This inference was supported by the presence of a narrow core of the Intermediate Western Boundary Current (IWBC) (velocity >0.30 m s\(^{-1}\)) at 800-m water depth on the south-eastern continental Brazilian margin, which probably promotes re-suspension of bottom sediments and hinders retention of organic matter. In the south-eastern Indian Ocean, *G. subglobosa* reflects well-oxygenated deep waters having strongly pulsed food supply (Eberwein, 2006) and good carbonate preservation in commonly oligotrophic environments (Singh and Gupta, 2004). According to Sen Gupta et al. (2009b), *Globocassidulina subglobosa* is a cosmopolitan species that is present in the entire Gulf of Mexico in a very wide water depth range of 2 to 3,850 m; its stratigraphic range is documented to be Oligocene to Holocene (Kender et al., 2008). This epifaunal/shallow infaunal species (Pérez-Asensio et al., 2012) is dominant in the southern Indian Ocean with an in situ temperature range of 1.7–5.2° C, dissolved oxygen of 2.1–3.8 mL/L, and low primary production (De and Gupta, 2010); Kaminski (2012) considers this species to be an oxic indicator (>2 mL/L), as did Qi et al. (2007). According to Hayward et al. (2010), the *Nutallides umbonifera–G. subglobosa* association occurs in the deepest water around New Zealand at mid-lower abyssal depths (>3,400 m) to the south-east of the Campbell and Bounty Plateaux, on Hikurangi Plateau and in the Kermadec Trench in the north-east. It appears to occur in sediments that show the dissolution effects of carbonate-corrosive lower Circumpolar Deep Water that flows around the edge of the New Zealand micro-continent and into the Kermadec Trench as the Deep Western Boundary Current. According to Mancin et al. (2013), *G. subglobosa* is mainly shallow infaunal and associated with oxygenated waters, low and mostly pulsed organic flux, sandy substrate, cold bottom water with strong and persistent near bottom currents, but can also tolerate suboxic bottom waters. Spezzaferri et al. (2013), however, opined that it prefers a muddy substrate and feeds on phytodetritus (Suhr et al., 2003), preferentially ingesting fresh diatoms, and associated with living cold water coral facies (Margreth, 2010). According to Caulle et al. (2014), *Globocassidulina subglobosa* is a major species in the lower part of the OMZ in the Arabian Sea, although it is also found in small numbers at deeper sites. They attributed its presence in the small fraction at these sites to its opportunistic behavior, i.e., rapid colonization of episodic fresh phytodetritus.

**Repository:** PK–AG–168

**Genus PARACASSIDULINA** Nomura, 1983

*Paracassidulina angulosa* (Cushman, 1933)

Pl. 7; Fig. 7

**Original citation:** *Cassidulina angulosa* CUSHMAN, 1933, v. 9, p. 4, p. 93; pl. 10, figs. 6a, b.

**Remarks:** Cushman et al. (1954) recorded this species as *Cassidulina angulosa* and noted that a few specimens from the Bikini and Eniwetok atolls were identical with this species described from the Marshall Islands. According to Todd (1965), *C. angulosa* was rare in the samples collected by the *Albatross* from the tropical Pacific Ocean, and she remarked, “This compressed species with elongate chambers and a lobulated, almost serrate, periphery was described from a deep-water sample off the Marshall Islands and has been recorded only from the area of the Marshalls. Specimens have never been found to occur commonly and are restricted to deep water”. Hofker (1978) reported the occurrence of *C. angulosa* at a station located north of Doi, Lododa Islands, at a water depth of 576 m in the eastern part of the Indonesian Archipelago. One of the more recent records for this species is by Debenay (2012), who recorded this species as *Paracassidulina*...
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Repository: PK–AG–169

Subfamily EHRENBERGININAE Cushman, 1927
Genus EHRENBERGINA Reuss, 1850
Ehrenbergina carinata Eade, 1967
Pl. 7; Fig. 8

Original citation: Ehrenbergina carinata EADE 1967, p. 448, fig. 8 (9), fig. 9 (1–4).
Remarks: The types for this species came from off New Zealand, and Eade (1967) recorded Ehrenbergina carinata in a water depth range of 900 to 2,700 m. In the north-western part of the Indian Ocean (Arabian Sea region), surface primary production has a major maximum during the summer monsoon season and a secondary maximum during winter monsoon season. This results in high organic flux to the seafloor, making the deep-sea one of the most oxygen-deficient regions in the world ocean, with a pronounced OMZ. This region is dominated by benthic foraminifers characteristic of low oxygen and high organic food flux, such as Ehrenbergina carinata (De and Gupta, 2010). Hayward et al. (2010) stated that except for one, all records for E. carinata were from bathyal depths ranging from 400 to 2,000 m, and gave a stratigraphic range of Late Miocene to Recent. However, almost a decade earlier, Hayward et al. (2001) had given a different depth range of 1,080 to 3,540 m in the offshore region east of New Zealand.
Repository: PK–AG–170

Ehrenbergina pacifica Cushman, 1927

Original citation: Ehrenbergina pacifica CUSHMAN, 1927, v. 70, p. 5, pl. 2, figs. 2a–c.
Remarks: The types for this species came from off the Ki Islands. The figures provided by Barker (1960) are of Brady’s specimens obtained from the material dredged at Challenger Station 192, off the Ki Islands, in the Pacific Ocean, at a water depth of 129 fathoms (~236 m). This species was referred by Brady to E. serrata Reuss, by Goes to E. trigona, and by Cushman (1922, p. 134) to E. bradyi. Later, Cushman (1927, p. 5) stated that there was an error and referred figs. 4?, 6 and 7 to E. pacifica. Cushman et al. (1954) observed that E. pacifica occurred fairly commonly in the Bikini Atoll samples and in two Eniwetok Atoll samples. They remarked that the test wall is smooth and polished and the peripheral angles and that the spines project outward nearly horizontally. Hofker (1978) recorded this species at varying water depths ranging between 500 and 900 m, in general, and at a much greater depth of 1,496 m in the Ceram Sea, west of Misool, in the eastern part of the Indonesian Archipelago. Enge et al. (2014) studied the uptake of phytodetritus by benthic foraminifera under oxygen depletion in the Arabian Sea, and observed Ehrenbergina pacifica to constitute 9% of the total foraminiferal abundance. They also recorded lowest total carbon labeled carbon uptakes of <1 mg C m⁻² and 1.6 ngC, respectively, by this species, which is considered to be a dysoxic indicator (Qi et al., 2007).
Repository: PK–AG–171

Ehrenbergina trigona Goës, 1896
Pl. 7; Fig. 10

Original citation: Ehrenbergina serrata REUSS var. trigona GOËS, 1896, p. 49, pl. 6, figs. 183, 184.
Remarks: The figures provided by Barker (1960) are of specimens of this species obtained from the material dredged at Challenger Station 296, south-west of Juan Fernandez, in the Pacific Ocean, at a depth of 1,825 fathoms (~3,338 m), and at Challenger Station 283 in the South
Pacific at 2,075 fathoms (~3,795 m). Hofker (1980) recorded the presence of *Ehrenbergina trigona* on the Saba Bank at water depths ranging from 300 to 730 m. Later, he (1983) reported it as *E. trigonalis* in association with soft muddy substrate at 400 m and 940 m water depth on the continental shelf of Surinam. Hermelin and Shimmield (1990) found this species to be present at mid-bathyal depths (770 m, 955 m and 1,048 m) within and below the core of the OMZ in the north-west Indian Ocean. Hayward *et al.* (2003) studied Recent benthic foraminifera from offshore Taranaki, in the eastern Tasman Sea, and provided a water depth range of 498 to 2,000 m for this species. In the Arabian Sea, the lower part of the OMZ (770 to 955 m; O$_2$ ~0.2 mL/L) has a high carbonate content and is dominated by *Ehrenbergina trigona*, *Hyalinea balthica* and *Uvigerina peregrina* (da Silva, 2005). According to Sen Gupta *et al.* (2009b), *Ehrenbergina trigona* is a cosmopolitan species that occurs in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a water depth range of 99 to 1,900 m. De and Gupta (2010) found *E. trigona* to be a constituent of a biofacies that was inferred to reflect low to intermediate primary productivity with low to moderate seasonality in the Indian Ocean. According to Hayward *et al.* (2010), *E. trigona* differs from *E. carinata* in having a distinct spined furrow down the ventral keel and smaller peripheral spines. They noted that in the New Zealand region, this species occurs from the outer shelf to lower abyssal depth (100 to 5,000 m), with slightly more records from southern deep water. Mallon (2011) observed this species to be very rare off the Ecuadorian margin; only a single specimen was found at one station off at a depth of 2,092 m in the 0 to 5 mm part of the sediment. Cauille *et al.* (2014) observed *E. trigona* to be one of the conspicuous faunal elements of the lower OMZ at depths of 1,306 m and 1,379 m in the northern Arabian Sea, where it can be used as an indicator species for the lower part of the OMZ, thereby making it a useful proxy for the past variability of the base of the OMZ. Although the environmental preferences of *Ehrenbergina trigona* are poorly known, species found in the lower part of the OMZ inhabit a transitional niche, with slightly higher oxygen concentration, less abundant organic supplies, and of a lower quality.

Repository: PK–AG–172

**Superfamily TURRILINACEA** Cushman, 1927  
**Family STAINFORTHIIDAE** Reiss, 1963  
**Genus STAINFORTHIA** Hofker, 1956  
*Stainforthia concava* (Höglund, 1947)

**Original citation:** *Virgulina concava* HÖGLUND, 1947, p. 257, v. 26, pl. 23, figs. 3, 4; pl. 32, figs. 4–7, textfigs. 273–275.  
**Remarks:** The types for this species came from the Gullmar Fjord, Sweden, from a water depth of 47 m. Höglund (1956) shifted genus *Virgulina* to genus *Stainforthia*. According to Haynes (1973) *S. concava* differs from *S. concava* (Höglund) var. *loeblichi* Feyling-Hanssen and *S. loeblichi* Feyling-Hanssen in possessing the initial spine, which is lacking in the former two taxa. Although he found all species of *Virgulina* in his material to be optically radial, Feyling-Hanssen (1964) favoured retention of the name *Virgulina*, rather than use of *Stainforthia*. However, Loeblich and Tappan (1961) showed that *Virgulina* must be suppressed and placed granular forms of “*Virgulina*” in *Fursenkoina*. Radial species must, therefore, be placed in *Stainforthia* (Haynes, 1973). Later, Loeblich and Tappan (1987) considered *Virgulina concava* Höglund as the type species of the genus *Stainforthia*. According to Cole (1981), *S. concava* is a common continental slope species, off north-east Newfoundland, occurring in a water depth of 400 to 3,210 m, but being most abundant at 1,800 to 2,600 m. Debenay and Basov (1993) listed this species among the Recent foraminifers distributed on the West African continental shelf and slope. Jorissen *et al.* (1994) observed its occurrence in the submarine canyons off New Jersey. According to Revets (1996),
who used etched sections to reveal the bilamellar nature of the toothplate-like structure, the usage of the term toothplate while describing this species is inappropriate. This is further reinforced by the peculiar mode of attachment of the structure to the septum.

Repository: PK–AG–173

**Stainforthia fusiformis** (Williamson, 1858)

**Original citation:** Bulimina pupoides D’ORBIGNY var. fusiformis WILLIAMSON, 1858, v. 63, pl. 5 figs. 129, 130.

**Remarks:** This species was reported from seawater almost depleted in dissolved oxygen in the Tyro Basin in the eastern Mediterranean Sea (Jongsma et al., 1983). **Stainforthia fusiformis** has been most often observed living in association with high levels of organic matter (Alve, 1990, 1994; Alve and Murray, 1997), which could be the reason why it seems to be associated with muddy substrates, as these two parameters are linked (Cato, 1977). On the Porcupine Abyssal Plain, Gooday (1993) noted that species of **Stainforthia** were opportunistic, able to exploit high levels of phytodetritus produced during the spring blooms, and constituted the low-diversity but high-dominance assemblages. This was attributed to their small size and thin-walled tests, adaptive capacity that reduced reproductive energy requirement and permitted rapid response to triggering events. Alve and Bernhard (1995) conducted experiments in which oxygen levels were incrementally reduced every month until they reached a minimum level of 0.2 mL/L. They observed that **S. fusiformis**, normally an infaunal species, came out of the sediment and became epifaunal on polychaete tubes that extended above the sediment surface, but returned to its infaunal habitat once the O2 levels were increased; this species has been described as tolerant to low oxic environment (Alve, 2003; Nordberg et al., 2000), and feeds on feed on fresh and labile organic matter (Bartels-Jónsdóttir et al., 2006). Based on nitrogen incubation experiments, Bernhard and Alve (1996) demonstrated that **S. fusiformis** is capable of surviving anoxic conditions suffering some ATP damage in the process and thereby suggesting survival by dormancy. According to Alve (2003), **S. fusiformis** is one of the most common benthic foraminiferal species in north-west European waters and living (stained) populations have been recorded in all elastic, soft bottom intertidal to outer shelf and slope areas with sediments consisting of at least some fines as long as the salinity is >28‰. Its predominance in ephemerales dysoxic/anoxic areas has caused it to be used as a proxy for severe oxygen depletion. A strong dominance (even >90%) of this species is, however, also reported from well-oxygenated coastal and shelf settings and, consequently, high abundance of this species occurs in habitats with very different environmental characteristics, suggesting that it can cope up rapidly to rapidly changing environmental conditions. For infaunal species such as **S. fusiformis** (Culver et al., 2008), it is probable that the oxygen content of sediment pore waters is more vital than the bottom water. It seems to prefer fine-grained substrate in the deepest parts of the Celtic Sea and is a significant indicator of frontal conditions, being dominant in the mixed-frontal and stratified-frontal transitional regions (Scott et al., 2003). In these areas, it is the most abundant live species, constituting up to 66% of the living fauna at some sites. They found it living at some “sandier” sites in the sea where organic detritus was available. **Stainforthia fusiformis** is an infaunal, opportunistic species which thrives even under stressed and rapidly changing conditions and favored by salinities higher than 30‰ (Murray, 2006). It can occur in fjord basins with short-term dysoxic/anoxic conditions and it is often reported from environments with frequent coastal hypoxia (e.g., Alve, 1995, 2003; Filipsson and Nordberg, 2004; Nordberg et al., 2000; Polovodova, Asteman and Nordberg, 2013).

Repository: PK–AG–174
Superfamily BULUMINACEA Jones, 1875
Family SIPHOGENERINOIDIDAE Saidova, 1981
Subfamily SIPHOGENERINOIDIDAE Saidova, 1981
Genus PARABRIZALINA Zweig-Strykowski and Reiss, 1976
Parabrizalina porrecta (Brady, 1881)

**Original citation:** Bolivina porrecta BRADY, 1881, p. 57; 1884, p. 418, pl. 52, figs. 22a–c.

**Remarks:** The types for this species came from Off Culebra Island, north of St. Thomas's, West Indies, at a water depth of 390 fathoms (~713 m), at the Challenger Station 24. Brady (1881) erected a new species, Bolivina porrecta, and gave its description as, “Test elongate, straight, slightly tapering, finger-shaped, somewhat compressed; margin and ends rounded. Segments about as broad as long, the earlier ones arranged on the normal Textularian plan, the later ones taking, a nearly triangular form, each extending the entire width of the test, the sutures forming a zigzag line from side to side. Walls thin and clear, very finely perforated; sutural depressions very slight. Aperture, large, terminal, oblique”. Cushman (1922) opined that the Atlantic specimens were very long, slender, and were very finely punctate, differing from the somewhat broader, very coarsely punctate form of the Pacific. Hofker (1978) recorded this species as B. porrecta at a single station in the eastern part of the Indonesian Archipelago, south-west of Pisang Islands, at a water depth of 216 m. Revets (1996) erected a new subfamily PARABRIZALININAE and described its characteristics as, “Test free, elongated, laterally compressed, biserial, with a tendency towards rectilinearity; chambers usually compressed, roughly as wide as high; aperture sub-terminal to terminal; toothplate asymmetrical, at least in later chambers with both borders free, fusing with the top of the foraminal toothplate; wall calcareous, perforate”, and assigned the genus Parabrizalina Zweig-Strykowski and Reiss, 1975 to it. According to Sen Gupta et al. (2009b), Parabrizalina porrecta occurs at a shallow depth of 24 m in the north-eastern and south-eastern parts of the Gulf of Mexico; it has also been recorded from the Caribbean Sea, Atlantic and Indian oceans. Margreth (2010) reported this species as Parabrizalina porrectum (Brady) and observed it to be associated with the cold-water coral ecosystems off the Norwegian margin, while McCloskey (2009) recorded it as Loxostomina porrecta in the Papua New Guinea region.

**Repository:** PK–AG–175

Genus SAIDOVINA Haman, 1984

*Saidovina karreriana* (Brady, 1881)

Pl. 7; Fig. 9

**Original citation:** Bolivina karreriana BRADY, 1881, v. 21, p. 58.

**Remarks:** This species was originally described and illustrated by Brady (1881), the type locality being in the North Pacific Ocean, south of Japan, at the Challenger Station 232, at a depth of 345 fathoms (~631 m), who referred it to *Bolivina*, but Cushman (1937, p. 184) preferred to place it under *Loxostoma* (*Loxostomum*). Cushman et al. (1954) recorded this species as *Loxostomum karrerianum* and observed the occurrence of a few typical specimens in the Bikini Atoll, Marshall Islands. This species was reported as *Bolivina karreriana* by Hofker (1978) at a depth of 513 m in the Moro Gulf, at 576 m north of Doi, Lododa Islands, and at 546 m north-west of Misool in the eastern part of the Indonesian Archipelago. Debenay and Basov (1993) listed this species as *Saidovina karrerianum* among the Recent foraminifera distributed on the continental shelf and slope off West Africa. *Saidovina karreriana* has been observed to be abundant in the sheltered oceanic embayments off the south-east coast of Australia (Yassini and Jones, 1995). According to Gupta (1997), who studied the paleoceanographic and paleoclimatic history of the Somali Basin during the Pliocene-Pleistocene, an assemblage that is constituted by *Loxostomum karrerianum* (=
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Ph.D. Thesis

Bolivina karrerianum, Trifarina angulosa and Bolivina spathulata, suggests an oxygen-deficient, organic carbon-rich environment. Bartels-Jónsdóttir et al. (2009) stated that the distribution of S. karreriana seems to be controlled by nutrients as well as oxygen conditions in the Tagus Prodelta, eastern North Atlantic, and a change in these environmental factors 100 years ago may be considered to be at least partly induced by anthropogenic pollution. They opined that the migration of this species around that time was probably indicative of water mass changes. Off New Zealand, this species has its greatest relative abundances (up to 20%) in quiet, deep inner shelf waters (20 to 40 m depth) inside or at the entrance to deep inlets, but its bathymetric range extends down to the upper bathyal (shallower than 600 m) with up to 6% relative abundance at mid shelf to upper bathyal depths (Hayward et al., 2010). Earlier it had been recorded at a depth of 1,320 m east of New Zealand (Hayward et al., 2001).

Repository: PK–AG–176

Subfamily TUBULOGENERININAE Saidova, 1981

Genus SIPHOGENERINA Schlumberger, 1882

Siphogenerina dimorpha (Parker and Jones, 1865)

Pl. 7; Fig. 11

Original citation: Uvigerina (Sagra) dimorpha Parker and Jones, 1865, v. 55, p. 420, pl. 18, fig. 18.

Remarks: The types for this species came from the Abrohlos Bank, off Brazil. Cushman (1926) opined that the Pacific form of this species differed from the typical in having more number of uniserial chambers, the cylindrical form of the test, and the much more prominent depressions at the base of the chambers along the sutures, and erected a new variety of S. dimorpha and named it S. dimorpha var. pacifica Cushman. 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 Siphogenerina 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, he (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, Hayward et al. (2007) recorded this species at depths shallower than 80 m. According to Sen Gupta et al. (2009b), Siphogenerina 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 (35º–49º S) at mid- to lower bathyal depths of 500–1,200 m (Hayward et al., 2001; Hayward et al., 2010). This could be the first record of this species from the Bay of Bengal.

Repository: PK–AG–177

Family BULIMINIDAE Jones, 1875

Genus BULIMINA d’Orbigny, 1826

Bulimina aculeata d’Orbigny, 1826

Pl. 7; Figs. 12, 12a

Original citation: Bulimina aculeata D’ORBIGNY, 1826, v. 7, ser. 1, p. 269, no. 7.

Remarks: The types for this species came from Rimini, Italy. The figures illustrated by Brady (Barker, 1960) for this species are of specimens recovered from the sediment dredged at Challenger Station 191A, Ki Islands, Central Pacific, at a depth of 580 fathoms (~1,061 m).
Cushman (1946) opined that this species had been confused with *Bulimina gibba* Fornasini, but said that it could be easily differentiated by its globular last-formed chambers, the rounded rather than three-cornered initial end and the more rapidly tapering test. Hermelin and Scott (1985) observed this species to be uncommon and scattered at depths ranging between 1,000 and 2,740 m in the central North Atlantic. In the Mediterranean region, this species is widespread and has been reported from infra-littoral depths (15 to 20 m), and is abundant in the circa-littoral and epi-bathyal muds, down to about 300 m. In the Gulf of Naples, *Bulimina aculeata* occurs scattered between 5 and 360 m, with an optimum in the depth range of 55 to 200 m (Sgarrella and Monchamont Zei, 1993). This species has also been recorded from the Mediterranean Sea by Cimerman and Langer (1991). Yassini and Jones (1995) observed this species to inhabit inner and middle shelf off the south-east coast of Australia. Shin et al. (1996) studied the Holocene deep-sea benthic foraminiferal paleoceanographic history of the Caribbean Sea, and reported *B. aculeata* from depths shallower than 3,000 m, and has its greatest abundance at depths ranging between 500 and 2,000 m (Phleger, 1960). Changes in species diversity are negatively related to changes in the percentage of infaunal calcareous tests. Abundance fluctuations of infaunal tests are commonly related to changes in the amount of C$_{org}$ reaching the seafloor and ultimately fluctuations in primary productivity (e.g., Corliss, 1985; Corliss and Chen, 1988; Rathburn and Corliss, 1994). This implies that the species diversity decreases when primary productivity increases and a few infaunal species such as *Bulimina aculeata* and *Uvigerina peregrina* dominate, both of which are detritus feeders. The increase in abundance and accumulation rate of these two species clearly indicates enhanced C$_{org}$ flux and, hence increased surface export productivity (Jian et al., 1999). A similar correlation of *B. aculeata* with enhanced C$_{org}$ flux had been observed by Collins (1989). *Bulimina aculeata* strongly dominates the benthic foraminiferal assemblage at bathyal depths just below the OMZ (Hermelin and Shimmield, 1990). The lower depth range for the occurrence of *B. aculeata* in the Indian Ocean is around 2,300 m, similar to that of many other areas; moreover, it does not occur at water depths >2,300 m, suggesting that the distribution of this species is controlled mainly by water depth (Rai and Srinivasan, 1994). In the South Atlantic, South China Sea, and Arabian Sea, this species is confined to depths between 1,500 and 2,500 m and is controlled by productivity and organic carbon flux (e.g., Miao and Thunell, 1993; Mackensen et al., 1995; Jannink et al., 1998; Altenbach et al., 1999). In the Gulf of Aden, *B. aculeata* shows higher abundances under present-day high productivity region and during interglacial stages, making it an indirect indicator of the extent of the south-west Indian Monsoon (Almogi-Labin et al., 2000). Nomaki et al. (2006) recognized three types of feeding strategy among deep-sea benthic foraminifera in Sagami Bay, and listed *B. aculeata* as a shallow infaunal (Hintz et al., 2004), seasonal-phytotrophic species, implying that it feeds on fresh phytodetritus selectively but sedimentary organic matter as well when phytodetritus is absent. According to Sen Gupta et al. (2009b), *B. aculeata* is a cosmopolitan species that is present all over the Gulf of Mexico in a wide water depth range of 55 to 3,200 m. Vidovic et al. (2009) studied the impact of fish farming on foraminifera and observed that *B. aculeata* was one of the dominant species in samples under the cages and at the edge of the farm (with higher abundance under the cages), but was present with very low abundance at the reference station, reflecting its dependence on a rather continuous abundance of organic matter. In the north-western Arabian Sea, *B. aculeata* is associated with in situ temperature of 2.2–5.6°C, oxygen of 1.1–2.9 mL/L, and high phosphates and nitrates where surface productivity is highest in the whole Indian Ocean (De and Gupta, 2010); this taxon reacts quickly to labile OM supply (Mojtahid et al., 2010). According to Mancin et al. (2013), this species is a typical component of foraminiferal assemblages from the OMZ in the Indian Ocean. At the dysoxic (1,495 m) and oxic (1,791 to 3,010 m) stations in the northern Arabian Sea, both *B. aculeata* and *U. peregrina* showed two in-sediment maxima: in the first half
centimeter, which was well oxygenated, and at 3–5 cm depth, below the oxygen and nitrate penetration depth (Caulle et al., 2014).

Repository: PK–AG–178

_Bulimina gibba_ Fornasini, 1902

**Original citation:** _Bulimina gibba_ FORNASINI, 1902, ser. 5, v. 8, p. 378, figs. 32, 34.

**Remarks:** This species was first described from the Adriatic Sea and it has also been recovered from cores in the western Mediterranean by Todd (1958), in the eastern Mediterranean by Parker (1958), and from the Gulf of Naples (Hofker, 1960). The figures illustrated by Brady (Barker, 1960) for this species are of specimens recovered from the sediments dredged at Porcupine Station 11, west of Ireland, Atlantic Ocean, at a depth of 1,630 fathoms (~2,981 m), and at Porcupine Station 10, also west of Ireland, Atlantic Ocean. _Bulimina gibba_ was referred to _B. elegans_ d’Orbigny. Cushman and Parker (1940, p. 14), however, placed _B. fusiformis_ Fornasini, _B. elegans_ of Brady, _non_ d’Orbigny, _B. fusiformis_ var. _baccata_ Fornasini and _B. gibba_ Fornasini in the synonymy of _B. baccata_ Fornasini. Thalmann (1942, p. 464) pointed out that the name _baccata_ was preoccupied by Yokoyama (1890) and proposed the name _B. parkeri_ for these figures. _Bulimina parkeri_, however, had already been used by Terquem and Terquem (1886), so Cushman and Parker (1947, p. 125) proposed reverting to the earliest valid name, _B. gibba_ Fornasini, and this was followed by Barker (1960) as well as in the present study. Pflum (1966) recorded _Bulimina gibba_ at water depths of 410 m and 1,765 m in the eastern Ross Sea, Antarctica. This species was reported by Hofker (1978) at water depths of 4,321 m and 1,496 m in the Sulu Sea and Ceram Sea, respectively, in the eastern part of the Indonesian Archipelago. Hayward et al. (2001) gave a water depth range of 110 to 720 m for _B. gibba_ in the offshore region east of New Zealand. According to Alday et al. (2006), small and fragile forms, such as _Bulimina gibba_, characterize a deep, low energy, muddy and poorly oxygenated environment. Musco (2011) opined that this species is exclusively marine and is frequent in the Adriatic Sea at water depths ranging between 15 and 18 m (Albani and Barbero, 1990). In situ experiments by Enge et al. (2014) in the Arabian Sea (Indian margin) revealed that the uptake of labeled nitrogen by _B. gibba_ (1.4 mg N m⁻²) was twice as high as by _B. aff. B. dilatata_ and _Cassidulina_ sp., and the results regarding uptake of C-org by this species was consistent with earlier observations and results obtained by Woulds et al. (2007).

Repository: PK–AG–179

_Bulimina marginata_ d’Orbigny, 1826

Pl. 7; Figs. 13, 13a

**Original citation:** _Bulimina marginata_ D’ORBIGNY, 1826, ser. 1, v. 7, p. 269, pl. 12, figs. 10–12.

**Remarks:** The holotype for this species was described from the Adriatic Sea, near Rimini, Italy, and there are numerous additional records (Haynes, 1973). D’Orbigny (1826) described _B. marginata_ and _B. aculeata_ as distinct species on the basis of chamber angularity, the arrangement and length of the spines, and test dimensions, which was, however, refuted by Höglund (1947), who opined that they were morphological variants of the same species. However, both Collins (1989), and Burgess and Schnitker (1990) concluded that _B. marginata_ could be distinguished from _B. aculeata_ based on morphological characteristics. It was recorded off Plymouth at depths of 10 to 60 m by Murray (1965), who later, in 1970, reported it from the Celtic Sea at greater depths, ranging from 128 to 138 m. It is a stenohyaline, shelf species (Murray, 1971). The figures illustrated by Brady (Barker, 1960) for this species are of specimens recovered from the sediment dredged at Porcupine Station 11, west of Ireland, North Atlantic, at a depth of 1,630 fathoms (~2,981 m). According to Vilks (1969), his specimens (rare) from the deep water of the Canadian
Arctic were less spinose than those from southern waters, and observed that the last two chambers had lost their margins; they resembled the ones collected by Cushman off Baltimore Island and reposited in the U.S. National Museum. In the Mediterranean region, *Bulimina marginata* is very widespread, and has been reported from the infra-littoral zone, and is frequent from the circa-littoral zone and bathyal muds. It has been recorded in the deeper water assemblages in the following areas: Eastern Mediterranean, down to 1,016 m (Parker, 1958), Sicily Channel, Tyrrhenian Sea down to 2,860 m (Parisi, 1981), and off the Algerian coast, where it is frequent at 2,315 m (Todd, 1958). *Bulimina marginata* has also been recorded in the Mediterranean Sea by Cimerman and Langer (1991). In the Gulf of Naples, this species occurs scattered, from 9 m downwards, and is frequent at depths greater than 50 m, and abundant deeper than 100 m (Sgarrella and Moncharmont Zei, 1993). According to Hayward *et al.* (1999), in the past, this species has, in New Zealand, been reported as either *B. marginata* or *B. submarginata*. Jorissen’s (1988) studies of *B. marginata* in its type area, the Adriatic Sea, resulted in the recognition of one highly variable species with three forms – *f. marginata*, *f. aculeata*, and *f. denudata*. There they have distinctive though overlapping ecological ranges. A *B. marginata* assemblage had been reported from muddy-sand substrates in numerous depths in the Atlantic seaboard of Europe and Africa within the temperature and salinity ranges of 25–35‰ and 5.5–13°C (Murray, 1991). He also stated that high percentages of *B. aculeata* and *B. marginata* had often been considered typical of highly stressed especially, oxygen-depleted, environments. In their experimental studies, Alve and Bernhard (1995) observed *B. marginata* to be abundant in the surface 0.5 cm of sediment, but rarely occurred on polychaete tubes, but during the course of the experiment wherein the O₂ levels were steadily decreased, this species densities increased substantially on the polychaete tubes until, at a stage, live specimens were found only on the tubes. During the re-oxygenation stage, tests of this species were still observed on polychaete tubes, but in considerably lower abundances, and started to inhabit the top 1.5 cm of the sediment column. This upward migration as far as possible into more oxygenated waters above the sediment-water interface made them to ponder about the reality of function of the apertural canal to channel oxygen into the cytoplasm. According to Yassini and Jones (1995), this species is rare in the inlet channels of coastal lagoons, open estuaries, middle and outer shelf off the south-east coast of Australia. The abundance of *B. marginata* is known to have positive correlation with nutrient contents (Donnici and Barbero, 2002), and its high abundance has been considered a good marker of high productivity waters (Phleger and Soutar, 1973; Lutze and Coulbourn, 1984) and is a warm water species (Scott *et al.*, 1984). *Bulimina marginata* is infaunal to a depth of at least 4 cm. It can withstand anoxic conditions and prefer to live in finer sand with high total organic carbon (TOC) (Murray, 2003; Murray, 2006). The sedimentary record of benthic foraminifera in an Iberian upwelling system suggests that several species of *Bulimina*, including *B. marginata*, are associated with increased thermal stratification and high organic carbon input to the bottom (Martins *et al.*, 2006). According to Sen Gupta *et al.* (2009b), *Bulimina marginata* is a cosmopolitan species with a very wide water depth range of 2 to 2,950 m in the entire Gulf of Mexico. Vidović *et al.* (2009) studied the impact of fish farming on foraminifers and observed that *B. marginata* was one of the dominant species in samples under the cages and at the edge of the farm (with higher abundance under the cages), but was present with very low abundance at the reference station, reflecting its dependence on a rather continuous abundance of organic matter. Eichler *et al.* (2013), in their sediment core analysis in the South Atlantic Ocean, demonstrated that the distribution of *Bulimina marginata* (shelf environment and deep-sea) is influenced by the front location and it could be used as a proxy of the sub-tropical shelf front (STSF). They observed that the distribution of *B. marginata* occurred mainly in the salinity range of 29–36‰ and temperature range of 7°–20°C. Their study confirmed that the opportunistic,
infaunal *B. marginata* flourishes in a relatively organic-enriched environment where organic matter ranges from 5 to 10% and is clustered to 20% of suspended matter.

**Repository**: PK–AG–180

*Bulimina notovata* Chapman, 1941

**Original citation**: *Bulimina notovata* CHAPMAN, 1941, v. 65, p. 166.

**Remarks**: The figure illustrated by Brady (Barker, 1960) is of the specimen recovered from the sediment dredged at Challenger Station 168, east of New Zealand, at a depth of 1,100 fathoms (~2,012 m). *Bulimina notovata* was referred by Brady to *B. ovata* d’Orbigny, but Galloway and Hemingway (1941, p. 423) referred Brady’s figures to *Bulimina socialis* Bornemann, but Barker gave preference to Chapman’s *B. notovata*, and the same has been followed in the present study. According to Cushman (1946), d’Orbigny obtained his fossil type from the Miocene of the Vienna Basin, and when it is compared with the living form, the differences could be easily seen. He opined that *B. ovata*, according to the figured type, was a long ovate form, with the segments slightly inflated and prominent and, therefore, specifically different from the *Challenger* specimen. In their study on deep-sea benthic foraminifera from the Ocean Drilling Program (ODP) Hole 716A on the Maldives Ridge, south-eastern Arabian Sea, Sarkar et al. (2009) reported this species as *Globobulimina notovata* (Chapman).

**Repository**: PK–AG–181

*Bulimina striata* d’Orbigny, 1826

Pl. 7; Fig. 14

**Original citation**: *Bulimina striata* D’ORBIGNY, 1826, v. 7, p. 269, pl. 18, fig. 2.

**Remarks**: According to Bandy (1960), *Bulimina striata* is one of the species which are most abundant in mid-lower bathyal depths. This species was recorded by Hofker (1978) at only one station, south of Makassar, south-west Point Celebes, at a water depth of 587 m in the eastern part of the Indonesian Archipelago. Papp and Schmid (1985) considered this species as synonymous with *B. buchiana* and *B. costata*, while Rögl (1969) described the same material as *B. striata* d’Orbigny. Hemleben (1989) remarked that *B. striata* differs from *B. inflata* in that the costae usually are cut off at the sutures which gives a collared effect to the test, whereas in *B. inflata* the costae often cross the sutures. An uppermost bathyal to lower bathyal water depth range was given for this species on the Sunda Shelf in the south-western South China Sea by Szarek (2001), while Hayward et al. (2001) observed a depth range of 110 to 2,250 m east of New Zealand. According to Hayward et al. (2003), *B. striata* is distributed in a rather wide water depth range of 194 to 2,150 m in the offshore Taranaki region, New Zealand. Hayward et al. (2010) presented an upper depth limit of 120±20 m, although these depths are variable in different offshore regions around New Zealand. They observed that populations have costae of variable strength with or without spinose ends, and opined that this species could not be distinguished from *B. mexicana*. They recorded depth ranges from outer shelf to upper abyssal (100–3,000 m), with greatest relative abundances (up to 5%) in the bathyal zone (200–2,000 m). *Bulimina striata* was recorded by Debenay (2012) at a water depth of 600 m on the northern shelf off New Caledonia in the south-western Pacific Ocean. According to Mancin et al. (2013), *Bulimina striata* is associated with rather high and quite sustained organic fluxes, intermediate dissolved oxygen content, and muddy substrate in the modern deep-sea environment.

**Repository**: PK–AG–182

**Genus GLOBOBULIMINA** Cushman, 1927

*Globobulimina pacifica* Cushman, 1927
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Pl. 8; Figs. 1, 1a

Original citation: *Globobulimina pacifica* CUSHMAN, 1927, v. 3, p. 67, pl. 14, fig. 12.

Remarks: The types for this species came from a water depth of 1,197 fathoms (~2,189 m) and this species is common along the west coast of North America (Cushman, 1927). Hofker (1978) recorded *Globobulimina pacifica* at depths varying from 378 m to as deep as 2,693 m in the eastern part of the Indonesian Archipelago. Pores are important for gas exchange in foraminifers, as illustrated by the osmiophilic organic lining of *Globobulimina pacifica* (Leutenegger and Hansen, 1979) that does not cover the pore entrance, allowing a faster rate of molecular transport at low oxygen concentrations; this was, however, refuted by Resig and Glenn (2003). Using transmission electron microscopy (TEM), Goldstein and Corliss (1994) were able to observe the presence of large volumes of sediment and organic detritus with adherent bacteria in food vacuoles of *G. pacifica*. *Globobulimina pacifica* differs from *G. pacifica* Cushman var. *scalprata* Cushman and Todd (1945), in not possessing the many fine, longitudinal striae (Bornmalm, 1997). Szarek (2001) gave a water depth range of outer shelf to middle bathyal for *G. pacifica* on the Sunda Shelf in the south-western South China Sea. The deep infaunal *G. affinis* and *G. pacifica* start to be present where dissolved oxygen is completely consumed, show peaks in standing stocks where the nitrate concentration approaches zero (Fontanier et al., 2002; Licari et al., 2003) and dissolved Mn$^{2+}$ and Fe$^{2+}$ increase (Fontanier et al., 2005). The occurrence of *Globobulimina* spp. is closely linked to the nitrate reduction zone in sediment, where the maximum abundances were recorded, and to a lesser extent by food availability as specimens were found in sediments relatively rich as well as poor in chloroplastic pigment equivalents (CPEs), which are used as a measure for labile organic matter (Koho, 2008). This preferential occurrence of *Globobulimina pacifica* in the nitrate reduction zone had earlier been documented by Licari et al. (2003) as well in the tropical east Atlantic. This is a cosmopolitan species which is distributed in a water depth range of 159 to 928 m in the north-eastern and north-western parts of the Gulf of Mexico (Sen Gupta et al., 2009b). According to Hayward et al. (2010), this species has scattered occurrences in low numbers off both coasts of central New Zealand (38°–44° S) at outer shelf to upper abyssal depths ranging from 150 to 2,500 m. Mallon (2011) recovered intact specimens from sub-surface samples from three stations at water depths of 697 m, 823 m and 2,092 m off Peru and Ecuador, and attributed its rarity to its fragile tests either not being preserved or getting broken during sieving.

Repository: PK–AG–183

*Globobulimina pyrula* (d’Orbigny, 1846)

Pl. 8; Fig. 3

Original citation: *Bulimina pyrula* D’ORBIGNY, 1846, p. 184, pl. 11, figs. 9, 10.

Remarks: The types for this species came from the Miocene at Baden, Vienna Basin, Austria (d’Orbigny, 1846). According to Cushman (1946), considerable confusion prevails in the literature regarding this species. He opined that many forms that have been recorded, especially from the Recent, belong to the genus *Globobulimina*, which is an involute form developed from *Bulimina*, showing only the last three chambers, at least in the adult. He remarked, “*Bulimina pyrula* approaches the *Globobulimina* type and it seems probable that it represents an ancestral form of that genus. The early chambers, however, though very narrow are easily seen. The presence of the occasional spines does not seem to be a specific character. The species is easily differentiated from other forms by its highly involute character, which makes the last whorl predominant. It differs from the species of *Globobulimina* in being acuminate at both ends, with the early whorls visible”. Papp and Schmid (1985) opined that the species *Bulimina papoides*, *B. ovata* and *B. pyrula*
are all synonymous. Hofker (1951), however, designated *Bulimina pupoides* as the type species of the genus *Protoglobobulimina*, while *Bulimina pyrula* was designated as type species of the genus *Globobulimina* Cushman, 1927 (Popescu and Crihan, 2005). The modern representative of *G. pyrula* displays a deep infaunal habitat close to the $O_2=0$ isopleth in oxygenated environments (Corliss and Emerson, 1990). It probably migrates to shallower depths under deteriorating oxygenation when the $O_2=0$ isopleth shoals resulting in a low-diversity infauna dominated by *Globobulimina pyrula* immediately prior to the development of truly anoxic bottom water conditions (Zachariasse et al., 1997). According to Gebhardt (1999), *Globobulimina pyrula* is associated with oxygen-deficient environment, perhaps due to sluggish bottom water circulation; Pezelj et al. (2007) opined that it is an indicator of suboxic conditions. *Globobulimina pyrula* is a deep-infaunal species and displays a delayed response to the input of organic matter compared to more opportunistic species such as *Uvigerina* ex. gr. *semiornata*. Based on fatty acid analysis, Larkin (2006) stated that *G. pyrula* preferentially ingests phytodetritus and is a dysoxic marker (Peryt and Gedd, 2010). Phipps (2012), however, deemed it as an intermediate infaunal species.

**Repository**: PK–AG–184

**Genus PROTOGLOBOBULIMINA** Hofker, 1951

*Protoglobobulimina pupoides* (d’Orbigny, 1846)

*Pl. 8; Figs. 2, 2a*

**Original citation**: *Bulimina pupoides* D’ORBIGNY, 1846, p. 185, pl. 11, figs. 11, 12.

**Remarks**: The types for this species came from the Miocene of Nussdorf and Baden, Austria (d’Orbigny, 1846). Chapman and Parr (1937) recorded this species as *Bulimina pupoides* from the Monterey Shale, California (Miocene) and stated that the shallow-water deposits of many oceans yield specimens of this species and that it ranges from “shoal depths down to 1,000 fathoms”. Cushman (1946) opined that *Bulimina pupoides* is a variable species, and stated that the specimens from Baden showed a wide range of variation in respect to length, width, number of whorls, etc. He remarked, “The only absolutely fixed characters are the angle that the sutures make with the vertical axis of the test, the shape of the chambers, and the position of the aperture”. He also stated that *B. pupoides* differs from *B. ovata* d’Orbigny in the shapes of the test as well as chambers, and from *B. affinis* in the shapes of the apertural face and test, and the greater number of chambers, the last whorl making up a smaller proportion of the test. The figure (fig. 14) reproduced by Barker (1960) is of Brady’s specimen obtained from the material dredged at Challenger Station 306, west of Patagonia, in the East Pacific at a depth of 345 fathoms (~631 m). This species was referred by Brady to *Bulimina affinis* d’Orbigny but Cushman and Parker (1947) regarded it, albeit with some element of doubt, as the microspheric form of *Bulimina pupoides*. Barker (1960) opined that if the latter opinion was correct, the species should perhaps be termed *Protoglobobulimina pupoides* (d’Orbigny) as suggested by Hofker (1951, p. 254), as it is being referred to at present. The other figure (fig. 15) was, however, referred by Brady to *B. pupoides* d’Orbigny. According to Kaiho (1994) and Bubenschchikova et al. (2010), *Protoglobobulimina pupoides* is an indicator of dysoxic conditions (0.1 to 0.3 mL/L of $O_2$) and is infaunal at >4–10 cm. Hayward et al. (2001) recorded this species as *Praeglobobulimina pupoides* at a water depth of 3,170 m in the offshore region east of New Zealand. According to Sen Gupta et al. (2009b), who referred this species as *Praeglobobulimina pupoidesi*, this cosmopolitan species has a bathyal and/abyssal habitat and is distributed in the north-eastern and south-eastern parts of the Gulf of Mexico in a water depth range of 305 to 1,335 m. Hayward et al. (2010) observed the occurrence of this species (as *Praeglobobulimina pupoides*) off both coasts of the North Island, but mostly off the east coast (33°–43° S), and gave a water depth range of mid shelf to upper abyssal (60 to 3,000 m). According to Mallon (2011), this species (reported as *Bulimina pupoides*), is common at...
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Ph.D. Thesis

Repository: PK–AG–185

Family UVIGERINIDAE Haeckel, 1894
Subfamily UVIGERININAE Haeckel, 1894
Genus SIPHOUVIGERINA Parr, 1950
Siphouvigerina ampullacea (Brady, 1884)

Original citation: Uvigerina asperula CZJZEK var. ampullacea BRADY, 1884, v. 9, p. 579, pl. 75, figs. 10, 11.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 344, Ascension Island, South Atlantic, at a depth of 420 fathoms (~768 m). This species was referred by Brady (1884) to Uvigerina asperula var. ampullacea, whereas Hofker (1951) referred it to Neouvigerina ampullacea (Brady). Thalmann (1937, p. 341) referred Brady’s figures to Uvigerina asperula var. probosidea Schwager. This was probably based on Cushman (1934, p. 126), who remarked, ”Brady records U. asperula and variety ampullacea from Fiji, which may be this species (U. probosidea Schwager)”. But Chapman and Parr (1937) recorded this species as Uvigerina asperula CZjzek var. ampullacea Brady from deep waters off Tasmania, but observed it to be rare. According to Cushman et al. (1954), who reported it as U. ampullacea, “This species occurs in a few deep-water samples at Bikini. It is characterized by a compact, rounded initial portion and a slender, attenuated apertural end. The species was described from Ascension Island and has been widely recorded in both the Atlantic and Pacific, and in the later Tertiary as well”. Hatta and Ujije (1992) recorded this species from the coral seas between Ishigaki and Iriomoto islands, Southern Ryukyu Island Arc, north-western Pacific Ocean, off Japan. According to Hottinger et al. (1993), species and sub-species described as Uvigerina auberiana d’Orbigny (Uchio, 1960), U. auberiana var. laevis Göes (Phleger and Parker, 1951), U. laevis Göes (Parker, 1954), and U. probosidea var. vadaescens (Cushman, 1942) all apparently belong to Neouvigerina ampullacea. Neouvigerina ampullacea was recorded by Hofker (1978) at variable depths ranging between 513 m in the Moro Gulf and 2,693 m west of Benteng in the eastern part of the Indonesian Archipelago. Hermelin (1989), while recording Uvigerina auberiana, remarked, “Numerous small, finely pitted uvigerinid species have been described in the literature and many of them seem to be conspecific with U. auberiana and are therefore regarded as junior synonyms to this species. Boltovskoy (1978) described several variants of what he called U. probosidea. In addition to the species in the synonymy above, some other species might after further investigation be regarded as junior synonyms of U. auberiana, e.g., Uvigerina asperula Cijzek, Uvigerina interrupta Brady and Uvigerina senticosa Cushman. The species figured by Burke (1981) as Siphouvigerina interrupta (Brady) is regarded as synonymous with U. auberiana”. According to Montaggioni and Véne-Peyré (1993), Siphouvigerina ampullacea is an exclusively tropical Indo-Pacific species. Yassini and Jones (1995) observed the occurrence of this species in the middle and outer shelf off the south-east coast of Australia. Bornmalm (1997) stated that the species figured by Ujije (1990) as Neouvigerina ampullacea and by Burke (1981) as Siphouvigerina interrupta (Brady) are synonymous with Uvigerina auberiana d’Orbigny, 1839. According to Szarek (2001), N. ampullacea occurs through the entire range of water depths from 50 m to 2,000 m in association with a clayey substrate on the Sunda Shelf in the south-western South China Sea. Carson (2008) opined that this species (recorded as N. ampullacea) could be distinguished from other uvigerinids.
by its finely hispid test surface. According to Sen Gupta et al. (2009b), who reported it as Neouvigerina ampullacea, this shallow infaunal species (Badawi et al., 2005) is cosmopolitan with a bathyal and abyssal habitat in the north-eastern and north-western parts of the Gulf of Mexico at depths ranging between 960 and 3,292 m.

Repository: PK–AG–186

Genus UVIGERINA d'Orbigny, 1826

_Uvigerina aculeata_ d'Orbigny, 1846

Pl. 8; Fig. 4

Original citation: _Uvigerina aculeata_ D'ORBIGNY, 1846, p. 191, pl. 11, figs. 27, 28.

Remarks: Chapman and Parr (1937) observed the occurrence of _Uvigerina aculeata_ in the samples dredged by Terra Nova, and noted that the specimens off New Zealand reached an enormous size. In the Southern Ocean and south of Tasmania, they found this species at water depth ranging from 1,475 to 2,600 fathoms (~2,698 to 4,755 m). The figures reproduced by Barker (1960) are of Brady's specimens obtained from the material dredged at Challenger Station 191A, off the Ki Islands in the Pacific Ocean, at a water depth of 580 fathoms (~1,061 m). These were referred by Brady to _Uvigerina_ and by Hofker (1951, p. 226) to _Euuvigerina aculeata_ (d'Orbigny). LeRoy (1964) observed _U. aculeata_ to occur in limited numbers and seemingly restricted to the Shinzato formation (Miocene/Pliocene) in his studies on the smaller foraminifers from the late Tertiary of Okinawa, Japan. Hofker (1978) reported this species as _Euuvigerina aculeata_ at water depths ranging between 378 and 615 m in the eastern part of the Indonesian Archipelago. Popescu and Crihan (2005) assigned specimens with the following features to _Euuvigerina aculeata_ (d'Orbigny): test small- to medium-sized, fusiform; surface covered with elongated, conical, irregularly distributed spines; long, slender, terminal apertural neck, placed in a slightly depressed area; chambers triserially arranged, with a tendency to reduce to biserial in the adult; euuvigerinid type toothplate. According to Peryt and Gedl (2010) _Uvigerina aculeata_ is a deep infaunal, dysoxic marker species and indicative of high primary productivity (Pezelj et al., 2013).

Repository: PK–AG–187

_Uvigerina asperula_ Czjzek, 1848

Pl. 8; Fig. 5


Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 191A, off the Ki Island in the Pacific Ocean, at a depth of 580 fathoms (~1,061 m; figs. 6, 7, 9), and at Challenger Station 323, South Atlantic, at a depth of 1,900 fathoms (~3,475 m; fig. 8). Figure 9 was referred by Brady to _Uvigerina asperula_ var. _asperula_ d'Orbigny, while Thalmann (1932) referred the same to _U. asperula_. Flint (1899) recorded _Uvigerina asperula_ at a depth of 1,019 fathoms (~1,864 m) off the Brazilian coast. Bagg (1912) observed _U. asperula_ to be rare in the Pliocene at San Pedro, California, but noted that it was rather common species, having a water depth range of 435 to 1,675 fathoms (~796 to 3,063 m). A few specimens of this species were recovered from a water depth of 1,998 fathoms (~3,654 m) by Pearcey (1914) from the Burdwood Bank. _Uvigerina asperula_ was reported by Albani and Geyskes (1969) from the north-western continental shelf of Australia at a depth of 95 m. Hayward (1979) attributed the presence of some less common benthic foraminiferal species such as _U. asperula_ in the inter-tidal zone at Kawerau, Northland, New Zealand, to their drifting from offshore caused by the prevailing west winds and Tasman Sea swells. This species was observed to be very rare, off north-east Newfoundland and was recorded by Cole (1981) at one
station only at 2,758 m water depth. According to Rositasari (2010), the high abundance of *Uvigerina asperula* might considered as a proxy of OMZ in the Makassar Strait, in view of the fact that organic-rich river inputs and phytoplankton blooms modulated by monsoonal variations in regional currents and eddies.

Repository: PK–AG–188

*Uvigerina bifurcata* d’Orbigny, 1839

Pl. 8; Fig. 6

Original citation: *Uvigerina bifurcata* D’ORBIGNY, 1839, v. 5, pt. 5, p. 53, pl. 5, fig. 113.

Remarks: The types for this species came from Islas Malvinas (Falkland Islands) (d’Orbigny, 1839). The figures reproduced by Barker (1960) are of the specimens obtained from the material dredged at the Challenger Station 232, south of Japan, in the North Pacific, at a depth of 345 fathoms (~631 m). This species was referred by Brady to *U. pygmaea* d’Orbigny, but Barker (1960) opined that Brady’s figures agreed well with the figures of *U. bifurcata* given by d’Orbigny and by Heron-Allen and Earland. Le Calvez (1972) reported this species from a water depth of 1,120 m of the Saharan coast in the Atlantic Ocean. According to Hayward et al. (2001), *Uvigerina bifurcata* is present at a water depth of 230 m in the offshore region east of New Zealand. In the Ubatuba Bay, on the northern coast of Sao Paulo State, Brazil, Burone and Pires-Vanin (2006) recorded *U. bifurcata* in a very shallow water depth range of 6 to 16 m. Eichler et al. (2012) found this species in the samples collected during both summer and winter off the sub-tropical South American coast, while Bonnin et al. (2014) recorded this species at a depth of 100 m off the Douro River (western Iberian margin). This might well be the first record of this uvigerinid from Indian waters.

Repository: PK–AG–189

*Uvigerina bradyana* Fornasini, 1900

Pl. 8; Fig. 7

Original citation: *Uvigerina bradyana* FORNASINI, 1900, ser. 5, v. 8, p. 390, text-fig. 40.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 191A, off Ki Island, in the Pacific Ocean, at a depth of 580 fathoms (~1,061 m; figs. 24, 25), and at Challenger Station 300, north of Juan Fernandez, East Pacific, at a depth of 1,375 fathoms (~2,515 m; fig. 26). This species was referred by Brady to *Uvigerina* sp., intermediate between *U. pygmaea* d’Orbigny and *U. aculeata* d’Orbigny. Fornasini (1900, p. 390) referred these figures to his *U. bradyana*. Todd (1948, p. 267) suggested that Brady’s fig. 26 (not figs. 24, 25) might be *U. peregrina* Cushman var. *dirupta* Todd. In the absence of comparative material, however, Barker (1960) followed Fornasini, and opined that, “future workers should keep in mind the possibility that these figures of Brady may represent more than one species, especially since his material came from widely separated localities”. In the present study, the systematics of Barker have been followed, and hence the name *Uvigerina bradyana* Fornasini. Yassini and Jones (1995) recorded its occurrence from the outer shelf and continental slope off the south-east coast of Australia. In the New Zealand region, this species has scattered records around the North and South islands, undoubtedly more widespread in deeper water (Hayward et al., 1999). *Uvigerina bradyana* has been observed to be widespread throughout the Pacific (Jones, 1994). This species has sporadic occurrence in low numbers in exposed, fully marine, mid-shelf depth, with greatest recorded abundances at bathyal depths (Lewis, 1979). It has been occasionally recorded washed into inner-shelf depth, and into exposed beaches (Hayward et al., 1999).
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Repository: PK–AG–190

_Uvigerina canariensis_ d’Orbigny, 1839

**Original citation:** *Uvigerina canariensis* D’ORBIGNY, 1839, pt. 2, p. 138, pl. 1, figs. 25–27.

**Remarks:** Bagg (1905) opined that living representatives of *Uvigerina canariensis* are distributed in a wide water depth range of “shore sands to 1,900 fathoms” (~3,475 m). Later, he (1912) observed that this species was “common in the California Miocene and not at all uncommon in the Pliocene of San Pedro”. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 323, South Atlantic, at a depth of 1,900 fathoms (~3,475 m; fig. 1), at Challenger Station 309, west coast of Patagonia, at a depth of 40 to 140 fathoms (~73 to 256 m; fig. 2), and at Challenger Station 33, off Bermuda, at a depth of 435 fathoms (~796 m; fig. 3). Cole (1981) listed this species among the bathyal zone benthic foraminifera from off north-east Newfoundland, but did not give any water depth range for it. *Uvigerina canariensis* was observed to constitute 8% of the fauna at only one station (at a depth of 1,000 m) among several in the central North Atlantic Ocean (Hermelin and Scott, 1985). Szarek (2001) gave a depth range of inner shelf to upper bathyal on the Sunda Shelf, in the southwestern South China Sea, for this species. Javaux and Scott (2003) reported *U. canariensis* at very shallow depths of 1 to 20 m from the nearshore areas and lagoons of Bermuda, West Indies. According to Mallon (2011), *U. canariensis* is a very rare species off the Peruvian and Ecuadorian margins, occurring in a water depth of 526 to 1,004 m, and is considered to be shallow infaunal (Pérez-Asensio _et al._, 2012).

Repository: PK–AG–191

_Uvigerina cushmani_ Todd, 1947

**Original citation:** *Uvigerina cushmani* Todd, 1947, In: Cushman and Todd, 1947, v. 23, p. 66, pl. 16, figs. 4, 5.

**Remarks:** The types for this species came from off Long Point, Catalina, at a water depth of 147 fathoms (~269 m) and, according to them, *Uvigerina cushmani* was recorded at more than 70 stations, mostly off the Channel Islands and in the Gulf of California at depths ranging from 10 to 212 fathoms (~18 to 388 m). They remarked, “This species differs from *U. sentiosa* Cushman in its slenderer form and the greater development of costae. It closely resembles *U. juncea* Cushman and Todd from the Pliocene of Timms Point, California, but differs in its larger, stouter test and more strongly developed ornamentation. It also resembles *U. pigmea* d’Orbigny from the Pliocene of Italy but differs in its much less prominent costae”. Being the senior author of the paper, Cushman transferred all the mounted material of the genera *Uvigerina, Hopkinsina, Trifarina* and *Angulogerina* to Miss Ruth Todd, who was working as a Research Associate in the Cushman Laboratory for Foraminiferal Research. She was given the responsibility for the synonymy, description of new species and the relevant discussions and remarks, and hence *U. cushmani* Todd, 1947 (Cushman and McCulloch, 1948). Smith (1973) recorded *Uvigerina cushmani* from the Aleutian Terrace in the North Pacific Ocean, off the Alaska Peninsula, but observed it to be rare. Hayward and Buzas (1979) observed several specimens of *Euuvigerina* very much similar to *Euuvigerina cushmani* (Todd) (as *Uvigerina cushmani* Todd, 1948, p. 257, pl. 33: fig. 1) and referred them to *Euuvigerina aff. E. cushmani* (Todd) from the Northern New Zealand and North Tasman Sea regions.

Repository: PK–AG–192

_Uvigerina peregrina_ Cushman, 1923
Original citation: *Uvigerina peregrina* Cushman, 1923, v. 161, no. 1, p. 166, pl. 42, figs. 7–10.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 24, West Indies, at a depth of 390 fathoms (~713 m). This species was referred by Brady to *Uvigerina pygmaea* d’Orbigny, but Cushman (1930, p. 63) pointed out that neither of Brady’s figures represented typical *U. pygmaea* and probably were of two distinct species, which he did not name. Cushman (1923, p. 166) erected *U. peregrina* for forms occurring off the north-east coast of the United States, and placed *U. pygmaea* of Flint, non d’Orbigny, in synonymy. Barker remarked, “This is a very variable species and it appears to include these figures figured by Brady”. Hofker (1932, p. 118) figured a similar form as *U. mediterranea*, which was placed by Höglund (1947, p. 279) in synonymy with *U. peregrina* Cushman. Hofker (1951, pp. 219–226), in a detailed discussion about *peregrina*, refuted Höglund’s views and retained *Euuvigerina mediterraneansis* (Hofker) (sic.) and *E. peregrina* (Cushman) as valid species in his new genus *Euuvigerina*, referring Höglund’s “*U. peregrina*” to *Aluvigerina pygmaea* (d’Orbigny). Since *pygmaea* is the genotype of *Uvigerina* d’Orbigny, *Aluvigerina* Hofker, 1951 is a synonym of that genus and cannot be upheld. Later, Hofker (1956, v. 15, pp. 82–84, pl. 9) referred forms from the West Indies to *Euuvigerina peregrina* (Cushman) and, in spite of discrepancies between Brady’s figures and typical *peregrina*, Barker (1960) felt that Brady was almost certainly dealing with a form of that highly variable species. Murray (1970) recorded *Uvigerina peregrina* as *U. finisterrensis* Colom from the Celtic Sea (128 to 138 m), and the shelf edge by the western approaches to the English Channel (420 to 1,002 m), and observed it to be an outer shelf species. According to Lohmann (1978), *U. peregrina* is most abundant at water depths ranging between 2,000 and 3,800 m. In the Mediterranean region, this species is less frequent than *Uvigerina mediterranea* in the Recent sediments, but it has a similar distribution. Studies involving well constrained ecologic parameters suggest that the distribution of *U. peregrina* is dominantly controlled by organic carbon supply and, secondarily, by oxygen levels (Miller and Lohmann, 1982; Rathburn and Corliss, 1994). According to Miao and Thunell (1993), *Uvigerina peregrina* is the most important benthic foraminiferal species in surface sediments from water depths above 1,500 m in the South China Sea, where pore water oxygen penetration depth is shallow and organic carbon contents are high. However, no obvious correlation between variations in the distribution of *U. peregrina* with changes in the content of sedimentary organic carbon was observed by Joyce and Williams (1986) in the Gulf of Mexico. Sen Gupta and Aharon (1994) examined benthic foraminifera of bathyal hydrocarbon vents of the Gulf of Mexico, and recorded that *U. peregrina* was one of the nine taxa that had abundance at 5% level, i.e., it constituted at least 5% of the living assemblage in one or more samples. According to Shin *et al.* (1996), *U. peregrina* is most abundant in oxygen-depleted water, and suggested that the distribution of this species is more influenced by the oxygen content rather than the water depth in the Caribbean Sea. This is in contrast to other reports wherein this species has been recorded from well oxygenated, shallow infaunal microhabitats (e.g., Lutze and Coulbourne, 1984; Corliss and Emerson, 1990; Fontanier *et al.*, 2002). According to Bornmalm (1997), *Uvigerina peregrina* is similar in some aspects to *U. mediterranea* but it has more chambers, which are less inflated and also ornamented by a larger number of smaller, discontinuous costae. The down-core distributions of *B. aculeata* and *U. peregrina* are controlled by changing *C_\text{org}* flux rates towards the seafloor (Altenbach and Sarnthein, 1989; Sarnthein and Altenbach, 1995). The increase in abundance and accumulation rate of these two species clearly indicates enhanced *C_\text{org}* flux and, hence increased surface export productivity during the last glacial along the southern slope and during the early Holocene along the northern slope in the South China Sea (Jian *et al.*, 1999). Observations from the north-western Mediterranean continental margin suggest that this species...
feeds from degraded food sources (Schmiedl et al., 2000). This observation is corroborated by Fontanier et al. (2002), who consider *U. peregrina* as one of the most tolerant species for low-quality organic matter, also tolerating dysoxic conditions. Rathburn et al. (2003) studied living benthic foraminifera in the vicinity of cold methane seeps in Monterey Bay, California, and noted that *U. peregrina* exhibited a high tolerance for H$_2$S concentrations exceeding 16 mM. Murray (2006) opined that the occurrence of *U. peregrina* is associated with “a rich supply of labile organic matter and a high concentration of bacteria”. *Uvigerina peregrina* is known to be characteristic of regions of high primary productivity in upwelling zones (Müntza et al., 2004; Schmiedl et al., 2004), and Eichler et al. (2012) correlated its occurrence off the sub-tropical South American coast to trace the movement of the South Atlantic Central Water (SACW) during summer in the northern part of the area. Kuhnt et al. (2007) opined that the *U. peregrina* assemblage seems to be indicative for a combination of abundant low-quality food but also sufficiently high oxygen levels in the Aegean Sea. According to Abu-Zied et al. (2008), the strong dominance of such superficially living taxa as *U. peregrina* suggests a food-limited, rather oligotrophic environment with high bottom-water oxygen concentration values. At the same time, low but repetitive percentage peaks of *U. peregrina* suggest periodical development of a microhabitat succession that reflects more mesotrophic conditions with a more constant organic flux to the sea floor. According to Sen Gupta et al. (2009b), this cosmopolitan species is distributed all over the Gulf of Mexico in a water depth range of 10 to 3,164 m. In the north-western part of the Indian Ocean (Arabian Sea region), surface primary production has a major maximum during the summer monsoon season and a secondary maximum during winter monsoon season. This results in high organic flux to the seafloor, making the deep-sea one of the most oxygen-deficient regions in the world ocean, with a pronounced OMZ. This region is dominated by benthic foraminifers that are characteristic of low oxygen and high organic food flux, intermediate to high organic carbon, and warm deep water, such as *Uvigerina peregrina* (De and Gupta, 2010). According to Mancin et al. (2013), the shallow infaunal *U. peregrina* is associated with intermediate to high and quite sustained food supply, low oxygen levels, fine-grained substrates, and can tolerate low oxygen conditions with refractory organic matter, but does not live in completely dysoxic environments. At the dysoxic (1,495 m) and oxic (1,791 to 3,010 m) stations in the northern Arabian Sea, both *B. aculeata* and *U. peregrina* showed two in-sediment maxima: in the first half centimeter, which was well oxygenated, and at 3–5 cm depth, below the oxygen and nitrate penetration depth (Caulle et al., 2014).

**Repository:** PK–AG–193

**Uvigerina schwageri** Brady, 1884

Pl. 8; Figs. 9, 9a

**Original citation:** *Uvigerina schwageri* BRADY, 1884, p. 575, pl. 74, figs. 8–10.

**Remarks:** The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the Challenger Station 174C, off Fiji, in the Pacific Ocean at a depth of 210 fathoms (~384 m), and Challenger Station 209, off the Philippines at 95–100 fathoms (~174 to 183 m). Hofker (1951, p. 226) opined that this was the megalospheric form of *Euuvigerina aculeata* (d’Orbigny), as it was commonly found associated with that species. Barker (1960), however, attributed the association to probably the environment and hence retained Brady’s name. According to Lamb and Miller (1984), *U. schwageri* species resembles *U. mexicana* with its inflated chambers and stout test, but differs in having thicker and less continuous costae. They made a comparison between their specimens and those from the Pliocene-Pleistocene interval of the South China Sea region and found them to be quite similar to what is called *Uvigerina schwageri* there. They also opined that its bathymetric range “is probably outer neritic to deep bathyal”. Szarek (2001) gave a water depth
range of inner shelf to uppermost bathyal for this species on the Sunda Shelf in the southwestern South China Sea. The response to the offered labeled phytodetritus varied largely among foraminiferal species with *U. schwageri* being by far the most important species in short-term processing during the experiments conducted by Enge *et al.* (2014). It yielded the highest TOC content and species biomass and was also largest in size. Total carbon uptake was highest for *U. schwageri* with 69.8 mg C m\(^{-2}\). They also remarked that their observation of highest uptake by *U. schwageri, U. peregrina,* and *B. gibba* was consistent with the earlier observations and results of Woulfs *et al.* (2007), where *Uvigerina* dominated short-term phytodetritus processing in the OMZ core on the Pakistan margin.

Repository: PK–AG–194

Subfamily ANGULOGERININAE Galloway, 1933
Genus TRIFARINA Cushman, 1923
*Trifarina carinata* (Cushman, 1927)

*Original citation:* *Angulogerina carinata* CUSHMAN, 1927, v. 1, p. 159, pl. 4, fig. 3.
*Remarks:* The figure reproduced by Barker (1960) is of Brady’s specimen recovered from the material dredged at Challenger Station 300, north of Juan Fernandez, in the East Pacific, at a depth of 1,375 fathoms (~2,515 m). This species was referred by Brady to *Uvigerina angulosa* Williamson, but Cushman (1927, p. 159) referred it to *Angulogerina carinata* and was retained by Barker (1960). Hayward and Grace (1981) recorded *Trifarina carinata* at shallow water depths of 15 and 20 m along a transect off south-west Cuvier Island, New Zealand, associated with medium to fine sand. Later, Hayward (1982) reported this species at a depth of 10 m, associated with “very shelly medium sand”, off the Little Barrier Island, New Zealand. Heinz *et al.* (2004) recorded this species as *Angulogerina carinata* and observed it to be confined to the plateau area at the Great Meteor Seamount, and invariably within the uppermost centimeter in the samples. According to Sen Gupta *et al.* (2009b), *Trifarina carinata* is distributed in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a wide water depth range of 16 to 1,067 m. Mallon (2011) stated that this species (reported as *Angulogerina carinata*) can be distinguished from *A. angulosa* Williamson in usually being bigger in size and in not having the several longitudinal costae present in the latter.

Repository: PK–AG–195

*Trifarina reussi* (Cushman, 1913)
Pl. 8; Figs. 10, 10a

*Original citation:* *Triplasia reussi* CUSHMAN, 1913, no. 71, pt. 3, p. 63, pl. 39, fig. 3.
*Remarks:* The figures reproduced by Barker (1960) are those of specimens obtained from dredging at the Challenger Station 192, off the Ki Islands in the Pacific Ocean, at a depth of 129 fathoms (~236 m). It was referred by Brady to *Rhabdogonium minutum* Reuss, but Cushman (1913, p. 63) referred it to *Triplasia reussi*. However, it was transferred by Cushman himself (1926) to the genus *Trifarina*. Hofker (1978) reported the occurrence of this species at a solitary station in the Ceram Sea, west of Misool, at a water depth of 1,496 m. Debenay (2012) recorded the occurrence of *Trifarina reussi* on the northern shelf off New Caledonia in the south-west Pacific Ocean, at a water depth of 600 m. There do not seem to be many records for this species; so this could well be the first record of this species from Indian waters.

Repository: PK–AG–196

Superfamily FURSENKOINACEA Loeblich and Tappan, 1961
Family FURSENKOIDAE Loeblich and Tappan, 1961  
Genus FURSENKOINA Loeblich and Tappan, 1961  
Fursenkoina bradyi (Cushman, 1922)

Original citation: *Virgulina bradyi* CUSHMAN, 1922, no. 104, p. 115, pl. 24, fig. 1.  
Remarks: The figures illustrated by Brady (Barker, 1960) are of the specimens recovered from the sediment dredged at Challenger Station 279C, off Tahiti, at a depth of 620 fathoms (~1,134 m; figs. 9a–c). This species was referred by Brady to *Virgulina subsquamosa* Egger, and by Cushman (1922, p. 115) to *Virgulina bradyi*. However, Barker (1960) opined that Brady’s figures were different from those of Egger. Loeblich and Tappan (1961) showed that *Virgulina* must be suppressed and placed granular forms of “*Virgulina*” in *Fursenkoina*, but according to Haynes (1973), radial species must be placed in *Stainforthia*. However, specimens recovered from the short cores used in the present study have the morphological characters typical of genus *Fursenkoina* Loeblich and Tappan, 1961, and the specific name has been retained after Cushman, 1922. Hofker (1978) recorded this species as *Virgulina bradyi* at a solitary station north-east of Manui, in the eastern part of the Indonesian Archipelago, at a water depth of 2,969 m. This species was reported by Bornmalm (1997) as *Rutherfordoides bradyi* (Cushman), but observed it to be very rare at both sites in the Caribbean Sea and eastern Equatorial Pacific Ocean. According to Hess *et al.* (2005), *Fursenkoina bradyi* was one of the few species to colonize after the turbidite deposition in the Cape Breton Canyon, Bay of Biscay; initially the assemblage had been monospecific, containing exclusively *Technitella melo*. In the north-west Indian Ocean, this species is part of an assemblage that is indicative of severe dysoxia and is commonly associated with laminated sediment lacking bioturbation and high organic flux (Murray, 2006). According to Lorz *et al.* (2012), who reported this species as *Cassidella bradyi* in their review of deep-sea benthic biodiversity associated with trench, canyon and abyssal habitats below 1,500 m depth in New Zealand waters, this species is distributed in a water depth range of 194–4,440 m. McKay (2015) studied the benthic environmental responses to climatic changes during the late Quaternary, and opined that *C. bradyi* is associated with fresh phytodetritus input and strong benthic-pelagic coupling (McKay *et al.*, 2014).

Repository: PK–AG–197

Fursenkoina davisi (Chapman and Parr, 1937)

Original citation: *Virgulina davisi* CHAPMAN and PARR, 1937, v. 1, no. 2, p. 88, pl. 8, fig. 15.  
Remarks: Chapman and Parr (1937) recorded the types from the colder waters of the Antarctic, and named this species in honor of Captain J. King Davis, R. N. R., the Commander of the *Aurora*. They stated, “The species most closely related to *V. damsi* appears to be *Virgulina longissima* (Costa), figured by Costa (1856, pl. XIII, figs. 22, 23) as *Polymorphina longissima*, from the Tertiary of Italy. The latter species has more chambers, is longer and has a narrower aperture”. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the material dredged at Challenger Station 276, in the South Pacific Ocean, at a depth of 2,350 fathoms (~4,298 m; figs. 1, 3). Brady referred this species to *Virgulina schreibersiana* Czjzek, while Chapman and Parr (1937, p. 88) referred it to *V. davisi*. However, specimens recovered in the present study have the morphological characters typical of genus *Fursenkoina* Loeblich and Tappan, 1961, and the specific name is retained after Chapman and Parr, 1937. *Fursenkoina davisi* differs from *F. bradyi*, in possessing a relatively smaller test, less inflated and less oblique to horizontal chambers, and less oblique to horizontal, slightly curved sutures. According to Bandy and Kolpack (1963), the genus *Virgulina* d’Orbigny, 1826, is a homonym, having been used by Bory de Saint Vincent in 1823 for a trematode worm. *Cassidella* Thalmann, 1952 is the first available name for this
foraminifer, and this could be the reason for Pflum (1966) to record this species as *Cassidella davisi*. Debenay (2012) recorded this species as *Cassidolina davisi* at shallow depths ranging from 10 to 40 m in the Gulf of Prony, off New Caledonia in the south-west Pacific Ocean.

**Repository:** PK–AG–198

*Fursenkoina schreibersiana* (Czjzek, 1848)

**Original citation:** *Virgulina schreibersiana* CZJZEK, 1848, v. 2, p. 11, pl. 13, figs. 18–21.

**Remarks:** The types for this species came from Baden, near Vienna, Austria, from the Miocene (d'Orbigny, 1826). However, the syntypes should have been deposited in the collections of the Geologische Bundesanstalt, Vienna, but specimens could not be traced due to the vagaries caused by the Second World War (Revets, 1996). Flint (1899) recorded this species as *Virgulina schreibersiana* and stated its occurrence at one station in the Chesapeake Bay, at a water depth of 430 fathoms (~786 m). As early as 1914, Pearcey had stated, “It has a very extensive distribution, and although it has been recorded from shallow water, its natural habitat would appear to be in the deeper waters of the great ocean basins; its range of depth is from 11 to 3,125 fathoms” (20 to 5,715 m). This species was recorded by Heron-Allen and Earland (1916) as *Virgulina schreibersiana*. The distributional data of *Fursenkoina schreibersiana* from Mindoro, Philippines, provided by Graham and Militante (1959) confirms a preference for muddy sediments, and suggests that it can range into very shallow water. Murray (1970) recorded this species from the south coast of Cornwall, at depths ranging between 14 and 42 m, and observed that the test wall is more coarsely perforate than in *Fusiformis* (Murray, 1971). According to Pflum and Frerichs (1976), “Twisted biserial and regular biserial forms, such as *Fursenkoina schreibersiana* (Czjzek) and *F. seminuda* (Natland), are distinct species lacking any suggestion of intergradation in form and structure. On the other hand, several species such as *F. punctata* (d'Orbigny), *F. pontoni* (Cushman), and *F. schreibersiana* are apparently closely related forms which represent a cline rather than distinct species. Specimens resembling *F. schreibersiana* are mostly middle to lower neritic in water depth distribution, whereas those with translucent areas in the upper portions of the chambers such as *F. seminuda* are middle and lower bathyal and even abyssal in distribution”. Debenay and Basov (1993) listed *Fursenkoina schreibersiana* among the Recent foraminifers distributed on the West African shelf and slope. Haig (1993) reported it from the basin of the Papuan Lagoon, New Guinea, at depths of 15 to 38 m, in “soupy” muds. Hottinger *et al.* (1993) reported a species of *Fursenkoina* as *Fursenkoina* sp. A, and remarked, “It resembles *Virgulina schreibersiana* Czjzek as figured by Graham and Militante (1959) (pl. 13, fig. 14) as well as by Cushman, 1942 (pl. 4, fig. 1). According to Feyling-Hanssen (1964), only forms whose aperture moves to a terminal position when fully grown should be assigned to *Stainforthia fusiformis*, while forms whose aperture remains, at all stages of development, a loop at the base of the final chamber should be placed under *S. schreibersiana*. However, *Fursenkoina schreibersiana*, placed in the synonymy of *F. acuta* (d'Orbigny) by Papp and Schmid (1985), is more slender and has much oblique sutures and a more lobulate periphery (see Papp and Schmid, 1985, pl. 75, figs. 1–6)”. Hofker (1978) recorded this species as *V. schreibersiana* at two stations: one in the Sulu Sea, at a water depth of 4,321 m, and the other in the Arofoera Sea at 354 m. According to Hageman (1979) both *Ammonia perluicida* and *Fursenkoina schreibersiana* appear to be species that have a preference for a muddy substrate and slightly hyposaline conditions. The tolerance for slightly deviating salinities seems to be somewhat lower for *F. schreibersiana* than for *A. perluicida*. On the other hand, Hayward (1981) observed this species to be associated with slightly shelly medium sand, at a water depth of 30 m, off Cuvier Island, north-east New Zealand. According to Revets (1996), there has been considerable amount of confusion in the literature between *F. schreibersiana* and *F. squammosa*. He stated that many of d'Orbigny’s collections had been lost over time and the
flooding by the Seine resulted in the drowning of all the glass tubes containing d’Orbigny's specimens. He also lamented the fact that, “Repeated and exhaustive searches have failed to yield any indication of *Virgulina squammosa*. Revets (op cit) stated that *F. schreibersiana* differs from *F. squammosa* in possessing much lower chambers and more twisted initial coils. Moreover, the aperture of *F. schreibersiana* is much more bulimine than that of *F. squammosa* (Revets, 1996). All the tubes, including unlabelled ones, and all the loose cardboard identification labels have been assembled and repeatedly checked to no avail. I therefore consider potential syntypes as being lost”. Rajeshwara Rao (1998) recorded this species from the inner shelf sediments of the Bay of Bengal, and observed its maximum abundance in the depth range of 38 to 55 m. In the New Zealand region, this taxon was recorded from the Upper Waitemata Harbour, Auckland, New Zealand (Hayward *et al.*, 1997). *Fursenkoina schreibersiana* is present around all the three main islands, and has also been recorded from Auckland Islands. This species has been observed to be widespread in low numbers in moderately sheltered to exposed, fully marine, inner shelf depths (Hayward *et al.*, 1999). It is considered to be a cosmopolitan species (Culver and Buzas, 1980, 1986; Loeblich and Tappan, 1994). While Hayward *et al.* (2001) presented a water depth range of 750 to 4,680 m in the offshore region east of New Zealand, Szarek (2001) gave a water depth range of inner shelf to upper bathyal for *F. schreibersiana* on the Sunda Shelf in the south-western South China Sea. According to Hayward *et al.* (2010), *F. schreibersiana*, a cosmopolitan species, is deep infaunal (Pérez-Asensio *et al.*, 2012) and is present right around the New Zealand region (35° to 51° S), and is widespread in low numbers at inner shelf to abyssal depths (30 to 5,000 m), but mostly shallower than 1,000 m. This species, reported as *Virgulina schreibersiana* by Mallon (2011), was observed to be very rare, and was found at only one station, at a water depth of 697 m, off the Peruvian margin. On the contrary, Debenay (2012) recorded this species at a water depth of 40 m in the south-western lagoon of New Caledonia in the south-western Pacific Ocean, corroborating one of the earliest observations by Pearcey (1914).

Repository: PK–AG–199

*Fursenkoina texturata* (Brady, 1884)

Pl. 8; Fig. 11

Original citation: *Virgulina texturata* BRADY, 1884, v. 9, p. 415, pl. 52, figs. 6a, b.

Remarks: The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 296, in the South Pacific Ocean, at a water depth of 1,825 fathoms (~3,338 m). The types for this species, referred by Brady (1884) to *Virgulina texturata*, came from the south-east Pacific, off Juan Fernandez Island, although Hayward *et al.* (2012) opined that the specimens were possibly reworked. However, Egger (1893) recorded this species from a *Gazelle* station off New Zealand at a depth of 2,769 m, while Chapman (1910) reported it from off Funafuti Atoll, Pacific Ocean, at a depth of 2,298 fathoms (~4,203 m). Perhaps the first record of *V. texturata* from the North Pacific was by Cushman (1907), who observed its occurrence at one *Albatross* station at a water depth of 1,783 fathoms (~3,279 m) and at two *Nero* stations at 1,850 and 1,990 fathoms (3,838 and 3,639 m), respectively. He noted that “the specimens from *Nero* station 166 were very smooth and somewhat different from the typical ones found at the other stations”. The figures reproduced by Barker (1960) are of the specimens obtained from material dredged at Challenger Station 296 in the South Pacific Ocean at a water depth of 1,825 fathoms (~1,669 m). Smith (1964), who studied the ecology of benthic foraminifera off El Salvador, opined that *Virgulina texturata* is similar to *V. sandiegoensis* Uchio, 1960 but is comparatively larger in test size. According to Hayward (2001, 2002) the last decline of foraminiferal fauna, between 3 and 0.6 Ma, during late Pliocene-middle Pleistocene, resulted in the extinction of the families Stilostomellidae and Pleurostomellidae, 17 genera and over 50,
mostly rare, elongate species, including *Fursenkoina texturata* in the area east of New Zealand. Although this event was considered global at that point of time, Heinz and Hemleben (2003) recorded living specimens of *F. texturata* in the Arabian Sea. Hayward et al. (2012) opined that if their identifications were correct, then this species might be another example of a species of the group of elongate benthic foraminifera that actually declined in abundance and geographic range during the Last Global Extinction, but did not become extinct; instead, they managed to survive through to the Recent in some refugia, and are listed them under the Die-Back Group (Hayward et al., 2012). They also presented a water depth range of 500 to 3,300 m for this cosmopolitan species. According to Mallon (2011), who reported it as *Virgulina texturata* from the Peruvian-Ecuadorian margin, it differs from the similar *Virgulina earlandi* (Cushman) by its straight growth and the simple oblique sutures, and in the chambers being more globular.

**Repository:** PK–AG–200

Genus RUTHERFORDOIDES McCulloch, 1981

*Rutherfordoides rotundata* (Parr, 1950)

**Original citation:** *Virgulina rotundata* PARR, 1950, v. 5, pt. 6, p. 337, pl. 12, figs. 14a, b.

**Remarks:** The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 279C, off Tahiti, at a depth of 620 fathoms (~1,134 m; figs. 10a, b; 11a, b). This species was referred by Brady to *Virgulina subquamosa* Egger, while Parr (1950, p. 337) referred it to *V. rotundata*. Hofer (1951, pp. 304, 305) figured specimens rather close to Brady’s figures as *Cassidulinoides subquamosa* (Egger), but did not refer to Cushman (l. c. supra 1937) or to Parr. Hofer (1978) recorded this species as *Virgulina rotundata* at a solitary station in the Gulf of Bone at a water depth of 1,829 m in the eastern part of the Indonesian Archipelago. According to Bernhard (2000), *Fursenkoina rotundata* harbours bacterial endosymbionts and is a dysoxic indicator (Kaiho, 1994). Bernhard et al. (2001) observed that *F. rotundata* was one of the few species that were generally more abundant and typically made up higher proportions in cold seep samples compared to non-seep sediment samples collected from Monterey Bay, California, in a water depth range of 900 to 1,000 m. According to Hayward et al. (2003), who reported this species as *Rutherfordoides rotundata*, its upper water depth limits are 500 m in the offshore region west of New Zealand, but lower at 300 m in the region east of it. They stated that these differences in upper depth limits were probably related, at least partly to the differences in primary productivity and consequently food supply to the seafloor on either side of New Zealand. Debenay and Patrona (2009) stated that the ecological requirements of this species are poorly known, but opined that it may be present in very small amounts in feed channels and basins. According to Sen Gupta et al. (2009b), who recorded this cosmopolitan species as *R. rotundatus*, it is found in only the north-western part of the Gulf of Mexico, at a water depth of 700 m. Hayward et al. (2010) revised the upper water depth limit for *R. rotundata* to 150 m west of New Zealand, and gave much higher limits of 2,500 m and 2,750 m for north-east of New Zealand and sub-Antarctic New Zealand, respectively.

**Repository:** PK–AG–201

Superfamily PLEUROSTOMELLACEA Reuss, 1860

Family PLEUROSTOMELLIDAE Reuss, 1860

Subfamily PLEUROSTOMELLINAE Reuss, 1860

Genus OBESOPLEUROSTOMELLA Hayward, 2012

*Obesopleurostomella brevis* (Schwager, 1866)

**Original citation:** *Pleurostomella brevis* SCHWAGER, 1866, p. 236, pl. 6, fig. 81.
Remarks: The types for this species came from the Pliocene of Car Nicobar, off Sumatra, in the Indian Ocean (Schwager, 1866). The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 279C, off Tahiti, at a depth of 620 fathoms (~1,134 m; figs. 20a, b). Todd (1970), who studied smaller foraminifera from the Late Eocene deposits on Tonga Island in the Pacific Ocean, recorded this species as *Pleurostomella brevis* and remarked, “Specimens of this long-ranging (Eocene to Holocene) found at Eua are robust and short and have a blunt initial end”. Hayward (1979) studied Altonian (early Miocene) foraminifera from the eastern Waitakere Ranges in Auckland, New Zealand, and recorded the presence of *P. brevis* from the Carter Road Quarry but not in the Shaw Road Quarry and gave a mid-bathyal depth range of 1,000 to 2,000 m for the fauna. Bornmalm (1997) studied the taxonomy and paleoecology of Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, and observed this species (reported as *P. brevis*) to be very rare (only a single specimen) at the site in the former at water depth of 3,051 m, and also rare with scattered occurrences in the latter at 3,672 m. Hayward (2002) opined that the broadly rounded *P. brevis* and the narrowly pointed *P. recens* “have all other features in common and occur together” and considered them to be macrospheric and microspheric forms of the former. According to Gupta and Thomas (2003), high to moderate organic flux and intermediate seasonality can be inferred in the eastern equatorial Indian Ocean, if *P. brevis* is a part of an assemblage consisting of *Stilostomella abyssorum*, *Melonis pompilloides* and *Cibicides bradyi*, and intermediate organic flux, intermediate to high seasonality and refractory organic matter, when associated with *M. barranum*, *Dentalina stimula* and *P. obtusa*. Yudhicara (2012) examined tsunami deposits after the 1996 tsunami on the Biak Coast, Papua, and found that the foraminiferal content seemed to indicate that the tsunami deposit was derived from >200 m seafloor depth (bathyal zone); he recorded the presence of *Pleurostomella brevis* and presented a water depth range of ~300 to 3,000 m for it. *Obesopleurostomella brevis* has been listed under the Extinction Group, a group of elongate species that disappeared during the *Stilostomella* extinction event (Hayward *et al*., 2012), but its presence in the short core at 3,042 m water depth in the study area may require it to be shifted to the Die-Back Group. They presented a water depth range of middle bathyal to middle abyssal (900 to 4,000 m) for this cosmopolitan species. This is supported by the fact that Mallon (2011) recorded a single, living specimen of this species (as *P. brevis*) from off Peru at a water depth of 511 m and remarked, “This is a rare species in this study. Although this species counts as extinct since about 600,000 years (Hayward and Kawagata, 2005 and other authors cited therein), the identification of this species matches clearly to *P. brevis*”.

Repository: PK–AG–202

Superfamily STILOSTOMELLACEA Finlay, 1947

Family STILOSTOMELLIDAE Finlay, 1947

Genus ORTHOMORPHINA Stainforth, 1952

*Orthomorphina challengeriana* (Thalmann, 1937)

Pl. 8; Fig. 12

Original citation: *Nodogenerina challengeriana* THALMANN, 1937, p. 341, pl. 64, figs. 25–27.

Remarks: *Orthomorphina challengeriana* was described by Brady (1884) from the Holocene off the Ki Islands, south-west of Papua, in the southern Pacific Ocean. The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at Challenger Station 192 at a depth of 129 fathoms (~236 m). This species was referred by Brady to *Nodosaria perversa* Schwager and by Thalmann (1937, p. 341) to *Nodogenerina challengeriana*. Stainforth (1952, p. 8), however, transferred this species to *Orthomorphina*. LeRoy (1964) recorded this species from the Late Tertiary of Southern Okinawa, Japan, as *Orthomorphina challengeriana* and observed it to be
common in the deep-water (deep neritic to bathyal) Yonabaru (Miocene) assemblages, but was rare in the Shinzato formation (Miocene or Pliocene) that represents an open sea, shallow neritic environment. Hayward (1979) recorded the presence of *O. challengeriana* in association with an unusual occurrence of the sea grass, *Zostera capricorni*, living in an inter-tidal pool on the storm-swept west coast of Northland, New Zealand, but attributed its presence to transportation from the offshore sands by the prevailing west winds and Tasman Sea swells. According to Bornmalm (1997), who studied the taxonomy and paleoecology of Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, *Orthomorphina challengeriana* was found to be a rare species with scattered occurrences at the site in the former at water depth of 3,051 m, but only a solitary specimen was found in the latter at 3,672 m. This might as well be the first record of this rare species from Indian waters.

Repository: PK–AG–203

*Orthomorphina jedlitschkai* (Thalmann, 1937)

**Original citation:** *Nodogenerina jedlitschkai* THALMANN, 1937, v. 310, p. 341, pl. 62, figs. 1, 2.

**Remarks:** The figures reproduced by Barker (1960) are of Brady's specimens obtained from the material dredged at the Challenger Station 192, off the KI Islands, in the Pacific Ocean, at a depth of 129 fathoms (~236 m). Brady (1884) referred this species to *Nodosaria radicula* var. *annulata* Terquem and Berthelin, while Thalmann (1937, p. 341) referred it to *Nodogenerina jedlitschkai* nom. nov. Later, Stainforth (1952, p. 9) transferred it to *Orthomorphina*. Bornmalm (1997) studied the taxonomy and paleoecology of Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, and recorded *Orthomorphina jedlitschkai* in only one sample from the Caribbean Sea (water depth of 3,051 m), but observed it to be absent in the eastern equatorial Pacific Ocean. According to Hayward and Kawagata (2005), the Recent specimens from off Indonesia (Brady, 1884) “are clearly reworked”. Five ODP sites in the Mediterranean Sea were examined for foraminifera by Hayward et al. (2009), who recorded the occurrence of this species as common (11 to 100 specimens) at Site 975, occasional (3 to 10 specimens) at the Sites 976 and 966, and rare (1 to 2 specimens) at Site 654. At the Site 967, *O. jedlitschkai* was absent. According to Hayward et al. (2012), *Orthomorphina jedlitschkai* resembles *Glandulonodosaria glandigena*, but can be distinguished by its more robust test and the presence of a distinct elevated apertural collar. They presented a water depth range of upper bathyal to middle abyssal (500 to 3,600 m). In all probability, this is the first record of this species from Indian waters.

Repository: PK–AG–204

**Genus SIPHONODOSARIA A. Silvestri, 1924**

*Siphonodosaria consobrina* (d'Orbigny, 1846)

**Pl. 8; Fig. 13**

**Original citation:** *Dentalina consobrina* D'ORBIGNY, p. 46, pl. 2, figs. 1–3.

**Remarks:** *Siphonodosaria consobrina* was first described (as *Dentalina consobrina*) by d'Orbigny (1846) from the Miocene of the Vienna Basin, Austria. While studying the Miocene foraminifera from the Monterey Shale in California, Bagg (1905) recorded this species as *Nodosaria consobrina* and remarked that the typical forms of this species can be differentiated from its variety (*Nodosaria consobrina* var. *emaciate*) by the smaller number of chambers and their larger size in the former. Bagg (1912) studied Pliocene and Pleistocene foraminifera from southern California and observed this species to be less abundant compared to its varietal form in the Pliocene sands of San Pedro, but exhibited more variations. According to Galloway and Morrey (1929–30), who...
studied Lower Tertiary fauna from Manta, Ecuador, “this species is a generalized form which is of little value in correlation. It has been recognized from the Middle Jurassic to the Recent”. The only record of this species (as Dentalina consobrina) from the Terra Nova dredgings was from off the coast of New Zealand (Chapman and Parr, 1937). They also stated that there are records of this species from the Great Barrier Island and Enderby Island, both in the New Zealand area. The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 191A, off the Ki Islands, in the Pacific Ocean, at a water depth of 580 fathoms (~1,061 m), and at Challenger Station 300, north of Juan Fernandez, in the East Pacific, at a depth of 1,375 fathoms (~2,515 m). This species was referred by Brady to Nodosaria but was transferred by Stainforth (1952, p. 12) to Siphonodosaria which was then considered as a synonym of Stilostomella. According to Bornmalm (1997), who studied the taxonomy and paleoecology of Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, Siphonodosaria consobrina was found to be relatively common with scattered distribution at the site in the Caribbean Sea (water depth of 3,051 m), while it was rare with few occurrences in the eastern equatorial Pacific Ocean (at 3,051 m). Recognition of the Stilostomella extinction event was extended to the western equatorial Pacific Ocean by Resig and Cheong (1997), where S. consobrina disappeared during the MPT (1.2 to 0.55 Ma). Hayward and Kawagata (2005) referred this species to Mylostomella costai (Schwager, 1866) and considered the specimens to be relict belonging to the Pleistocene. In his studies on the systematic and paleoecology of Middle and Late Eocene benthic foraminiferal fauna from the Hungarian Paleogene basin, Oszvárt (2007) listed this species as Stilostomella consobrina (d’Orbigny). According to Grunert et al. (2010), the infaunal species, Siphonodosaria consobrina, from an Early Miocene sample revealed the only positive values in all 19 measured species (12 planktic and 7 benthic) and thus showed highest values in both δ¹⁸O and δ¹³C (0.72‰ and 0.47‰). Siphonodosaria consobrina is an indicator of suboxic conditions and is infaunal (Pezelj et al., 2013). Repository: PK–AG–205

Genus STILOSTOMELLA Guppy, 1894

*Stilostomella abyssorum* (Brady, 1881)

Pl. 8; Fig. 14

Original citation: *Nodosaria abyssorum* BRADY, 1881, v. 9, p. 584, pl. 63, figs. 8–9.

Remarks: The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 296, in the South Pacific Ocean, south-west of Juan Fernandez Island, at a water depth of 1,825 fathoms (~3,338 m). This species was referred by Brady (1884), albeit with doubt, to Nodosaria, but Stainforth (1952, p. 11) placed it under the genus *Siphonodosaria*, which was then considered to be a synonym of *Stilostomella*. Earlier, Jedlitschka (1935, p. 66) had placed this species in the synonymy of *Siphonodosaria pauperata* (d’Orbigny), but this was not accepted by later workers as it did not appear to be justified. A few typical specimens of *S. abyssorum* were reported from a core retrieved from Bikini Atoll in the Marshall Islands (Cushman et al., 1954). Bornmalm (1997) studied the taxonomy and paleoecology of Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, recorded this species as *Siphonodosaria abyssorum*, and observed it to be very rare (a solitary specimen) in the Caribbean Sea (water depth of 3,051 m), but with more scattered occurrences in the eastern equatorial Pacific Ocean. According to Gupta and Thomas (2003), high to moderate organic flux and intermediate seasonality can be inferred in the eastern equatorial Indian Ocean, if *S. abyssorum* is a part of an assemblage consisting of *Pleurostomella brevis*, *Melonis pompilloides* and *Cibicides bradyi*. Specimens that resembled this species were recorded as *Stilostomella aff. abyssorum* by Kender et al. (2008) from the Early to Middle Miocene of the
Deep-sea Congo Fan, off Algeria, at a depth of 2,920 m. According to Sarkar and Gupta (2009), *Stilostomella abyssorum* is one of the species that is indicative of moderate to high to moderate organic flux and intermediate seasonality in the Indian Ocean (Gupta and Thomas, 2003).

Repository: PK–AG–206

*Stilostomella antillea* (Cushman, 1923)
Pl. 8; Fig. 15

**Original citation:** *Nodosaria antillea* CUSHMAN, 1923, no. 104, pt. 4, p. 91, pl. 14, fig. 9.

**Remarks:** It is not known where the types for this species came from as no locality was mentioned by Cushman. It was referred by Brady (1884) *Sagrina virgula* Brady, but Cushman (1923, p. 91) referred it to *Nodosaria antillea*. Later, Church (1928, p. 267) placed this species under the genus *Nodogenerina*, while Stainforth placed it under *Siphonodosaria*. Barker (1960), however, opined that *Stilostomella* was the correct generic name for all the above mentioned forms. Bandy and Rodolfo (1964) examined the living and dead foraminifera in the Peru-Chile trench and found a rather limited number of species, although their most interesting observation was on the occurrence of living *Stilostomella antillea* at a water depth of 6,011 m. Thomas (1987) recovered a solitary specimen that closely resembled *S. antillea* from the lower Scotian slope and reported it as *Stilostomella* sp. cf. *antillea*. In the Peru-Chile Trench area, however, a modern benthic foraminiferal bathymetric zone (upper limit 3,257 m), defined in the 1960s, is characterized by the *Stilostomella antillea* group, containing some living *Stilostomella* forms (e.g., *Stilostomella antillea*) (Gavrilloff, 2006). As this species has been listed as extinct, he preferred to call it a "living fossil". Spezzaferri and Tamburini (2007) studied paleodepth variations on the Eratosthenes Seamount in the eastern Mediterranean Sea and presented a water depth range of 100 to 2,500 m for this species. Although it is considered that many species of the genera *Stilostomella* and *Pleurostomella* became extinct during the so-called “Stilostomella extinction event” (mid-Pleistocene Transition) (Bhaumik et al., 2011), they have been recovered from Recent deep-sea sediments: Andaman Sea (Frerichs, 1967); tropical Indo-Pacific (Van Marle, 1989, 1991); eastern Indian Ocean (Rai and Singh, 2004); and the Peru-Chile Trench (Douglas and Woodruff, 1981). This is sufficient evidence to prove that *S. antillea* is extant.

Repository: PK–AG–207

*Stilostomella fistuca* (Schwager, 1866)

**Original citation:** *Nodosaria fistuca* SCHWAGER, 1866, p. 216, pl. 5, figs. 36–37.

**Remarks:** The types for this species came from the Pliocene of Car Nicobar in the Indian Ocean (Schwager, 1866). Cushman (1939) studied Schwager’s original figures and remarked, “From a study of this material the species should be known as *Ellipsonodosaria fistuca* (Schwager) based on the character of the aperture . . .” LeRoy (1964) recorded this species from the Late Tertiary of Southern Okinawa, Japan, as *Nodosaria fistuca* and observed it to be very rare in both Yonabaru and Shinzato assemblages. Hofker (1978) recorded this species as *Stilostomella fistula* (most probably a typographical error) at a solitary station in the Timor Sea, east of Roti, at a water depth of 378 m in the eastern part of the Indonesian Archipelago. *Scallopostoma conica* (Neugeboren) was considered by Srinivasan and Sharma (1980) to be a junior synonym of *Stilostomella fistuca*, but it differs by its smaller test with spherical to sub-spherical chambers, and the presence of a very narrow neck with a scallop-edged aperture. This species was referred by Hayward *et al.* (1999) to the genus *Laevidentalina*, but later Hayward (2002) and Hayward and Kawagata (2005) placed it under *Stilostomella*; the latter, however, considered tests of this species as relict forms that had been reworked. During the Late Pleistocene, a group of species are
considered to have disappeared (the Stilostomella extinction event) (Bhaumik et al., 2011), among which this species (reported as Orthomorphina fistuca) is supposed to have become extinct at the base of the Brunhes epoch (Lutze, 1979). Subsequently, Hayward et al. (2012) listed S. fistuca under the Extinction Group, among the elongate, cylindrical, mostly uniserial taxa recorded in the IMAGES site MD 97-2114 on the northern side of the Chatham Rise, east of New Zealand, and gave a present-day bathymetric range of middle bathyal to middle abyssal (900 to 3,300 m) for this cosmopolitan species. They also remarked, “This species is of similar shape to S. parexilis from which it is distinguished by its pustulose rather than smooth chamber walls”. This could well be the first record for this species from Indian waters.

Repository: PK–AG–208

Genus UNIDENS Hayward and Kawagata, 2012

Unidens retrorsa (Reuss, 1863)

Pl. 8; Figs. 16, 16a

Original citation: Dentalina retrorsa REUSS, 1863, v. 48, p. 46, pl. 3, fig. 27.

Remarks: The types for this species were fossils from the Oligocene Septaria-clay of Offenbach in Germany (Reuss, 1863), and was later described by Egger (1899) from the Chalk of Bavaria. The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 191A, off the KI Islands, in the Pacific Ocean, at a water depth of 580 fathoms (~1,061 m). Brady (1884) referred this species to Nodosaria (D.) retrorsa, and gave its description as follows: “A slender Dentaline variety, with elongate-oval or fusiform segments, the basal ends of which are armed with a small number of delicate spines”. Barker (op cit.), however, opined that it appeared to belong to the genus Orthomorphina but if examination of the type revealed a toothed aperture, it should be placed under the genus Stilostomella. In their discussion on the Early Pliocene re-colonization of the Mediterranean Sea by benthic foraminifera and their pulsed Late Pliocene–Middle Pleistocene decline, Hayward et al. (2009) recorded this species as Strictocostella retrorsa (Reuss). A new genus Unidens was erected by Hayward and Kawagata (2012) with Nodosaria retrorsa Reuss, 1863 as its type species. They noted that “Unidens differs from Strictocostella and Siphonodosaria by having a smooth rather than denticulate or crenulate inner margin of the aperture”, and stated that U. retrorsa possesses a “few, long backwards-pointing spines on their lower part”. According to Hayward et al. (2012), Unidens retrorsa is distinguished by its lack of costae and its widely-spaced, more elongate chambers, and has a present-day bathymetric range of 1,200 to 2,200 m.

Repository: PK–AG–209

Superfamily DISCORBACEA Ehrenberg, 1838

Family BAGGINIDAE Cushman, 1927

Subfamily BAGGININAE Cushman, 1927

Genus CANCRIS de Montfort, 1808

Cancris auriculus (Fichtel and Moll, 1798)

Original citation: Nautilus auricula FICHTEL and MOLL, 1798, pp. 108, 110, pl. 20, figs. a–c (var. a), d–f (var. b).

Remarks: This species was first described from British waters with Skye as the chief locality. Bagg (1905) recorded this species as Pulvinulina auricula and remarked, “The bathymetric range of the species in the North Atlantic, where it is most common, is from the littoral zone down to 200 fathoms, and specimens have been dredged at over 500 fathoms, but the form is typically a shallow-water species”. Colom (1952) studied the foraminifera along the coast of Galicia, and
observed *C. auriculus* to be rare in a water depth range of 42 to 607 m, except at 94 m, where it was common. Murray (1970) recorded this species (as *Cancris auricula*) from the Bristol Channel (66 to 91 m) and the Celtic Sea (128 to 138 m) and observed it to be a shelf species. Later, he (1971) remarked, “This species has sometimes been recorded as *C. oblonga* (Williamson)”. Haynes (1973) recorded it from the Cardigan Bay, British Isles, as *C. oblongus* and remarked, “This species, as shown by Cushman and Todd (1942) and Le Calvez (1958) is distinguished from *C. auriculus* by its more elongate and compressed test and narrower chambers as well as by the pronounced incision of the sutures in the umbilical area; *C. oblongus* also appears to be more flattened on the dorsal side and to possess a larger umbilical lobe”. In the Arosa Bay, Galicia, Spain, Voorthuysen (1973) observed this species to be rare (0.2–2.9%) and concluded that although it has a preference for the shelf environment of the open ocean, it can “maintain itself in the deeper parts of bays, where it has been brought from the open ocean”. He further stated that this species was an important indicator of connectivity between the bay and the open ocean. Hofker (1978) observed this species to occur at three stations: north of Halmameira, Sepi, Moratai, at a water depth of 75 m; in the Timor Sea, east of Roti, at 378 m; and north-west of Damar, at a depth of 3,358 m, in the eastern part of the Indonesian Archipelago. The relatively high numbers of *Cancris auricula* in the Plio-Pleistocene silty clays and sands in Greece suggest that this species has a preference for shallow, normal marine environments with a high sedimentation rate and not too high energy conditions (Hageman, 1979). Yassini and Jones (1995) observed its occurrence in the inlet channels of coastal lagoons, open estuaries, inner and middle shelf, off the south-east coast of Australia. Revets (1996) opined that de Montfort’s very florid drawing of *Cancris auriculus* led to a complete neglect of this genus until studies were initiated by Cushman, and new species began to be described under the genus *Cancris* only post-1940. According to Haig (1997), who recorded this species from the Exmouth Gulf, Western Australia, the specimens figured by Loeblich and Tappan (1994, pl. 266, figs. 1–13) as *C. carinatus* (Millett) may actually belong to *C. auriculus* as they lack the triangular cross-section in the last chamber, which is characteristic of Millett’s species. Increased abundance of *C. auriculus* (along with *Nouria polymorphinoides* and *Tetragonostomia rhombiformis*) was attributed to high primary productivity and fresh organic matter in the sediments off the Ivory Coast and near the Volta delta (Schiebel, 1992; Altenbach et al., 1999). According to Altenbach et al. (1999), *Cancris auriculus*, an epifaunal species, is recorded in environments characterized by seasonal upwelling leading to the combination of a high organic flux and moderate oxygen deficiency. Szarek (2001) presented an inner shelf to uppermost bathyal bathymetric range for this species on the Sunda Shelf in the south-western South China Sea. In the Arabian Sea, Silva (2005) found *Cancris auriculus* in the top layer at the shallowest stations, but down to 4 cm in the sediment at an 850-m site. At the 400-m site, this species was entirely absent from the dead assemblage down to 5 cm in the sediment; instead all individuals were live, something that was beyond any explanation. According to Murray (2006), this species is remarkably one of those that regularly appear as dominant or subsidiary (>10%) in the Atlantic Ocean. *Cancris auriculus* is common at 300 m on the Pakistan margin, while it is present at 300 m on the Oman margin (Gooday et al., 2009). According to Sen Gupta et al. (2009b), this cosmopolitan species is shallow infaunal and has a bathymetric range of 18 to 576 m in the north-easter, north-western and south-western parts of the Gulf of Mexico. Debenay (2012) recorded and illustrated the shallow infaunal (Pérez-Asensio et al., 2012), detrivorous (Musco, 2011) *C. auriculus* from the south-western lagoon (at a water depth of 30 m) in New Caledonia, south-western Pacific Ocean.

Repository: PK–AG–210
Genus VALVULINERIA Cushman, 1926

Valvulineria rugosa (d’Orbigny, 1839)

Pl. 8; Fig. 17

Original citation: Rosalina rugosa D’ORBIGNY, 1839, p. 42, pl. 2, figs. 12–14.

Remarks: This species was first described from off Patagonia by d’Orbigny (1839). The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 185, in the Torres Strait, Pacific Ocean. Brady (1884) referred this species to Discorbina rugosa (d’Orbigny), while Cushman (1921, p. 306) placed it in genus Discorbis; Barker (op cit.), however, referred it to Valvulineria. According to Cushman (1921), this species was observed to be best developed at two Albatross stations, one off Mindanao, and the other in Sogod Bay, southern Leyte, at water depths of 494 fathoms (~903 m) and 554 fathoms (~1,013 m), respectively. He remarked, “It is worth noting that the Challenger material off Tahiti was from depths of 420 and 620 fathoms (768 and 1,134 m), while the Mediterranean records are from less than 100 fathoms (183 m)”. Few specimens of this species were recovered by Cushman et al. (1954) from all the four atolls in the Marshall Islands. They remarked, “They are large and are distinguished by their very coarsely perforate wall and chambers which are flat on the dorsal surface and inflated ventrally”. Todd (1965) studied foraminifera from the Albatross collections and remarked on Rosalina rugosa as follows: “It is characterized by its coarse pores and by its chambers becoming progressively more inflated as added, so that the periphery is lobulated and the sutures slightly indented. The aperture is rather widely open beneath a projecting lip and extends from the umbilicus to the periphery”. Smaller foraminifera from the Midway drill holes were examined by Todd and Low (1970), who obtained a single specimen of Rosalina rugosa from the top sample of Sand Island and stated that it was typical in having dense coarse pores. Later, they (1971) recorded a few typical specimens of this species from the Bahama Bank, west of Andros Island, but observed it to be rare. Debenay (2012) recorded and illustrated this species as R. rugosa from the south-western lagoon (at a water depth of 30 m) in New Caledonia, south-western Pacific Ocean.

Repository: PK–AG–211

Valvulineria wilcoxensis Cushman and Ponton, 1932

Original citation: Valvulineria wilcoxensis CUSHMAN and PONTON, 1932, p. 70, pl. 9, fig. 6.

Remarks: The types for this species came from the Eocene Tuscahoma sand from a railroad cutting, one mile north of Ozark, Alaska (Cushman, 1951). He remarked, “The species has not previously been recorded from the Paleocene, but rather typical specimens occur at a number of localities”. This species was one of the more common species of foraminifers which were recorded from the Aquia formation (Pleocene-Pliocene) of Virginia by Cushman (1944), while Shiflett (1948) reported it from the Piscataway member. Browne and Herrick (1963) recorded, described and illustrated (p. 265, pl. 55, figs. 22, 23) this species from the Paleocene of Kentucky. The Paleocene epoch in California is divided into two stages – Upper and Lower Bulitian – the upper being named after Valvulineria wilcoxensis (Mallory, 1959), a pointer to the stratigraphic significance of this species. Hayward et al. (2010) recorded a species named Hanzawaia cf. wilcoxensis (Cushman and Pontin, 1932) and remarked, “The North American Eocene species Valvulineria wilcoxensis is the closest described taxon that we have found to our modern specimens. The main difference seems to be the limbate early sutures described for the fossil species. Our specimens do not fit any described genus well. They lack the more prominent umbilical flap/plug and short arched aperture of type Valvulineria, and most Hanzawaia are more compressed and have an angled, often keeled periphery”. They found it to have sporadic rare
occurrences around New Zealand between 33° and 56° S latitudes with a middle shelf to upper abyssal bathymetric range (40 to 3,000 m) (Hayward et al., 2012). This could well be the first record of this seemingly rare species from Indian waters. 

Repository: PK–AG–212

Family ROSALINIDAE Reiss, 1963
Genus GAVELINOPSIS Hofker, 1951
Gavelinopsis praegeri (Heron-Allen and Earland, 1913)

Original citation: Discorbina praegeri HERON-ALLEN and EARLAND, 1913, v. 31, no. 64, p. 122, pl. 10, figs. 8–10.
Remarks: According to Todd (1965), the upper and lower depth limits of G. praegeri in the modern equatorial Pacific Ocean are 1,100 m and 2,000 m, and its association with Cibicides wuellerstorfi is indicative of the Pacific Intermediate Water at depths between 1,500 and 2,400 m (Akimoto, 1994). Gavelinopsis praegeri was recorded by Hofker (1978) at a solitary station in the Moro Gulf at a depth of 513 m, in the eastern part of the Indonesian Archipelago. Cole (1981) studied benthic foraminifera from the bathyal zone off north-east Newfoundland, and observed this species in a water depth range of 1,408 to 1,550 m. According to Heinz et al. (2005), both shallow and deep water foraminiferal species (infaunal as well as epifaunal) construct cysts in which they remain for several weeks to hours. In their laboratory experiments, they observed that specimens of G. praegeri, kept in a glass aquarium, climbed up the glass walls and tended to cover them with sediment and construct a cyst. Gavelinopsis praegeri is a cosmopolitan, clinging/attached species (Murray, 2006) which occasionally moves around with a speed of ~1.24 μm/min (Gross, 2000). Although commonly considered a shelf species (Murray, 2006), including estuaries (Debenay et al., 2006), it has been reported living (stained) down to 3,736 m water depth in the Gulf of Guinea (Altenbach et al., 2003). Alve and Goldstein (2010) noted that G. praegeri is extremely rare in the Skagerrak Basin, North Sea, and only two specimens were found in the shallowest station at a depth of 117 m; they collected 56 samples at depths up to 652 m. As this species epifaunal in high energy environments, its tests can be readily transported either towards the inner shelf or slope, as corroborated by its presence on southern slope of the basin, north-west of Denmark (Bergsten et al., 1996; Alve and Murray, 2007). According to Musco (2011), Gavelinopsis praegeri is widespread in the Mediterranean Sea, occurring frequently in the circum-littoral zone, but is also present in the infra-littoral zone in a depth range of 60 to 100 m. In the Tyrrenian Sea, however, it was recorded by Parisi (1981) at a considerable depth of 3,588 m. It is a common cosmopolitan species that dominates some associations in the North Atlantic (e.g., Schnitker, 1969; Murray, 1979) and Indian (e.g., Frerichs, 1970) oceans. It is less common in deeper water (e.g., Murray, 1991), where it has been recorded as co-dominating an association only around New Zealand (Hayward et al., 2013).

Repository: PK–AG–213

Genus ROSALINA d’Orbigny, 1826
Rosalina globularis d’Orbigny, 1826

Original citation: Rosalina globularis D’ORBIGNY, 1826, v. 7, p. 271, pl. 13, figs. 1, 2.
Remarks: This species was reported by Flint (1899) as Discorbina globularis (d’Orbigny) from the Albatross dredging off Carysfort Light, Florida, at a water depth of 60 fathoms (~110 m). Bagg (1912) recorded this species as Discorbina globularis from the Pleistocene of Santa Barbara, and remarked, “This species has a wide range in present oceans but is most common in temperate and cold waters. It is a shallow-water type, the Challenger expedition obtaining no specimens at
Deeper to very rare in the Antarctic Expedition samples. They found that most of the specimens were 'thin-shelled' and poorly developed and stated, "The species is widely distributed, and is usually common in the shallower zones of temperate and sub-tropical seas. In Australian fossil deposits, *Discorbis globularis* first appears in the Balcombian deposits (L. Miocene) of Port Phillip". The figures reproduced by Barker (1960) are of Brady's specimens obtained from the material dredged at the Challenger Station 33, off Bermuda, in the Atlantic Ocean, at a water depth of 435 fathoms (~796 m). Brady (1884) referred this species to *Discorbina*, but Galloway and Wissler (1927, p. 62) placed it under the genus *Rosalina* d'Orbigny, as the genotype. According to Sliter (1965), *Rosalina globularis* passively grazes when food is readily available, but switches to active foraging as food resources diminish. Murray (1968) recorded this species from Christchurch Harbour and opined that it is a stenohaline form. Later, Murray (1970) observed its occurrence in the Bristol Channel, at depths of 66 to 91 m, and in the English Channel, south of the Lizard, at depths between 84 and 95 m, and stated, "This species clings to substrates such as seaweeds (umbilical side down)". In the eastern part of the Indonesian Archipelago, Hofker (1978) recorded *R. globularis* in the Bay of Amboina (water depth not mentioned), and in the Basilan Strait, at a depth of 72 m. According to Ward (1984), *R. globularis* was found to be rare in 12 samples from the McMurdo Sound, Antarctica, at depths ranging between 79 and 796 m, but most common as dead tests at 289 m, where the substrate was 59% mud. *Rosalina globularis* is characterized by its plano-convex test morphology that facilitates its epifaunal, sessile habitat on rocky substrates and seagrasses, and has also been suggested to be a passive herbivore which gathers food from the site of attachment within the photic zone (Murray, 1991). According to Alexander and DeLaca (1987), it sticks to the substrate using an organic adhesive and feeds mainly on diatoms (Kitazato, 1988). This taxon is an example of temporarily attached, trochospiral species with apertures facing the substrates comprising the Morphotype B of Langer (1993), who classified epiphytic taxa based on different modes of surface attachment and the feeding strategies. According to Javaux (1999), *R. globularis* is characteristic of Bermuda mangrove and lagoon assemblages, where it displays large morphological variability, and has been reported in nearshore waters, caves, reefs and lagoons of the Florida-Bahamas and on the Belize Shelf (Javaux and Scott, 2003). It was later recorded from the mangrove ecosystem of Qeshm Island in the Persian Gulf (Sohrabi-Mollayousefy et al., 2006). A bathymetric range of inner shelf to upper bathyal was given for this species by Szarek (2001) on the Sunda Shelf in the southwestern part of the South China Sea. Gądzicki and Majewski (2003) recorded *R. globularis* from Goulden Cove (Admiralty Bay) of King George Island, Antarctica, at water depths of 20, 35 and 75 m. This species was one of the 26 benthic foraminiferal taxa observed to be living inside 10 individuals of *Mycale (Carmia) microspigmatasa* Arndt, 1927 (a sponge species), collected at Itaipu Beach, Rio de Janeiro State, Brazil (Mazzoli-Dias et al., 2007). According to Sen Gupta et al. (2009b), this cosmopolitan species has a water depth range of 1 to 55 m in the north-eastern, north-western and south-eastern parts of the Gulf of Mexico. Saraswat et al. (2011; 2015) studied the effects of salinity-induced pH variations on living *R. globularis* in the laboratory and observed that its growth, calcification capability and reproduction were affected at progressively reduced salinities and pH values. Kaminski (2012) considers this species as a suboxic indicator. Debenay (2012) recorded this species at a water depth of 40 m in the south-western lagoon of New Caledonia in the south-western Pacific Ocean.

Repository: PK–AG–214

Family SPHAEROIDINIDAE Cushman, 1927
Genus SPHAEROIDINA d’Orbigny, 1826
*Sphaeroidina bulloides* d’Orbigny, 1826

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Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Original citation: Sphaeroidina bulloides D’ORBIGNY, 1826, v. 7, p. 267, no. 1, mod. no. 65.

Remarks: Sphaeroidina bulloides was recorded by Chapman and Parr (1937) in samples collected in a water depth range of 675 to 2,700 fathoms (~1,234 to 4,938 m) mainly around Tasmania; they observed that specimens from a station at 1,180 fathoms (~2,158 m) were thin-walled and small-sized. Cushman et al. (1954) recorded a few specimens of this species from several of the deep Bikini and Eniwetok atoll samples from the Marshall Islands and remarked, “They are very thin walled and translucent and smaller than the topotypes of S. bulloides from the Adriatic, but otherwise seem very similar”. LeRoy (1964) examined Tertiary foraminifera from Okinawa, Japan, which is the largest island of the Kyukyu chain, and observed this species to be common in both Shinzato and Yonabaru members of the Shimajiri Formation. Pflum and Frerichs (1976) noted a minor size increase of S. bulloides with increasing water depth in the Gulf of Mexico, increasing from a size of less than 500 µm in the neritic zone to about 1 mm in the lower bathyal and abyssal zones. It was recorded by Hofker (1978) at a depth of 587 m, south of Makassar, and off Lifamatola at 432 m in the eastern part of the Indonesian Archipelago. Sphaeroidina bulloides was recorded by Hofker (1980) at water depths ranging from 290 to 890 m on the Saba Bank, a seemingly a submerged island to the south-east of Saba Island. Later, he (1983) reported at 37 to 940 m on the continental shelf and beyond off Surinam and the Guyanas. The shallow infaunal S. bulloides (Corliss, 1985; Fontanier et al., 2006) is frequent in high productivity slope areas influenced by seasonal input or coastal upwelling (Licari and Mackensen, 2005). Sphaeroidina bulloides thrives in well-oxygenated water and is intolerant to oxygen depletion (Barmawidjaja et al., 1992), and indicates low organic flux (Denne and Sen Gupta, 1991). In the Southern Atlantic, dominance of this species is generally considered as typical to that of high productivity areas (Gooday, 2003) and may be influenced by coastal upwelling (Schiebel, 1992). However, Loubere and Fariduddin (1999) found this taxon dominant on continental slopes under low seasonality. Szarek (2001) observed it to occur in the full bathymetric range studied (50 to 2,000 m) on the Sunda Shelf in the south-western part of the South China Sea. According to Gupta and Thomas (2003), intermediate organic flux and intermediate to high seasonality in the eastern equatorial Indian Ocean can be inferred when S. bulloides is associated with Cassidulina carinata, Gyroidinoides nitidula and Pullenia bulloides, while the presence of cool, active currents, low to intermediate organic flux, high seasonality and high oxygenation can be inferred when it is in association with Cibicides wuellerstorfi and Anomalina globulosa. Eberwein (2006) observed high standing stocks of this species in two transects off Morocco at water depths ranging from 1,431 to 1,788 m, showing affinity to intermediate to high chlorophyll-α concentrations (0.8 to 1.3 mg/m³), high fragmented planktic foraminiferal contents (16 to 29%), low sand contents (6 to 8%), and low to intermediate salinities (34.90 to 35.30‰). Some workers (e.g., van der Zwaan et al., 1990; van Hinsbergen et al., 2005; Báldi and Hohenegger, 2008) have interpreted Pullenia bulloides and S. bulloides as stress markers, while others such as van Kouwenhoven and van der Zwaan (2006) have considered them to be oxyphylic species; Kaminski (2012), however, listed it as a suboxic indicator. According to Hayward et al. (2010), S. bulloides is a cosmopolitan, shallow infaunal (1 to 4 cm), suboxic (Kaiho, 1994) species that is abundant in a water depth range of 50 to 600 m around New Zealand, but occurs in wide depth range in low numbers at mid shelf to lower abyssal depths (50–5,000 m). They also noted that it was sometimes washed into inner shelf depths, harbours and onto exposed beaches. Debenay (2012) illustrated and described this species from the northern shelf off New Caledonia in the south-western Pacific Ocean, at a water depth of 600 m.

Repository: PK–AG–215
Superfamily DISCORBINELLACEA Sigal, 1952  
Family PARRELLOIDIDAE Hofker, 1956  
Genus CIBICIDOIDES Thalmann, 1939  
Cibicidoides pseudoungerianus (Cushman, 1922)

Original citation: Truncatulina pseudoungeriana CUSHMAN, 1922, p. 97, pl. 10, fig. 9.

Remarks: According to Todd (1957), who recorded this species as Cibicides pseudoungerianus, “it occurs both from shallow (around 20 fathoms) to deep water (around 2,000 fathoms) but is more frequently found in deeper water”. Cibicidoides pseudoungerianus was found from circa-littoral to bathyal environment in the Mediterranean Sea (Blanc-Verner, 1969). Pujos (1972) found this species in fine sands in Bay of Biscay with percentages less than 1% at depths comprised between 90 and 110 m, and between 5 and 10% from 110 to 200 m. In general, this species is present from the circa-littoral zone and increases in abundance toward the outer circa-littoral zone (Gaboardi, 1996). Pflum and Frerichs (1976) opined that this species has its upper water depth limits within the middle neritic zone in the Gulf of Mexico, but also extends down into the upper bathyal zone with sporadic occurrences in deeper water. In the eastern part of the Indonesian Archipelago, Hofker (1978) recorded its occurrence in the Moro Gulf at a water depth of 513 m, and in the Gulf of Bone at 1,829 m. Cibicidoides pseudoungerianus is an open-marine dweller living in muddy substrate with no tolerance to oxygen deficiency or increased salinities (van der Zwaan, 1982). Sztrakos (1979) reported the presence of this species with high abundance in the circa-littoral environment (from 100 to 150–200 m) in the Oligocene of Hungary. Hofker (1980) reported this species at water depths ranging between 125 and 700 m on the Saba Bank, seemingly a submerged island to the south-east of Saba Island. Later, he (1983) recorded it in a water depth ranging from 120 to 940 m on the Surinam Shelf, and observed that the megalospheric proloculi were very large, with diameters up to 150 µm. The frequent occurrence of Cibicidoides (in particular C. dutemplei and C. pseudoungerianus) and Melonis is attributed to high food supply by some authors (Caralp, 1988; Meulenkamp and Van der Zwaan, 1990). Cibicidoides pseudoungerianus has been described in a wide range of trophic conditions (Rathburn and Corliss, 1994; Almogi-Labin et al. 2000, Schmiedl et al., 2000, Fontanier et al., 2002). This species flourished in the environment permanently influenced by upwelling from off north-western Africa (Jorissen et al., 1998). According to Altenbach et al. (1999), the high dominance of C. pseudoungerianus can be linked to fluxes of primary productivity ranges comparable to those required by uvigerinid species. This species has been generally considered to be epifaunal (Jorissen, 1987), doubtfully oxyphilic (Kouwenhoven, 2000) and preferential of well-oxygenated bottoms under high organic carbon fluxes (Woodruff, 1985; Jones, 1996; Murgese and De Deckker, 2005). In the Gulf of Cadiz, Alboran Sea and Tyrrenhian Sea (Coppa and Di Tuoro, 1995; Villanueva-Guimerans and Currado, 1999; Schönfeld, 2002; Panieri et al., 2005; Martins et al., 2007), C. ungerianus was typically observed to be associated with high-energy shelf environments and sandy substrates. According to Murgese and DeDeckker (2005), this species typical of upper-bathyal depths, and is correlated with a warm (>2.5°C) environment characterized by high carbon-flux rate (>2.5 g C m⁻² year⁻¹). C. pseudoungerianus is a taxon that does not tolerate any environmental stress, particularly reduced oxygen levels in bottom water (Jorissen, 1999), and is considered to be an oxic indicator species that is associated with a well oxygenated and nutrient-rich middle shelf paleoenvironment (Pezelj et al., 2007). According to Sen Gupta et al. (2009), Cibicidoides pseudoungerianus is a cosmopolitan species (Van Morkhoven et al., 1986) that occurs all over in the Gulf of Mexico in a very wide water depth range of 4 to 1,417 m, and is an oxic indicator species (Kaminski, 2012).

Repository: PK–AG–216
Cibicidoides subhaidingerii (Parr, 1950)
Pl. 9; Fig. 6

Original citation: Cibicides subhaidingerii PARR, 1950, v. 5, no. 6, p. 364, pl. 15, figs. 7a–c.
Remarks: The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 185, in the Torres Strait, Pacific Ocean, at a depth of 155 fathoms (~283 m). Brady (1884) referred this species to Truncatulina haidingerii (d’Orbigny), but Parr (1950, p. 364) preferred to refer it to Cibicides subhaidingerii. This species was originally described and illustrated by Parr (1950), the types coming from off Tasmania, southern Australia. According to Van der Zwaan (1982) specimens referred to Cibicides dutemplei show some variation in the height of the dorsal side; in particular most of them are biconvex, but some others are planoconvex. Such variants intergrade with types belonging to Cibicidoides subhaidingerii, reported as Cibicides ungerianus by Van der Zwaan (1982). Also van Morkhoven et al. (1986) pointed out a general similarity between Cibicidoides dutemplei and C. subhaidingerii, and gave a bathymetric range of neritic to abyssal depths for the latter. According to Hatta and Ujjie (1992), who reported this species as Cibicides cf. C. subhaidingerii, their specimens differed from Cibicides subhaidingerii Parr in having coarse perforation limited to peripheral areas of the umbilical side. Coarse perforation developed even on the umbilical and spiral sides can be seen in typical specimens figured by Parr (1950) and by Brady (1884) under the name of Truncatulina haidingerii (d’Orbigny), which was designated same as C. schlumbergerii by Parr (1950). Hottinger et al. (1993) reported it (as Heterolepa cf. H. subhaidingerii) from the Gulf of Aqaba, Red Sea, and remarked, "Our species is smaller and more convex on the umbilical side than the typical H. subhaidingerii (see Perelis and Reiss, 1975). It is noteworthy that Cibicides subhaidingerii Parr as figured by Margerel (1977, unpublished) shows strongly thickened sutures on the umbilical side, not shown in either Brady's or Parr's figures but present in our species." Rajeshwara Rao (1998) recorded this species as Heterolepa subhaidingerii from the inner shelf sediments of the Bay of Bengal, and observed that the spiral side was more coarsely perforate than the umbilical side, and that in the latter the perforations were more in the peripheral areas. According to Szarek (2001), who reported it as H. subhaidingerii from the Sunda Shelf in the south-western part of the South China Sea, it differs from Heterolepa aff. dutemplei in larger size of the test, bluntly rounded periphery and less convex ventral side, and gave a bathymetric range of inner shelf to upper bathyal.
Repository: PK–AG–217

Family PSEUDOPARRELLIDAE Voloshinova, 1952
Subfamily PSEUDOPARRELLINAE Voloshinova, 1952
Genus EPISTOMINELLA Huseri and Maruhasi, 1944
Epistominella exigua (Brady, 1884)

Original citation: Pulvinulina exigua BRADY, 1884, v. 9, p. 696, pl. 103, figs. 13a–14c.
Remarks: In the Gulf of California, this species was reported by Bandy (1961) from the upper middle bathyal zone, where it showed abundances up to 22% of the total fauna. Cole (1981) observed Epistominella exigua to be a common species in the bathyal zone off north-east Newfoundland and occurring in a depth range of 2,560 to 3,210 m, but also noted that it was most common between 2,938 and 3,210 m. Hofker (1978) recorded this species at two stations in the eastern part of the Indonesian Archipelago – north-east of Manui, at a water depth of 2,969 m, and north-west of Damar, at 3,358 m. Unfortunately, exact relationships between benthic species and properties of the water masses are not yet clear. For instance, Miller (1983) and Tjalsma and Lohmann (1983) observed that Nuttallides unbonifera was abundant in old, sluggish, oxygen-poor bottom waters, whereas Woodruff and Douglas (1981) concluded that this species
(Epistominella umbonifera in their nomenclature) is indicative of young, oxygenated bottom waters in the western Pacific Ocean. Peterson (1984) analyzed deep-sea benthic foraminifera from the Ninetyeast Ridge and identified two major assemblages associated with deep-water masses and their physicochemical properties: Globocassidulina subglobosa–Pyrgo spp.–Uvigerina peregrina, above 3,800 m, associated with the Indian Deep Water, and Epistominella exigua–Nuttallides umbonifera, below 3,800 m, associated with the more corrosive and oxygenated Indian Bottom Water. Epistominella exigua is considered to have an upper depth limit of ~2,000 m in mid to low latitudes during the Neogene (van Morkhoven et al., 1986), but the species lives today in the Ross Sea at depths of only a few meters (Bernhard, 1987). Studies of modern seasonal phytodetrital deposits in the North Atlantic have shown that a small group of taxa, dominated by Epistominella exigua and Alabaminella weddellensis, is adapted to feeding directly on these seasonal inputs (Gooday, 1986; Gooday and Lambashead, 1989; Gooday and Turley, 1990). Based on the association of E. exigua with phytodetritus in the modern environment, Smart et al. (1994) suggested that this species may be an indicator of palaeoproductivity. In the deep sea, where the sudden arrival of phytodetritus on the deep sea floor is known to lead to a rapid increase in opportunistic taxa such as Epistominella exigua, whereas its effect on the remainder of the fauna is less dramatic (Gooday, 1996). In very oligotrophic conditions, episodic phytodetritus inputs can lead to an opportunistic response of some adapted species, as exemplified by the reproductive response of E. exigua to a phytodetritus deposit at 4,800 m depth (Gooday, 1988). In contrast to Schmiedl et al. (1997), who observed the E. exigua community in regions at the continental margin to be restricted to sediments with less than 3% total organic carbon (TOC), Kurbjeweit et al. (2000) found a significant positive correlation between its distribution and Corg flux, oxygen and ammonia in the sediment in the Arabian Sea. The most common species, Epistominella exigua, which has been reported elsewhere to be an epifaunal phytodetritus feeder (Smart et al., 1994), was most abundant in surface (0 to 0.02 m) samples but was also found stained down to 0.08 to 0.10 m off east of New Zealand (Hayward et al., 2001), suggesting that this species is not obligately epifaunal. In the eastern Indian Ocean, the food fluxes have been related to the monsoonal climate where E. exigua thrives in deep environment with a temperature of >2.5°C and oxygen of >3.5 mL/L (Murgese and De Deckker, 2005). Epistominella exigua has the advantage over other species when there is an input of fresh, labile organic matter (Caralp, 1989; Gooday, 1994), and it can be used as a proxy for pulsed organic inputs to the deep ocean and, therefore, can be used as an indicator of relative changes in productivity (Smart et al., 1994; Ohkushi et al., 2000; Hayward et al., 2004). Saraswat et al. (2005) reconstructed temporal variation in abundance and mean proloculus diameter of E. exigua over the last ~50,000 yr B.P., from a core collected from the distal Bay of Bengal fan, to assess its potential application in palaeoceanographic reconstruction studies. Downcore variations of this species showed significant changes in its abundance and, in view of the present day abundance of this species from areas with strong seasonal organic matter supply, they concluded that at ~7,000, ~22,000, ~33,000 and ~46,000 years B.P., strong seasonality prevailed in the distal Bay of Bengal fan, probably indicating either strong or prolonged north-east monsoon or weakened south-west monsoon. They also observed, for the first time, a strong correlation between abundance and mean proloculus diameter of E. exigua, and concluded that this species could be used to infer past climatic variations from the distal Bay of Bengal fan. Epistominella exigua is an epibenthic, cosmopolitan, abyssal species, which feeds opportunistically on phytodetritus deposited seasonally on the sea floor (Gupta et al., 2008). It is suggested that this species is most abundant at highly seasonal food fluxes that occur more than once a year (e.g., spring and fall blooms (Schmiedl and Mackensen, 2006). A molecular study by Lecroq et al. (2009) revealed high genetic similarity among Arctic, Atlantic and Antarctic populations of this species, as revealed by the almost identical small-subunit (SSU) and internal transcribed spacer (ITS) rDNA sequences from
the three oceans, in stark contrast to the prevalence of highly differentiated populations in planktonic and shallow-water benthic foraminifers. *Epistominella exigua* is widely distributed in the northern Gulf of Mexico, except around the Mississippi River Delta. It has been reported from 2 to 3,700 m (Sen Gupta et al., 2009b) with the highest frequencies generally between 500 and 1,000 m. In the west central Indian Ocean, *E. exigua* is dominant with low primary production, an in situ temperature of 1.3–2.6°C and oxygen content of 2.5–4.5 ml/l and is indicative of an oxic environment with low productivity and seasonal food flux (De and Gupta, 2010). Mallon (2011) recorded the occurrence of this species at water depths ranging between 79 and 995 m off the Peruvian and Ecuadorian continental margins. *Epistominella exigua* is widespread and abundant around New Zealand (33° to 56° S) between the outer shelf to lower abyssal depths (100 to 5,000 m), and has a zone of highest relative abundance (10–45%) at lower bathyal and abyssal depths ranging from 1,000 to 5,000 m (Hayward et al., 2010). Debenay (2012) recorded this species at a water depth of 600 m on the northern shelf off New Caledonia in the south-western Pacific Ocean. According to Mancin et al. (2013), the abundance of the shallow infraunal *E. exigua* is indicative of low seasonal phytodetritus, high oxygen content, and slightly less carbonate-corrosive conditions.

**Repository:** PK–AG–218

**Family** DISCORBINELLIDAE Sigal, 1952  
**Subfamily** DISCORBINELLINAE Sigal, 1952  
**Genus** DISCORBINELLA Cushman and Martin, 1935  
*Discorbinella bertheloti* (d’Orbigny, 1839)

**Original citation:** *Rosalina bertheloti* D’ORBIGNY, 1839, p. 135, pl. 1, figs. 28–30.  
**Remarks:** The types for this species came from the shallow waters off Samoa (d’Orbigny, 1839). Bagg (1898) recorded this species as *Discorbina bertheloti* and stated that it was similar to *Truncatulina lobatula*, but could be distinguished from the latter by being more depressed and having more finely perforate walls. This species was recorded as *Discorbina bertheloti* by Flint (1899) as well as three stations in the North Atlantic and Gulf of Mexico in samples dredged by the *Albatross* in a water depth range of 79 to 403 fathoms (~145 to 737 m). Chapman and Parr (1937) recorded this species as *Discorsibus bertheloti* (d’Orbigny) at two stations east of Tasmania, at water depths of 1,320 and 1,300 fathoms (~2,414 and 2,377 m), respectively, and stated, “It is interesting to note that the only "Terra Nova" records of *Discorsibus bertheloti* were confined to the New Zealand area”. The figures illustrated by Brady (1960) are of specimens recovered from the sediments dredged at Challenger Station 209, off the Philippines, at a depth of 95 to 100 fathoms (~174 to 183 m), and Porcupine Station 6, west of Ireland, in the Atlantic Ocean, at a depth of 90 fathoms (~165 m). *Discorbinella bertheloti* was referred by Brady to *Discorbinia*, while Cushman and others referred it to *Discorbis*. Hofker (1951, p. 449) made this species the genotype of *Discopulvinulina*. Hofker and Bermúdez both included under this heading a variety of “Discorbius” species, such as *D. globularis* (which is a *Rosalina*), *D. advena*, *D. turbo* (a *Discorbina* according to Hornibrook and Vella), *D. bradyi* (a *Rosalina*), etc., but Hornibrook and Vella (l. c. supra) restricted the genus to forms of the *D. bertheloti* type. Barker (1960) stated that the species *Discorbinella subbertheloti* proposed by Cushman (1924) was very close to *D. bertheloti*, and opined that it should be considered as a junior synonym of the latter. This species was reported as *Rosalina bertheloti* by Albani and Geyskes (1969), who noted that *Rosalina bertheloti* was restricted to waters shallower than 150 m, and in all three traverses it was most abundant at a depth of about 75 m on a part of the north-west Australian continental shelf. *Discorbinella bertheloti* was found by Hayward (1979) to be one of the eight species found living and, therefore, considered as one of the main elements of the autochthonous fauna of the bottom sands of a *Zostera* inter-tidal pool.
community at Kawerau, Northland, New Zealand. It was also recorded at shallow depths ranging from 6 to 37 m on medium to fine sandy substrates off Cuvier Island, north-east New Zealand, by Hayward and Grace (1981). According to Hermelin and Scott (1985), this species is rare in the central North Atlantic, at depths ranging from 1,850 to 2,760 m. In the Mediterranean region, this species has been reported to be more frequent in the infra-littoral zone (Blanc-Vernet, 1969); however, it is frequent from the circa-littoral zone in the Gulf of Taranto (Moncharmont Zei et al., 1981), Gulf of Salerno, Gulf of Policastro and in the Motril-Nerja shelf. In the Adriatic Sea, Discorbinella bertheloti has been reported mostly from circa-littoral sandy bottoms in the depth range of 60 to 100 m (Jorissen, 1987). Jorissen (1988) observed that Discorbinella bertheloti was frequent in the infra-littoral and circa-littoral zone, particularly on sandy substrates in the depth range of 60 to 100 m. According to Hermelin (1989), this species differs from D. floridensis (Cushman) in possessing more number of chambers (6 to 8) in the last whorl; D. floridensis has only 4 to 5. Sgarrella and Moncharmont Zei (1993) observed this species to be frequent in the infra-littoral zone of the inner shelf, middle shelf and rarely in the inlet channels of coastal lagoons, off the south-east coast of Australia. This species is widespread and common in exposed or moderately sheltered, fully marine, deep inner shelf to bathyal depths, mostly deeper than 30 m, and may comprise up to 10% of the foraminiferal fauna at mid-shelf depths (Hayward et al., 1999). Szarek (2001) presented a water depth range of inner shelf to middle bathyal for this species on the Sunda Shelf in the southwestern part of the South China Sea. High percentages of Discorbinella bertheloti suggest mid-outer shelf depths (Hayward et al., 2003), and this species has been found to be more abundant off the west (Taranaki) side of New Zealand than off the west (Chatham Rise) side (Hayward et al., 2001; 2002). Smith and Gallagher (2003) studied Recent foraminifera and facies of the Bass Canyon in Gippsland, off the coast of south-eastern Australia, and observed this species to be rare to common across the shelf; they gave a stratigraphic range of Late Oligocene to Recent. The cosmopolitan species D. bertheloti inhabits various shelf and deep-sea environments and has a clear preference for fine-grained substrates (Milker et al., 2009), where it possibly profits from specific biogeochemical conditions and the availability of sufficient food particles on and below the sediment surface. According to Hayward et al. (2010), this fully marine species has widespread occurrences around New Zealand between 34° and 54° S, with greatest abundances in the north (north of 40° S). They gave a bathymetric range of 30 to 2,000 m (deep inner shelf to bathyal), and opined that the few abyssal records for this species might be displaced. Its greatest relative abundances (5 to 20%) are at mid shelf to upper bathyal depths (50 to 600 m). For the first time, Walker et al. (2011), who recorded this species as Discobis bertheloti, observed it to bore very small (<0.001 mm) holes within the internal apertural area of gastropod shells, and opined that its trace could be used as a bio-depth indicator for shallow tropical water (<33 m) on the Lee Stocking carbonate platform, Exuma Cays, in the Bahamas. Debenay (2012) recorded Discorbinella bertheloti from the northern shelf, off New Caledonia, in the south-western Pacific Ocean, at a depth of 600 m. On the inner shelf off Khao Lak (Andaman Sea, Thailand), this species is confined to depressions in the reef flat that operate as sediment traps for muddy sediments (Feldens et al., 2012) and is considered to be an oxic indicator (Hayward et al., 2010; Kaminski, 2012).

Repository: PK–AG–219

Genus LATICARININA Galloway and Wissler, 1927
Laticarinia pauperata (Parker and Jones, 1865)
Pl. 9; Fig. 1

160
Original citation: Pulvinulina repanda (FICHTEL and MOLL) var. menardii (D’ORBIGNY) subvar. pauperata PARKER and JONES, 1865, p. 395, pl. 16, figs. 50, 51a, b.

Remarks: The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 120, off Pernambuco, Atlantic Ocean, at a depth of 675 fathoms (~1,234 m; figs. 4, 6, 11), at Challenger Station 335, South Atlantic, at a depth of 1,425 fathoms (~2,606 m; figs. 5, 10) and at Challenger Station 146, Southern Ocean, at a depth of 1,375 fathoms (~2,515 m; figs. 7–9). Laticarinina pauperata was referred by Brady to Pulvinulina Parker and Jones, which was designated the genotype of Laticarinina Galloway and Wissler, 1928. Finlay (1940, pp. 467, 478) studied toptype material from Stache’s Whaingaroa beds and found abundant “L. pauperata”, which matched Brady’s figures exactly and also Stache’s figures Robulina halophora Stache, 1864. He, therefore, concluded that pauperata and “Robulina corona-lunae Stache” are to be regarded as synonyms of Laticarinina halophora (Stache). Chapman and Parr (1937) recorded this species at three stations at depths of 1,320, 1,300 and 1,660 fathoms (~2,414, 2,377 and 3,036 m, respectively), but it was very rare in the first two and very common at the third station. They remarked, “This species is widely distributed in the living condition”. Laticarinina pauperata, recovered rarely from two samples, is a bathyal-abyssal taxon with an upper depth limit of 205 m in the clastic deposition-dominated, north-western Gulf of Mexico (Phleger, 1951). However, Parker (1954) recorded an upper limit of 255 m for this species in the carbonate-dominated, north-eastern Gulf of Mexico. According to Pflum and Frerichs (1976), a remarkable size increase occurs in Laticarinina pauperata (Parker and Jones) in the Gulf of Mexico. Its diameter is only slightly greater than 1 mm near its upper depth limits in the upper bathyal zone; however, it attains diameters of more than 3 mm in the middle and lower bathyal zones and below. In the eastern Pacific Ocean, its upper depth limits appear to be in the lower part of the lower bathyal zone where the size is about 2 mm. Hofker (1978) reported the occurrence of this species in a water depth range of 522 to 3,523 m, with an average temperature of 5.4°C, in the eastern part of the Indonesian Archipelago. Laticarinina pauperata was recorded by Hofker (1980) at water depths ranging from 430 to 730 m on the Saba Bank, a seemingly a submerged island to the south-east of Saba Island, but he stated, “This species, commonly known as Laticarinina pauperata, according to the Rules of Zoological Nomenclature should be called Laticarinina halophora (Finlay, 1940)”. Cole (1981) recorded this species as L. halophora among the bathyal zone benthic foraminifera off north-east Newfoundland at water depths ranging from 2,560 to 3,000 m, but observed that though it was not common, its specimens were usually >1 mm in size. According to Hermelin and Scott (1985), this species occurs in low frequencies at all stations sampled by them in the central North Atlantic, except at two shallow stations. Loeblich and Tappan (1987, p. 578, pl. 631, figs. 1–13) gave illustrations of four species of Laticarinina: L. pauperata (Parker and Jones) from the Caribbean region; L. altocamerata (Heron-Allen and Earland) from the Altonian, south of Whaingaroa, New Zealand; L. inferillata (McCulloch) from the Holocene, James Bay, James Island, Galapagos, Pacific Ocean, at a depth of 55 m; and L. velata (McCulloch) from the Holocene, off Hood Island, Galapagos, Pacific Ocean, at a depth of 323 m. However, considering that halophora is not accepted at present (WoRMS), the forms in this study have been placed under Laticarinina pauperata. According to Weinberg (1990), who maintained this species, collected from 775 m water depth in the north-west Atlantic Ocean, in the laboratory for 772 days, estimated its survival rate to range from 0 to 67% over a 1- to 2-year period, thereby demonstrating that it was feasible to maintain continental slope fauna in the laboratory for long periods of time. Cameron (1995) recorded this species as L. halophora (Stache) at water depths ranging between 26 and 940 m from the continental shelf and slope off the Kaikoura Peninsula, New Zealand. Bornmalm (1997) studied the taxonomy and paleoecology of Neogene benthic foraminifera from the Caribbean Sea and eastern equatorial Pacific Ocean, and observed this species to be common and represented in most samples at both the Caribbean...
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Sea (3,051 m) and eastern equatorial Pacific Ocean (3,672 m) sites. He remarked, “The most distinctive characteristics of Laticarinina pauperata are the strongly compressed test and broad, transparent keel”. Characteristic species from the abyssal depth, such as L. pauperata were found in both Holocene pelagic and in situ Late Pleistocene hemipelagic sediments collected at sites across the Amazon Fan (Vilela and Maslin, 1997). Szarek (2001) estimated a water depth range of middle bathyal to lower bathyal for this species on the Sunda Shelf in the south-western part of the South China Sea. In the Indian Ocean, Laticarinina pauperata is linked to strongly pulsed, low to intermediate organic environmental setting (Gupta and Thomas, 2003), and low to intermediate primary productivity with low to moderate seasonality (De and Gupta, 2010). Hayward et al. (2003) observed the upper water depth limits for this species to be the same off both east and west New Zealand at 2,000 m. This cosmopolitan species is distributed in the entire Gulf of Mexico in a water depth range of 144 to 3,850 m (Sen Gupta et al., 2009b). According to Hayward et al. (2010), L. pauperata has scattered records around New Zealand between 36° and 50° S with a bathymetric range of 1,500 to 3,000 m (lower bathyal to upper abyssal); its stratigraphic range is Late Eocene to Recent.

Repository: PK–AG–220

Superfamily PLANORBULINACEA Schwager, 1877
Family PLANULINIDAE Bermúdez, 1952
Genus HYALINEA Hofker, 1951
Hyalinea balthica (Schröter, 1783)

Pl. 9; Figs. 2, 2a

Original citation: Nautilus balthicus SCHROETER, 1783, p. 20, pl. 1, fig. 2.

Remarks: The types for this species came from Recent sediments from the Baltic Sea (Schröter, 1783). The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Porcupine Station 11, west of Ireland, in the East Atlantic, at a depth of 1,630 fathoms (~2,981 m). Hyalinea balthica was referred by Brady to Operculina ammonoides (Gronovius), where as Cushman (1931, p. 108) referred it to Anomalina balthica. Earland and Parr both placed the species in Operculina, while Hofker demonstrated it to possess a canal system. Later, Hofker (1951, p. 508) made it the genotype of Hyalinea. Bermúdez (1952, p. 74) regarded this as too close to Hyalinia Agassiz and proposed the new name Hofkerinella. Loeblich and Tappan (personal communication with Barker) pointed out that such similarity of spelling did not constitute homonymy according to the rules of nomenclature, and the name Hyalinea was retained. According to Feyling-Hanssen (1964), Hyalinea balthica appeared in the Mediterranean at the beginning of the Quaternary period and is, together with Cassidulina laevigata carinata, an index fossil in Quaternary deposits there. In the Mediterranean region, this is a widespread species and is characteristic of circa-littoral and especially epibathyal muds. It has been reported from the north-western Mediterranean down to 700 m (Bizon and Bizon, 1984), and in the eastern Mediterranean down to 799 m (Parker, 1958). Its occurrence is very rare in the deep water assemblages of the Sicily Channel (only at 1,486 m), and Tyrrenhian Sea at 1,063 m and 2,860 m (Parisì, 1981). Hyalinea balthica is frequent only at few stations off the Algerian coast, in the depth range of 1,400 to 2,620 m (optimum at 2,315 m). On a part of the north-western Australian continental shelf, Albani and Geyskes (1969) observed this species to be very rare, and recorded it at only station at a water depth of 104 m. Blanc-Vernet (1969) pointed out that this species was capable of “lifting” locally up to 25 to 30 m (e.g., in the Gulf of Salonicco). It has also been recorded, with few specimens at 13 m from the Gulf of Gabès, 23 m from the Gulf of Salerno, and 20 m from the Gulf of Taranto (Iaccarino, 1969). In the Gulf of Naples, Italy, H. balthica has been observed to occur in a depth range of 70 to 780 m, and is frequent between 90 and 500 m;
it has also two scattered records at 25 m and 39 m (Sgarrella and Moncharmont Zei, 1993). *Hyalinea balthica* prefers a shallow to intermediate infaunal microhabitat (e.g., Corliss and Van Weering, 1993; Fontanier et al., 2002; Fontanier et al., 2008), indicating that there is some oxygenation at least close to the sediment/water interface (e.g., Jorissen et al., 1995; Jorissen et al., 1998; Kaiho, 1999). It feeds on fresh phytodetritus (e.g., Mackensen and Hald, 1988; Gooday and Lambshead, 1989; Altenbach, 1992; De Rijk et al., 2000; Eberwein and Mackensen, 2006) and has relatively lower tolerance for oxygen deficiency, thereby fitting presumably into the phytophagous or seasonal-phytophagous category (Bruckner, 2008). Moreover, *H. balthica* is considered to be an early colonizing and opportunistic species (e.g., Jorissen et al., 1994; Hess et al., 2005; Koho et al., 2007). In the Marmara Sea, *H. balthica* made its first appearance at ~11.0 ka B.P. (McHugh et al., 2008), who interpreted the occurrences of large increases of its specimens at 9.1 ka B.P. and 16.0 ka B.P. as having been produced by outflow of Black Sea waters manifested by water stratification and high nutrient levels, and due to deepening as sea-level reached near its present position, and the establishment of a two-layer circulation (Schonfeld, 1997, 2001; den Dulk et al., 2000; Evans et al., 2002; Fontanier et al., 2002, 2003; Murray 2006; Major et al., 2006), respectively. *Hyalinea balthica* evolved in the late Pliocene, and has been recorded in the Atlantic, Pacific, and Indian Oceans, Gulf of Mexico, and Caribbean, Barents, North, and Mediterranean Seas. It has a preference for shallow infaunal microhabitats in the topmost sediment levels, where maximum densities are found (e.g., Fontanier et al., 2002; Fontanier et al., 2008; Hess and Jorissen, 2009). However, some specimens are often present in deeper sediment layers also, down to the zero oxygen level. Hess and Jorissen (2009) described uncommonly high densities of *H. balthica*, of about 1,400 live specimens in a 71 cm² core, at a 380 m deep site in Cape Breton Canyon on the French Atlantic coast. According to Margreth (2010), *Hyalinea balthica* is an epifaunal, opportunistic species that prefers a muddy substrate, feeds on phytodetritus and has a high tolerance to varying organic flux; it is associated with seasonal organic fluxes.

**Repository:** PK–AG–221

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**Family CIBICIDIDAE** Cushman, 1927  
**Subfamily CIBICIDINAE** Cushman, 1927  
**Genus CIBICIDES** de Montfort, 1808  
*Cibicides dispars* (d’Orbigny, 1839)

**Original citation:** *Truncatulina dispars* D’ORBIGNY, 1839, v. 5, pt. 5, p. 38, pl. 5, figs. 25–27.  
**Remarks:** *Cibicides dispars* can live both in shallow waters as in deep zones (Boltovskoy, 1966) and is associated with high-energy environments (Hromic, 2007). According to Boltovskoy et al. (1980), *Cibicides dispars* occurs along the Argentine continental shelf between 35° S and 56° S. It is typical of the Malvin current zone. It has been cited as a eubathyal species, and its abundance increases with depth; it is found in shallow waters to deep waters up to 4,000 m, in Patagonian channels and fjords, and the Strait of Magellan (Boltovskoy and Watanabe, 1980; Hromic, 1996, 2002a, 2002b; Hromic and Zúñiga-Rival, 2005). According to Hayward et al. (2001), who studied the depth distribution of Recent deep-sea benthic foraminifers east of New Zealand, *C. dispars* has a bathymetric range of 90 to 4,430 m. Many shallow water cibicidid species, such as *Cibicides refulgens* de Montfort, 1808 or *Cibicoides dispars* (d’Orbigny, 1839) are often considered synonymous with *Cibicoides lobatulus* (Walker and Jacob, 1798) (e.g., Hageman, 1979; Heron-Allen and Earland, 1932). However, these species are well separated genetically from *C. lobatulus*, and even the morphospecies *C. lobatulus* itself could be a mosaic of different species (Schweizer et al., 2009). Hayward et al. (2010) summarized variable recent plano-convex *Cibicides* morphologies as *C. dispars*, which are also sometimes referred to as *C. cf. wuellerstorfi* (Kersten, 2013), and opined that this species presumably likes current-swept environments and may be adapted to
feeding on laterally-transported larger food particles, preferring clean sandy or gravely substrates. They observed it to be abundant and widespread around New Zealand (33° to 56° S), and occurring in large numbers at all depths from inner shelf to lower abyssal, with the greatest relative abundances (10 to 30%) at shelf and upper bathyal depths (0 to 600 m). Also, they (op cit.) gave a stratigraphic range of Middle Miocene to Recent for this species. According to Schweizer et al. (2011), though, who reported this species as *Cibicoides dispars*, both *C. dispars* and *Cibicoides variabilis* are two neritic cibicidids commonly found on the Patagonian coasts. Phylogenetic analyses of partial SSU rDNA sequences have shown that they both belong to the genus *Cibicoides*. They found that *Cibicoides dispars* branches close to *Cibicoides wuellerstorfi*, whereas *C. variabilis* clusters with *Cibicoides paechyderma*. In both cases, species clustering together are well separated morphologically and ecologically, but close genetically. Their molecular data clearly indicated that *C. dispars* and *C. variabilis* are well separated genetically from *Cibicoides lobatulus*, another shallow water cibicidid sharing similar ecology and morphology.

Repository: PK–AG–222

*Cibicides praecinctus* (Karrer, 1868)

Original citation: *Rotalia praecincta* KARRER, 1868, v. 58, p. 189, pl. 5, fig. 7.

Remarks: Cushman (1921) recorded this species as *Truncatulina praecincta* (Karrer) from “about a hundred stations, mostly within the Archipelago”, and also in the vicinity of Darvel and Sibuko bays, Borneo, and adjoining areas, in a water depth ranging from 6 to 976 fathoms (~11 to 1,785 m). He remarked, “This is the most common species of the genus in this area, and is evidently at home in warm, comparatively shallow waters”. The figures illustrated by Brady (Barker, 1960) are of the specimens recovered from the sediments dredged at Challenger Station 209, Philippines, in the Pacific Ocean, at a depth of 95 to 100 fathoms (~174 to 183 m), at Challenger Station 217A, off Papua, Pacific Ocean, at a depth of 37 fathoms (~68 m), and Challenger Station 219A, Admiralty Islands, Pacific Ocean, at a depth of 17 fathoms (~31 m). *Heterolepa praecincta* was referred by Brady to *Truncatulina*. According to Barker (1960), this species was placed in the genus *Eponides*, but material from off Papua and the Malacca Straits, which is identical with Brady’s figures, shows a typical *Cibicides* aperture; he, therefore, placed it under *Cibicides*. Zobel (1973) recorded this species (as *Cibicides praecinctus*) in the sediments from the Indian and Pakistan continental margins during the course of his biostratigraphic investigation. Later, it was reported as *Heterolepa praecincta* from the Persian Gulf by Lutze (1974). Hofker (1978) recorded this species as *Cibicides praecinctus* at only one station at a water depth of 216 m, south-west of Pisang Islands, in the eastern part of the Indonesian Archipelago. In the Indo-Pacific Province, extensive outer platform areas and fore-slopes within the euphotic zone (30 to about 130 m deep) are typified by such anomalinids as *Heterolepa praecincta*, which is considered to be an exclusively tropical species (Montaggioni and Vénece-Peyré, 1993). On the Sunda Shelf in the south-western part of the South China Sea, *H. praecincta* has a water depth range of inner shelf to uppermost bathyal (Szarek, 2001). On the other hand, Tu and Zheng (1991) stated its depth range to inner/middle shelf (50 to 100 m), while Violanti (2005) gave a range of deep shelf to bathyal for this species. According to Debenay (2012), who studied and illustrated 1,000 species of benthic foraminifera from off New Caledonia, in the south-western Pacific Ocean, *H. praecincta* occurs in the south-western lagoon and on the southern shelf, at water depths greater than 30 m. Milker et al. (2013) observed *Neoeponides praecinctus* to be dominant at water depths greater than ~45 m on the inner shelf off Khao Lak (Andaman Sea, Thailand), but it was also present between 16 and 34 m; they opined that this species is adapted to low light intensities and low water energy.

Repository: PK–AG–222
**Cibicides refulgens** de Montfort, 1808  
Pl. 9; Figs. 3, 3a

Original citation: *Cibicides refulgens* DE MONTFORT, 1808, v. 1, p. 123, fig. 122.  

Remarks: Much confusion exists in the literature as to the distinction between *Cibicides refulgens* (de Montfort, 1808) and *Cibicides lobatulus* (Walker and Jacob, 1798). Holland (1910) recognized both species but illustrated only a test identified as *Truncatulina refulgens*. Holland writes of *C. refulgens* (p. 10), "This is but a variety of the common Truncatulina lobatula in which the convexity of the oral surface is more pronounced and the sutures and peripheral margins of the chambers on the aboral surface are more distinctly emphasized". This species was recorded by Cushman (1915) in the Pacific Ocean, at water depths ranging between 187 and 2,779 m; later, he (1921) observed its occurrence in the Philippine waters at 58 to 1,622 m. In the Broken Bay (Albani, 1968) and Port Hacking (Johnson and Albani, 1973), this species was recorded at water depths of 5 m and 6 m, respectively. Albani and Geyskes (1969) reported this species from a part of the north-west Australian continental shelf and stated, “This species is the most abundant of the genus reaching the 30% at a few stations. The specimens are very often, small and variable and they are present to a depth of 300 m which seems to be the lower limit in the area studied”. On the Iberian coast, it was reported mostly from the north (Colom, 1974); in the Mediterranean, it was observed to be rare in the neritic zone of Motril-Nerja (Sánchez-Arizá, 1979). Höfker (1978) recorded this species at water depths ranging from 378 to 1,496 m in the eastern part of the Indonesian Archipelago, and remarked, “It is possible that all specimens with low dorsal side are megalospheric, and that only the microspheric specimens are high-domed”. According to Alexander and DeLaca (1987), the calcareous foraminifer *Cibicides refulgens* is a conspicuous and abundant component of the epifaunal community living on the valves of the free-swimming Antarctic scallop, *Adamussium colbecki*. They examined this association using light microscopy, scanning electron microscopy, radiotracer, and resin-casting/sectioning techniques, and demonstrated that this species possesses a combination of morphological and physiological adaptations, which seem to be unique to benthic calcareous foraminifera, and enhance its ability to acquire nutrients in an otherwise oligotrophic and seasonal environment. Their studies revealed that it employs three distinct modes of nutrition: (1) grazing the algae and bacteria living upon the scallop shell surface, (2) suspension feeding through the use of a pseudopodial net deployed from a unique superstructure of agglutinated tubes which form an extension to the calcareous test, and (3) parasitism by eroding through the scallop’s shell, and using free amino acids from the highly concentrated pool in the extra-pallial cavity. *Cibicides refulgens* is relatively more frequent in the Alborán Sea (Mateu, 1992), while on the Portuguese continental shelf, it is sporadic and especially abundant between Nazaret and Lisbon (Levi et al., 1995). According to Villanueva-Guimerans and Currado (1999), *Cibicides refulgens* is widespread in the surface sediments on the northern margin of the Gulf of Cadiz in the depth-range from 20 to 600 m, mainly in gravel and sand sediments, with maximum frequencies of about 18% of total assemblage. It occurs in the outer bay and at depths ranging between 10 and 200 m in the north-eastern part of the gulf (Villanueva-Guimerans and Canudo, 2008). It occurs (living) from inner to middle shelf depths on the modern Otway Shelf at depths between 30 m and 70 m (Smith et al., 2001), which differs significantly from the distribution documented by Murray (1991) in the Southern Ocean region, where it is recorded from depths between 136 and 950 m. The distribution of this taxon is substrate-controlled. It occurs most commonly on bioclastic sand substrates, where it can attach itself onto grains of sand or bioclasts, allowing it to survive high energy environments (op cit). Species of the genus *Cibicides* have a relatively high oxygen requirement (Sen Gupta et al., 2007), which means that even the slightest oxygen depletion caused by enhanced nutrient input could be the explanation for their absence from sediments.
According to Sen Gupta et al. (2009b), this species has a bathymetric range of 137 to 1,940 m in the south-eastern and south-western parts of the Gulf of Mexico. Epiphytic species, such as C. refulgens (Langer, 1993), were absent from the fish farm stations (Vidović et al., 2009), probably due to the degraded community of the sea grass *Posidonia*. According to Hayward et al. (2010), this species is rare off eastern New Zealand between 33° and 56° S latitudes, with an upper to lower bathyal water depth range of 200 to 2,000 m, and having a stratigraphic range of Early Miocene to Recent; in the Bass Canyon, however, Smith and Gallagher (2003) gave a range of Pliocene to Recent. Debenay (2012) recorded this species from the southern shelf off New Caledonia in the south-west Pacific Ocean at a water depth of 600 m. *Cibicides refulgens* is a cosmopolitan, neritic species (Fenero et al., 2013) species, living in tropical to polar regions (Alexander and DeLaca, 1987; Javaux and Scott, 2003), that does not appear to be limited by light and seems to be a putative suspension feeder (Walker et al., 2011) and an oxic indicator (Kaminski, 2012). This species appears to be a highly invasive benthic foraminiferal species that colonizes rapidly and acts like opportunistic species, but unlike them, it maintains its spatial distribution and increase in its population over time. Thus, these species may be opportunistic ecological incumbents, where they invade new territory relatively quickly with high numbers of propagules, but rather than have population crashes like true opportunistic species, they increase their abundance through time (Walker et al., 2011). Margreth (2010) and Spezzaferri et al. (2013) observed *C. refulgens* to be an indicator of an environment characterized by strong bottom currents (Musco, 2011), elevated oxygen levels, and a high flux of organic matter, including phytodetritus.

Repository: PK–AG–224

*Cibicides wuellerstorfi* (Schwager, 1866)

*Original citation:* Anomalina wuellerstorfi SCHWAGER, 1866, v. 2, p. 256, pl. 7, figs. 105, 107.

*Remarks:* The types for this species came from the Pliocene of Kar Nikobar, off Sumatra (Schwager, 1866). This species was recorded by Flint (1899) as *Truncatulina wuellerstorfi* at several stations in Gulf of Mexico, Atlantic Ocean and Panama Bay in a wide water depth range of 25 to 2,069 fathoms (~46 to 3,784 m). Bagg (1905) also listed this species as *T. wuellerstorfi* among the foraminiferal taxa identified from the Miocene of California, and estimated the water depth range of living representatives in the present day oceans to be 200 to 2,000 fathoms (~366 to 3,658 m). The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediment dredged at Challenger Station 166, off the west coast of New Zealand, at a depth of 275 fathoms (~503 m). Brady referred this species to *Truncatulina*, but Cushman (1929, p. 104) referred it to *Planulina*. Hofker (l. c. 1951) referred this species to *Cibicides*, but gave no reason for dropping *Planulina*. According to Corliss (1979), *Planulina (= Fontbotia)* is marked by a compressed, discoidal test with a low trochospiral chamber arrangement, whereas *Cibicides* has a planoconvex test: the spiral side is flat to excavated and the umbilical side is strongly convex and trochospiral. The specimens obtained by Corliss (op cit.) from the south-east Indian Ocean had tests that varied from weakly planoconvex to almost discoidal shape and hence were placed by him under genus *Planulina*. Corliss (1979) also observed his specimens to vary in the rate of expansion of the final chambers, the width of the final whorl, and the curvature of the sutures. *Fontbotia wuellerstorfi* is an important deep-sea form found in all oceans and, in the south-east Indian Ocean, it is found between 2,500 and 4,600 m water depths (Corliss, 1979). This species was recorded as *Planulina wuellerstorfi* by Hofker (1978) at water depths ranging between 513 and 2,969 m in the eastern part of the Indonesian Archipelago. Later, he (1980) recorded it at two stations having water depths of 730 and 890 m on the Saba Bank, a seemingly submerged volcanic island to the
south-east of the island of Saba, and stated that it is adapted to very low temperatures and “does not occur at higher temperatures”. In his study on the bathyal benthic foraminifera off north-east Newfoundland, Cole (1981) observed *P. wuellerstorfi* to be common at depths ranging from 1,530 to 3,210 m, particularly between 2,560 and 3,000 m. He noted that the tests were usually >1 mm in size and generally brown in color or, otherwise, transparent. The distribution of bathyal to abyssal, living foraminifera in the sediments of box cores from the north-west Atlantic Ocean was investigated by Corliss (1985), who observed this species (reported as *F. wuellerstorfi*) to have an epifaunal preference, which dominates the top 1 cm of the sediment. Hermelin and Scott (1985) observed this species to be present in low frequencies at most of the sampling stations in the central North Atlantic Ocean. According to Lutze and Thiel (1987), *C. wuellerstorfi* prefers an elevated position above the sediment-water interface up to 14 cm above the sea floor for a better chance to catch food particles from slightly streaming water (Altenbach and Sarnthein, 1989). It was reported from depths ranging from 1,500 to 2,700 m (Polyak, 1990, Scott and Vilks, 1991) throughout the Arctic Ocean. According to Miao and Thunell (1993), *Cibicidoides wuellerstorfi* is abundant at 1,500 to 3,200 m water depths in the South China Sea, and at 1,000 to 2,200 m in the Sulu Sea. This epifaunal taxon is also able to develop in environment where bottom water oxygenation values indicate hypoxic conditions (Rathburn and Corliss, 1994; Jorissen et al., 2007). *C. wuellerstorfi* is a species typical of environments characterized by low carbon-flux rate (e.g., Mackensen et al., 1985; Altenbach, 1992; Burke et al., 1993; Altenbach et al., 1999) or by pulsed fluxes of organic matter (Mackensen et al., 1985). Mackensen et al. (1993) showed that *F. wuellerstorfi*, which is generally regarded as a strictly epifaunal taxon, responds to seasonal input of organic matter at the sediment–water interface. It obviously calcifies within this phytodetritus deposit and thus reflects the very low δ13C values within the so-called fluffy layer. Consequently, δ13C values of *C. wuellerstorfi* tests do not always strictly reflect bottom water δ13C values in a 1:1 manner. *C. wuellerstorfi* is a raised epifaunal benthic foraminifer (Rathburn and Corliss, 1994) and widely used for isotopic study owing to its capacity to record δ13C and δ18O in equilibrium with marine water (Katz et al., 2003). Yassini and Jones (1995), who recorded it as *Cibicidoides wuellerstorfi*, observed this species to be very abundant on the outer shelf and continental slope off the south-east coast of Australia. According to Ishman and Foley (1996), this species (reported as *F. wuellerstorfi*) occurs in small but significant percentages from the Northwind Ridge, off Alaska, at depths ranging from 1,055 to 2,135 m. According to Altenbach et al. (1999), *C. wuellerstorfi* is found in habitats with low to intermediate flux rates from 0.2 to 10 g organic carbon per m² and year, and is an oxic indicator (Gebhardt, 1999). As food particles decrease with increasing water depth (Weinelt et al., 2001), this species is successful in oligotrophic and deep habitats. The distribution of suspension feeders such as *C. wuellerstorfi* is also controlled by the intensity of bottom currents that contribute to the lateral advection of particulate nutrients (Kaminski et al., 1988; Sarnthein and Altenbach, 1995). This implies that the low accumulation rates of this species in the Holocene indicate weakened bottom current activity in the South China Sea (Jian et al., 1999). Loubere and Fariduddin (1999) suggested *Cibicides wuellerstorfi* as an indicator of high seasonale food supply under oligotrophic conditions, whereas Gupta (1997) related this species with the oxygenated, strong bottom currents with strongly pulsed food supply in the Indian Ocean. *Fontibokia wuellerstorfi* has a depth distribution between 900 and 3,500 m, but maximum abundance (19 to 47%) occurs in the in the intermediate-depth waters (1,533 to 2,400 m) of the Chukchi Basin and Mendeleeyev Ridge and the north-western slope of the Lomonosov Ridge (Osterman et al., 1999). They attributed its elevated abundance to increased food supply carried by a branch of Atlantic water that crosses the Lomonosov Ridge near the Russian Continental Shelf. Szarek (2001) presented a bathymetric range of upper bathyal to lower bathyal for this species on the Sunda Shelf in the south-western part of the South China Sea, while Hayward et al. (2003) gave upper water depth limits of 250 m and 350 m for this species west and east of New
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Zealand, respectively, and an overall range of 234 to 2,150 m. Dissolution in C. wuellerstorfi was observed to be more in the northern part of the Denmark Strait (Lorenz, 2005), and is attributed to the presence of dense, cold, saline, and CO₂-rich bottom water, which is linked to sea-ice production and the position of the Oceanic Polar Front (Steinsund and Hald, 1994). Living specimens were associated with relatively higher current velocities, implying that this species clearly prefers the epibenthic mode of living as a suspension feeder, although it is also able to live endobenthic as a substrate feeder. Lorenz (2005) noted that this species attaches itself so tightly to the substrate that even dead individuals were difficult to remove for further investigations, confirming their suspension feeding habit. In the eastern Indian Ocean, C. wuellerstorfi is typical of an environment characterized by a high dissolved-oxygen concentration and a low carbon-flux rate (Murgese, 2003). Studies of living (rose-Bengal stained) specimens support this interpretation. Periods dominated by this taxon are characterized by high species-diversity, an increased percentage of porcellaneous species and a low infaunal species relative abundance, indicating high oxygen levels and reduced organic matter supply (Gupta and Thomas, 2003; Murgese and De Deckker, 2005). Active deep-water circulation and extremely high dissolved-oxygen levels determined by the increased influence of the Antarctic Intermediate Water were postulated by Murgese and De Deckker (2007) based on high δ¹³C values for C. wuellerstorfi and by a faunal dominance by this species. At intermediate depths (1,000 m) and south of 20° S, the presence of strong bottom currents and the lateral advection of small amounts of organic matter, favour this suspension feeder. Sen Gupta et al. (2009a) observed the occurrence of this species (as Cibicides wuellerstorfi) in three canyons in the Gulf of Mexico: De Soto Canyon, at 1,850 m; Alaminos Canyon, between 2,218 and 2,227 m; and Farnella Canyon, at 2,918 m. They found this species attached to elevated microhabitats, such as rock fragments and hydroids, in several non-seep areas outside the Gulf of Mexico, but at seep sites, where bacterial and particulate food is plentiful (Levin, 2005), its attachment to tubeworm surfaces above the seafloor also offers freedom from hypoxia and sulfide toxicity (Freytag et al., 2001; Cordes et al., 2003). This attachment to tube worms, above the sediment–water interface was also observed at an abyssal seep site on the Aleutian margin (Adamic et al., 2005). Cibicides wuellerstorfi occurs in moderate numbers all around New Zealand between 33° and 56° S with a bathymetric range of 400 to 3,000 m (upper bathyal to upper abyssal) and has a stratigraphic range of Early Miocene to Recent (Hayward et al., 2010). Cibicidoides wuellerstorfi has a bathyal and/abyssal habitat in the entire Gulf of Mexico and occurs in a water depth range of 457 to 3,850 m (Sen Gupta et al., 2009b). Off the Peruvian and Ecuadorian continental margins, Mallon (2011) observed Cibicidoides wuellerstorfi to be common but occurring in small quantities at water depths ranging between 207 and 2,092 m. Debenay (2012) recorded this species as Fontbotia wuellerstorfi from the northern shelf off New Caledonia in the south-western Pacific Ocean at a water depth of 600 m. According to Mancin et al. (2013), who reported it as Cibicides wuellerstorfi, this species is epibenthic (raised) and associated with low, mostly pulsed organic fluxes, high oxygen content, elevated substrate, and high-energy environments with strong bottom water currents (Margreth, 2010), and can tolerate temperatures below 0° C (Spezzaferri et al., 2013). The δ¹³C and δ¹⁸O values provided by this species are reliable indicators of organic carbon flux to the sea floor and bottom water temperature, respectively (Bhaumik et al., 2014). This is in contrast to the opinion voiced earlier by Mackensen et al. (1993).

Repository: PK–AG–225

Genus LOBATULA Fleming, 1828
Lobatula lobatula (Walker and Jacob, 1798)
Pl. 9; Fig. 5
Original citation: *Nautilus lobatulus* WALKER and JACOB, 1798, p. 642, pl. 14, fig. 36.

Remarks: Bagg (1905) recorded this species as *Truncatulina lobatula* from the Pliocene of California and remarked that this species “is probably as widely diffused as *Globigerina bulloides* which is known in every ocean, in every sea, and at all depths. The earliest record of the form as a fossil is in Carboniferous strata and it is well known in every subsequent deposit”. This species, recorded as *Cibicides lobatulus* by Cushman et al. (1954), was found to be more abundant at the deeper stations in the Bikini, Eniwetok and Rongelap atolls in the Marshall Islands. They observed two different forms, one showing signs of attachment, and the other without any evidence of being attached. Many authors included this species with others, such as *C. refulgens*, compelling McLean (1956) to write, “Unfortunately, so many different forms have been ascribed to Walker and Jacobs’s species that assigning the name *lobatulus* to a *Cibicides* is tantamount to giving the form a status more truthfully described by the term *incertae sedis*. This well-known cosmopolitan species was recorded by Todd and Low (1971) as *Cibicides lobatulus*, but observed to be rare on the Bahama Bank, west of Andros Island, present only in samples from the outer edge and at one central reef station. Ward (1984) observed that all the tests assigned to *Cibicides lobatulus* were all quite similar, the greatest variety being in test shape, and she attributed this to their attachment to different substrates such as rocks or sponge spicules during life. Epiphytic forms such as *Lobatula lobatula* are abundant in the photic zone where coralligenous and seagrass bioecosystems are present (e.g., Langer, 1988; Sgarrella and Monchamont Zei, 1993; Sen Gupta, 1999). According to Gázdzicki and Webb (1996), “*C. lobatulus* tends to spread laterally and may assume irregular shapes, this being attributed to attachment strategies. The sutures, chambering and porosity on the spiral side may not be as well developed as in *C. refulgens*, again this probably resulting from the effects of attachment”. They stressed upon the point that the differences between the two species were probably ecophenotypically induced. According to Kitazato (1988), *C. lobatulus* represents attached, immobile mode of life, and lives by attaching itself with organic “glue” to the seaweeds or hard substrates, and mainly feeds on diatoms. Wollenburg and Mackensen (1998) reported that a *Lobatula lobatula* assemblage is found associated with strong currents and coarse sediments at <500 m water depth along the Svalbard/Barents Sea Shelf in the Arctic Ocean. Villanueva-Guimerans and Currado (1999) found *L. lobatula* to be an abundant and easily distinguishable species on the Cadiz coast, closely comparable with populations occurring elsewhere off the Iberian coast. On the northern margin of the Gulf of Cadiz, its distribution is similar to that of *C. refulgens*, but with low frequencies. The observed δ¹³C values in the epibenthic *Lobatula lobatula* off northeast Greenland are 0.4% higher than the δ¹³C of ambient bottom water indicating that this species calcifies before the ice-free season, when bottom water δ¹³C is higher than at the time of sampling (Mackensen et al., 2000). Lukina (2001) listed this species as *L. lobatula* and observed it to occur at water depths ranging from 40 to 1,658 m in the Laptev Sea, but remarkably is absent in the southern part of the sea. According to Szarek (2001), who reported it as *Cibicides lobatulus* (Walker and Jacob) from the Sunda Shelf in the southwestern part of the South China Sea, the species shows wide variety in test morphology that depends on the surface to which it is attached. The suspension feeding, attached, epifaunal foraminifer *Lobatula lobatula* was found in great abundance inside the sponges and interpreted to gain its food from the sponge’s inhalant currents (Mazzoli-Dias et al., 2007). According to Martins et al. (2007), this taxon is an indicator of well oxygenated bottom waters and low concentrations of organic matter, and considered to be an oxyphilic marker (Báldi and Hohenegger, 2008; Pezelj et al., 2013). Spezzaferrì and Tamburini (2007) studied paleodepth variations on the Eratosthenes Seamount in the Eastern Mediterranean Sea, and gave a bathymetric range of 5 to 120 m for this species. *Lobatula* Fleming 1828, based on this species, is regarded as a valid genus by Loeblich and Tappan (1987). However, as there is, however, no distinguishing character on which *Lobatula* can be unequivocally separated from *Cibicides*, Sen
Gupta et al. (2009c) agreed with Jones (1994) that Lobatula is a junior synonym of Cibicides and recorded this species as Cibicides lobatulus from the Gulf of Mexico. According to Raddatz et al. (2011), stable oxygen and carbon isotope records of benthic foraminiferal species indicate that Lobatula lobatula provides a reliable isotopic signature for paleoenvironmental reconstructions. Debenay (2012) provided an illustrated guide to a thousand benthic foraminifera and recorded this species to occur attached to algae at water depths ranging from 30 to 100 m off New Caledonia in the south-western Pacific Ocean. According to Margreth (2010) and Spezzaferri et al. (2013), L. lobatula, a passive suspension feeder, is associated with living coral facies, hard substrates and coarse sediments, well oxygenated waters, and high energy environments on the Norwegian cold water coral reefs.

Repository: PK–AG–226

Family PLANORBULINIDAE Schwager, 1877
Subfamily PLANORBULININAE Schwager, 1877
Genus PLANORBULINA d'Orbigny, 1826
Planorbulina variabilis (d’Orbigny, 1826)

Remarks: Bagg (1905) listed this species as Truncatulina variabilis among the foraminiferal taxa identified from the Miocene of California, and observed all the specimens were obtained from shallow water, except for one that was from 2,000 fathoms (~3,658 m). This species was found by Pearcey (1914) to be common at a depth of 56 fathoms (~102 m). He noted that this wild-growing form was a common species in the warmer waters of the sub-tropical and temperate seas, in shallow water, but also observed that it had been obtained at depths >2,000 fathoms (~3,658 m). In the Mediterranean Sea, Cibicidella variabilis occurs as two forms, “one a small, rather feebly outspread and complanate variety, and the other, very large, coarsely perforated and often showing a number of heavily lipped orifices” (Sidebottom, 1909). Chapman and Parr (1937) observed that their specimens of this species were of the first variety of Sidebottom, and opined that it was a wild growing form of Cibicides lobatulus, with which it usually occurred, and that the shape of the test was determined by the “nature of the object to which it is attached”. This opinion was later supported by Cushman et al. (1954), who also stated that, “This is a highly variable species, the early stages like Cibicides but the later chambers taking many different shapes, probably partly due to the surface to which it is attached”. Todd (1957) listed this species as Cibicidella variabilis among the 27 benthic species in the Miocene rocks of Saipan and in the Recent sediments around Saipan Mariana Islands. According to Hayward et al. (2001), who studied the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, Cibicides variabilis has a bathymetric range of 90 to 4,680 m. Cibicides variabilis occurs all around New Zealand (Hayward et al., 2010) between 33° and 56° S latitudes, but appears to be more abundant off the east coast of the South Island than in the north or off the west coast, with a mid shelf to lower bathyal depth range of 50 to 2,000 m. They opined that the several deeper records of this species were possibly displaced. According to Kaminski (2012), who calibrated Kaiho’s (1994) benthic foraminiferal oxygen index (BFOI) in the Marmara Sea, C. variabilis is one of the thick-walled epifaunal oxic indicators (>2 mL/L O₂). Planorbulina variabilis is an epiphytal species typical of carbonate environments colonized by seagrass and associated with bioclastic sands associated mainly with colonization by Caulerpa prolifera and Posidonia oceanica on the shoreface and inner shelf off Valencia in the Western Mediterranean (López-Belzunce et al., 2014).

Repository: PK–AG–227
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Superfamily ASTERIGERINACEA d’Orbigny, 1839
Family EPISTOMARIIDAE Hofker, 1954
Subfamily NUTTALLIDINAE Saidova, 1981
Genus NUTTALLIDES Finlay, 1939
Nuttallides umbonifera Cushman, 1933

**Original citation:** Pulvinulina umbonifera Cushman, 1933, p. 90, pl. 9, figs. 9a–c.

**Remarks:** The types for this species came from the South Pacific Ocean at a water depth of 2,243 m (Cushman, 1933). Streeter (1973) stated that the upper limit of Nuttallides umbonifera is variable in different oceans, depending on the vertical water mass structure. Miller (1982) attempted to relate changes in the N. umbonifera percentages to the carbon-isotope record at the bottom. He suggested that an acme of this species in the middle Oligocene correlated with increased age and corrosiveness of bottom waters. The occurrence of N. umbonifera, a species generally found below 3,000 m in Antarctic Bottom Water (Streeter and Lavery, 1982; Thomas et al., 1990), is a notable conundrum. It is not solely a question of how it can survive out of its normally cold and very saline bottom water, but that it would have to migrate from 3,000 m to ~500 m into the mouth of the Northeast Channel (Hawkes and Scott, 2005). According to Hermelin (1989), this species has been generally associated with low temperature or bottom waters and is most common on the sea floor between the lysocline and the CCD. The distribution of N. umbonifera has been associated with AABW or waters which are under-saturated with respect to calcium carbonate (e.g., Streeter, 1973; Bremer and Lohmann, 1982; Mackensen et al., 1995) and/or to areas of low productivity (e.g., Gooday, 1993; Smart and Gooday, 1997; Loubere and Fariduddin, 1999). The main ecological difference between Nuttallides umbonifera and Epistominellina exigua is that the former is a non-opportunist species that is able to survive, when necessary, on a lower food supply than the latter (Gooday, 1993). Also, N. umbonifera has a relatively large, thick-walled test (Mackensen et al., 1990), which suggests a slow rate of growth compared with the small, thin-walled tests of E. exigua. Thus, N. umbonifera may be outcompeted, or at least numerically swamped, by fast-growing opportunists such as E. exigua (Gooday, 1993). Nuttallides umbonifera may, therefore, have greater chance to grow vigorously where food supply is reduced (Loubere, 1991). The availability of food for benthic foraminifers is assessed with the relative abundance of Nuttallides umbonifera, higher values of which suggest increased oligotrophy and reduced food. Its increased relative abundance has been widely correlated with the occurrence of young, cold, carbonate-corrosive, oligotrophic and oxic bottom waters (e.g., Mackensen et al., 1995; Smart and Gooday, 1997; Hayward et al., 2002, 2004). Some authors have correlated its increased relative abundance with corrosiveness of the water mass (e.g., Corliss, 1979; Bremer and Lohmann, 1982; Mackensen et al., 1995; McDougall, 1996), whereas others have considered this species as an indicator of extreme oligotrophy (e.g., Gooday, 1993; Loubere, 1994). Bornmalm (1997) stated that the generic placement of this species was unclear, as some workers have referred this species to Nuttallides while others have referred it to Epistominellina. In his study, however, he followed Todd (1965) and placed this species in Nuttallides rather than in Epistominellina because of the position of the aperture and the presence of an umbilical plug. According to Gupta and Thomas (2003), this species is an indicator of cool waters, strongly pulsed but low to intermediate organic flux coupled with high seasonality in the eastern equatorial Indian Ocean, and the influence of the Antarctic Bottom Water (AABW) in the northern Indian Ocean (Rai and Srinivasan, 1993; Thomas, 2007). This is a cosmopolitan, living species which dominates (although with lower abundances) the abyssal plains of deep oceans basins, also below 4,000 m water depth. Most of the authors consider N. umbonifera as adapted to highly oligotrophic, carbonate-under-saturated bottom water (e.g., Gooday, 2003). However, findings of N. umbonifera-dominated assemblages in areas with strong seasonal phytodetrital pulses (Gooday, 1993; Kurbjeweit et al., 2000) indicate
that the ecology of this important species is far from being fully understood. The relative abundance of *N. umbonifera* may be used in combination with the fragmentation index as a proxy for corrosive deep bottom water, particularly in time series studies at a core site (Hayward et al., 2004). In the North Atlantic Ocean, the species occurs at lower latitudes, to the south of the strongly seasonal food input which leads to high abundance of phytodetritus species (Sun et al., 2006). Singh and Gupta (2004) proposed that in the late Oligocene to Miocene, *N. umbonifera* was abundant in the south-eastern Indian Ocean where other taxa could not grow optimally, either because of low food inputs or high carbonate corrosivity. Kurbjeweit et al. (2000), however, argued that in the modern Arabian Sea, *N. rugosus* (= *N. umbonifera*) is not clearly related to either corrosive AABW or low productivity, but is significantly positively correlated with increased oxygen concentrations and sand content of the sediment. *Nuttallides umbonifera* has been considered to be a proxy of oligotrophy in the Caribbean region (Jain and Collins, 2007), and an epifaunal, corrosive bottom water species in the eastern Indian Ocean (e.g., Smart et al., 2007; Thomas, 2007; Hayward et al., 2010; Gupta et al., 2013). Hayward et al. (2010) opined that there is some uncertainty about the generic placement of this species, and stated that they chose to place it in *Nuttallides* because of its umbilical plug and the position of the aperture. They observed it to be most abundant (10 to 60%) at mid-lower abyssal depths (3,000 to 5,000 m) beneath the corrosive Circumpolar Deep Water, with a few rare lower bathyal records at depths ranging between 1,000 and 2,000 m. According to Rai and Gupta (2010), the lower bathyal to abyssal species *Nuttallides umbonifera* shows a major increase at ~11.5 Ma coinciding with a significant increase in Neodymium (Nd) isotope values, indicating substantial transport of deep Pacific water to the Indian Ocean through the Indonesian seaway. The high abundance of *N. umbonifera* during this time indicates presence of carbonate corrosive deep/bottom water in the eastern Indian Ocean (Singh and Gupta, 2010), coinciding with the opening of the Drake Passage and subsequent development of the ACC in the late Oligocene (Pfuhl and McCave, 2005). *Nuttallides umbonifera* is a shallow infaunal species (Fontanier et al., 2002) found associated with corrosive bottom water in the Atlantic Ocean (Bremer and Lohmann, 1982). In the south-east Indian Ocean, this species was observed at depths with coldest (−0.2 to 0.4°C) AABW (Corliss, 1979). In the south-west Indian Ocean, *N. umbonifera* has been observed dominating 3,600 to 4,800 m water depths with cold (temperature ~0.3 to 0.8°C), low salinity AABW (Corliss, 1983). This taxon has also been interpreted as an indicator of low productivity (Gooday, 1994, 2003; Loubere, 1998; Loubere and Fariduddin, 1999). Across the Indian Ocean, *N. umbonifera* occurs in areas with in situ temperature of 1.2 to 1.6°C, oxygen content of 3.9 to 4.5 mL/L and low primary production (De and Gupta, 2010). According to Hayward et al. (2010), *N. umbonifera* is a cosmopolitan species with a bathymetric range of 3,000 to 4,200 m around New Zealand.

Repository: PK–AG–228

Genus OSANGULARIELLA Saidova, 1952

*Osangulariella bradyi* (Earland, 1934)

**Original citation:** *Eponides bradyi* EARLAND, 1934, p. 187, pl. 8, figs. 36–38.

**Remarks:** The figures portrayed by Barker (1960) are of the specimens obtained from the material dredged from the Challenger Station 64, at a water depth of 2,750 fathoms (5,029 m; fig. 10), and at Challenger Station 5, in the North Atlantic Ocean at 2,740 fathoms (~5,011 m). This species was referred by Brady to *Truncululina pygmaea* Hantken. Cushman (1927, p. 165) referred fig. 10 to *Pulvinulina bradyana*, but Earland (1934, p. 187) stated that Brady's form is not a *Pulvinulina* and, therefore, was not conspecific with *bradyana*, which he regarded as a distinct west American form. He named Brady's species as *Eponides bradyi*. Phleger, Parker and Peirson (1954, p. 43) referred Brady's figures, albeit doubtfully to *Epistominella (?) umbonifera* (Cushman),
with Earland's *E. bradyi* itself doubtfully in synonymy. Barker (1960) opined that their figures did not appear to be the same as those of Brady and indicated relationship with *Pseudoparrella* and *Epistominella* and hence retained Earland's name. Chapman and Parr (1937) remarked, “A comparison of Brady's figures with the type figure of von Hantken will show that the two forms represented by those authors are generically distinct. Hantken's species is a *Cibicides*, while that of Brady belongs to the genus *Eponides*. With reference to *Pulvinulinella bradyana* Cushman (1927 p. 165,) it is difficult to see how this can be correlated with Brady's figure 10, an apertural view of which is not given. According to Nuttall, Brady's figures 9 and 10 represent specimens from the North Atlantic, and without doubt relate to the same species. The apertural view of figure 9 is characteristic of *Eponides* and is quite unlike that of *Pulvinulinella*. According to Brady, the species is confined to very deep water, and is widely distributed. It is very common in many of the dredgings of the *Aurora*. Bornmalm (1997) observed that *Eponides bradyi* was a common species at certain depths at both investigated sites (the Caribbean Sea and eastern equatorial Pacific Ocean); at other depths it was rare with scattered occurrences. According to Strong and Webb (2000), who examined Oligocene and Miocene foraminifers from a core retrieved in the Victoria Basin, Antarctica, their specimens closely resembled Leckie and Webb’s (1985) figures and Bolton’sky’s (1978) figured specimen as well. They had a more lobulate periphery than Earland's (1934) specimens, but opined that “his drawings appear to be somewhat diagrammatic”. On the Sunda Shelf, in the south-western South China Sea, Szarek (2001) recorded this species (as *Neoeponides bradyi*) to be distributed only on the continental shelf. Debenay (2012) recorded this species as *Neoeponides bradyi* (Le Calvez, 1974) from the southern shelf off New Caledonia in the south-western Pacific Ocean, at depths greater than 45 m. This species was observed to occur at water depths ranging from 5 to 90 m from Tuzla Bay in the south-western part of the Karaburun Peninsula in the Aegean Sea (Meriç et al., 2012), and in the coastal environment of the northern Marmara Shelf (north-west Turkey) (Avşar, 2010).

Repository: PK–AG–229

Superfamily NONIONACEA Schultze, 1854
Family NONIONIDAE Schultze, 1854
Subfamily NONIONINAE Schultze, 1854
Genus NONIONELLA Cushman, 1926

**Nonionella auris** (d’Orbigny, 1839)
Pl. 9; Fig. 7

Remarks: The types for this species came from the west coast of South America (d’Orbigny, 1839), where the species was recorded as often abundant from Chile to Ecuador. Wefer et al. (1994), who used stable isotope composition of *Bolivina seminuda* and *Nonionella auris* to understand their response to methane fluxes, suggested that the latter, which feeds on methane-oxidizing bacteria, could be a reliable indicator of the presence of methane. According to Hayward et al. (2001), who studied the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, *N. auris* has a bathymetric range of 400 to 4,680 m, but Lörz et al. (2012) gave a modified depth range of 194 to 4,680 m. In the region off New Zealand, the upper water depth limits given for this species were 375 m and 400 m west and east of the island nation, respectively (Hayward et al., 2003). Based on Saidova’s (1975) opinion to transfer this genus to the genus *Nonionoides*, Kaminski et al. (2002) recorded this species as *Nonionoides auris* from the Holocene marine sediments of the Marmara Sea. *Nonionella auris* occurs preferentially in low energy, deep environments with muddy substrates within the San Matías Gulf, Rio Negro Province of Argentina (Bernasconi and Cusminsky, 2005). This species is considered to be one of
the characteristic species in sedimentary settings with pronounced chemoclines and strong sulfide production (Risgaard-Petersen et al. 2006; Leiter and Altenbach, 2010). Bhaumik and Gupta (2007) opined that this species is one of the high organic carbon taxa independent of deep-sea oxygenation. According to Shepherd et al. (2007), larger individuals of N. auris have a deeper distribution than the juveniles, suggesting that reproduction or early growth takes place near the water–sediment interface, whereas the “adult” individuals can thrive deeper into the sediment. This species is characterized by its unequally biconvex test, numerous chambers (10 to 12) and the last chamber forms a valvular on the umbilical area, with the aperture extending from the umbilicus to the rounded periphery (Anan, 2010). This cosmopolitan species (Hayward et al., 2010) has a geographical distribution off New Zealand between 33° and 56° S, with an overall wide bathymetric range of 200 to 5,000 m (upper bathyal to lower abyssal). They further observed that a zone of maximum relative abundance (4 to 13%) of this species spans the upper bathyal to upper abyssal (400 to 3,000 m). According to Bhaumik et al. (2011), N. auris survives low oxygen, even anoxic conditions, occurs in H2S-containing sediments, cold-seep environments, feeds on bacteria (Wefer et al., 1994), and is generally abundant under high productivity regimes (Gooday, 2003). According to Mallon (2011), who studied benthic foraminifers from the Peruvian and Ecuadorian continental margins, this species was observed to be very rare and was found at only one station at 145 m water depth off Peru. Cardich et al. (2012) postulated that the abundance of N. auris in the sulfidic inner-shelf stations might be explained by the combination of (i) its nitrate storage capacity that allows the continuation of the de-nitrification activity when nitrate is depleted in the pore water (Risgaard-Petersen et al., 2006), (ii) the oxygenation episodes that bring incoming nitrate-rich waters to the bottom (Gutiérrez et al., 2008), and (iii) the high porosity of the flocculent surface sediment in the inner-shelf that permits nitrate replenishment in the pore waters. In turn, the pattern of vertical distribution among young/adult individuals might result from the larger storage and motility capacities that adult individuals present over the juveniles, so that the former can stay longer, deep into the sediment.

Repository: PK-AG-230

Nonionella labradorica (Dawson, 1860)

Original citation: Nonionina labradorica DAWSON, 1860, v. 5, p. 191, fig. 4.
Remarks: Dawson's (1860) types for this species came from the Gulf of St. Lawrence. This species is characterized by its small size with a very broadly triangular apertural face, a feature observed by Cushman (1939) in specimens from the Atlantic Ocean. Hessland (1943) recorded this species in Late Glacial as well as post-Glacial samples from Bohuslån in south-western Sweden. It was most frequent in sediments supposed to be 10,000 to 12,000 years old. According to Nørvang (1945, p. 28), N. labradoricum was, in Recent waters, mainly distributed in the Arctic parts of the Atlantic, but it occurred also in the Boreal ones. Brotzen (1951) found it in the Late Glacial part of a boring at Surte near Gothenburg, Sweden. Phleger (1952) and Parker (1952) reported the species in moderate abundance but in very small, isolated patches across the western Gulf of Maine. According to Todd and Low (1967), who examined Recent foraminifers from the Gulf of Alaska and south-eastern Alaska, and recorded this species as Florilus labradoricus, “This species occurs in typical form and in some abundance in Kasaan Bay and Clarence Strait, and more rarely in four other samples. It is distinctive in its broadly triangular and bulging apertural face. It has also been found in beds as old as Pliocene in California”. According to Smith (1973), who recorded this species as Nonion labradoricum, it was present in only one core sample retrieved from a water depth of 2,410 m, wherein all the specimens were stained. However, she also noted that it was present in shallow water samples south of the Aleutian Islands. Cole (1981) studied
benthic foraminifers from the bathyal zone from off north-east Newfoundland and observed this species to be common at water depths from 390 to 2,800 m, but was most common between 400 and 1,400 m. Ultra-structural investigations by Cedhagen (1991) showed free chloroplasts in the cytoplasm of *Nonionellina labradorica* from depths well below the photic zone in the Gullmarfjord, Kosterfjord, Skagerrak and Kattegatt, Sweden. This symbiosis is facultative as the species is able to survive without chloroplast sequestration. According to Sen Gupta and Machain-Castillo (1993), *Nonionella labradorica* is adapted to dysoxic conditions due to its infaunal habitat. Research has indicated that this species has accomplished this adaptation through the sequestration of algal chloroplasts in its cytoplasm, though the exact mechanism is unknown (Guilbault et al., 2003). This species has been recorded in sediments from Drammensfjord (Norway) and is associated with normal saline deep water conditions (Alve, 1991; Gustafsson and Nordberg, 2002). It is a species that is well adapted to dysoxic conditions because of its ability to use opportunistically the increased organic loads generally associated with dyoxia. However, the species is present in oxic environments as well, although its numbers are often reduced due to competition with other species (Sen Gupta and Machain-Castillo, 1993). *Nonionella labradorica*, which is a high Arctic species requiring stable salinities, open ocean water connection and glacier-distal environments (Hald et al., 1994; Kelly et al., 1999), is an indicator species of a high seasonal flux of fresh nutrients (Hald and Korson, 1997), and an indicator of open-ocean bottom waters (Kubischtka, 2011). It is a typically a deep endobenthic species (up to 8 to 10 cm) associated with areas of high seasonal productivity and fresh phytodetritus fluxes to the seafloor, particularly in the Polar Frontal Zone and at the summer sea-ice edge (e.g., Cedhagen, 1991; Hunt and Corliss, 1993; Hald and Steinsund, 1992, 1996; Polyak et al., 2002; Rytter et al., 2002; Jennings et al., 2004). *Nonionella labradorica* is common in areas of high productivity (Polyak et al., 2002) and areas with fresh phytoplankton (Hald and Steinsund, 1992). This species prefers cold waters (<1° C) of normal salinity (>34.5‰) in the high latitude fjords of Greenland, Svalbard and Scandinavia (Murray, 2006), but is present in the deeper part of Skagerrak with salinities ranging from 30 to 35‰ and temperatures from 0 to 16° C (Conradsen et al., 1994). Lloyd (2006) interpreted the distribution of *N. labradorica* to reflect enhanced nutrient delivery via the warm Atlantic component of the WGC relative to the Arctic Water component. A number of studies find *N. labradorica* associated with warm Atlantic water (temperature 3 to 4° C, salinity >34.5 ppt) on the Labrador shelf between ca. 500 and 600 m water depth (e.g., Vilks, 1980; Mudie et al., 1983; Scott et al., 1984). *Nonionellina labradorica* prefers the temperate, saline Transformed Atlantic Water (TAW) that occupies the deeper, outer, and middle parts of the western Spitsbergen fjords (Hald and Korson, 1997) and it is used as an indicator of high-productivity settings (Lloyd et al., 2007). Ivanova (2008) recorded this species as infaunal, living up to 8-cm depth in the sediment, and observed that it calcifies in isotopic disequilibrium with ambient seawater. Sen Gupta et al. (2009b) observed that this species (recorded as *Nonionellina labradorica*) is confined to a water depth range of 267 to 290 m in the north-western part of the Gulf of Mexico; it has also been reported from the Atlantic, Pacific and Arctic oceans. *Nonionellina labradorica* which, in natural environments, often shows a preference for levels below ~1 cm and seems to migrate to the sediment surface after the sediment input, while it has its maximum abundance in the 1–2 cm layer in the test sediment cores. This might reflect a special food preference of this species (Hess et al., 2013).

Repository: PK–AG–231

**Genus NONIONOIDES Saidova, 1975**

**Nonionoides elongatum** (d’Orbigny, 1826)

Original citation: *Nonionina elongata* D’ORBIGNY, 1826, v. 7, p. 294, no. 20.

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Remarks: The types of this species came from the Miocene of Dax, in France. Cushman (1939) observed that *Nonionoides elongatum* can be distinguished from *N. fabum* (Fichtel and Moll) as the latter has fewer chambers and less marked umbilical filling; it can be distinguished from *N. boueuanum* (d'Orbigny) in having a rounded periphery and in not having prominently limbate sutures. The fact that there do not seem to be any records from other than the Indian region implies that utmost care is needed to compare the existing records from the Bay of Bengal and the Arabian Sea with d'Orbigny’s and Cushman’s figures to decide whether they really match, or shift it to the relevant species/genus as required and mandated by the International Code of Zoological Nomenclature (ICZN).

Repository: PK–AG–232

Subfamily ASTRONONIONINAE Saidova, 1981
Genus ASTRONONION Cushman and Edwards, 1937
*Astrononion novozealandicum* Cushman and Edwards, 1937

Original citation: *Astrononin novozealandicum* CUSHMAN and EDWARDS, 1937, v. 13, p. 35, pl. 3, figs. 18a, b.
Remarks: *Astrononion novozealandicum* was described from the Holocene off the coast of New Zealand. In the northern South China Sea, *A. novozealandicum* has a bathymetric range of 1,200 to 2,600 m, while in its southern part, it occurs at water depths >1,300 m (LeRoy, 1964). According to Hermelin (1989), who investigated Pliocene benthic foraminifera from the Ontong-Java Plateau in the western equatorial Pacific Ocean, “This species has probably been reported as *Melonis guadelupae* Parker. Woodruff in Mead (1985) found that *M. guadelupae* is actually an *Astrononion*. The type figure of *M. guadelupae* is too poor to make this relationship clear. Murray (1984) figured *Astrononion guadelupae* from the Neogene of the North Atlantic. This figure is virtually identical to the type figure of *A. novozealandicum*. *M. guadelupae* is regarded, therefore, as a junior synonym to *A. novozealandicum*. Specimens referred by Corliss (1979) and Mead (1985) to *A. echolsi* Kennett agree well with the type-figures of *A. novozealandicum* with tube-like supplementary chambers extending from the umbilicus to about two-thirds of the distance to the periphery. The supplementary apertures of *A. echolsi* extend only about one-third of the distance to the periphery. *A. echolsi* might be a junior synonym of *A. novozealandicum*. The form described by Cushman and Edwards (1937) from the Pliocene of Italy as *A. italicum* is also probably synonymous with *A. novozealandicum*. The specimen figured as *A. schwageri* (Cushman) by Resig (1981) is considered to be identical to *A. novozealandicum*. The species *A. umbilicatulum* as described by Uchio (1952) is virtually identical to *A. novozealandicum* and is, therefore, also regarded as a junior synonym”. Debenay (2012) illustrated and described this species as *A. novozealandicum*, and observed that it occurs on the southern shelf off New Caledonia in the south-western Pacific Ocean at a depth of 70 m.

Repository: PK–AG–233

Genus MELONIS de Montfort, 1808
*Melonis barleeanus* (Williamson, 1858)
Pl. 9; Figs. 8, 8a

Original citation: *Nonionina barleeanus* WILLIAMSON, 1858, p. 32, pl. 3, figs. 68, 69.
Remarks: *Melonis barleeanus* occurs throughout the north-east Atlantic Ocean, but is particularly abundant in areas where there are active bottom currents (Murray, 1984). Highest concentrations of *M. barleeanus* were reported from fine-grained sediments, typically enriched with organic detritus (e.g., Corliss, 1985, 1991; Korsun and Polyak, 1989; Murray, 1991). This species cannot
tolerate high sedimentation rates, particularly in locations influenced by seasonal meltwater (Caralp, 1989). Its distribution on the Arctic shelf was also somehow tied to Atlantic-derived water (Mudie et al. 1984; Khusid and Polyak, 1989), although not necessarily to increased bottom temperatures (Polyak and Solheim, 1994). According to Bornmalm (1997), “Melonis barleeanus is similar to M. pompilioides, but is more compressed and more finely perforate”. He opined that many authors had placed this species under the genus Nonion, but because of the fact that the umbilical region is open rather than closed, he retained it in the genus Melonis (Hermelin, 1989).

*Melonis barleeanus* has been reported to feed on organic detritus, which can be delivered with fine sediments from shallow areas and then deposited in local depocenters (Polyak et al., 2002). It also feeds on bacteria and, as a methane-rich environment is always rich in bacteria (Wellesbury et al., 2000), this species can be used as an indicator of biogenic methane generation by bacterial degradation of SOM (Rathburn et al., 2000; Bernhard et al., 2001; Panieri, 2005). Gupta and Thomas (2003) suggested that presence of *M. barleeanus* in the Indian Ocean indicates intermediate organic flux with intermediate to high seasonality and the presence of degraded organic matter (Fontanier et al., 2000). It tolerates dysoxic and suboxic pore water, but has maximum abundance under oxic conditions near the sediment surface (Schönfeld, 1997); it has also been reported in the absence of oxygen and decreasing nitrate (Jorissen et al., 1998). Investigations on the microhabitat preferences of *M. barleeanus* in the Gulf of Lions (France) (e.g., Schmiedl et al., 2000; Fontanier et al., 2008) and in the Bay of Biscay (France) (e.g., Fontanier et al., 2002; and Fontanier, 2006) record an average living depth (ALD) in the upper 3 cm with a large spatial variability. This cosmopolitan species, recorded as *M. barleeanum* by Sen Gupta et al. (2009b), is distributed in the entire Gulf of Mexico and has a water depth range of 2 to 2,200 m. According to Nardelli et al. (2010), the rich fauna of Nazaré Canyon is characterized by a strong dominance of intermediate and deep infaunal species (*e.g.*, *Melonis barleeanus* and *Chilostomella oolina*) in superficial sediment layers, suggesting a low bottom-water oxygen concentration and a minimal oxygen penetration into the sediment. Several studies on the ecological preferences of *M. barleeanus* have shown that the occurrence of this species is linked to the quality of organic matter deposited in the sediment (*e.g.*, Caralp, 1989; Mackensen et al., 2000; Schmiedl and Mackensen, 2006; Alve, 2010; Alve et al., 2011). The species prefers organic matter in a more altered form, and migrates in the sediment depending on the organic matter supply and remineralization (*e.g.*, Caralp, 1989; Mackensen et al., 2000; Schmiedl and Mackensen, 2006). The organic matter decomposition is dependent on the source of the organic matter itself, the oxygen penetration depth, and thus the sediment accumulation rate, the substrate composition and bioturbation. The decomposition of organic matter results in an enhanced accumulation of δ13C-enriched carbon, which is added to the pore water and ultimately incorporated in the calcite shell of *M. barleeanus* (Schmiedl et al., 2000, 2004; Loubere et al., 2011). Mallon (2011), who examined benthic foraminifera of the Peruvian and Ecuadorian continental margin, observed this species to be rare; it was found at only two stations off Ecuador at water depths of 995 and 2,092 m. *Melonis barleeanus* was found down to 3 to 4 cm at a water depth of 1,791 to 2,470 m in the northern Arabian Sea (Caulle et al., 2013). The conspicuous occurrence of this intermediate infaunal taxon suggests a relative dominance of refractory organic matter (*e.g.*, Caralp, 1989; Schmiedl et al., 2004; Fontanier et al., 2006; Fontanier et al., 2008; Koho et al., 2013). It appears in fairly high numbers in ten intermediate infaunal microhabitats at all stations from 1,495 to 3,010 m depth. Its microhabitat depth mimics the oxygen penetration depth, and gradually deepens from 0 to 1 cm at 1,495 m, 0.5/1 to 3 cm at 1,791 and 1970 m, and 2 to 3 cm at 3,010 m depth. According to Sen Gupta et al. (2009b), *M. barleeanum* is a cosmopolitan species that is distributed in the entire Gulf of Mexico with a very wide water depth range of 2 to 2,200 m. The occurrence of *M. barleeanus* below the oxygen penetration depth and above the nitrate penetration depth is consistent with numerous previous studies (*e.g.*, Jorissen et al., 1995, 1998; Koho, 2008; Mojtahid
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

et al., 2010). It appears that this species is able to thrive in absence of oxygen as long as nitrate is present in the pore-water (Caulle et al., 2013). Morphometric studies on this species (as *M. barleeanum*) were carried out by Bhaumik et al. (2014) on 15 core top samples from the Indian Ocean. They revealed that the growth rate of its test was normal under regular conditions when food was available, but when the food became scarce, there was more elongation of the test. They also observed that thinning or thickening of the wall and septa in this species did not have any relation with water depth. According to Groot et al. (2014), the increase of *M. barleeanus* is concurrent with the increasing total organic carbon (TOC) content within sediments with continued high percentage of fine-grained material in the western Barents Sea.

Repository: PK–AG–234

*Melonis pompiliodes* (Fichtel and Moll, 1798)

Original citation: *Nautilus pompiliodes* FICHEL and MOLL, 1798, p. 31, pl. 2, figs. a–c.

Remarks: Brady (1884) recorded this species as *Nonionina pompilioides* from the Atlantic and Pacific oceans at depths ranging from 1,000 to 2,421 fathoms (~1,829 to 4,428 m), and observed that its “test is thicker than that of *Nonionina ambilicatula*, usually of somewhat smaller diameter, and with rather fewer chambers in the outer convolution; but otherwise it is built on the same compact nautiloid plan”. Chapman and Parr (1937) recorded it as *Nonion pompilioides* from the Southern Ocean at five stations of water depth ranging from 1,475 to 2,600 fathoms (~2,698 to 4,755 m) but observed it to be rare to very rare, associated with *Globigerina ooze*. Voloshinova (1958) recognized that Fichtel and Moll’s holotype was from a Pliocene neritic deposit, but opined that it differed from deep-water forms that had been recovered from the North Atlantic. In naming the latter form *Melonis sphaeroides*, she chose Brady’s figured specimen from 2,840 m in the north-east Atlantic as the holotype. According to Pflum and Frerichs (1976), reports of *M. pompilioides* in shallower water are incorrect; the shallow-water forms that have the general form of *M. pompilioides* are better referred to *M. soldanii* (d’Orbigny) which differs in having a smoother surface and finer perforations (Frerichs, 1969). It may be possible that populations of *M. soldanii* and *M. pompilioides* intergrade in some deep-water areas and thus represent a cline. According to Pflum (1983), incorrect identifications of *Melonis pompilioides* and the probably automatic assignment of an abyssal environment to stratigraphic sections containing this species led to controversy and, at times, to serious questions regarding the reliability of this genus for paleoenvironmental interpretations. He, therefore, made an attempt to rectify the problems of identification of this species and related forms by studying and evaluating such characteristics as pores, umbilical size, sutures, apertures, and height/width ratios. *Melonis pompilioides* s. l. is commonly reported from lower bathyal to abyssal zones deeper than 2,000 m in the North Pacific (Smith, 1973; Bergen and O’Neil, 1979; Hasegawa, 1984). However, *M. pompilioides* s. l. has been reported from Japanese Tertiary faunas associated with shallow benthic foraminifers (Asano, 1958; Chiji, 1960; Hasegawa, 1979, 1984; Konda, 1980). These occurrences suggest that *M. pompilioides* s. l. may have inhabited sub-littoral to upper bathyal depths until the Pliocene (Hasegawa, 1984). Van Morkhoven et al. (1986) considered *M. pompilioides* and *M. sphaeroides* to be conspecific, but retained the *sphaeroides* nomen as a forma because of its ecological significance. According to Loeblich and Tappan (1987), a lectotype from the Fichtel and Moll collection was designated by Rögl and Hansen (1984, p. 30). Although two localities were cited (Pliocene of Coroncina, Italy, and Recent of the Mediterranean), the provenance of the lectotype was not indicated. Hermelin and Scott (1985) observed *Melonis pompilioides* to be rare in the central North Atlantic, at depths between 1,850 and 2,590 m. The illustrations provided by Loeblich and Tappan (1987) are of specimens recovered from the Mediterranean Sea by Rögl and Hansen. Thomas (1987) examined the surficial sediments from the lower Scotian Slope and Rise for
benthic foraminifers and noted that *M. pompilioides* occurred in small numbers in most samples from water depths ranging from 2,400 m to 4,046 m, but was most common below 2,750 m. According to Murray (1991), the genus *Melonis* is infaunal and occurs on the muddy and silty bottom of the shelf and bathyal zones. It is characteristic for cold marine waters (temperature <10°C). This extant species occurs in the depth-range from 50 to 4,000 m (Rögl and Spezzaferri, 2003), and is typical in the range from 1,000 to 3,000 m (Wenger, 1987). According to older literature, the maximum depth of occurrence has moved downward (Blake and Douglas, 1980); in the Atlantic down to 4,900 m (Longinelli, 1956), in the North Pacific down to 5,000 m and in the South Pacific down to 4,400 m (Dieci, 1959). In the Tyrrenhenian Sea, the tests were found in soft sediments at 130 m, and in the Adriatic Sea in detrital sands at 55 m (Cimerman and Langer, 1991). Bergamin *et al.* (1997) carried out a biometric study on *M. pompilioides* and *M. barleeanus* from circa-littoral and upper bathyal sediments of Pliocene, Pleistocene and Holocene of central Italy, and observed that the Holocene tests were smaller and less inflated than those from the Pliocene-Pleistocene. The variability of benthic foraminifera north and south of Denmark Strait was examined by Lorenz (2005), who observed the occurrence of this species only in the region south of the strait. Spezzaferri and Tamburini (2005) studied the paleodepth variations on the Eratosthenes Seamount in the eastern Mediterranean Sea and presented a water depth range of 50 to 4,800 m for this species. Living benthic foraminifera at water depths ranging from 140 to 4,800 m in the Bay of Biscay (north-east Atlantic) were studied by Mojtahid *et al.* (2010), who observed that at the lower slope and abyssal plain stations (>2,000 m), faunal densities were very low, and that the fauna was composed exclusively by such shallow infaunal species as *Nutallides umbonifera* and *M. pompilioides*. According to Finger (2013), the Chilean Miocene populations of *M. pompilioides* varied inconsistently with regard to size, coiling, umbilical depth, increase in chamber size and sutures, but the overall trend was towards deep-water morphology. Infaunal species, such as *M. pompilioides* have pores that are widely distributed over most of the test surface, which reflect low oxygen level in the porewater (Corliss and Rathburn, 2008). There is evidence, however, that this species inhabits oxygen-rich, saline deep waters as well (Lukashina and Bashirova, 2015). Setoyama and Kaminski (2015) studied Neogene benthic foraminifera from the Bering Sea and assigned their specimens of *Melonis* to *Melonis pompilioides* rather than to *Melonis spheroides* (Voloshinova, 1958) following the remarks by Belanger and Berggren (1986) that *M. spheroides* is more involute and possesses narrower and shallower umbilici, indistinct sutures and larger pores. The same has been followed in the present study.

Repository: PK–AG–235

Genus PULLENI A Parker and Jones, 1862

*Pullenia bulloides* (d'Orbigny, 1846)

Pl. 9; Figs. 9, 9a

Original citation: *Nonionina bulloides* D'ORBIGNY, 1846, p. 107, pl. 5, figs. 9, 10.

Remarks: D'Orbigny named this species in 1826 from Pliocene material from the Sienna region of Italy. Since it lacked both a type figure and a type description, *Nonionina bulloides* d'Orbigny 1826 is a nomen nudum. He (1846) later described and figured *N. bulloides* from the Miocene (Late Upper Badenian) of the Vienna Basin, thus validating the name. Parker (1954) reported *Pullenia bulloides* in the north-eastern Gulf of Mexico with frequencies of 1 to 2% at depths greater than 900 m, and frequencies of <1% at shallower depths. The extant species occurs down to 5,000 m and is more frequent deeper than 550 m (Dieci, 1959). *Pullenia bulloides* is a deep water form, normally occurring at not less than several hundred fathoms off the Saipan Islands (Todd, 1957). According to Porkorny (1963), *Pullenia bulloides* has experienced a "depth-migration" through time and is quite common in shallow-water sediments of Miocene age, whereas today it
is characteristic of deep-sea assemblages. This species was represented in Deep Freeze 61 project material collected from the Antarctic region by a solitary specimen, which was found at a depth of 3,545 m (Pflum, 1966). Cicha and Zapletalova (1967) recorded fossil specimens of *Pullenia bulloides* from the Central Paratethys sediments and inferred shelf to bathyal water depth range for it, while Berggren et al. (1976) considered it to occur in predominantly middle to lower bathyal water depths. According to Pflum and Frerichs (1976), *P. bulloides* includes forms that are spherical and have about four to five chambers in the final whorl; these specimens range from the lower neritic zone into the abyssal zone. In the south-east Indian Ocean, *P. bulloides* is an important deep-sea foraminifer and is found at 2,500 to 4,600 m (Corliss, 1979). On the Saba Bank, a seemingly subsided volcanic island to the south-east of the island of Saba, Hofker (1980) observed *P. bulloides* in a rather wide water depth range of 235 to 850 m. Cole (1981), who examined benthic bathyal zone foraminifera from off north-east Newfoundland, reported it in a depth range of 390 to 3,210 m, with abundance between 600 and 1,380 m. He observed that its test size varied considerably. Later, Hofker (1983) recorded this species at a single station on the continental shelf of Surinam at a water depth of 120 m. An assemblage of *P. bulloides* and *Cassidulina teretis* indicates high sediment organic carbon. In the Norwegian Sea, off south-west Norway, the former was found to be abundant at water depths between 1,000 and 1,400 m, where the slope is covered by organic-rich terrigeneous mud (Mackensen et al., 1985). According to Thomas (1987), *P. bulloides* enjoys a widespread distribution in surface material from the lower Scotian Slope, where it is absent below 4,046 m, but from that point up to 2,400 m, it often constitutes 2.0 or 3.0% of the benthic total. He stated that, “The only other species that *P. bulloides* could possibly be confused with in the study material is *Melonis pompilioides*, but even this resemblance is quite superficial, the former being more spherical, and lacking the large pores of the latter”. Hermelin (1989) compiled the data published earlier by Culp (1977) and Burke (1981), and observed that *P. bulloides* is the species characteristic of the Pacific Deep Water (PDW) on the Ontong Java Plateau; in addition, as an associate species of *Nutallides umbonifera*, it is an indicator the Pacific Bottom Water (PBW) in this region. According to Burke et al. (1993), the relatively high abundance of *Pullenia bulloides* may be associated with areas of low productivity in the surface waters and, therefore, low flux of organic matter to the sea floor. Cameron (1995) studied the Recent foraminifer from the continental shelf and slope off Kaikoura, New Zealand, and observed its occurrence in a wide water depth range of 94 to 2,155 m, but was abundant at the greatest depth sampled. According to Rathburn and Corliss (1994), the abundance of this shallow infaunal (0 to 2 cm, with a maximum at 1.5 cm) species in the Sulu Sea, indicates intermediate flux of organic matter, and poorly ventilated deep waters. Off the south-eastern coast of Australia, Yassini and Jones (1995) reported this species from the outer shelf and bathyal (outer shelf and continental slope) areas. Bornmalm (1997) observed that *Pullenia bulloides* was a common species at both the investigated sites (the Caribbean Sea and eastern equatorial Pacific Ocean), showing absolute abundances of 0 to 11 individuals per sample. According to Szarek (2001), *Pullenia bulloides* occurs in a water depth range that is uppermost bathyal to lower bathyal on the Sunda Shelf in the south-western part of the South China Sea. In association with *Globocassidulina subglobosa* and *Oridorsalis umbonatus*, *P. bulloides* is indicative of relatively warm, intermediate organic flux, intermediate seasonality, and moderate oxygenation in the eastern equatorial Indian Ocean (Gupta and Thomas, 2003); on the other hand, its association with *Cassidulina carinata* and *Cyclaminoidea nitidula* is suggestive of intermediate organic flux, and intermediate to high seasonality. According to Hayward et al. (2003), *P. bulloides* has a relative abundance of ≥5% in a water depth range of 950 m to 2,100 m+ in the New Zealand region. Spezzaferri and Tamburini (2007) studied the paleodepth variations on the Eratosthenes Seamount in the eastern Mediterranean Sea and presented a water depth range of 70 to 4,000 m for this species. In the Gulf of Mexico, Sen Gupta (2009a) recorded *P. bulloides* in the Shallow
Green Canyon at a water depth of 245 m, from the Deep Green Canyon in a depth range of 562 to 696 m, on the Garden Banks at 640 m, in the De Soto Canyon at 1,850 m, and from the Alaminos Canyon in a depth range of 2,218 to 2,227 m. In the Indian Ocean, *P. bulloides* occurs in a water depth range of 2,226 to 4,741 m, temperature range of 1.2° to 1.7° C (low temperature), dissolved oxygen range between 3.78 and 4.46 mL/L (high oxygen), and annual primary production of 90 to 135 g C/cm² (De and Gupta, 2010). In the western North Atlantic Ocean, *P. bulloides* in association with *Oridorsalis umbonatus*, is indicative of a well oxygenated environment, with relatively low organic carbon (Bhaumik *et al*., 2011). Intermediate to high organic carbon flux and low oxygen, and possibly the influence of bottom currents can be inferred if this species is associated with *Gyrodinium cibaoensis* and *Cibicides bradyi*. According to Mallon (2011), who investigated benthic foraminifera of the Peruvian and Ecuadorian continental margin, *P. bulloides* is rare and was found at only two stations off Peru, at 995 m and 1,923 m. Pérez-Asensio *et al.* (2012), who used benthic foraminifera to trace the Messinian paleoenvironmental evolution in the lower Guadalquivir Basin, south-west Spain, inferred that *Pullenia bulloides* has a bathymetric range of 60 to 4,000 m. According to Chauhan *et al.* (2015), who studied the paleoceanography of the Barents Sea continental margin, *P. bulloides* is a shallow infaunal (Basak *et al*., 2009) species associated with high organic flux and influence of Antarctic Water, especially in terms of bottom water temperature. It prefers a narrow salinity interval close to 35‰ and temperature between 2° and 4° C.

**Pullenia quinqueloba** (Reuss, 1851)

*Original citation:* Nonionina quinqueloba REUSS, 1851, v. 3, p. 47, pl. 5, figs. 31a, b.

*Remarks:* *Pullenia quinqueloba* was first described from the Oligocene (Septarien clays) of Germany (Hermsdorf surroundings) by Reuss (1851). Flint (1899), who presented a descriptive catalogue of specimens dredged by the *Albatross*, recorded this species at water depths ranging from 463 to 843 fathoms (~847 to 1,542 m) in the North Atlantic and Gulf of Mexico regions. According to Chapman and Parr (1937), this species was observed to be rare to very rare in the Southern Ocean, at variable depths ranging from 205 to 1,900 fathoms (~375 to 3,475 m), and often associated with *Globigerina*, diatom and spicular ooze. Blanc-Vernet (1969) found *P. quinqueloba* at bathyal depths in modern Mediterranean sediments, while Pujos (1972), in the Biscay Bay, found this species from the outer continental margin at depths >200 m. According to Pflum and Frerichs (1976), *Pullenia quinqueloba* has a water depth range from the middle neritic zone into the abyssal zone. They observed that in the original counts of species of *Pullenia* from the Alaminos Canyon in the Gulf of Mexico, specimens with four chambers in the final whorl had been referred to *P. quadriloba* (Cushman and Todd), but opined that the distribution of 4- and 5-chambered forms was more or less the same, and regarded both forms as morpho-variants of *P. quinqueloba*. Hofker (1978) recorded this species north of Doi, Lododa Islands, at a depth of 576 m, and in the Banda Sea at 2,663 m, in the eastern part of the Indonesian Archipelago. Later, he (1980) observed *P. quinqueloba* to be rare and recorded it at only one station on the Saba Bank, a submerged volcanic island to the south-east of the island of Saba, at a water depth of 890 m. This species is characterized by its five chambers in the last whorl, with semi-compressed test and semi-lobate periphery. Tjalsma and Lohmann (1983) included the four-chambered forms in this species, while Hulsbus *et al.* (1989) included the 5- to 6-chambered forms in the last whorl as well under *P. quinqueloba*, which has a stratigraphic range of Paleocene to Recent (Feyling-Hanssen and Ulleberg, 1984). According to Cameron (1995), who studied Recent foraminifera from the continental shelf and slope off Kaikoura, New Zealand, *P. quinqueloba* is common at water depths of 90, 94 and 665 m, but was observed to be rare at 240, 380, 810 and 890 m.
a deposit feeder (Liu et al., 1997), is a common species at the Caribbean Sea site with relative abundances of 0 to 5%, while it was observed to be rare with scattered occurrences at the eastern equatorial Pacific Ocean site (Bormalm, 1997). According to Hayward et al. (2001), who studied the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand, this species has an overall range of 230 to 4,680 m in this region. Szarek (2001) observed it to be distributed in the full bathymetric range on the Sunda Shelf in the south-western part of the South China Sea. Fontanier et al. (2005), who studied the faunal response of living benthic foraminifera to refractory organic matter in the Bay of Biscay, observed that *P. bulloides* occupies an intermediate infaunal microhabitat, with a mean weighed average living depth (ALD) of 2.7 cm. According to Gupta et al. (2009a, c), *Pullenia quinqueloba* differs from *P. bulloides* in having more compressed shape and a greater number of chambers in the final whorl. They observed its occurrence in all canyons in the Gulf of Mexico, except the Farnella Canyon, at water depths ranging between 245 and 2,227 m. *Pullenia quinqueloba* occurs from mid shelf to lower abyssal (50 to 5,000 m), becoming restricted to mid-bathyal depths south of 50°S around New Zealand (Hayward et al., 2010), with slightly higher relative abundances (3 to 4%) at mid and lower abyssal depths (3,000 to 5,000 m). According to Sen Gupta et al. (2009), this cosmopolitan species is observed to occur in the entire Gulf of Mexico and has a water depth range of 57 to 3,700 m. While studying the deep-sea benthic foraminiferal distribution in the south-west Indian Ocean, Jayaraju et al. (2010) observed *P. quinqueloba* at a water depth of 3,790 m; surprisingly, they did not record this species at depths of 3,150, 3,465 and 4,125 m during the course of their study. In the western North Atlantic Ocean, the association of *P. quinqueloba* with *Globobulimina pacifica* and *Astrononion umbilicatum* is an indication of high organic carbon (Schnitker, 1986) and potentially low oxygen (Kaminski, 2012), along with the presence of refractory organic carbon (Bhaumik et al., 2011). According to Valchev et al. (2013), *P. quinqueloba* differs from *P. jarvisi* Cushman by the presence of five chambers in the last whorl.

**Repository:** PK–AG–237

*Pullenia salisburyi* R. E. Stewart and K. C. Stewart, 1930

**Original citation:** *Pullenia salisburyi* R. E. STEWART and K. C. STEWART, 1930, v. 4, no. 1, p. 72, pl. 8, figs. 2a, b.

**Remarks:** *Pullenia salisburyi* was first described and illustrated from the Pliocene of California (Stewart and Stewart, 1930). According to Cushman et al. (1954), this species has a stratigraphic range of Miocene to Recent, and “is more common in the Marshall Islands than is *P. bulloides* (d’Orbigny)”. They observed that their specimens varied considerably in relative thickness. Smith (1964) studied the ecology of benthic foraminifera from off El Salvador, Central America, and recorded *Pullenia salisburyi* at water depths ranging from 140 to 450 m. An analysis of the records of *Pullenia salisburyi* by Todd and Low (1967) indicate that it ranges from the Miocene to the Recent along the Pacific coast, even as far north as north-eastern Alaska. According to Yassini and Jones (1995), *Pullenia salisburyi* is distributed on the outer shelf and continental slope, off the south-east coast of Australia. This species has been recorded by Jorissen et al. (1998) in the zone of nitrate reduction. On the Sunda Shelf, in the south-western South China Sea, Szarek (2001) observed a bathymetric range of outer shelf to lower bathyal for this species. An *Epistominella exigua* biofacies in the eastern equatorial Indian Ocean, consisting of *Laticarinina pauperata*, *Pullenia osloensis* and *P. salisburyi* is an indicator of cool bottom water, strongly pulsed, low to intermediate organic flux, with high seasonality (Gupta and Thomas, 2003). Hayward et al. (2003) observed that *P. salisburyi* was one of the several taxa that have significantly shallower upper depth limits off New Zealand, with a depth of 500 m from offshore Taranaki, west of the nation, because
from east of New Zealand, Hayward et al. (2001) had earlier recorded an upper depth limit of 900 m for it; they gave an overall bathymetric range of 154 to 2,150 m for this species. According to Hayward et al. (2010), *P. salisburyi* is widespread around all, except the southernmost part of the New Zealand region, and occurs in low numbers from outer shelf to lower abyssal depths (150 to 5,000 m), with slightly higher relative abundances (2 to 3%) at mid-bathyal to upper bayssal depths (500 to 3,000 m). Off the Portuguese margin, Phipps (2012) observed *P. salisburyi* to be one of the two dominant species at water depth with a relative abundance of 9% at 2,475 m in the 63–150 µm fraction, with an ALD of 1.6 cm, and significant densities between 0.5 and 4 cm depth; however, it was almost absent at 2,908 m with a rather diffuse distribution between 0 and 5 cm. At the deepest station of 4,987 m, he noted that *P. salisburyi* (7%) was the only calcareous species with relative abundance of >5%, and an ALD of 1.7 cm, showing a clear infaunal maximum between 1 and 2 cm, but again in the 63–150 µm fraction. Moreover, it consistently displayed a preference for substrate distributions in both bioturbated and non-bioturbated stations between water depths of 2,475 and 4,908 m, although it never appeared in the fractions >150 µm, and appears to be tolerant to oligotrophic conditions.

**Repository:** PK–AG–238

Superfamily CHILOSTOMELLACEA Brady, 1881
Family CHILOSTOMELLIDAE Brady, 1881
Subfamily CHILOSTOMELLINAE Brady, 1881
Genus CHILOSTOMELLA Reuss, 1849
Chilostomella oolina Schwager, 1878

**Original citation:** *Chilostomella oolina* SCHWAGER, 1878, v. 9, p. 527, pl. 1, fig. 16.

**Remarks:** The figures depicted by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 191A off the Ki Islands in the Central Pacific Ocean at a water depth of 580 fathoms (~1,061 m), at Challenger Station 232, south of Japan, in the Pacific Ocean, at 345 fathoms (~631 m), and at Challenger Station 209, off the Philippines, in the North Pacific, at 95 to 100 fathoms (~174 to 183 m). Although Brady (1884) referred this species to *Chilostomella ovoidea* Reuss, Thalmann (1933, p. 252) placed the specimens under *C. oolina* Schwager. Albani and Geyskes (1969) gave a preliminary account of Recent benthic foraminifera on a part of the north-western continental shelf of Australia and recorded “this typical species” to be very abundant and one of the three most common species at a station where the water depth was 90 m. In the Gulf of Mexico, Pflum and Frerichs (1976) noted minor size increases with increasing water depths in the tests of such species as *C. oolina*; from a length of ~0.4 mm near its upper depth limits in the lower neritic zone, its size increased to ~0.6 mm in the lower bathyal and abyssal zones. Hofker (1978) recorded this species at water depths ranging from 522 to 3,523 m in the eastern part of the Indonesian Archipelago. Corliss (1985) investigated the distribution of bathyal to abyssal, living foraminifera in the sediments of box cores. He found that *C. oolina* lives from 6 to 15 cm depth, and that the species distribution is not directly controlled by the overlying bottom water but is influenced by variations of the pore-water oxygen content, implying that deeper-dwelling species would migrate closer to the surface if the oxygen content of the bottom water decreases. *Chilostomella oolina* is well known from intermediate and/or deep infaunal microhabitats in eutrophic upper slope environments (e.g., Corliss and Emerson, 1990, Van der Zwaan and Jorissen, 1991; Sen Gupta and Machain-Castillo, 1993; Bernhard and Sen Gupta, 1999; De Rijk et al., 2000 and Schumacher, 2001; Basak et al., 2009). Its life position and abundance maxima close to the zero oxygen boundary (Fontanier et al., 2008) shows that this species is particularly well adapted to the presence of suboxic conditions. This is confirmed by the fact that it often strongly dominates benthic foraminiferal
faunas just before the onset of Mediterranean sapropels (Jorissen, 1999; Schmiedl et al., 2003), which testify to prolonged periods of anoxic bottom waters. In the short periods immediately preceding the anoxic conditions, less tolerant taxa rapidly disappear, and *C. oolina* (together with some small bolviniid taxa) appears to take over the niches close to the sediment-water-interface. These observations show that *C. oolina* can as well feed on very labile food particles that are concentrated close to the sediment-water interface, as on the more refractory particles present deeper down in the sediment (Jorissen et al., 2009). Hayward et al. (2001) studied the depth distribution of Recent deep-sea benthic foraminifera east of New Zealand and presented an overall bathymetric range of 280 to 2,330 m for this species. According to Szarek (2001), *C. oolina* differs from *C. ovoida* Reuss in more elongated than ovoid shape of the test, and shorter apertural slit placed at nearly half length of the entire test. She observed a bathymetric range of outer shelf to lower bathyal for this species on the Sunda Shelf in the south-western South China Sea. During the last 15 years or so, there have been contrasting results with regard to the food preference exhibited by *C. oolina*. While Fontanier et al. (2002) stated that this species prefers to feed from labile organic matter, while others (e.g., Kitazato et al., 2003; Nomaki et al., 2005) observed that it did not show any clear response. At a station of water depth of 140 m in the Bay of Biscay, Fontanier et al. (2002) observed the highest foraminiferal density (1,989 individuals/72 cm²), strongly concentrated in the uppermost cm of the sediment. At the 1.0–1.5 cm level, in a completely anoxic environment, they were able to record ~350 live foraminifera/50 cm³, with an ALD of 1.1 cm; the fauna was dominated by *C. oolina* (30.2%). Moreover, they found that it settled together with *Nonion scabrum* in strongly suboxic and anoxic sediments down to 3-cm depth. In these stressed environments, these two species appeared to have a competitive advantage over more superficially living taxa. They attributed their proliferation possibly to the input of large quantities of organic matter into the deeper sediment layers, re-mineralized by anaerobic pathways, and the near-absence of less resistant competing taxa (Rathburn and Corliss, 1994; Langezaal et al., 2006). According to Murray (2006), *C. oolina* is one of the “remarkably few species that regularly appear as dominant or subsidiary (>10%) in the Atlantic Ocean. Based on their observations and population trends of benthic foraminifera at the Blake Ridge ODP Hole 997A in the north-western Atlantic Ocean, Bhaumik and Gupta (2007) classified this species as one of the high organic carbon taxa that are independent of deep-sea oxygenation (Bhaumik et al., 2013). *Chilostomella oolina* is distributed in the north-eastern, north-western and south-western parts of the Gulf of Mexico in a rather wide water depth range between 86 and 3,550 m (Sen Gupta et al., 2009b). On the Portuguese margin, at a depth of 3,125 m, Griveaud et al. (2010) observed that one of the six cores contained an exceptionally rich deep infaunal community (up to 450 individuals/50 cm), dominated by the calcareous taxa *Fursenkoina bradyi*, *Globobulimina affinis* and *Chilostomella oolina*. They attributed the enrichment to probably a process that strongly concentrates metabolizable organic matter in deeper sediment layers, and opined that the observed high infaunal standing stocks could be a recurrent phenomenon. *Chilostomella oolina* has shown rare occurrences off the west and east coasts of central New Zealand between 38° and 44° S, with a scattered distribution through bathyal and abyssal depths ranging between 300 and 4,500 m (Hayward et al., 2010). According to Nardelli et al. (2010), the rich fauna of Nazaré Canyon is characterized by a strong dominance of intermediate and deep infaunal species (e.g., *Melonis barleeanus* and *Chilostomella oolina*) in superficial sediment layers, suggesting a low bottom-water oxygen concentration and a minimal oxygen penetration into the sediment (Basak et al., 2009). Benthic foraminifera of the Peruvian and Ecuadorian continental margin were investigated by Mallon (2011), who observed *C. oolina* to be rare; it was found at only two stations off Peru in 437 and 465 m water depth. Gooday and Jorissen (2012) analyzed partial SSU rDNA sequences of specimens of *C. oolina* from disjunct, bathyal (611–1,449 m), moderately hypoxic sites in the
Deep-Sea Holocene Foraminiferal studies on short cores from the Bay of Bengal

Ph.D Thesis

Pacific and Atlantic Oceans and Mediterranean Sea, which revealed three distinct genetic types that could not be distinguished morphologically. These types, which were supported by internal transcribed spacer (ITS) data, occurred in (a) the Bay of Biscay and Mediterranean (Atlantic-Mediterranean), (b) Sagami Bay (Japan) and the Oregon slope (North Pacific), and (c) Sagami Bay and the Costa Rica slope (Central Pacific). The latter two types occurred on both sides of the Pacific Ocean, probably reflecting recent or ongoing genetic exchange across the Pacific mediated by the passive dispersal of propagules (Grimm et al., 2007). On the Portuguese margin, Phipps (2012) observed C. oolina in the >150 µm fraction between 2 and 6 cm, with a maximum abundance between 3 and 5 cm, suggesting maximum nitrate concentrations at ~1.5 cm depth and a zero oxygen depth at ~3 to 4 cm. Kuhnt et al. (2013) investigated the relationship between pore density in calcareous benthic foraminiferal tests and environmental factors like bottom-water oxygen and nitrate concentration, water depth, and temperature in living (rose Bengal-stained) specimens of the deep-infaunal species Chilostomella oolina (Pezelj et al., 2013). Their results showed no significant relationship between pore density and bottom water O2, suggesting that C. oolina, rather than increasing its pore density, has another life-strategy to survive sustained low-oxic conditions, possibly nitrate respiration. They opined that the non-correlation between pore densities and bottom water NO3, however, suggests that pores are not involved in the denitrification process.

Repository: PK–AG–239

Family OSANGULARIIDAE Loeblich and Tappan, 1964
Genus OSANGULARIA Brotzen, 1940
Osangularia bengalensis (Schwager, 1866)

Original citation: Anomalina bengalensis SCHWAGER, 1866, v. 2, p. 259, pl. 7, fig. 111.
Remarks: The types for this species came from the Pliocene of Kar Nicobar (Sewager, 1866). Plummer (1926) recorded this species as Truncateulina culter (Parker and Jones) and observed it to be restricted to the upper faunule of the Midway formation where it was very frequent. This species was reported as Cibicides culter (Parker and Jones) by Chapman and Parr (1937) from the Southern Ocean; it was observed to be rare to very rare at depths of 706, 1,180 and 1,320 fathoms (~1,291, 2,158 and 2,414 m, respectively). Todd (1970) recorded Osangularia bengalensis from the Late Eocene beds on Tonga Islands and remarked, “Specimens of this species show considerable variation in number of chambers per whorl, width of keel, and limination of sutures. The Tonga specimens have about 15 chambers in the final whorl, the keel is thick and very wide, and the dorsal surface is nearly buried under the coalescing of clear shell material that originates from the limination of the sutures, both spiral and radial”. Osangularia bengalensis was recorded by Hofker (1978) at a depth of 546 m north of Misool, at 1,829 m in the Gulf of Bone, and at 4,048 m in the Banda Sea, in the eastern part of the Indonesian Archipelago. Hayward and Buzas (1979) described and illustrated this species as Osangularia culter (Parker and Jones) and stated that there seemed to be no specific difference between O. bengalensis and O. culter (Todd, 1966). Osangularia bengalensis demonstrates definite latitudinal and depth-related gradients which persist through the Miocene and Pliocene. In the shallower-water sites there is a marked gradient in its abundance; it is more common toward lower latitudes. It is the converse for O. culter, which is more frequent at mid to higher middle latitudes, whereas O. bengalensis is more frequent both at lower latitudes and at greater depths (Boersma, 1986). This species was described and illustrated by Hermelin (1989) as O. culter from the Pliocene on the Ontong-Java Plateau in the western equatorial Pacific Ocean. He opined that Osangularia bengalensis might represent a shallow-water form of O. culter and remarked, “Although some authors distinguish between the two forms, I have regarded O. bengalensis as a junior synonym of O. culter”. Szarek (2001) also listed it by the
same name from the Sunda Shelf in the south-western part of the South China Sea but not mention its bathymetric range. Hayward et al. (2003) gave upper water depth limits of 400 m and 500 m for this species west and east of New Zealand, respectively, and an overall range of 379 to 2,150 m. According to Sen Gupta et al. (2009b), this cosmopolitan species (reported as O. culler) has a bathyal and abyssal habitat and is present in the entire Gulf of Mexico in a water depth range of 400 to 3,850 m. Osangularia bengalensis, a cosmopolitan species, occurs throughout the New Zealand region (34° to 46° S), though more frequently off the coasts of the North Island (north of 40° S) in a bathymetric range of upper bathyal to mid abyssal (400 to 4,000 m) with a zone of greater relative abundance (4 to 13%) at mid to lower bathyal depths (500 to 1,300 m) (Hayward et al., 2010). According to Hanagata and Nobuhara (2015), who recorded this species as Osangularia culter (Parker and Jones), it has been listed as Osangularia bengalensis in many reports. Revets (1996) discussed that the type bengalensis has supplementary trematopores on the apertural face and concluded that it belonged to the genus Cribraparella. However, the nomenclature proposed by the World Register of Marine Species (WoRMS) has been followed and bengalensis has been placed under Osangularia.

Repository: PK–AG–240

**Family ORIDORSALIDAE** Loeblich and Tappan, 1984

**Genus ORIDORSALIS** Anderson, 1961

*Oridorsalis tenerus* (Brady) subsp. *profundus* Saidova, 1975

Pl. 9; Figs. 10, 10a

**Original citation:** *Oridorsalis tenerus* BRADY subsp. *profundus* SAIDOVA, 1975, pt. 3, p. 275, pl. 75, fig. 9; pl. 76, fig. 1.

**Remarks:** The holotype and paratypes for this species came from Recent sediments off Hatutu, northern Marquesas Islands, while another paratype came from a depth of 2,760 m, in the north-west Pacific Basin, south-east of Honshu, Japan, at a water depth of 3,491 m (Saidova, 1975). She opined that this species inhabits “the lower bathyal subzone of all realms of the ocean, and upper abyssal subzone of the tropical realm. The greatest number of specimens are found at depths of 3,107–4,426 m”, and associated with “mainly aleuritic-clay silt”. Mallon (2011) investigated the benthic foraminifera of the Peruvian and Ecuadorian continental margin and observed this species to be very rare. It was found only at one station off Peru at a water depth of 627 m. The present record could well be the first for this species from Indian waters.

Repository: PK–AG–241

*Oridorsalis umbonatus* (Reuss, 1851)

**Original citation:** *Rotalina umbonata* REUSS, 1851 p. 75, pl. 5, figs. 35a–c.

**Remarks:** This species was first described and illustrated from the Tertiary of Germany (Reuss, 1851). Chapman and Parr (1937) recorded this species as *Eponides umbonatus* from several stations in the Southern Ocean at water depths ranging between 706 and 2,700 fathoms (~1,291 and 4,938, respectively), often associated with *Globigerina* and spicular oozes. According to Todd (1957), who also recorded it as *E. umbonatus*, it occurs both from shallow (~20 fathoms = ~37 m) to deep (~2,000 fathoms = ~3,658 m), but is more frequently seen in deeper water. Smith (1964) discussed the depth distribution of benthic foraminifera in relation to ecological factors off El Salvador, Central America, and recorded this species as *Pseudoeponides umbonatus* at water depths from 885 to 1,700 m. According to Pfum and Frerichs (1976), the species of *Oridorsalis* represent a cline where *O. tener umbonatus* is the largest form with an upper depth limit in the upper middle bathyal zone, and *O. tener tener* has an upper limit slightly below but also in the
upper bathyal zone; both forms range down to the abyssal zone. Hofker (1978) reported this species (as *E. umbonatus*) from only two stations, one in the Arafura Sea at a depth of 345 m, and the other in the Timor Sea, east of Roti, at 378 m, in the eastern part of the Indonesian Archipelago. Later, he (1980) recorded it at depths ranging between 410 and 980 m on the Saba Bank, a seemingly submerged volcanic island, south-east of the island of Saba. Cole (1981) observed *Oridorsalis umbonatus* to be abundant at water depths from 2,200 to 2,930 m, and found it to occur everywhere off north-east Newfoundland <506 m. He found that test size varied considerably, as did the presence of an umbonal boss. The dorsal sutural apertures were not always visible, making small specimens difficult to distinguish from *Eponides*. Based on their studies on surface sediments and piston cores in the Sulu Sea, Linsley et al. (1985) found that *O. umbonatus* was the most abundant species between 1,600 and 4,000 m water depth. Mackensen et al. (1985) observed that *O. umbonatus* and *Triloculina frigida* dominate the fauna on the continental slope and rise off south-west Norway, at depths below 3,000 m. High frequencies of both species coincide with low organic carbon content. They opined that *O. umbonatus* may tolerate lower food supply preferring well-oxygenated interstitial waters. According to Hemleben (1989), who compared the type figures of *Rotalina umbonata* Reuss (1851) and *Truncatulina tenera* Brady (1884), *Oridorsalis umbonatus* and *O. tener* are similar, with morphological characteristics that are nearly identical. He stated, “Because of the difficulties of consistently differentiating the two forms, I have treated them as the same species, with *O. tener* as a junior synonym to *O. umbonatus*”. Miao and Thunell (1993) observed *O. umbonatus* to be abundant in the Sulu Sea at depths below 3,000 m and in sediment associated with relatively low organic carbon content and deep pore water oxygen-penetration depths. The higher abundance of *Oridorsalis umbonatus* is widely attributed to lower Caco flux and decreased food supply associated with regions of low surface productivity (Burke et al., 1993; Sarnthein and Altenbach, 1995; Kuhnt et al., 1999). According to Bornmalm (1997), the morphological differences between *Oridorsalis umbonatus* and *Oridorsalis tener* are almost negligible. The former has straight sutures on the spiral side, chambers of equal size in the last whorl, and a trochoidal cross-sectional outline, whereas the latter has curved sutures, more rapid whorl expansion, and a more compressed outline (e.g., Lohmann, 1978; Corliss, 1979; Mead, 1985). Osterman et al. (1999) identified a deep-water calcareous biofacies including an abundance of *O. umbonatus* between 1,100 and 3,500 m in the surface sediments of the Arctic Ocean. Szarek (2001) studied benthic foraminifer al assemblages on the Sunda Shelf in the south-western South China Sea and gave a bathymetric range of outer shelf to lower bathyal for this species. *Oridorsalis umbonatus* is an extant species that is found in deep-sea sediments spanning the entire Cenozoic. Comparison of *O. umbonatus* Mg/Ca from a variety of modern oceanographic settings with fossil *O. umbonatus* Mg/Ca gives some constraint on the extent to which seawater Mg/Ca may have varied in the past (Lear et al., 2002). Hayward et al. (2003) studied Recent benthic foraminifera from offshore Taranaki, New Zealand, and estimated the relative abundance of *O. umbonatus* to be >10% in a water depth range of 1,700 to 2,100+ m, with an overall range of 91 to 2,150 m. According to Schmiedl et al. (2003), this species one of the several taxa that has a shallow to intermediate infaunal microhabitat, are more opportunistic, but less resistant to low oxygen conditions. These taxa are common in mesotrophic to eutrophic environments with moderate oxygen depletions in the bottom and pore water (e.g., Lutze and Coulbourn, 1984; Sen Gupta and Machain-Castillo, 1993; Gooday, 1994; Rathburn and Corliss, 1994). Kaiho (1988), however, opined that *O. umbonatus* is probably environmentally flexible, as it occurs over wide depth range and age range, since Late Cretaceous. A set of modern core top samples collected along a depth transect on the continental slope off Namibia (320 to 2,300 m water depth) was used by Rathmann et al. (2004) to calibrate the Mg/Ca ratio of *O. umbonatus* against the bottom water temperature (BWT). They suggested that this ratio is a valuable proxy for thermocline and deep water temperature. Spezzaferri and Taburini (2007) attempted to analyze paleodepth variations
on the Eratosthenes Seamount in the eastern Mediterranean and gave an inferred bathymetric range of 200 to 4,000 m for this species. According to Sen Gupta et al. (2009b), this species is present throughout the Gulf of Mexico in a very wide water depth range of 36 to 3,700 m. A cosmopolitan species (Murray, 1991), *Oridorsalis umbonatus* is widespread right around the New Zealand region (33° to 56° S), common at outer shelf to lower abyssal depths (100 to 5,000 m), and most abundant (3 to 7%) at mid bathyal to lower abyssal depths (600 to 5,000 m) (Hayward et al., 2010). According to Bhaumik et al. (2011), this species in association with *P. bulbiloides* indicates they can survive with low oxygen and intermediate to high organic carbon-rich environment. Significant warming of the bottom water was inferred by Genovesi et al. (2011) based on a decrease in the relative abundance of *Nonionellina labradorica*, concomitant with a relatively higher occurrence of *O. umbonatus* in the upper part of a core retrieved at 409-m water depth in the Laurentian Channel, south of Anticosti Island. Debenay (2012) provided a guide to 1,000 species of benthic foraminifera from off New Caledonia in the south-western Pacific Ocean, and recorded *O. umbonatus* from the northern shelf at a water depth of 600 m. Mallon (2011) investigated the benthic foraminifera of the Peruvian and Ecuadorian continental margin, and observed this species to be rare; it was present at only two stations at water depths of 492 and 579 m. Pérez-Asensio et al. (2012), who used benthic foraminifera to trace the Messinian paleoenvironmental evolution in the lower Guadalquivir Basin, south-west Spain, inferred that *O. umbonatus* has a bathymetric range of 65 to 4,000 m. According to Mancin et al. (2013), this species is shallow infaunal, prefers food supply in quite low and mainly pulsed fluxes, mainly high oxygen content, and generally lives in cold, deep waters (De and Gupta, 2010), but can tolerate suboxic bottom waters. Mawbey and Lear (2013) used the *O. umbonatus* Mg/Ca records with the *O. umbonatus* calibration of Lear et al. (2002) to calculate variations in the BWT from cores drilled on the Ceara Rise in the equatorial Atlantic as this species is a faithful recorder of this parameter. According to Spezzaferri et al. (2013), who examined benthic foraminiferal assemblages from the Norwegian cold water coral reefs, this species is associated with deep mud facies, prefers a mud-sand substrate, feeds on phytodetritus but can thrive in nutrient-poor waters, prefers well oxygenated waters, and cold waters.

Repository: PK–AG–242

Family HETEROLEPIDAE Gonzáles–Donoso, 1969
Genus ANOMALINOIDES Brotzen, 1942
*Anomalinooides colligera* (Chapman and Parr, 1937)
Pl. 9; Fig. 11

Original citation: *Anomalina colligera* CHAPMAN and PARR, 1937, p. 117, pl. 9, fig. 26.
Remarks: Chapman and Parr (1937) described and illustrated this species for the first time but there was no mention of the type locality; instead, they mentioned that it was rare at a water depth of 1,180 fathoms (~2,158 m) and very rare at 1,900 fathoms (~3,475 m) in the Southern Ocean. They remarked, “This species has hitherto been confused with Reuss's *Rosalina ammonoides* described from the Chalk of Bohemia, and a common species in the Cretaceous of Europe. Reuss's form is a true *Cibicides*; and is perfectly distinct from the form figured under the name of *Anomalia ammonoides* (Reuss) by Brady. However, Barker (1960, p. 194, pl. 94) realized the confusion and placed this species under *Anomalina*, Said (1949, p. 41), though, had earlier referred it to *Anomalina bradyi*. Hofker (1978) listed this species as *Anomalina colligera* but observed its occurrence at only one station, south of Sarmata, at a water depth of 522 m, in the eastern part of the Indonesian Archipelago. Van Marle (1988), while studying the bathymetric distribution of benthic foraminifera on the Australian-Irian Java continental margin, eastern Indonesia, reported this species as *Anomalinooides colligera*. On the Sunda Shelf, in the south-western part of the South
China Sea, Szarek (2001) noted that *A. colligerus* had a bathymetric range of inner shelf to middle bathyal. According to Popescu and Crihan (2008), who recorded a species named *Riminopsis boueana*us (d'Orbigny, 1846), it has a very close resemblance to *Anomalina colligera*; they also suspected that *Rotalina cryptophalae* Reuss (1850, p. 371, pl. 47, figs. 2a-c) described from "Salzthone von Wieliczka” is a synonym of these species. *Anomalinoides colligerus* is a cosmopolitan species that seems to be confined to the south-eastern part of the Gulf of Mexico where it inhabits shallow waters in a depth range of 0 to 29 m (Sen Gupta *et al*., 2009b). Although Hayward *et al.* (2010) observed this species to be rare in their studies on the taxonomy, ecology and distribution of Recent deep-sea benthic foraminifera off New Zealand, there was no mention about its bathymetric range. Debenay (2012) recorded *A. colligerus* from the northern shelf off New Caledonia in the south-western Pacific Ocean, at a water depth of 600 m.

Repository: PK–AG–243

Genus HETEROLEPA Franzenau, 1884

*Heterolepa bradyi* (Trauth, 1918)

**Original citation:** *Truncatulina bradyi* TRAUCH, 1918, v. 95, p. 235.

**Remarks:** The figures illustrated by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 323 in the South Atlantic, at a water depth of 1,900 fathoms (~3,475 m). This species was referred by Brady (1884) to *Truncatulina dulemplei* (d'Orbigny) and by Trauth (1918) to *Truncatulina bradyi*. Thalmann (1942, p. 464), however, transferred the species to *Cibicides*, which was followed by Barker (op cit). *Cibicides bradyi* has been referred in the literature to several genera and species. Hofker (1951), in proposing the species *Cibicides hyalina*, stated that this species previously had been confused with *C. bradyi* and that it exhibited a much higher spiral side. Hofker (1956) placed *C. hyalina* together with *Cibicoides wulferstorfi* in a new genus, *Parrelloides*. Loeblich and Tappan (1964) placed *Parrelloides* in the synonymy of *Cibicoides*. Smith (1973) observed this species (recorded as *Cibicides bradyi*) to be rare but widely distributed between 32° and 52° N in her studies on the foraminifera of the Pacific Ocean; she also noted that except for a few samples in the core, all tests were stained. In the western Pacific Ocean, *Cibicoides bradyi* has its upper depth limit in the upper middle bathyal zone (Ingle and Keller, 1980). It appears to have the same upper depth limit in the Gulf of Mexico, near the upper boundary of the upper middle bathyal zone (Pflum and Frerichs, 1976). According to Hermelin (1989), *Cibicoides bradyi* differs from *C. robertsonianus* in its smaller size and in not having an angular periphery or an imperforate keel. According to Rathburn and Corliss (1996), who studied the ecology and stable isotopic compositions of living (stained) benthic foraminifera from the Sulu and South China Seas, and recorded this species as *Cibicoides bradyi*, it lives between 0 and ~4 cm inside the sediment and has lower carbon isotope values than the epifaunal species of this genus. They attributed the isotopic differences between *C. bradyi* and many other *Cibicoides* species to differences in microhabitat preferences between species. Jian and Wang (1997) observed that this species has a bathymetric range of 480 to 1,200 m in the South China Sea, what they termed as “intermediate water”. According to Jannink *et al.* (1998), who recorded it as *Cibicides bradyi*, this is one of the species considered to be typical of well-oxygenated bottom waters in low oxygen environments, and the least bottom water oxygen level at which they found living specimens (rose Bengal-stained) was estimated to be 0.3 mL/L. In association with *Stihostomella abyssorum*, *Mellonis pompilioides*, *Pleurostomella brevis* and *P. obtusa*, the presence of this species is indicative of high to moderate organic flux and intermediate seasonality in the eastern equatorial Indian Ocean (Gupta and Thomas, 2003). Szarek *et al.* (2005), while studying deep sea benthic foraminiferal assemblages from the dysoxic Sulu Sea, recorded this species as *Parrelloides bradyi* (Trauth) and observed it to inhabit the uppermost
centimeter of the sediment; this species was low in abundance below 3,000 m in contrast to its abundance in the South China Sea. According to Sen Gupta et al. (2009), who recorded this species as *Gyrodina bradyi* (Trauth), it is a cosmopolitan species that inhabits the entire Gulf of Mexico, at water depths ranging from 110 to 3,550 m.

**Repository:** PK–AG–244

**Heterolepa broeckhiana** (Karrer, 1878)

**Original citation:** *Rotalia broeckhiana* Karrer, 1878, p. 98, pl. 5, fig. 26.

**Remarks:** The types for this species came from the Tertiary of the Luzon Island in the Philippines (Karrer, 1878). In his studies on foraminifera from the Arabian Sea, Chapman (1895) recorded this species as *Rotalia broeckhiana* but observed it to be rather rare and stated, “This species has previously been recorded off the Ki Islands, at a depth of 580 fathoms” by Brady (1884). Chapman and Parr (1937) recorded this species as *Gyrodina broeckhiana* (Karrer) from the Southern Ocean to be very rare, and remarked, “The species figured under this name by Dr. Cushman in his work on the Foraminifera of the Philippine and adjacent Seas (1921, p. 346, pl. LXXII, fig. 1) is apparently *Eponides umbonatus* (Reuss) or a closely related form”. Hayward and Buzas (1979) recorded this species as *Eponides broeckhianus* (Karrer) in their study on the taxonomy and paleoecology of early Miocene benthic foraminifera of northern New Zealand and the north Tasman Sea. This species was reported by Hermelin (1989) as *Gyroidinoides broeckhianus* (Karrer) but observed it to be rare in the Pliocene samples collected from the Ontong–Java Plateau in the western equatorial Pacific Ocean. Szarek (2001) presented a bathymetric range of upper bathyal to lower bathyal for this species on the Sunda Shelf in the south-western part of the South China Sea. This is the first record of this species from the Bay of Bengal.

**Repository:** PK–AG–245

Family GAVELINELLIDAE Hofker, 1956
Subfamily GAVELINELLINAE Hofker, 1956
Genus GYROIDINA d’Orbigny, 1826
*Gyroidina altiformis* (Stewart and Stewart, 1930)

**Original citation:** *Gyroidina soldanii* D’ORBIGNY var. *altiformis* R. E. STEWART and K. C. STEWART, 1930, v. 4, p. 67, pl. 9, figs. 2a-c.

**Remarks:** This species was originally described and illustrated by Stewart and Stewart (1930) from the Pliocene of California. *Gyroidina altiformis* occurs in water depths between 1,662 and 2,205 meters in the Gulf of Alaska (Bergen and O’Neil, 1979), between 2,375 and 2,700 m off the west coast of Vancouver Island (Enbysk, 1960), and approximately 1,000 m in basins along the California Borderland (Uchio, 1960). Smith (1964) examined the ecology of benthic foraminifera and their depth distribution off El Salvador, Central America, and noted that this species was rare at water depths ranging between 1,600 and 1,700 m. Pfum and Frerichs (1976) divided *Gyroidina altiformis* into different subspecies and regarded *Gyroidina altiformis acuta* Boogaart, as representing a lower bathyal and abyssal member of a cline which also included the upper bathyal to neritic subspecies *Gyroidina altiformis cushmani* Boogaart. *Gyroidina altiformis* is an important constituent of the characteristic assemblage of the Balearic abyssal plain, which is known to be the largest of the entire Mediterranean, very flat and regular, ranging in depth from 2,650 to 2,900 m (Cita and Zocchi, 1978). According to Wright (1978), this species has its shallowest occurrences at 200 m in the Mediterranean, becomes abundant below 600 m, and very abundant below 800 m. Hofker (1980) recorded this species at water depths ranging between 290 and 730 m on the Saba Bank, a seemingly submerged volcanic island, south-east of the island of Saba, but
found it to be more abundant at 350 to 730 m. Later, he (1983) observed its occurrence at only one station on the continental shelf of Surinam at a depth of 400 m. Barbieri (1991) defined *Gyroidinoides altiformis* as an isobathyal species, as the taxon provides a reliable bathymetric control to identify the upper limit of the epibathyal zone. According to Burke *et al.* (1993), *Gyroidina altiformis* is found to be more abundant during glacial periods than during inter-glacials on the Ontong Java Plateau. *Gyroidina altiformis* is considered a mesotrophic–oligotrophic benthic foraminifer (De Rijk *et al.*, 2000; Fontanier *et al.*, 2002). Bornmalm (1997) remarked, “*Gyroidina altiformis* differs from *Gyroidina neosoldanii* in having raised, oblique sutures on the spiral side rather than flush, radial sutures”. However, he observed it to be rare at both the Neogene sites he investigated, in the Caribbean Sea and eastern equatorial Pacific Ocean. According to Bernhard *et al.* (2001), *Gyroidina altiformis* had higher densities in one or two seep samples and generally made up a larger proportion of the stained assemblage in seep samples compared to non-seep samples. They suggested that the cellular organization of species associated exclusively with seeps may provide clues concerning the survival of these aerobic protists in such potentially toxic environments, and that ultra-structural studies would assist in solving this cell-biological enigma. Szarek (2001) observed this species to occur in the full bathymetric range on the Sunda Shelf, in the south-western South China Sea. Paleodepth variations on the Eratosthenes Seamount in the eastern Mediterranean Sea were investigated by Spezzaferri and Tamburini (2007), who presented a water depth range of 100 to 4,000 m for *Gyroidinoides altiformis*. Abu-Zied *et al.* (2008) opined that *G. altiformis* is an opportunistic species characteristic of “poorer environments” implying reduction of food supply to the sea floor. This species was recorded by Kender *et al.* (2008) as *Gyroidinoides altiformis* from the early to middle Miocene from the deep-sea Congo Fan, offshore Angola, who noted that this species has also been recorded from Oligocene to Holocene sediments from Central America and the Gulf of Mexico. According to Mikhailievich (2008), this is one of the benthic foraminiferal species that inhabits the tropical and subtropical regions, and is an epifaunal, free-living detritivore (Muscio, 2011). In the Gulf of Mexico, this species occurs over the entire area of the gulf, at water depths ranging between 0 and 3,515 m (Sen Gupta *et al.*, 2009); it has also been reported from the Atlantic and Pacific Oceans.

Repository: PK–AG–246

*Gyroidina orbicularis* d’Orbigny, 1826

**Original citation:** *Gyroidina orbicularis* D’ORBIGNY, 1826, v. 7, p. 278, modèles no. 13.

**Remarks:** The figures reproduced by Barker (1960) are of Brady’s specimens obtained from the material dredged at the Challenger Station 142, off South Africa, at a water depth of 150 fathoms (~274 m). This species was placed by Brady (1884) in *Rotalia*, but was originally placed by d’Orbigny (1826) in *Gyroidina* and his nomenclature has stood the test of time. Pflum and Frerichs (1976) opined that *Gyroidina orbicularis* d’Orbigny and *G. soldanii* d’Orbigny are distinct species with upper depth limits within the upper and middle bathyal zones, respectively. They also estimated the upper water depth limit for this species at ~1,200 feet (~366 m) and observed that it was twice as abundant in the bathyal zone of the western part of the Gulf of Mexico as the eastern. Hofker (1978) observed the occurrence of this species at only station, in the Ceram Sea, west of Misool, in the eastern part of the Indonesian Archipelago, at a water depth of 1,496 m. Later, he (1980) recorded this species at water depths ranging between 280 and 980 m on the Saba Bank, a supposedly submerged volcanic island, south-east of the island of Saba. The consistent presence of this species is indicative of upper bathyal water depths (Ingle, 1980). In his studies on the benthic foraminifera from the bathyal zone off north-east Newfoundland, Cole (1981) observed *G. orbicularis* to be rather uncommon between 2,938 to 3,210 m. According to Revets (1996), *Gyroidina* has always been a problematical genus, due to the inadequate original
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proposal of the genus and the nature of its type species. He stated, “The absence of subsequent study of the original material, but plenty of reinterpretation at the hand of specimens purportedly being G. orbicularis, led to a vague, unstable concept. The proposal of the separate genus Gyroidinoides by Brotzen compounded the problem considerably, since the criteria to do so rested on details of the apertural complex, which had not been described for C. orbicularis. Loebliech and Tappan (1964) discussed the features of both genera in great depth, but unfortunately based their discussion of Gyroidina on a misidentification, something that came to light when Hansen (1967) selected and illustrated a lectotype for G. orbicularis”. The species Gyroidinoides orbicularis is one of the few rotaliid species inhabiting the recent deep basin areas (De Rijk et al., 1999). It is obviously adapted to very oligotrophic conditions although it also occurs in significant numbers at higher trophic levels of the bathyal continental slope (Schmiedl et al., 2000). Szarek (2001) reported this species as Gyroidina orbicularis (Parker, Jones and Brady, 1865), as did Fontanier et al. (2005) from the Bay of Biscay, and observed that it inhabits the full bathymetric range on the Sunda Shelf in the south-western part of the South China Sea. According to Sen Gupta et al. (2009c), this is a widely distributed species with a long history of nomenclatural confusion (see Jones, 1994), primarily because the features of d’Orbigny’s original Gyroidina orbicularis are unknown. The name, with d’Orbigny as the author, has been used by numerous workers, but they have actually followed the concept of Parker et al. (1865) and Brady (1884) regarding the diagnostic characters of the species. Pending a thorough study of its comparative morphology, and possibly the designation of a new name, they followed the safe procedure of Jones (1994) in calling the species "Gyroidina orbicularis (sensu Parker, Jones, and Brady)". Gyroidinoides orbicularis is suspected to be a phytodetritus feeder (Jorissen et al., 1999), and is an opportunistic species, which require an oxygenated environment, and has the ability to colonize the seafloor during short oxygenation pulses under unstable environmental conditions (Jorissen, 1999; Schmiedl et al., 2003). It prefers a shallow infaunal habitat (Kuhnt et al., 2007), but Musco (2011) opined it to be an epifaunal, free living detrivore. In the Gulf of Mexico, this cosmopolitan species inhabits the north-eastern, north-western and south-western regions at water depths ranging between 71 and 3,515 m (Sen Gupta et al., 2009b). According to Mojtahid et al. (2010), who examined living benthic foraminiferal fauna along a bathymetrical transect (140–4,800 m) in the Bay of Biscay, north-east Atlantic Ocean, Gyroidina orbicularis occupies a somewhat deeper microhabitat with an ALD of 1.5 cm. In their studies on the depth distribution of deep sea benthic foraminifera off New Zealand, Hayward et al. (2010) observed this species to have a scattered but widespread occurrence between 33° and 56° S latitudes. They also noted that it occurs with rather even distribution throughout the bathyal and abyssal (200 to 5,000 m) with no zone of peak abundance. Gyroidina orbicularis is one of the species that characterizes a low food environment, and is more abundant in the eastern part of the Mediterranean than the western (Minto'o et al., 2015).

Repository: PK–AG–247

Gyroidina soldanii d'Orbigny 1826

Original citation: Gyroidina soldanii D'ORBIGNY, 1826, ser. 1, v. 7, p. 278, no. 5, modeles no. 36. Remarks: The topotypes for this species came from Rimini, Italy (d'Orbigny, 1826). It was recorded by Flint (1899) from the North Atlantic, Gulf of Mexico and the Pacific Ocean in samples dredged by the Albatross and noted to be a widely distributed deep water species. Bagg (1905) recorded this species as Rotalia soldanii (d'Orbigny) from the Miocene of California wherein he found only a few specimens, and remarked, “The species is known as far back as the Cretaceous, and is present in every succeeding formation. In existing oceans it is universally distributed in deep waters, and is seldom found at depths of less than 300 fathoms”. Gyroidina soldanii was observed by Chapman and Parr (1937) to be frequently occurring at water depths of
1,670, 2,400 and 2,570 fathoms (~3,054, 4,389 and 4,700 m, respectively) in the Southern Ocean; it was common at only one station at 1,660 fathoms (~3,036 m) and was otherwise rare to very rare at depths exceeding 706 m (~1,291 m). Cushman et al. (1954) recorded this species from the Bikini and Eniwetok atolls of the Marshall Islands and stated their specimens were identical to the topotypes from Rimini. The figures illustrated by Brady (Barker, 1960) are of specimens recovered from the sediments dredged at Challenger Station 302, in the South Pacific, at a depth of 1,450 fathoms (~2,652 m), and Challenger Station 246, in the North Pacific, at a depth of 2,050 fathoms (~3,749 m). *Gyroidinoides soldanii* was referred by Brady to *Rotalia soldanii* (d'Orbigny), but Brotzen (1942, p. 156) referred it to *Gyroidina neosoldanii*. According to Pflum and Frerichs (1976), *Gyroidina soldanii* d'Orbigny and *G. orbicularis* d'Orbigny are distinct species with upper depth limits within the upper and middle bathyal zones, respectively. They also did not find any evidence of a cline existing between these two species. In the eastern part of the Indonesian Archipelago, Hofker (1978) recorded this species as *Gyroidina neosoldanii* Brotzen and observed its occurrence at six stations at water depths ranging between 216 and 1,829 m. Corliss (1979) observed that this important deep-sea form was found in the south-east Indian Ocean between 2,500 and 4,600 m. *Gyroidina soldanii* was observed to be a commonly occurring species at water depths between 1,000 and 3,210 m, with greater abundance from 2,560 to 3,000 m off north-east Newfoundland (Cole, 1981). Hermelin (1989) listed this species as *Gyroidina neosoldanii* Brotzen from the Pliocene on the Ontong-Java Plateau in the western equatorial Pacific Ocean and remarked, “According to Brotzen (1936) Brady's (1884) figures of *Rotalia soldanii* differ from the original description of *Gyroidina soldanii* (d'Orbigny, 1826) and he proposed a new name for this species, *Gyroidina neosoldanii*. Subsequent to this, authors have either followed Brotzen (1936) and named specimens identical to Brady's figures as *G. neosoldanii* or have disliked Brotzen's subdivision of the species and retained the name *G. soldanii*. I have followed Brotzen (1936) and used *G. neosoldanii*." Hottinger et al. (1993) recorded this species as *Gyroidinoidea* cf. *G. soldanii* and observed their species to strongly resemble *G. soldanii* as illustrated by SEM photographs of specimens from d'Orbigny's material by Papp and Schmid (1985). *Gyroidina soldanii* was selected as the type species of *Hansenica* Loeblich and Tappan, 1987. On the other hand, the specimen figured as *H. soldanii* by them (pl. 719; figs. 5–9) possesses a wide open umbilicus with small folia visible in most chambers in the last whorl, while the specimens of *G. soldanii* from d'Orbigny's material, as figured by Papp and Schmid (1985) show clearly a large folium covering preceding ones and the umbilical bowl. *Gyroidina soldanii* inhabits a shallow infaunal microhabitat in mesotrophic to eutrophic environments lacking severe oxygen deficiencies (Rathburn et al., 1996; Schmiedl et al., 2000), and is a dissolution resistant species (Corliss and Honjo, 1981). Revets (1996) recorded this species as *Hansenica soldanii* (d'Orbigny) and remarked, “The genus was created by Loeblich and Tappan (1987) to accommodate a very large number of *Gyroidina* species erroneously assigned to this genus as a result of the misinterpretation of *Gyroidina* by Loeblich and Tappan (1964). The lectotypification of *Gyroidina orbicularis* by Hansen (1967) showed that the specimens illustrated by Loeblich and Tappan (1964) belonged to *G. soldanii*, rather than *G. orbicularis*. The major morphological differences between these two species most certainly warrant generic recognition, and the proposed separation is herein fully underwritten". *Gyroidina neosoldanii* was observed by Bornmalm (1997) to be common at both the Caribbean Sea and eastern equatorial Pacific Ocean sites (Neogene) with 0 to 18 individuals in each sample. According to Edelman-Furstenberg et al. (2001), *G. soldanii* is a dominant constituent of an assemblage at the lower margin of the OMZ (at ~600 m water depth). There, it co-occurs with *Neovigerina porrecta* and is associated with oxygen concentrations between 1 and 1.2 mL.L\(^{-1}\), moderate organic carbon fluxes around 2.5 g C m\(^{-2}\) year\(^{-2}\), and rather low TOC content of 0.3%.

Szarek (2001) reported it as *Gyroidinoidea soldanii* from the Sunda Shelf in the south-western part of the South China Sea and observed a bathymetric range of uppermost bathyal to upper bathyal.

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Interestingly, she also recorded and illustrated *Gyroidina neosoldanii* with a water depth range of outer shelf to lower bathyal; the former, however, was not figured. According to Hayward *et al.* (2003), *Gyroidinooides soldanii* is more abundant off the west (Taranaki) side of New Zealand than the off the east (Chatham Rise) side, and upper depth limits of 150 and 200 m, respectively, with an overall wide range of 18 to 2,150 m. Stefanelli *et al.* (2005) recorded this species as *Gyroidinooides neosoldanii* from early to middle Pleistocene; it is a species with infaunal microhabitat living in environments with meso-eutrophic conditions (Schmiedl *et al.*, 2003) and is considered to be a taxon transitional between conditions of sapropel and normal sedimentation (Mullineaux and Lohmann, 1981). Pezelj *et al.* (2007; 2013) listed it as *Hansenica soldanii* (d’Orbigny) from the Late Badenian (Neogene) of Croatia and opined this epifaunal species is an indicator of suboxic conditions. From the Gulf of Mexico, this species has been recorded as *Gyroidinooides soldanii* by Sen Gupta *et al.* (2009b); they observed it to be a cosmopolitan species distributed at water depths ranging from 110 to 2,975 m in the north-eastern, north-western and south-eastern parts of the gulf. According to Hayward *et al.* (2010), *Gyroidina soldanii* has scattered but widespread occurrences right around New Zealand between 33° and 56° S latitudes, and occurs from outer shelf to lower abyssal (100 to 5,000 m). They noted that there are no obvious zones of greater abundance, except that it appears to be more common off the west coast of the North Island and almost absent at shelf and bathyal depths in the sub-Antarctic. Margreth (2010) observed it to be associated with sandwave facies in the Norwegian cold water coral ecosystem, preferring muddy substrate, and opined it to be a suboxic/dysoxic indicator. Mallon (2011) examined benthic foraminifera of the Peruvian and Ecuadorian continental margin, recorded this species as *Gyroidinooides soldanii* Broten, and stated that it resembles *G. soldanii* but differs from it by the backward swept sutures on the spiral side. This species was found between 114 m and 700 m water depth off Peru and Ecuador, respectively. This species was recorded by Debenay (2012) as *Hansenica soldanii* from south of the Grande Terre, off New Caledonia, in the south-western Pacific Ocean, at a shallow depth of 40 m. Pérez-Asensio *et al.* (2012) studied the Messinian paleoenvironmental evolution in the lower Guadalquivir Basin in south-west Spain, and inferred a bathymetric range of 100 to 5,000 m for *Gyroidinooides soldanii*.

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Superfamily ROTALIACEA Ehrenberg, 1839  
Family ROTALIIDAE Ehrenberg, 1839  
Subfamily AMMONIINAE Saidova, 1981  
Genus AMMONIA Brünich, 1772  
*Ammonia batava* (Hofker, 1951)

**Original citation:** Streblus batava HOFKER, 1951, pp. 492, 501, figs. 340.  
**Remarks:** Hofker (1951) separated *A. batava* from *A. beccarii* (Linnaeus) as a smaller and less compressed form. Whereas the diameter of the tests of the latter from the Adriatic Sea ranged from 0.62 mm to 1.62 mm, with tops at 0.80 mm and 1.37 mm, the diameter of tests of *A. batava* from the North Sea ranged from 0.30 mm to 0.80 mm. He also discussed the differences in apertural and internal structures. This species was described by Van Voorthuysen (1957) from Selsey Bill as a species with 8 to 10, usually 9, chambers in the last-formed whorl with an indistinct or divided umbilical plug. He also opined that its lobulate marginal outline is characteristic of this species. According to Feyling-Hansen (1964), the North Sea *Ammonia batava* occurs in abundance in shallow water (Risdal, 1964), but it has been reported from deep waters as well (van Voorthuysen, 1960; Richter, 1961). Collison (1980) studied the vertical distribution of living benthic foraminifera in cores from off the coast of Northumberland and observed *A. batava* to be dominantly surficial. According to Stevenson *et al.* (1993), *Ammonia*
batava is an indicator of high salinity, a fact pointed out as early as 1954 by Hofker from the Netherlands. Sadri et al. (2011) examined foraminifera from the sea grass communities and observed Ammonia beccarii batava to be the most dominant species in Tor Bay and is quite common in the coastal waters of the U.K. (Murray, 2006).

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Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIINAE Galloway, 1933
Genus ELPHIDIUM de Montfort, 1808
Elphidium cf. E. reticulosum Cushman, 1933

Original citation: Elphidium reticulosum CUSHMAN, 1933, no. 161, pt. 2, p. 51, pl. 12, figs. 5a, b.
Remarks: The types of this species came from Vavau Anchorage, Tonga Islands, at a water depth of 18 fathoms (~33 m). Cushman (1933; 1939) also recorded this species in its typical form from Rotonga at a depth of 7 fathoms (~13 m), and remarked, “The wall of this species is very peculiar in its ornamentation, being a very fine network of irregular pattern, entirely covering the inflated chambers. This form is hardly to be confused with any other species from the South Pacific”. Whittaker and Hodgkinson (1979) recorded this species as Cribrionion reticulosus (Cushman) from a section in the upper Togopi River, type-locality of the Togopi Formation, eastern Sabah, Malaysia, based on the presence of a series of pores at the base of the apertural face; on earlier chambers the aperture appears as an interio-marginal slit. They remarked, “Forms very close to Elphidium hyalocostatum Todd occur in our samples and these would seem to be no more than a variety of E. reticulosum with stronger and more aligned ornamentation on the final chambers. Ahmed (1981) studied the distribution and ecology of Recent benthic foraminifera from the Tarut Bay, Arabian Gulf, and observed a restricted distribution for E. reticulosum, mainly to the inter-tidal zone with algae and to the shallow sub-tidal zone with seagrass. Dead individuals were more widely distributed in Safwa Bay where there was no seagrass or algae and in the deeper sub-tidal zone, and he opined that there might have drifted from the shallow zone during an ebbing tide. On the Sunda Shelf in the south-western part of the South China Sea, Szarek (2001) recorded E. reticulosum and observed it to be restricted to the shelf region. Tsujimoto et al. (2006) examined benthic foraminiferal assemblages in Osaka Bay, south-western Japan and listed (p. 147) and illustrated this species (p. 149, fig. 5.8). Elphidium reticulosum is an opportunistic species on the Great Barrier Reef, distributed in the Whitsunday, Townsville and Innisfail sectors (Nobes and Uthicke, 2008). According to Schaffelke et al. (2008), Elphidium reticulosum is a symbiont-bearing benthic foraminifer, which is symbiotic with plastids on the Great Barrier Reef, Australia. Debenay (2012) listed (p. 325) this species as Parrellina reticulosa (Cushman, 1951) among the benthic foraminifers from off New Caledonia in the south-western Pacific Ocean, but did not give any description or illustrations for it.

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