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Benthic foraminifera indicate Glacial North Pacific Intermediate Water and reduced primary productivity over Bowers Ridge, Bering Sea, since the Mid-Brunhes Transition

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Abstract. The Mid-Brunhes Transition (MBT) saw an increase in the amplitude of glacial cycles expressed in ice core and deep ocean records from about 400 ka, but its influence on high-latitude climates is not fully understood. The Arctic Ocean is thought to have warmed and exhibited reduced sea ice, but little is known of sea ice marginal locations such as the Bering Sea. The Bering Sea is the link between the Arctic and Pacific Ocean and is an area of high productivity and CO_2 ventilation; it hosts a pronounced oxygen minimum zone (OMZ) and is thought to be the location of Glacial North Pacific Intermediate Water (GNPIW) formation in the Pleistocene. To understand palaeoceanographic change in the region, we analysed benthic foraminiferal faunas from Bowers Ridge (Site U1342, 800 m of water depth) over the past 600 kyr, as they are uniquely well preserved and sensitive to changes in deep and surface ocean conditions. We identified and imaged 71 taxa and provide a full taxonomy. Foraminiferal preservation is markedly higher during glacials, indicating the presence of less corrosive GNPIW. The most abundant species are *Bulimina exilis*, *Takayanagia delicata*, *Alabaminella weddellensis*, *Gyroidina* sp. 2, *Cassidulina laevigata*, *Islandiella norcrossi*, and *Uvigerina bifurcata*, consistent with broadly high net primary production throughout the last 600 kyr. Correspondence analysis shows that the most significant Assemblage 1 comprises *B. exilis*, *T. delicata*, *Bolivina spissa*, and *Brizalina*, which occur sporadically within intervals of laminated, biogenic-rich sediment, mostly during glacials and also some deglacials, and are interpreted as indicating very high productivity. Other assemblages contain the phytodetritivore species *A. weddellensis*, *I. norcrossi*, and *C. laevigata*, indicative of seasonal phytoplankton blooms. Before the MBT, more numerous intervals of the very high-productivity Assemblage 1 and *A. weddellensis* occur, which we suggest reflect a time of more sea-ice-related seasonal stratification and ice edge blooms. Our inference of a decrease in sea ice meltwater stratification influence in the central Bering Sea after the MBT is consistent with records showing that the Arctic and Pacific Ocean warmed during glacials and suggests that high-latitude productivity and sea ice changes were an important feature of this climate event.

1 Introduction

The Mid-Brunhes Transition (MBT) was a period of climate change that saw the emergence of greater glacial–interglacial variability in temperature and CO_2 from ∼ 400 ka (Jouzel et al., 2007; Lüthi et al., 2008). Glacials became slightly colder over Antarctica, interglacials warmer, and global deep ocean $\delta^{18}O$ records (Lisiecki and Raymo, 2005) show greater variability after the MBT, indicating changes to deep ocean temperature and global ice volume. The cause of the MBT is under debate but may have been related to changes in high-latitude Southern Ocean sea ice, windiness, upwelling, and deep ocean ventilation (Kemp et al., 2010; Yin, 2013). However, there is a need for high-latitude palaeoceanographic records over the MBT to test the global expression of this climate event (Barth et al., 2018) and determine if the amplification of climate change occurred in the higher latitudes (Cronin et al., 2017). Intermediate water temperature and sea ice records from the Arctic Ocean have shown that the MBT was associated with a pronounced warming and reduction in sea ice influence (Cronin et al., 2017). The Bering Sea is a critical region, as there is a pronounced OMZ, deep ocean upwelling, CO_2 ventilation to the atmosphere (Stabeno et al., 1999), sea ice, and an oceanographic link between the Arctic and Pacific Ocean.

Study Site U1342 (Fig. 1) is located on Bowers Ridge, an extinct arc system extending 300 km north from the Aleutian Island arc, and was the shallowest site cored during the Integrated Ocean Drilling Program (IODP) Expedition 323 (818 m of water depth; Expedition 323 Scientists, 2011). Deep water connections are restricted to the Aleutian Island passes (< 4000 m of water depth; Hood, 1983; Stabeno et al., 1999) such that the majority of Bering Sea deep water is sourced from aged low-oxygen North Pacific Deep Water (NPDW). Nutrient-rich intermediate nutricline water upwells over Bowers Ridge, particularly along the northern slope, inducing high primary productivity and associated organic carbon flux to the sea floor (Stabeno et al., 1999; Takahashi, 2005). There is also significant slope-shelf water exchange that brings nutrients up from the slope (Stabeno et al., 1999) and a very minor component of deep water (∼ 4000 m) formed within the Bering Sea, probably from sea ice brine rejection (Warner and Roden, 1995). Today, seasonally sea-ice-covered areas of the Bering Sea are found mainly over the northern continental shelf (Fig. 1). Bowers Ridge and the southern Bering Sea are affected by the relatively warm and high-salinity Alaskan Stream surface water current (Fig. 1). The onset and termination of summer stratification, from the solar warming of surface water and also sea ice melt, causes spring and autumn phytoplankton blooms (Niebauer et al., 1995; Eslinger and Iverson, 2001; Kuroyanagi et al., 2002) and associated high seasonal phytodetrital flux to the sea floor. High productivity, combined with the low-oxygen NPDW-sourced water bathing Bowers Ridge (Stabeno et al., 1999), causes the OMZ to be pronounced (∼ 0.6 $\mathrm{mL\,L^{-1}}$ at the depth of Site U1342; Conkright et al., 2002).

Studies have shown that sea ice was present in the Bering Sea through at least the last 2.5 Myr, became more prevalent during the mid-Pleistocene (Stroynowski et al., 2015, 2017; Detlef et al., 2018), and likely resulted in GNPIW expansion (Horikawa et al., 2010; Knudson and Ravelo, 2015; Kender et al., 2018; Worne et al., 2019) and a reduced OMZ. However, high-resolution Bering Sea records of organic carbon flux and OMZ presence have not yet been produced over the MBT. Existing low-resolution records at the Bering Sea slope do suggest that sea ice was reduced at ∼ 500 ka (Stroynowski et al., 2017), but there are no existing records with the resolution required to test the sea ice influence on productivity at a marginal location in the central Bering Sea. Diatom assemblage records from several piston cores in the Bering Sea and North Pacific (Katsuki and Takahashi, 2005) have been used to reconstruct Quaternary sea ice variation (see Leventer et al., 2007). Katsuki and Takahashi (2005) showed that during the Last Glacial Maximum (LGM), when sea level was over 100 m lower than today and much of the continental shelf was exposed (Fig. 1), seasonal sea ice covered the northwestern slope, drift ice covered the majority of the central Bering Sea and much of Bowers Ridge, and open water covered the south–central Bering Sea and parts of northern Bowers Ridge, including the location of Site U1342 (Fig. 1). However, there is currently little information on the evolution of intermediate water properties over Bowers Ridge during this time period or of sea ice, organic carbon flux, and OMZ and GNPIW presence over the MBT.

Deep sea benthic foraminifera respond to changes in organic carbon flux and oxygen availability in modern settings (e.g. Kaiho, 1994; Thomas and Gooday, 1996; Jorissen et al., 2007; Gooday and Jorissen, 2012; Kaminski, 2012) and have been shown to respond to environmental variability in the Bering Sea during the last glacial cycle (Gorbarenko et al., 2005; Okazaki et al., 2005). For instance, the phytodetritivore species *Alabaminella weddellensis* dominated faunas during the LGM over the Umnak Plateau (Site UMK-3A; Fig. 1), and the high-productivity–low-oxygen genera *Rutherfordoides* and *Bulimina* dominated faunas during the deglacial when surface water productivity peaked (Okazaki et al., 2005). Coretop "mudline" samples from U1342 of sub-recent age reveal an assemblage dominated by the high-productivity–low-oxygen taxa *Bulimina*, *Brizalina*, *Globobulimina*, *Stainforthia*, *Rhumblerella*, and *Martinottiella* (Expedition 323 Scientists, 2011; Kender and Kaminski, 2017), which is consistent with the position of U1342 within the core of the modern OMZ. To better understand surface and deep water evolution over glacial–interglacial cycles of the last 600 kyr at ∼ 800 m of water depth (within the modern OMZ), we analysed benthic foraminiferal assemblages in high resolution at Site U1342 to constrain palaeoceanographic changes.

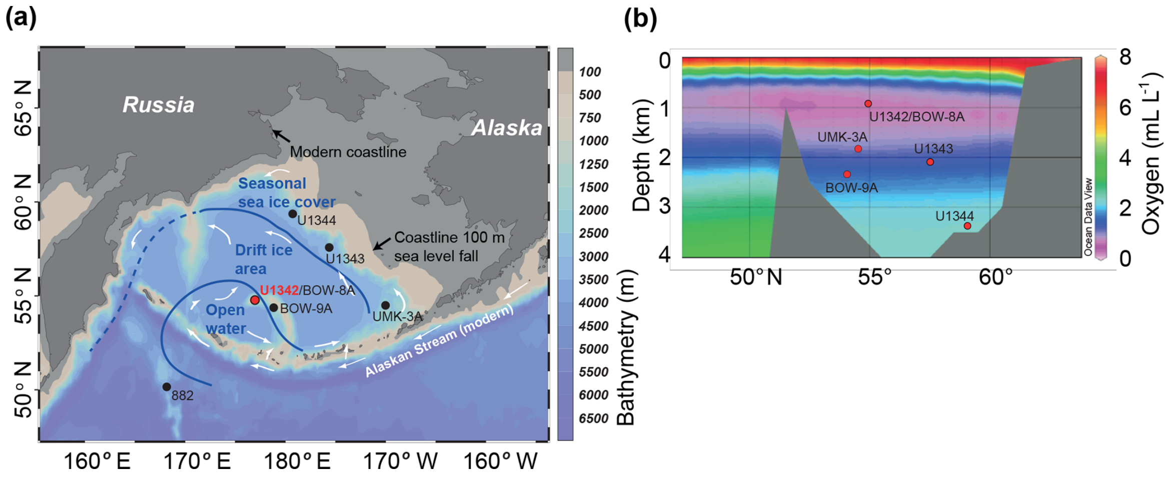

Figure 1. **(a)** Map of the Bering Sea with modern surface ocean flow (white arrows), showing the position of Site U1342 (this study) and other sites referred to in the text. Bathymetry above 100 m of depth is marked as grey, approximating glacial coastlines. Last Glacial Maximum (∼ 30 kyr ago) sea ice conditions (blue lines and text) are from Katsuki and Takahashi (2005), interpreted from diatom assemblages. Map drawn in Ocean Data View (Schlitzer, 2019). **(b)** Bering Sea north–south section showing dissolved oxygen concentrations (Schlitzer, 2019) and the position of core sites discussed in this study.

2 Methods and materials

The sediments at Site U1342 are a mixture of biogenic material (largely diatom frustules and foraminifera, with minor nannofossils, silicoflagellates, sponge spicules, and radiolarians), intermittent laminated intervals (predominantly parallel but occasionally cross-bedded), volcaniclastic material (fine to coarse ash) occurring in both discrete layers and scattered in the sediment, and rare clay to pebble-sized siliciclastics (Expedition 323 Scientists, 2011). This site is chosen as it is on a ridge at ∼ 800 m of water depth, and the lysocline is shallow in the North Pacific such that calcite dissolution is strong below ∼ 1000 m. As the Bowers Ridge region is far from continental areas and was submerged during at least the Pleistocene, the coarser siliciclastic component was likely derived from sea ice and/or icebergs (Aiello and Ravelo, 2012). The laminated sediments have a distinct biogenic composition dominated by diatom and foraminiferal tests. Conversely, the homogenous intervals contain a variety of sedimentary components that include both biogenic and terrigenous particles (Aiello and Ravelo, 2012). Expedition 323 Scientists (2011) report that the majority of laminated intervals are bedding-parallel, while cross-bedding and scouring indicative of bottom water currents are less common.

The age–depth tie points used to plot our data against age are derived from detailed benthic foraminiferal oxygen isotope (δ^{18}O) analyses carried out on *Uvigerina peregrina* in the same samples by Knudson and Ravelo (2015). The isotope stratigraphy of U1342 has a correlation coefficient of 0.64 with the global reference stack LR04 (Lisiecki and Raymo, 2005) after a three-point running mean was applied. The accuracy of the age model is probably better than ±10 ka, which is taken into account when evaluating the data with respect to global glacial–interglacial cycles.

A total of 160 samples were collected from the top ∼ 20 m CCSF (composite depth scale; Expedition 323 Scientists, 2011) of Site U1342 at ∼ 14 cm spacing, corresponding to the last ∼ 600 kyr, and an average time resolution of ∼ 3.7 kyr between each sample. Sample processing was carried out at the University of California, Santa Cruz. Samples were freeze-dried, gently washed over a 63 µm mesh screen, and stored in glass vials before picking. Slides are housed in collections at the University of Exeter, UK. Due to the small size of the samples (ranging between 10 and 20 cc), we aimed to pick a minimum of 100 specimens of benthic foraminifera per sample into cardboard reference slides. Samples that contained many more than 300 specimens were subdivided using a micro-splitter. Benthic foraminiferal fragmentation percentage was determined by calculating the percentage of broken specimens (fragments) to the sum of whole (unbroken) and fragmented specimens in each sample.

Correspondence analysis (CA) (using the software PAST; Hammer et al., 2005) was carried out on samples containing > 50 specimens and with species with fewer than 50 specimens in the whole dataset removed. Using a reciprocal averaging algorithm (Greenacre, 1984; Hammer and Harper, 2006) to compare species occurrences across samples, similar CA scores for samples indicate comparable faunal characteristics (e.g. Kuhnt et al., 2002; Hammer and Harper, 2006; Kender et al., 2008). CA attempts to show multidimensional data in fewer dimensions, with axis 1 (describing the largest variance in the dataset) being shown to represent the strongest ecological parameter in many studies (Hammer and Harper, 2006).

3 Results

We identified and counted a total of 71 taxa (Table S1 in the Supplement) and completed detailed taxonomic analysis and imaging of each one (see Taxonomy section in the Supplement). In total, 106 of the 160 samples contained > 100 specimens (Fig. 2c). Diversity averaged 12 taxa per sample but ranged up to over 20 in several samples (Fig. 2c). The number of taxa typically increased in samples with greater abundance (Fig. S1 in the Supplement), with samples having fewer than 50 specimens ($n = 43$) showing the most reduced diversity (Fig. 2c). In these samples, the foraminifera showed a higher degree of fragmentation (Figs. 2b, S1 in the Supplement), which has been used as a qualitative proxy for dissolution (Metzler et al., 1982; Thunell, 1976; Berger, 1970). We therefore removed these 43 samples from assemblage analysis. Intervals of less dissolution and good preservation, as defined by abundance, diversity, and fragmentation, appear to be restricted to glacial maxima as defined by benthic foraminiferal δ^{18}O (Fig. 2a, grey bars). A tight correlation with abundance, diversity, and glacial cycles can be identified, with the highest abundances in the glacial periods before 400 ka (Fig. 2). The species that make up the majority of the assemblages are *Bulimina exilis*, *Takayanagia delicata*, *Alabaminella weddellensis*, *Gyroidina* sp. 2, *Cassidulina laevigata*, *Islandiella norcrossi*, and *Uvigerina bifurcata*, which change in their dominance multiple times throughout the core (Fig. S2 in the Supplement).

CA axis 1 describes 19% of the variance within the dataset, with positive values signifying times of abundant *B. exilis*, *T. delicata*, *Epistominella exigua*, *Bolivina spissa*, *Brizalina alata*, and *Brizalina earlandi*. These species make up Assemblage 1, which correlates very well with CA axis 1 (Fig. 3b). CA axis 2 (14 % of the variance) shows a good correlation with *A. weddellensis*, *Cassidulinoidies parkerianus*, *Globobulimina auriculata* and *Stainforthia fusiformis* (Assemblage 2) for positive values, and *C. laevigata* (Assemblage 3) for negative values (Fig. 3c). Other axes do not define further meaningful assemblages, although *I. norcrossi* and *U. bifurcata* are important constituents of the fauna outside these three assemblages (Fig. S2 in the Supplement) and plot near the CA axes 1 and 2 origin (Fig. 3a), signifying no particular abundance preference for the three defined assemblages. Both CA axes 1 and 2 show considerable variability with time when plotted against age (Fig. 4), with numerous intervals of dominant Assemblage 1 co-occurring with laminated sediment but no clear glacial–interglacial variability. Of the 15 samples analysed from laminated sediments, 13 (87 %) have CA axis 1 values above 0. Of the 98 samples analysed from non-laminated sediments, 78 (80 %) have CA axis 1 values below 0. In contrast, CA axis 2 shows a weak preference for unlaminated, homogenous samples.

4 Discussion and conclusions

Each glacial period of the past 600 kyr experienced a remarkable increase in the preservation of calcareous benthic foraminifera at Site U1342 (fragmentation, abundance, and diversity; Fig. 2). The most likely reason is the presence of a different, less corrosive glacial water mass over Bowers Ridge, which has been identified as GNPIW from offsets in oxygen and carbon isotopes at U1342 (Knudson and Ravelo, 2015) and other sites (Cook et al., 2016; Kender et al., 2018; Worne et al., 2019), and neodymium isotope changes within the Bering Sea (Horikawa et al., 2010). Positive benthic δ^{13}C and depleted benthic δ^{18}O during glacials at U1342 were interpreted as the export of surface waters to depth via sea ice brine rejection and intermediate water formation (Knudson and Ravelo, 2015). Surface waters were likely depleted in ^{12}C, CO_2, and DIC compared with aged deeper NPDW due to primary productivity, which could have led to an increased carbonate ion concentration and better preservation of $CaCO_3$. Modern NPIW is formed partially in the Sea of Okhotsk, which has typical δ^{13}C values of -0.2 ‰ to -0.4 ‰ at 800 m of water depth compared with -0.6 ‰ to -0.7 ‰ in the Bering Sea (Keigwin, 1998; Cook et al., 2016) where intermediate water does not currently reach. Alternative possible causes of increased glacial preservation are decreased primary productivity, which is not supported by the distribution of laminated sediment and benthic foraminiferal assemblages (see below), and lower sea level, which is unlikely as the modern δ^{13}C chemocline is at ~ 250 m of water depth in the Bering Sea (Keigwin, 1998).

To assess the palaeoecological changes at Site U1342, we removed samples heavily affected by poor preservation and examined the underlying benthic foraminiferal assemblage changes. Surprisingly, although preservation shows strong glacial cyclicity, foraminiferal assemblages do not show a glacial trend but a preference for laminated sediment that also does not follow glacial cyclicity (Fig. 4). Benthic foraminiferal faunas are controlled by a range of factors that include primary productivity and organic carbon supply, sediment heterogeneity, bottom water currents, organic carbon type, quantity and seasonality, bottom water and sediment pore water oxygen levels (Sun et al., 2006; Jorissen et al., 2007) and the ability of organic carbon to reach the sea floor after passing through different water masses with varying degradative constituents (Arndt et al., 2013). In the deeper Bering Sea, organic carbon flux and oxygen levels are the major two variables, controlled by a combination of export production and intermediate water ventilation (Kender and Kaminski, 2017). Of our most dominant species, *C. laevigata*, *Uvigerina peregrina*, and species from the genera *Bulimina*, *Bolivina*, *Stainforthia* and *Globobulimina* are known denitrifiers able to survive in anoxic water in the modern ocean by respiring nitrate (Piña-Ochoa et al., 2010). We interpret the assemblages described here as generally tolerant of low oxygen, even though the majority of

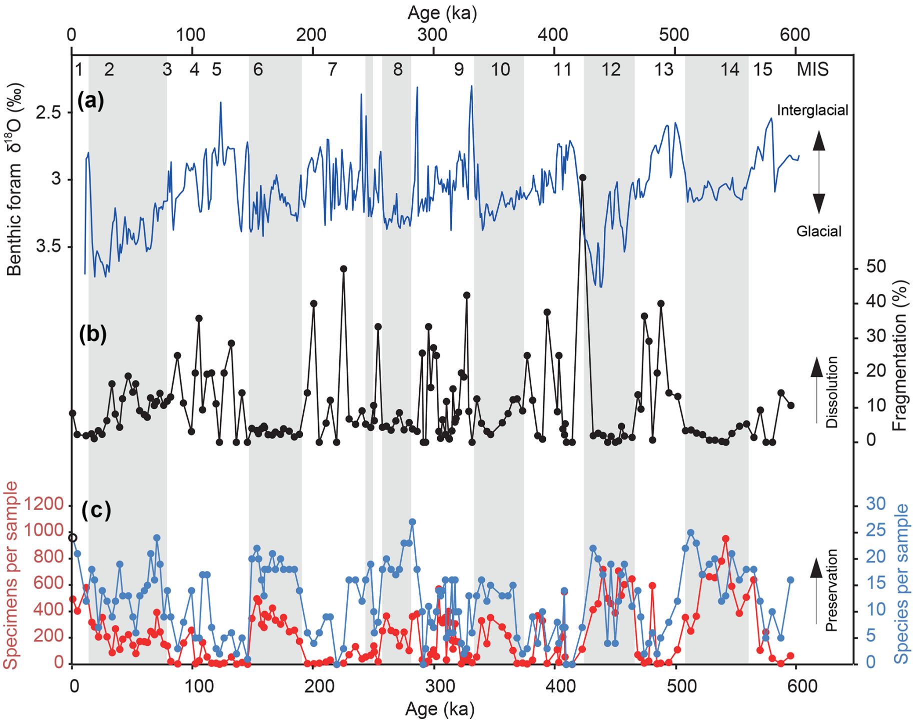

Figure 2. **(a)** U1342 benthic foraminiferal δ^{18}O record used to construct the age model (Knudson and Ravelo, 2015). **(b)** The degree of foraminiferal fragmentation at Site U1342 as a proxy for bottom water dissolution. **(c)** Abundance (red) and diversity (blue) of benthic foraminifera at Site U1342 as a proxy for preservation. Grey bars indicate glacial maxima as defined by the positive δ^{18}O.

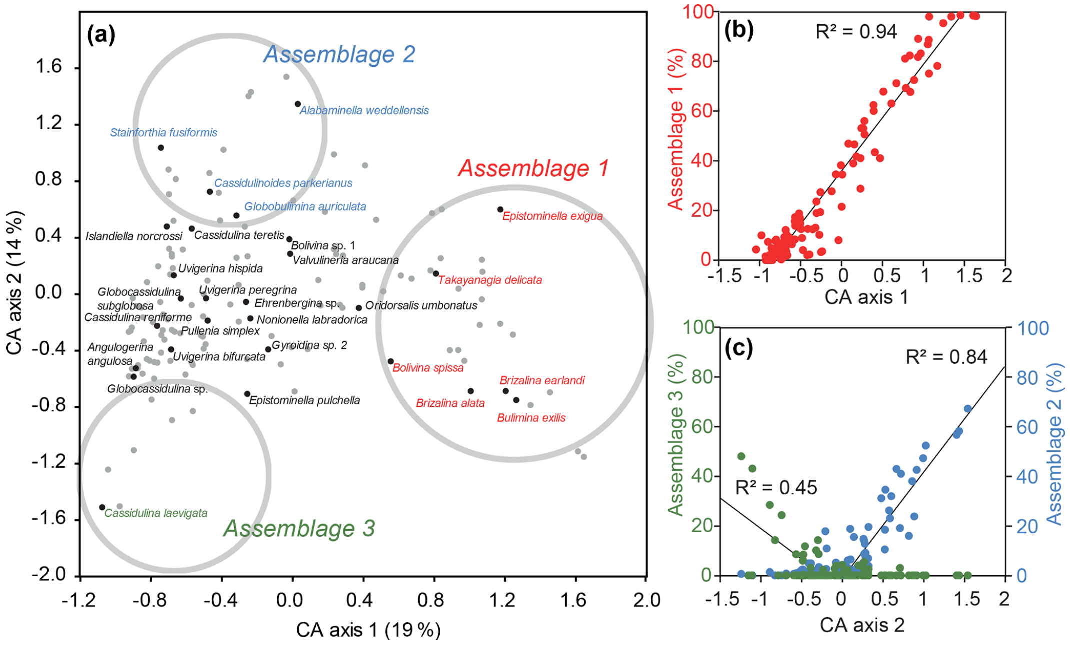

Figure 3. **(a)** Correspondence analysis (CA) of the dataset for samples with > 50 specimens and for species with > 50 individuals. Samples are marked with grey dots, and grey circles are the approximate position of the interpreted assemblages. **(b)** Percentage counts for Assemblage 1 (*B. exilis*, *T. delicata*, *E. exigua*, *B. spissa*, *B. alata*, and *B. earlandi*) against CA axis 1 scores for each sample (with > 50 specimens). **(c)** Percentage counts for Assemblage 2 (*A. weddellensis*, *C. parkerianus*, *G. auriculata*, and *S. fusiformis*) and Assemblage 3 (*C. laevigata*) against CA axis 2 scores for each sample (with > 50 specimens). Linear regression for Assemblage 2 is only for samples with positive CA scores, and Assemblage 3 is only for negative CA scores.

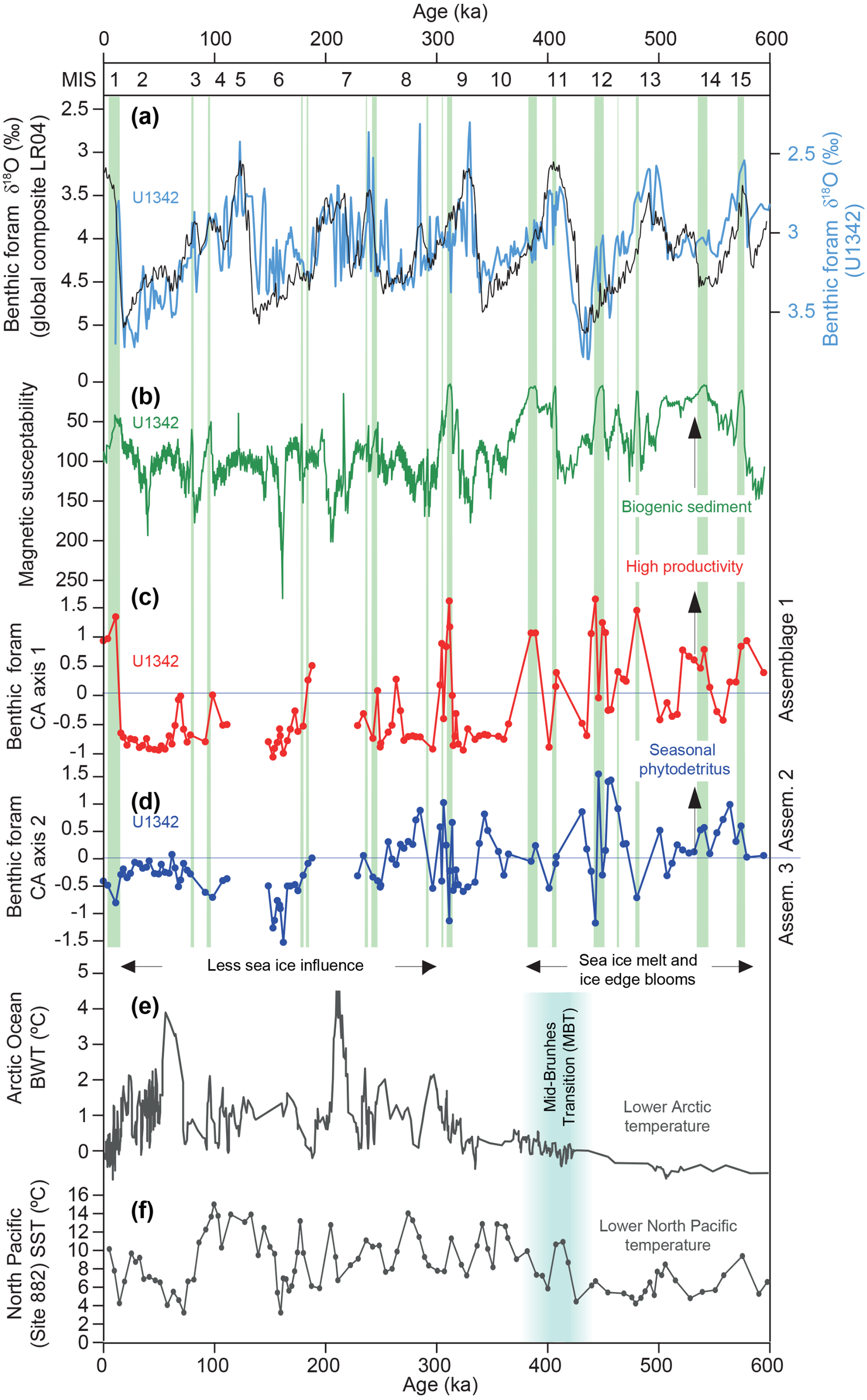

Figure 4. Benthic foraminiferal dataset CA axis 1 and 2 scores compared with various other records plotted on age. Marine Isotope Stages (MISs) are shown at the top. **(a)** The Site U1342 benthic foraminiferal δ^{18}O record (blue) used to construct the age model (Knudson and Ravelo, 2015) against the global benthic δ^{18}O composite record (Lisiecki and Raymo, 2005). **(b)** Site U1342 magnetic susceptibility record (Expedition 323 Scientists, 2011). **(c)** Benthic foraminifera CA axis 1 scores, with high values indicating Assemblage 1 (Fig. 3). **(d)** Benthic foraminifera CA axis 2 scores, with high values indicating Assemblage 2 and low values Assemblage 3 (Fig. 3). **(e)** Bottom water temperature (BWT) record from Mg/Ca of ostracods in various Arctic Ocean intermediate water depth sites (Cronin et al., 2017). **(f)** Sea surface temperature (SST) record from alkenones at North Pacific Site 882 (Martínez-Garcia et al., 2010). Green bars indicate laminated sediment at Site U1342 (Knudson and Ravelo, 2015).

our species have not yet been analysed for nitrate reduction. Whilst *E. exigua*, *Cibicidoides*, and other minor constituents found here are unable to respire nitrate (Piña-Ochoa et al., 2010), *E. exigua* is abundant in the OMZ of the Peru–Chile Trench (Sen Gupta and Machain-Castillo, 1993; Erdem and Schönfeld, 2017), and if the majority of species at U1342 are able to respire nitrate it appears as though oxygen limitation alone is unlikely the predominant control on benthic faunas. Some species may still have a competitive advantage over others in low-oxygen settings, and indeed various OMZs today contain faunas that have characteristic assemblages (Hermelin and Shimmield, 1990; Sen Gupta and Machain-Castillo, 1993; Kaminski et al., 1995; Kaiho, 1999; Gooday et al., 2000; Schumacher et al., 2007). In the core of the OMZ of the Arabian Sea ($\sim 0.1\,\mathrm{mL\,L^{-1}}$), *C. laevigata*, *B. exilis*, *Uvigerina semiornata* (a morphologically similar species to *U. bifurcata*), *U. peregrina*, *Globobulimina*, and *Bolivina* species all show high abundance at different depths (Schumacher et al., 2007). *Bulimina* spp., *T. delicata*, *Bolivina spissa*, and *U. peregrina* were abundant in OMZs of offshore California (Sen Gupta and Machain-Castillo, 1993), and *I. norcrossi* was abundant in the Okhotsk Sea where oxygen levels were $0.3\,\mathrm{mL\,L^{-1}}$ (Bubenshchikova et al., 2008). The only abundant species in our dataset that does not typically occur in high abundance in OMZs at lower latitudes is *A. weddellensis*, although it is associated with low-oxygen-tolerant species in this study, and it is present in six of our laminated samples with an abundance greater than 50. Thus, relatively high organic carbon flux conditions were likely present throughout much of the past 600 kyr, as the defined assemblages and the residual fauna, consisting largely of *U. bifurcata*, are all indicative of modern high-productivity OMZs, and typical abundant deep water benthic foraminifera from oligotrophic well-oxygenated settings, such as *Planulina wuellerstorfi* and *Cibicidoides mundulus*, are all but absent.

It seems most likely that the assemblages in our study are controlled predominantly by changes in the supply of organic carbon to the sea floor, as most of the species are tolerant of low oxygen. The high correlation of Assemblage 1 with laminated sediments (in $> 80\,\%$ of the samples – green vertical bars in Fig. 4) is evidence that those species are indicative of the highest organic carbon flux to low-oxygen regime to the sea floor at this site. That is because (1) the associated low oxygen (the absence of deep bioturbation, allowing laminations to be preserved) was likely caused by high benthic respiration rates from high organic carbon flux, and (2) the laminations are enriched in biogenic material as indicated by diatom-rich layers (Expedition 323 Scientists, 2011) and consistent low magnetic susceptibility (MS) (Fig. 4) signifying non-magnetic biogenic material (Expedition 323 Scientists, 2011). *Alabaminella weddellensis* (from Assemblage 2) is regarded as an opportunistic species, blooming at times of high seasonal phytodetrital flux to the sea floor (Smart et al., 1994; Thomas and Gooday, 1996). On the Arctic shelf, high proportions of *I. norcrossi* coincide with seasonal sea ice and probable summer ice edge productivity (Steinsund, 1994; Polyak et al., 2002; Ivanova et al., 2008), and the species is considered to respond and reproduce with highly seasonal phytodetritus deposition (Wollenburg et al., 2004). A laboratory experiment by Alve (2010) showed that living *C. laevigata* (Assemblage 3), in contrast to many other species, disappeared from the assemblage after a halt in the supply of fresh phytodetritus, indicating that this species requires an input of fresh phytodetritus to survive. Outside Assemblage 1 (highest organic carbon flux), it appears as though *I. norcrossi*, *A. weddellensis*, and possibly *C. laevigata* were competing as seasonal phytodetritus species in a relatively (compared to Assemblage 1) lower organic carbon flux environment, responding to changes in the type, quantity, and quality of organic carbon supplied to the sea floor.

Diatom assemblages from nearby Site BOW-8A (Fig. 1) can be used to indicate surface ocean conditions proximal to U1342 over the past 270 kyr (Katsuki and Takahashi, 2005). BOW-8A is dominated by *Neodenticula seminae*, indicating that the Alaskan Stream (Sancetta, 1982) influenced the palaeoceanography at the western Bowers Ridge over this time, and low proportions of the sea-ice-living diatoms *Thalassiosira gravida* and *Fragilariopsis cylindricus* indicate that this location was similarly unaffected by persistent sea ice over much of this time period (Katsuki and Takahashi, 2005). Jin et al. (2006) modelled Bering Sea reductions in spring thermal stratification, wind mixing and tidal mixing, and found that – even though they had different effects on the timing of blooms and zooplankton–phytoplankton concentrations – all caused reduced net primary production, thus providing possible mechanisms for past changes in organic carbon flux to the sea floor. We propose three broad scenarios for the annual cycling of surface water masses at Bowers Ridge over the Quaternary in the absence of significant sea ice (as indicated by diatom records; Katsuki and Takahashi, 2005). The first scenario is the modern setting (interglacials) in which water mixing brings intermediate nutricline water, influenced by nutrient-rich NPDW, into the photic zone, and summer warming causes spring–summer blooms and high net primary production (Eslinger and Iverson, 2001; Katsuki and Takahashi, 2005). The second scenario is weaker glacial spring thermal stratification due to colder glacial conditions, coupled with enhanced glacial wind mixing as modelled due to the presence of larger North American ice sheets (Gray et al., 2018). Although mixing would have brought deeper water into the photic zone, reduced thermal stratification would have acted to reduce net spring–summer bloom productivity (Katsuki and Takahashi, 2005; Jin et al., 2006). In addition, during glacial times, wind mixing would have brought a smaller proportion of nutrients into the photic zone due to enhanced nutrient-poor GNPIW presence (Kender et al., 2018; Knudson and Ravelo, 2015). The third scenario is glacial spring–summer stratification from southward-flowing cold low-salinity surface water sourced from melting sea ice, causing a spring–summer bloom and elevated seasonal phytodetrital flux (Eslinger and Iverson, 2001; Katsuki and Takahashi, 2005; Aguilar-Islas et al., 2007). Site U1342 was probably affected by seasonal stratification over the majority of glacials (Fig. 4), as suggested by the high proportions of phytodetritivores *I. norcrossi*, *A. weddellensis*, and possibly *C. laevigata*, perhaps similar to scenario three. Although sea ice melt stratification would likely have been more extensive during strong glacials, we may not expect to see an increase in net primary production as the greater presence of GNPIW would have separated high-nutrient deeper water from the photic zone. These competing mechanisms at Bowers Ridge may explain why there is no clear glacial–interglacial cyclicity to the foraminiferal assemblages and laminated sediments. The lack of abundant sea ice diatoms over the last ∼ 270 kyr indicates that the bloom production, suggested by abundant phytodetritivores, may have been caused by stratification from low-salinity spring water from melting sea ice in the north and east (Katsuki and Takahashi, 2005). The intervals low in phytodetritivore abundance may indicate episodes of little spring stratification and associated seasonal blooms.

There may be different possible causes of the sporadic, relatively short-lived episodes of very high productivity and organic carbon flux at U1342, as indicated by Assemblage 1 and the laminated intervals (Fig. 4). (1) During warming (deglacials), a widespread reduction in regional subarctic North Pacific sea ice occurred, which shut down GNPIW formation (Kender et al., 2018; Worne et al., 2019) and promoted the expansion of high-nutrient–low-oxygen NPDW to intermediate and nutricline depths (Site U1342), aiding productivity. This could be comparable to the scenario proposed for the last deglacial Bølling–Allerød (e.g. Shibahara et al., 2007; Gray et al., 2018) in which laminated sediments appear to have been formed across the North Pacific and Bering Sea. In addition, melting ice sheets could have delivered an increase in surface nutrients (Katsuki and Takahashi, 2005). The deglacial collapse of the GNPIW scenario could only explain high Assemblage 1 at the termination of Marine Isotope Stages (MISs) 2, 8, 14, and 15 in our records (Fig. 4), as the remaining high-productivity episodes occurred during glacials. (2) During colder intervals (early glacials), enhanced wintertime sea ice formation in the northeast Bering Sea could have aided the production of springtime low-salinity stratification over Bowers Ridge from melting sea ice, causing an associated local increase in primary productivity (Katsuki and Takahashi, 2005). An increase in productivity large enough to produce Assemblage 1 and laminated sediment may have only been possible at times when GNPIW was not yet extensive (compared with glacial maxima) to allow for the mixing of high-nutrient intermediate water sourced from NPDW into the photic zone.

Our conceptual model indicates that both very high-productivity episodes (Assemblage 1 and laminated sediment) and longer periods of bloom productivity (phytodetritivores in Assemblages 2 and 3) required spring–summer stratification from sea ice melt elsewhere in the Bering Sea, as glacial air masses were likely a lot colder than at present (Gray et al., 2018) and less able to cause strong summer thermal stratification. We observe that Assemblage 1 is more prevalent in the earlier part of the record (from 400–600 ka), and our increased ice melt–productivity interpretation is consistent with overall higher benthic foraminifera abundance (Fig. 2c) and higher abundances of *A. weddellensis* (Assemblage 2) in the earlier part of the record. During the Last Glacial Maximum *A. weddellensis* was very abundant (60 % of the fauna) over the eastern Bowers Ridge (BOW-9A, Fig. 1) and Umnak Plateau (UMK-3A) (Okazaki et al., 2005), and both of these locations were interpreted as being influenced by sea ice (Fig. 1) (Katsuki and Takahashi, 2005). In contrast, we find very low abundances of *A. weddellensis* at western Bowers Ridge (U1342) during the LGM (Fig. 4), where open water conditions were likely present during glacials over the past 270 kyr (Katsuki and Takahashi, 2005). Older diatom records do not exist from Bowers Ridge, but low-resolution records from Bering slope Sites U1343 and U1344 do show a reduction in pack-ice-related diatom species from ∼ 500 ka (Stroynowski et al., 2017), consistent with our suggestion. This time period approximately coincides with the MBT, for which alkenone-based sea surface temperatures indicate that North Pacific (Site 882; Fig. 1) glacials warmed (Martínez-Garcia et al., 2010), and Mg/Ca intermediate water temperatures indicate that Arctic Ocean glacials warmed and sea ice became more seasonal (Cronin et al., 2017) (see Fig. 4). Our records may therefore suggest that the Bering Sea responded to regional warming during the MBT after initial cooling and sea ice expansion in the mid-Pleistocene (Stroynowski et al., 2015, 2017).

Data availability. All of the data underlying this research are available in the Supplement.

Supplement. The supplement related to this article is available online at: https://doi.org/10.5194/jm-38-177-2019-supplement.

Author contributions. With assistance from SK, MW, JZ, and MAK, AA generated the underlying data and carried out the taxonomy. The overall project was designed by SK, MW, and JZ. The data analysis and interpretation were carried out by SK and all coauthors.

Competing interests. Sev Kender is an editor of the *Journal of Micropalaeontology*. The authors declare no other potential conflicts of interest.

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Benthic foraminifera indicate Glacial North Pacific Intermediate Water and reduced primary productivity over Bowers Ridge, Bering Sea, since the Mid-Brunhes Transition

Sev Kender et al.

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Systematic Palaeontology

The order of species presented below follows the suprageneric classification of Loeblich and Tappan (1987). Synonymy lists are not exhaustive, with most entries in the lists being selective, based on well illustrated material from the Pacific region (e.g., Kaiho, 1992; Jones, 1994; Debenay 2013; Holbourn et al., 2013) or material considered to be of direct comparative importance (e.g., Finger, 1990 and Abu-Zied, 2008).

Family EGGERELLLIDAE Cushman, 1937
Subfamily EGGERELLINAE Cushman, 1937
Genus *Eggerella* Cushman, 1935
Type species *Verneuilina bradyi* Cushman, 1911, designated by Cushman (1911), p. 54

***Eggerella* sp. 1**
Plate 1, figures 1-5.

Eggerella sp. 1 – KAMINSKI et al., 2013, p. 338, figs. 2A, Ha - Hb.

Distribution in core: 10 specimens from 8 samples; first occurrence at 8.72 m, intermittent occurrences down the core.

Description: Test trochospiral, conical or ovoid, slightly elongate, rapidly becoming triserial after a short biserial stage; overall shape is pyramidal. Wall finely agglutinated; wall surface rough, containing ~ 40% cement. Test chambers compact, strongly overlapping. Chambers inflated and increasing in size as added; average number of chambers ranges from 9 to 13; sutures thin and slightly depressed. Length of the test ranges between 0.40 and 0.67 mm and the width between 0.26 and 0.32 mm; average width of the last chamber is 0.25 mm. The average length to width ratio is 1.7 (0.42/0.25). Apertural morphology varies; ranging from a simple slit-like to a rounded opening, positioned centrally on a very short neck at the base of the final chamber; aperture surrounded by a thickened but narrow lip.

Remarks: This species is very similar to *Eggerella* sp. 1 described from the Bering Sea by Kaminski et al. (2013). *Eggerella* sp. 1 possesses numerous pores, thought to be an adaptation to survive low-oxygen conditions present in the deep Bering Sea (Kaminski et al. 2013; Kaminski and Kender, 2017). The type species *Eggerella bradyi* was originally described from the Atlantic and Pacific Oceans (see Phleger et al. 1953 and references therein). Brady's (1884) material referred to *Verneuilina pygmea* (Egger) was recognised as *Eggerella bradyi* by Cushman (1937).

Specimens of *Eggerella* from the Bering Sea (including those illustrated by Kaminski et al., 2013) differ from the type specimens of *E. bradyi* (Cushman) in being smaller and having fine pores that are open to the surface. In 7 out of the 10 specimens from the Bering Sea, the aperture is narrow and slit-like, while in the other 3 it is round. However, there is no discernible trend in aperture type through the samples studied. In all cases the aperture is situated on a very short neck on the terminal chamber (Plate 1, figs. 1-5).

***Martinottiella* sp. 3**
Plate 1, figures 6-10.

Martinotiella sp. 3 – KENDER and KAMINSKI, 2017, p. 213, figs. 10.2-10.5.

Occurrence: 7 specimens, from depths 9.40, 12.98, 13.99, 15.10 m and 19.22 m

Description: Test a trochospiral tube; initially trochospiral then triserial, later reducing to uniserial, uniserial portion making up about ¾ of the test; test tends to be elongate, the specimen is typically 1.35

mm in length and 0.15 mm in width; wall arenaceous, finely agglutinated with fine pores open to the surface; chambers indistinct in the early portion; increasing gradually in size as added, sutures indistinct, slightly depressed; aperture is circular (~0.05 mm diameter) and produced on a short tube-like neck, at the centre of the terminal chamber.

Remarks: This species was initially recorded in core top material of Site U1342 (Kender and Kaminski, 2017), and differs from *Martinottiella* sp. 1 (Kaminski et al., 2013) by its larger size, and *Martinottiella* sp. 2 (Kaminski et al., 2013) by its finer grains. The Bering Sea species differ from *Martinottiella communis* (D'Orbigny, 1846) in having a finely agglutinated wall, central circular aperture and fine pores that are open to the surface.

Family HAUERINIDAE Schwager, 1876
Subfamily HAUERININAE Schwager, 1876
Genus *Quinqueloculina* d'Orbigny, 1826
Type species *Serpula seminulum* Linné, 1758, designated by Parker and Jones (1859), p. 480

***Quinqueloculina* sp.**
Plate 1, figures 11-13.

Distribution in core: 4 specimens from 4 samples, at depths 13.46, 14.88, 16.21 and 19.61 m respectively.

Description: Test ovate in outline, twice as long as broad, average dimensions: length 0.75 mm, width 0.32 mm and thickness 0.30 mm. Wall calcareous, slightly imperforate. The chamber arrangement is "quinqueloculine": four chambers are visible from one side and three from the other side, chamber margins are curved; aperture is not clearly seen, but is located on a very short neck. Test surface is rough, ornamented with minute microstriae.

Remarks: These Bering Sea specimens are morphologically similar to *Quinqueloculina parvula* Schlumberger recorded by Milker and Schmiedl (2012) from the Holocene shelf of the western Mediterranean Sea, but differ by the morphology of the aperture, which is relatively wide and round in *Q. parvula* (Milker and Schmiedl, op. cit.; fig. 15: 26, 27). Though not clearly visible in the specimens of *Quinqueloculina* sp. from the Bering Sea, the aperture doesn't appear to be either wide or rounded, and is more triangular in outline.

Subfamily MILIOLINELLINAE Vella, 1957
Genus *Pyrgo* Defrance, 1824
Type species *Pyrgo laevis* Defrance, 1824

Pyrgo murrhina (Schwager, 1866)
Plate 1, figures 14-17.

Biloculina murrhina SCHWAGER, 1866, p. 203, pl. 4, figs. 15 a-c
Pyrgo murrhina CUSHMAN, 1929, p. 71, pl. 19, figs. 6, 7.
Pyrgo murrhina (Schwager). – CUSHMAN, 1930, p. 357, pl. 32, figs. 7 a, b.
Biloculina depressa, var. *murrhyna* Schwager. – BRADY, 1884, p. 146, pl. 2, figs. 10, 11, 15.
Pyrgo murrhina (Schwager). – PHLEGER, PARKER and PEIRSON, 1953, p. 28-29, pl. 5, figs. 22-24. – BARKER, 1960, p. 4, pl. 2, figs. 10, 11, 15. – Le ROY, 1975, p. 439, pl. 7, figs. 4, 5. - SEJRUP et al, 1981, pl. 2, fig. 9. – MULLINEAUX and LOHMANN, 1981, p. 38, pl. 1, fig. 13. – KAIHO and NISHIMURA, 1992, p. 312, pl. 3, fig. 2. – GUPTA, 1994, p. 357, pl. 1, fig. 14. – DOWSETT and ISHMAN, 1995, p. 154, pl. 1, fig. 2. – OHKUSHI et al., 2000, p. 138, pl. 1, figs. 5a-c. – ABU-ZIED et al., 2008, p. 51, pl. 1, figs. 16-17. – HOLBOURN et al., 2013, p. 458.

Distribution in core: 6 specimens from 6 samples, at depths 1.03, 4.97, 5.26, 5.41, 5.74 and 5.96 m respectively.

Description: Test ovate in outline, biconvex: one side more convex than the other; wall calcareous and smooth, imperforate and porcelaneous; two chambers making up the exterior, extended with a carinate periphery, somewhat longer than broad; maximum diameter of the test is 1.05 mm, thickness is up to 0.75 mm. Aperture nearly circular, at the end of a produced tubular neck, a small bifid tooth is attached to the apertural opening.

Remarks: Schwager (1866) originally assigned his material to *Biloculina. Pyrgo murrhina* from the Bering Sea is morphologically similar to specimens illustrated by Abu-Zied et al. (2008: pl. 1, fig. 16, 17) from the Mediterranean Sea, and differs from specimens illustrated by Cushman (1930) which have a larger bifid tooth associated with the aperture, partially filling the nearly circular apertural opening.

Distribution: *Pyrgo murrhina* is cosmopolitan in deeper waters, it has a geographical distribution in the Pacific (Kaiho and Nishimura, 1992; Ohkushi et al., 2000; Bubenshchikova et al., 2010), and Indian Oceans (Corliss, 1979; Gupta, 1994), the Gulf of Mexico (Le-Roy, 1975; Sen Gupta et al., 2009), the Red Sea (Gupta, 1994) and other seas (Le-Roy, 1975; Abu-Zied et al., 2008; Sen Gupta et al., 2009; Wilson and Costelloe 2011). *Pyrgo murrhina* has a water depth range extending from 181 to 839 m in the Okhotsk Sea (Bubenshchikova et al., 2010), down to 4600 m in the southeast Indian Ocean (Corliss 1979). *P. murrhina* was considered an indicator of oxic seabed conditions by Kaiho, 1994 and Matul et al. 2013. Bubenshchikova et al. (2010) classified *P. murrhina* as a suboxic and epifaunal species. Its stratigraphical range is from the Miocene to Recent (Jones 1994).

Genus *Triloculina* d'Orbigny, 1826
Type species *Miliolites trigonula* Lamarck, 1804, designated by Cushman (1917), p. 65

Triloculina frigida Lagoe, 1977
Plate 2, figures 1-3.

Triloculina frigida Lagoe, 1977, p. 120, pl. 1, figs 12, 17, 18. – SEJRUP et al., 1981, p. 292, pl. 2, fig. 11; MURRAY, 1984, pl. 3, figs. 12-14. – MACKENSEN et al., 1990, p. 254, pl. 1, fig. 6. - ISHMAN and FOLEY, 1996, p. 216, pl. 2, fig. 8. – WOLLENBURG and MACKENSEN, 1998, p. 179, pl. 3, figs. 2, 3; OHKUSHI et al., 2000, pl. 1, figs. 3 a-c. – GOODAY and HUGHES, 2002, p.97, pl. 1, fig. g.

Distribution in core: 22 specimens in 14 samples; the first occurrence is at 2.78 m, other intermittent occurrences down core from this level.

Description: Test with early chambers quinqueloculine, test triangular in cross-section, ovate in lateral outline, somewhat tubular; test has an equilateral triangular shape from apertural view, twice as long as broad, average dimensions being 0.37 mm in length and 0.12 mm in width. Wall calcareous, porcelaneous, imperforate; chambers added in the plane of the last preceding, covering it so that the exterior of the test is composed of about three visible chambers; aperture sub-rounded with a tiny tooth (on the flat side of the aperture) on a short but distinct neck at the end of the final chamber.

Remarks: *T. frigida* differs from the similar *Quinqueloculina lamarckiana* d'Orbigny, which has 5 visible chambers and an ovate aperture. The material from the Bering Sea compares well with the illustrations of *T. frigida* in Mackensen et al. (1990: pl. 2, fig. 6) from the Weddell Sea. The apertural tooth in *T. frigida* from the Bering Sea is tiny, and it is similar to specimens illustrated from the NE Atlantic by Gooday and Hughes (2002; pl. 1, fig. g). *T. frigida* has been described associated with phytodetritus-rich samples from the NE Atlantic (Gooday and Hughes, 2002), and this may signal this species to be opportunistic in nature, responding to seasonally high influx of organic detritus.

Distribution: *T. frigida* has a geographical distribution in the Atlantic and Arctic Oceans (Wollenburg and Mackensen 1998; Osterman et al, 1999; Gross, 2001; Gooday and Hughes, 2002), and from bordering seas (Sejrup et al., 1981; Mackensen et al., 1995; Gross, 2001). Its water depth ranges from 1388 m to 1920 m in the North Atlantic (Gooday and Hughes, 2002), extending to between 2500 and 3600 m in the Weddell Sea (Mackensen et al., 1990) and deeper to 4427 m in the Arctic Ocean (Wollenburg and Mackensen, 1998). *T. frigida* has a stratigraphical range from the Eocene to Recent (Murray, 1984).

Family NODOSARIIDAE Ehrenberg, 1838
Subfamily NODOSARIINAE Ehrenberg, 1838
Genus *Dentalina* Risso, 1826
Type species *Nodosaria cuvieri* d'Orbigny, 1826, designated by Risso (1826), p. 255

Dentalina ittai Loeblich and Tappan, 1953
Plate 2, figures 4-9.

Nodosaria calomorpha Reuss. – EARLAND, 1933, p. 117, pl. 4, fig. 19.
Dentalina cf. *calomorpha* (Reuss). – CUSHMAN, 1948, p. 44, pl. 5, figs. 4, 5.
Dentalina ittai LOEBLICH and TAPPAN, 1953, p. 56, pl. 10, figs. 10-12. – FEYLING-HANSSEN, 1964, p. 273, pl. 9, figs. 1, 2. – DABBOUS and SCOTT, 2012, p. 199, fig. 26, 3.

Distribution in core: 5 specimens in 5 samples; few occurrences between intervals 1.28, 2.38 and 2.54 m.

Description: Test elongate, uniserial, tubular, circular in cross-section, 2 mm in length; test wall calcareous, smooth. Chambers gradually increasing in size slightly inflated and curved, average chamber width is 0.20 mm, while length is 0.51 mm. There are 8 to 9 chambers, with the last chamber being largest; first chamber (proloculus) has a spine at the end. The size of the last chamber reduces towards the aperture, forming a conical shape; sutures slightly depressed; aperture rounded and terminal at the conical end.

Remarks: *Dentalina ittai* specimens examined are broken specimens, but nonetheless can be differentiated from *Dentalina cuvieri* (d'Orbigny) which has longitudinal costae on its test and a radiate aperture (see Loeblich and Tappan, 1986, pl. 439, figs. 19). The Bering Sea material may be conspecific with *Dentalina* sp. 1 illustrated by Sen Gupta et al. (2009) from the Gulf of Mexico.

Distribution: *Dentalina ittai* has been recorded from 21–50 m water depth at the northern Melville Peninsula, Canadian Arctic; Quaternary deposits in southwestern Sweden (Klingberg, 1997); Lake Uppsalstjänet and Lake Östen, southwestern Varmland, in southwestern Sweden (Wastegård, 1995), between 50 and 100 m at Tail of the Grand Banks, western North Atlantic (Sen Gupta, 1971) and from the Barents Sea, Arctic Ocean (Tarasov and Pogodina, 2001).

Genus *Lotostomoides* Hayward and Kawagata in Hayward et al. 2012
Type species *Nodosaria asperula* Neugeboren, 1852

Lotostomoides calomorphus (Reuss, 1866)
Plate 2, figures 10-1.1

Nodosaria (*Nodosaria*) *calomorpha* REUSS, 1866, p. 129, pl. 1, figs. 15–19.

Glandulonodosaria calomorpha (Reuss). – JONES, 1994, p. 72, pl. 61, figs. 23–26?, 27, supplementary plate 1, figs 10–11.
Lotostomoides calomorphus (Reuss). – HAYWARD, KAWAGATA, SABAA, GRENFELL, VAN KERCKHOVEN, JOHNSON and THOMAS, 2012, p. 125, pl. 6, figs 24–29. – SETOYAMA and KAMINSKI 2015, fig. 8, 22

***Distribution in core*:** 8 specimens in 8 samples, first occurrence at 0.10 m and other occurrences intermittently down the core to depth 20.59 m.

***Description*:** Test elongate, uniserial with up to three chambers that are tubular and weakly inflated, test divided into pillars or tubes; wall calcareous, unornamented; depressed sutures, aperture not clearly seen, probably terminal on a short neck.

Remarks: All specimens are fragmentary, consisting mostly of two chambers; only one specimen out of the eight examined has three chambers. Setoyama and Kaminski (2015: fig. 8, 22) referred to a morphologically close specimen from the Bering Sea as *Lotostomoides calomorphus.* Some of the fragments described here are similar to the specimens illustrated as '*Nodosaria* sp.' from surface sediments of the Weddell Sea in Antarctica by Anderson (1975: pl. 4, fig. 11), which has two tubular and weakly inflated chambers, with depressed sutures and an aperture which is terminal. Another morphologically similar specimen illustrated from Northern Gulf of Mexico by Sen Gupta (2009: pg. A-168) was referred to as *Siphonodosaria calomorpha* (Reuss).

***Distribution*:** *Lotostomoides calomorphus* has been reported by Setoyama and Kaminski (2015) from the Bering Sea at a water depth of ~2140 m. A similar specimen illustrated by Jones (1994) as *G. calomorpha* was recorded at a depth range between 11 and 4026 m in the South Atlantic.

Family VAGINULINIDAE Reuss, 1860
Subfamily LENTICULININAE Chapman, Parr, and Collins, 1934
Genus *Lenticulina* Lamarck 1804 (=*Lenticulites* Lamarck, 1804, objective synonym)
Type species: *Lenticulites rotulata* Lamarck, 1804, designated Children (1823), p. 153

Lenticulina rotulata Lamarck, 1804,
Plate 2, figures 12-16.

Lenticulites rotulatus LAMARCK, 1804, p. 188, pl. 62, fig. 11.
Lenticulina rotulata CHILDREN, 1823, p. 153.
Cristellaria rotulata (Lamarck). – CUSHMAN, 1926, p. 599, pl. 19, fig. 4; – PLUMMER, 1926, p. 91, pl. 7, fig. 8.
Lenticulina rotulata (Lamarck). – CUSHMAN, 1931, p. 37, pl. 5, fig. 1. – CUSHMAN, 1946, p. 56, pl. 18, fig. 19; pl. 19, figs. 1-7.
Lenticulina comptoni (Sowerby). – HOFKER, 1956, p. 114, text-figs. 117, 118.
Lenticulina rotulata (Lamarck). – DONDI and BARBIERI, 1982, pl. 10, figs. 6. – KAHIO, 1992, p. 304, pl. 2, figs. 14a, 14b. – PERYT and LAMOLDA, 1996, fig. 7 no. 7. – ORTIZ and THOMAS, 2006, p. 139, pl.8 fig. 5. – FRENZEL, 2000, pl. 14, fig. 1.
Lenticulina sp. – SETOYAMA and KAMINSKI, 2015, fig. 7. 9a, b.

***Distribution in core*:** 31 specimens from 10 samples between depths 0.10 and 15.56 m; highest abundance between intervals 1.28 and 2.24 m.

***Description*:** Sub-circular in outline, closely coiled and compressed chambers, periphery weakly carinate, test with umbonal boss. Test wall calcareous, hyaline, smooth except on the sutures; broad chambers increasing slowly in size as added, forming a closed spire in overall morphology. Specimens are relatively large, average dimension of the longer diameter is 1.50 mm, 1.40 mm at the shorter diameter and thickness of 0.62 mm. About 9 to 12 chambers are visible in the final whorl (~90% of the specimens have 10 chambers), the last two chambers tend to flare; sutures distinct, non-depressed, radial to oblique, straight to curved, gently tangential to the slightly elevated umbo; aperture radiate and terminal.

Remarks: Frenzel (2000) considered *Lenticulina comptoni* (Sowerby, 1818) to be a junior subjective synonym of *L. rotulata*. *L. rotulata* possesses an umbonal boss, which is absent from *L. gibba* (d'Orbigny): for other differences see 'remarks' for *L. gibba* below. The presence of the umbonal boss in *L. rotulata* makes this species similar to *L. convergens* (Bornemann) and *L. iota* (Cushman); however, there are more chambers in *L. iota* than in *L. rotulata*, while *L. convergens* has oblique sutures fusing into a relatively large umbilical boss. *L. muensteri* (Roemer) recorded from the Oxford Clay in England by Holbourn et al. (2013; p. 338, figs. 1 and 2) is morphologically similar to *L. rotulata,* but is differentiated by its wide apertural form. Holbourn et al. (2013) described the test as 'radiate and terminal'): this species is also older than the youngest (Eocene) occurrence of *L. rotulata*. *L. rotulata* recorded from the Bering Sea is morphologically similar to *Lenticulina* sp. recorded from the same area by Setoyama and Kaminski (2015).

Bartenstein and Bolli (1986) highlighted difficulties in separating *L. rotulata* (Lamarck), *L. muensteri* (Roemer), *L. roemeri* (Reuss), *L. macrodisca* (Reuss) and *L. subalata* (Reuss) due to transitional forms. *L. rotulata* specimens show intraspecific variation in the test outline down core: about 60% of the specimens have their test outline almost circular, while others are slightly angled. There appears to be no stratigraphical pattern in the distribution of these morphologies.

Distribution: *Lenticulina rotulata* is a cosmopolitan species that has a geographical distribution in the North American Atlantic Coast (Culver and Buzas, 1980); Japan Sea (Kaiho, 1992), Tyrrhenian Sea (Panieri et al., 2005), and the Caribbean Sea (Wilson and Costelloe 2011)), also from Betic Cordillera, southeastern Spain (Ortiz and Thomas, 2006). *L. rotulata* has been recorded at water depths extending from ~60 to ~300 m in the Tyrrhenian Sea (Panieri et al., 2005), between 7-1,054 m at the Bay of Biscay and Celtic Sea, down to a depth of 2300 m in the Pacific (Kaiho, 1992). *Lenticulina* spp. were classified as indicators of sub-oxic conditions by Kaiho (1994). It is present in dissolved oxygen range between 0.159 - 4.586 ml/l (Hayward, 2014). The stratigraphical range of *L. rotulata* is from Eocene to Recent (Kaiho, 1992).

Lenticulina gibba (d'Orbigny 1826)
Plate 2, figure 17-18; Plate 3, figures 1-7.

Cristellaria gibba D'ORBIGNY, 1826, p. 292, no. 17. – BRADY, 1884, p. 546, pl. 69, figs. 8, 9. – CUSHMAN, 1923, p. 105-106, pl. 25, fig. 4.
Robulus oblongata CORYELL and RIVERO, 1940, p. 332, pl. 43, fig. 7, figs. 12
Robulus gibba (d'Orbigny). – BERMÚDEZ, 1949, p. 126, p. 7, figs. 53-54.
Lenticulina gibba (d'Orbigny). – BARKER, 1960, p. 144, pl. 69, figs. 8-9. – DENNE, 1990, pl. 8, fig. 6. – JONES, 1994, p. 81, pl. 69, figs. 8-9. – ROBERTSON, 1998, p. 66. pl. 22, fig. 4. – KAMINSKI et al, 2002, p. 172, pl. 2, fig. 6. – SEN GUPTA et al., 2009, p. A-100, pl. 98, figs. 1- 2. – CHENDEŞ et al., 2004, p. 77, pl. 1, fig. 13. – HOLBOURN et al., 2013, p. 334, figs. 1, 2.

Distribution in core: 5 specimens in 4 samples between depths 15.95-16.65 m and 18.55-18.65 m.

Description: Test planispiral, elongate in outline, involute, weakly biconvex in cross section, with keeled, sub-acute periphery; wall calcareous, smooth, and finely perforate; the later chambers are narrower, approximately twice as wide as long. Some six to nine chambers in the final whorl, tending to uncoil as added; average dimension of the test is 0.45 mm in length, 0.25 mm in width at the widest diameter and 0.12 mm in thickness; sutures flush with chambers; primary aperture in form of radial slits, terminal on the narrow later chamber.

Remarks: D'Orbigny (1826) first described his material as *Cristellaria gibba;* this was later accepted as a synonym of *Lenticulina gibba* (d'Orbigny, 1826): see Gross, 2001 and Hayward (2013). *L. gibba* is differentiated from *L. rotulata* (Lamarck), *L. convergens* (Bornemann), *L. iota* (Cushman) and *L. muensteri* (Roemer) by its more elongated outline, and by its keel becoming narrower in later uncoiled chambers. *L. iota* has more chambers (13 to 15) in its final whorl. *L. convergens* (Bornemann) has numerous inflated chambers, increasing gradually in size, and these are separated by flush, oblique sutures that fuse into a large umbilical boss. *L. anaglypta* (Loeblich and Tappan) differs from *L. gibba* by having depressed sutures with ornamented, numerous and prominent raised costae. However, the primary apertures of these species are similar to that of *L. gibba*, being radiate and terminal. *L. gibba* from Site U1342 is morphologically similar to the specimen illustrated from the Mediterranean Sea by Kaminski et al. (2002: p. 2, fig. 6) as *L. gibba*, having its aperture as radial slits. Specimens illustrated by Chendeş et al. (2004: pl. 1, fig. 13) from the southern shelf of the Marmara Sea as *L. gibba* d'Orbigny differ from the studied specimens in that the aperture is somewhat oval in shape. Whether this represents intraspecific variation, or this material represents a different species, is unclear.

Distribution: *L. gibba* is cosmopolitan, being typically recorded from the Gulf of Mexico (Sen Gupta et al., 2009; Gupta and Smith, 2010), Caribbean Sea (Wilson and Costelloe, 2011) and at the 'Challenger' stations in the West Indies (Jones, 1994). *L. gibba* has a depth range from 15 to 350 m in the shelf of Marmara Sea (Chendeş et al, 2004) to 714 m in the West Indies (Jones, 1994) and 2918 m in the Gulf of Mexico (Sen Gupta et al., 2009; Gupta and Smith, 2010). Jones (1994) classified *Lenticulina* spp. as indicators of sub-oxic seabed conditions. The stratigraphical range of *L. gibba* is Early Miocene to Recent (Holbourn et al., 2013).

Family LAGENIDAE Reuss, 1862
Subfamily LAGENINAE Brady, 1881
Genus *Lagena* Walker and Jacob, 1798
Type species *Serpula (Lagena) sulcata* Walker and Jacob 1798, designated by Parker and Jones, (1859), p. 337

Lagena hispida Reuss, 1858
Plat 3, figures 8-15.

Lagena hispida Reuss, 1858, p. 335, pl. 6, figs. 77-79.
Lagena hispida Reuss. – BRADY, 1884, p. 459, pl. 57, figs. 1, 2. – CUSHMAN, 1923, p. 26-27, pl. 4, figs. 7, 8. – CUSHMAN, 1946, pl. 39, fig. 13. – BARKER, 1960, p. 116, pl. 57, figs. 1, 2. – JONES, 1994, p. 63, pl. 57, figs. 1, 2. – SEN GUPTA et al., 2009, p. A-9, pl. 89, fig. 1.

Distribution in core: 12 specimens in 8 samples at depths 2.38, 2.60, 8.60, 9.00, 9.25, 16.88, 15.69 and 17.09 m.

Description: Test is unilocular, ovate in outline, flask shaped to globular, circular in cross section. Wall calcareous, hispids are distributed over the test, longer and greater number of hispids around the base of an elongated apertural neck; average dimension of the test is between 0.40 mm and 0.50 mm in length; and between 0.25 mm and 0.33 mm in width/thickness (at the widest diameter). Aperture rounded, terminal at the end of the apertural neck, margin of the aperture possesses a lip; neck varies in length from 0.05 to 0.01 mm.

Remarks: Some of the *L. hispida* recorded in our samples differ from those illustrated by Jones (1994: pl. 57, figs. 1 and 2) in being more elongate (flask-shaped) than globular. This variation in shape is considered intraspecific in accordance with the observation of Cushman (1946) that "under *Lagena hispida*, are included a wide range of forms with somewhat differing shapes"; all the Bering Sea specimens have finely spinose surfaces. Setoyama and Kaminski (2015: fig. 8; 29) illustrated a similar specimen with less densely distributed hispids as *Lagena hispidula* Cushman from the Bering Sea; this is slightly different from our material which has more hispids that are densely distributed on the test, and more at the base of the neck. *L. hispida* is uniquely different from other species of *Lagena* because of the hispids distributed uniformly on its test. In the Bering Sea material, 8 of the specimens have elongated chambers that are flask shaped, ovate in outline, while the rest are globular. Variation in the length of the apertural neck is likely to be related to maturity; smaller specimens have shorter apertural necks.

Distribution: *Lagena hispida* is recorded from the South Atlantic and North Pacific Oceans (Jones, 1994), the Gulf of Mexico (Sen Gupta et al. 2009), and the Caribbean Sea (Wilson and Costelloe 2011). Its water depth ranges from 632 m in the North Pacific to between 1061 and 2918 m in the Gulf of Mexico (Sen Gupta et al., 2009; Gupta and Smith, 2010; Wilson and Costelloe, 2011) to 3477 m in the South Atlantic (Jones 1994). The stratigraphical age of *L. hispida* is not known beyond the Recent (Hesemann, 2013).

Lagena sulcata Walker and Jacob, 1798
Plate 3, figures 16-18.

Lagena sulcata Walker and Jacob, 1798. – BAGG, 1912, p. 122, pl. XIV, fig. 10, 11, 12 a, b. – MICHEAL, 1967, p. 76, pl. 4, fig. 36. – NEAGU, 1975, pl. 69, figs. 18-19. – LOEBLICH and TAPPAN, 1987, p. 415, pl. 455, figs 12-13. – WEIDICH, 1990, p. 122, pl. 40, figs. 25-26; pl. 45, figs. 6, 14. – JONES, 1994, p. 64, pl. 57, figs. 23, 25-27, 33-34; p. 65, pl. 58, figs. 5-6, 18.

Distribution in core: 35 specimens in 20 samples; first occurrence at depth 1.38 m, low but consistence occurrence from 18.55 to 19.44 m.

Description: Test is unilocular, globular, ovate in outline, circular in cross-section; wall is calcareous, prominent and with longitudinal costae which run from the apertural neck to the bottom of the chamber. Test is 0.63 mm in length, 0.33 mm diameter (at its widest diameter); aperture terminal, rounded, at the end of a thin, elongate neck which may be long or short, with hexagonal ornament on the neck.

Remarks: About 60% of the *L. sulcata* examined here are ovate in outline, while the others are rounder. *Lagena sulcata* from the Bering Sea is more elongate than the specimens of this species illustrated in Jones (1994: pl. 54, fig. 1, 2) from the North and Central Pacific and Southern Japan sea. *L. sulcata* is differentiated from *Lagena striata* (d'Orbigny) by the hexagonal ornament on the elongate neck of the aperture (see Jones, 1994, pl. 57, figs. 23, 25-27, and 33-34): both of these species have longitudinal costae as ornamentation on their tests (Jones, 1994: pl. 57, figs. 23; 25-27, 33-34 and fig. 22, 24), but the costae are more prominent, delicate (Bagg, 1912) and fewer on *L. sulcata* than on *L. striata* (d'Orbigny).

Lagena acuticosta (Reuss) differs from *L. sulcata* by having only a few sharp costae, extending over the entire chamber; the species is usually stout and larger. *L. striata* (d'Orbigny) illustrated by Setoyama and Kaminski (2015) is morphologically similar to *L. sulcata* from core U1342 by possessing a neck that is ornamented, and by having costae that run from the apertural neck to the bottom of the chamber.

Distribution: *Lagena sulcata* is a cosmopolitan species with a geographical distribution in the Pacific and Indian Oceans (Jones, 1994; Holbourn and Kaminski, 1997). *L. sulcata* has a bathymetric range from neritic to bathyal. Its water depth ranges from 37 to 4300 m at the 'Challenger' stations in the Pacific Ocean (Jones, 1994). *L. sulcata* is an indicator of sub-oxic conditions (Jones, 1994; Bubenshchikova et al., 2010) and a shallow infaunal species (~ 0-2 cm; Bubenshchikova et al. 2010). The stratigraphical range of *L. sulcata* is recorded as Early Cretaceous to Recent (Neagu, 1975; Weidich, 1990; Holbourn and Kaminski, 1997); however, a stratigraphical range of Miocene to Recent was assigned by Jones (1994).

Lagena nebulosa Cushman, 1923

Plate 3, figure 19.

Lagena leavis (Montagu 1803) var. *nebulosa.* – CUSHMAN 1923, p. 29, pl. 5, figs. 4, 5.
Lagena nebulosa Cushman, 1923. – BARKER, 1960, pl. 56, fig. 12. – JARKE, 1960, pl. 5, fig. 6. – VILKS, 1969, p. 55, pl. 2, fig. 21. – FAGERLIN, 1971, p. 54, pl. 3, fig. 16. – ANDERSON, 1975, p. 83, pl. 5, fig. 12. – O'NIELL, 1981. – BOLTOVSKOY and KAHN, 1983, p. 305, pl. 1, figs. 16-17. – JONES, 1994, pl. 56, fig. 12.

***Distribution in core*:** 3 specimens in 2 samples at depths 0.11 m and 15.95

***Description*:** Test unilocular, globular to rounded, circular in cross section, widest at the middle of the chamber, average dimension of 0.70 mm in length (including the neck), 0.53 mm diameter. Wall calcareous, finely perforate and smooth; aperture is rounded, diameter is ~0.05 mm, terminal, produced on a long neck.

***Remarks*:** Based on published illustrations, this species is variable in shape from elongate to round, globular to cylindrical (Boltovskoy and Kahn, 1983). The three Bering Sea specimens are more rounded and globular.

Distribution: *Lagena nebulosa* has a geographical range in the Atlantic, Pacific and Arctic Oceans (Boltovskoy and Kahn 1983; Jones, 1994; Gross, 2001) and the 'Challenger' Station 279C French Polynesia off the French territories (Jones 1994; Vilks, 1969). Its water depth ranges from 1133 m at the aforementioned the 'Challenger' Station (Jones, 1994) to 5014 m in the Pacific (Jones, 1994). *Lagena* may be an indicator of sub-oxic conditions and has been designated an infaunal species (Kahio 1994; Bubenshchikova et al, 2008). The stratigraphical range is not known beyond the Recent (Jones, 1994).

***Lagena* sp. 1**
Plate 3, figures 20-22; Plate 4, figures 1-4.

***Distribution in core*:** 4 specimens at depths 13.30 m, 13.71 m, 14.28 m and 14.88 m.

***Description*:** Test unilocular, globular to ovate in outline, circular in cross-section; walls calcareous, ornamented with about 16-18 longitudinal costae in the form of concentric ridges (with 6-7 prominent longer costae), with alternation of long and short prominent longitudinal costae on the test (about 8 each); the longer costae reach to the apertural end, while the shorter costae terminate before getting to the base of the neck. Test size is twice as long as broad, average dimension of 0.58 mm in length, 0.26 mm in diameter at the widest part of the chamber. Aperture is terminal, rounded at the end of a produced neck.

***Remarks*:** *Lagena* sp. 1 differs from *Lagena strumosa* Reuss illustrated by Milker and Schmiedl (2012; fig. 18, 34) from the Western Mediterranean Sea, which has a crown-like aperture on a long neck that is covered by concentric ridges. *L. multicostata* Copeland (reproduced in Ellis and Messina, 1940) from the Eocene and Miocene of North Carolina is differentiated from *Lagena* sp.1 by its smaller size and the slightly tapering neck with horizontal annulations. Jones (1994) illustrated *Cushmanina desmophora* (Jones 1872) as a morphologically similar species from the 'Challenger' Station in the North Pacific and the Atlantic Oceans, but this differs from *Lagena* sp. 1 by the hollow that is present on the pronounced longitudinal costae.

***Lagena* sp. 2**
Plate 4, figure 5, 6.

***Distribution in core*:** 1 specimen at depth 15.23 m

Description: Test unilocular, globular, ovate in outline, circular in cross-section; wall is calcareous, ornamented with 6-7 high longitudinal costae which later bifurcate towards the base of the neck about one-fourth the distance along the chamber, and then merge again, forming raised polygonal ridges arranged in a honeycomb pattern around the base of the apertural neck in the form of a collar. This species is 0.50 mm in length, 0.25 mm in diameter at the widest part of the chamber. Aperture is terminal, round, at the end of a short, well-differentiated, smooth neck.

Remarks: *Lagena* sp. 2 resembles *Oolina acuticosta* (Ruess) recorded from the Champlain Sea, New York, Quebec (Cronin, 1977; pl. 2, fig. 15) and *Oolina emaciata* (Reuss, 1862), but differs by having raised polygonal ridges in the form of a honey-comb pattern around the base of the neck. *Oolina emaciata* (Reuss, 1862) has a more broad apertural neck, which is not pitted. *Lagena* sp. 2 is similar to *Lagena bifurcata* LeRoy illustrated in Ellis and Messina (1940), which has a smaller test and is more globose. *Lagena recticulocervix* Poag recorded from the Lower Miocene of Alabama and Mississippi reproduced in the Ellis and Messina Catalogue (1940) differs from this species by having a neck that is ornamented by a reticulate network to which the longitudinal costae are attached, with no distinct aperture.

***Lagena* sp. 3**
Plate 4, figures 7-11.

Distribution in core: 1 specimen at depth 16.21 m

Description: Test unilocular, globular, ovate in outline, circular in cross-section; wall is calcareous, ornamented with 7-8 prominent (thick) longitudinal costate, about 8 less pronounced horizontal short costae lie in a row separating the longitudinal costae, but do not dissect the longitudinal costae themselves, forming a sort of 'square' structure with a conspicuous pore at the centre of each of the 'square' structures. The test of this species is 0.50 mm in length, 0.25 mm in diameter at the widest part of the chamber. Primary aperture is terminal, rounded at the end of a non-distinct, relatively short neck.

Remarks: *Lagena* sp. 3 is similar in size and shape to *Lagena* sp. 2, but differs by having thin horizontal costae in between the pronounced longitudinal costae with pores, and by lacking bifurcate ornament on the apertural neck.

Genus *Procerolagena* Puri, 1954
Type species *Lagena gracilis* Williamson, 1848, designated by Puri (1954), p. 104

Procerolagena gracilis (Williamson, 1848)
Plate 4, figures 12-13.

Lagena gracilis WILLIAMSON, 1848, p. 13, pl. 1, fig. 5. – BRADY, 1884, p. 464, pl. 58, figs. 19, 22-24; - p. 24, pl. 8, figs. 5, 6. – VILKS, 1969, p. 55, pl. 2, fig 17. – ANDERSON, 1975, p. 86, pl. 5, fig. 7. – BOLTOVSKOY and de KAHN, 1983, pl. 1, figs. 12-13.
Procerolagena gracilis (Williamson, 1848). – CLARK and PATTERSON, 1993, fig. 2, 4. – JONES, 1994, p. 65, pl. 58, figs. 9? 11- 15. – PATTERSON, BURBIDGE AND LUTERNAUER, 1998, p. 9, pl. 6, fig. 1
Procerolagena distoma (Parker and Jones). – IGARASHI et al., 2001, pl. 7, fig. 12
Procerolagena gracilis (Williamson, 1848). – RIVEIRO and PATTERSON, 2007, fig. 6, 7.

Distribution in core: 5 specimens in 4 samples at depths 6.37 m, 9.40 m, 16.21 m and 19.22 m.

Description: Test unilocular, elongated into neck-like extensions at both ends of the chambers, average length of test is 0. 85 mm and diameter of 0.16 mm, circular in cross-section, widest near middle of the chambers; wall calcareous, hyaline; 16 to 20 longitudinal costae extend from the base of one neck to the other, in some specimens the costae unite to form an elongate process in the terminal regions; small and circular aperture at the termination of both necks.

Remarks: There is intraspecific variation in the thickness of the longitudinal costae on the chambers among the few specimens studied: 3 out of the 5 specimens have more pronounced costae. *Procerolagena gracilis* is differentiated from *P. gracillima* above. *P. gracilis* differs from *Procerolagena mollis* (Cushman, 1944) by being more bulbous (Riveiros and Patterson, 2007).

Distribution: *Procerolagena gracilis* is typically recorded from the Atlantic, Pacific and Southern Oceans (Cushman 1923; Anderson, 1975; Jones, 1994), and bordering seas (Vilks, 1969; Boltovskoy and de Kahn, 1983 and Jones, 1994). *P. gracilis* ranges from 117 and 137 m depth in the North Atlantic (Jones, 1994) to 300 m in waters of the Canadian Arctic (Vilks, 1969), to 631 m in the East Pacific (Jones, 1994). The stratigraphical range of *P. gracilis* is from Holocene to Recent (Hesemann, 2014)

Procerolagena gracillima (Seguenza, 1862)
Plate 4, figures 14-15.

Amphorina gracillima SEGUENZA, 1862, p. 51, pl. 1, fig. 39.
Lagena sulcata var. *distoma polifa* PARKER and JONES, 1865, p. 357, pl. 13, figs. 8, 21.
Lagena gracillima (Seguenza). – BRADY 1884, p. 456, pl. LVI, figs 19-28. – BAGG, 1912, pl. 13, fig. 3. – LOEBLICH and TAPPAN, 1953, p. 60, pl. 11, figs. 1-4. – CRESPIN, 1960, pl. 1, fig. 14. – COLE and FERGUSON, 1975, pl. 5, fig. 12.
Hyalinonetrion gracillimum (Seguenza). – CIMERMAN and LANGER, 1991, p. 52, pl. 55, figs.1, 2
Hyalinonetrion gracillis (Costa). – HOTTINGER, HALICZ and REISS, 1993, p. 78, pl. 90, figs. 7, 8
Procerolagena gracillima (Seguenza). – JONES, 1994, p. 62, pl. 56, figs. 19-22, 24–2 [cop. Brady, 1884, figs. 19-22, 24-29].
Hyalinonetrion gracillimum (Costa). –MILKER and SCHMIEDL, 2012, p. 74, fig. 18. 30.

Distribution in core: 5 specimens in 4 samples at depths 8.86m, 16.21 m, 18.26 m and 19.44 m respectively.

Description: Test elongate, slender and tubular, wall calcareous, hyaline and smooth; test straight and slightly bulbous at the middle of the test, widest diameter at the centre of the test; the best preserved specimen has an average length of 0.65 mm and diameter of 0.21 mm; test typically straight, long tapering extension at each end of the test. Aperture is terminal and rounded, on a long, tapering neck at both ends.

Remarks: *Procerolagena gracillima* (Seguenza) is similar to *Lagena elongata* (Ehrenberg) except that the test of *L. elongata* is less bulbous and more attenuated, with a relatively short taper at the ends (see Jones, 1994; pl. 56, fig. 29); while *Lagena dentaliformis* Bagg is also similar to *P. gracillima* (Seguenza) but more bulbous at the centre of the test. *P. gracillima* is differentiated from *P. gracilis* by its smooth test surface; *P. gracilis* has 16-20 longitudinal costae that extend from the base of one neck to the other.

Distribution: *P. gracillima* has been reported from South Pacific and North Atlantic Oceans (Parr, 1950; Jones, 1994; Hayward et al. 2012), Southern Ocean (Jones, 1994), Norway (Bagg, 1912) and North Alaska (Loeblich and Tappan, 1953). *P. gracillima* (Seguenza) has a depth range extending from about 25 m water in the Adriatic Sea (Panieri, 2006), to between 45 and 1958 m at the 'Challenger' stations in the Pacific (Jones, 1994), to 4758 m in the Southern Ocean (Jones 1994). The stratigraphical range of *P. gracillima* is Holocene through Quaternary (Hesemann, 2014).

Genus REUSSOOLINA Colom, 1956
Type species *Oolina apiculata* Reuss, 1851, p, 22; original designation

Reussoolina apiculata (Reuss, 1851)
Plate 4, figures 16-19

Oolina apiculata REUSS, 1851, p. 22, pl. 2, fig. 1.
Reussoolina apiculata (Reuss, 1851). – CLARK and PATTERSON, 1993, fig. 2.7. – SETOYAMA and KAMINSKI, 2015, fig. 7.11.
Reussoolina cf. R. *apiculata* (Reuss 1851a). – FINGER, 2013, p. 424, p. 11, fig. 26.

Distribution in core: 8 specimens in 8 samples; the first occurrence is at 0.10 m, intermittent occurrences down core from this level to 20.59 m depth.

Description: Test unilocular, elongate, globular to ovate, test twice as long as wide, average length of 0.63 mm and 0.33 mm at the maximum diameter; wall calcareous, perforate, surface smooth; aperture terminal, radiate or rounded, bordered by radiating grooves, produced on the tip of the chamber on an indistinct apertural neck.

Remarks: *Reussoolina apiculata* specimens from Bering Sea are morphologically similar to one another, having the same form of aperture, and almost the same size. Aboral spine is present in the specimen illustrated by Setoyama and Kaminski (2015: fig. 7.11), *Glandulina laevigata* has close resemblance with *R. apiculata*, but it is characterised by more than one chamber. Most of our specimens are not as well preserved.

Distribution: *R. apiculata* occurs in the SW Pacific Ocean (Clark, 1990), the NW Atlantic Ocean (Friedrich and Hemleben, 2006) and the Bering Sea (Setoyama and Kaminski, 2015) at depth of ~2139 m. The stratigraphical range of *R. apiculata* is from Lower Jurassic to Recent (Loeblich and Tappan, 1987).

Family ELLIPSOLAGENIDAE A. Silvestri, 1923
Subfamily OOLININAE Loeblich and Tappan, 1961
Genus *Cushmanina* R.W. Jones, 1984
Type species *Lagena vulgaris* Williamson var. *desmophora* Jones, (1872), p. 54

Cushmanina striatopunctata (Parker and Jones, 1865)
Plate 4, figure 20

Lagena sulcata Williamson var. *striatopunctata*. – PARKER and JONES, 1865, p. 350, pl. 13, figs. 25-27.
Cushmanina striatopunctata (Parker and Jones, 1865). – CLARK and PATTERSON, 1993, pl. 4, fig. 19. – PATTERSON and RICHARDSON, 1987, pl. 1, 2-6. – WILCOX and TURPIN, 2009, p. 11, pl. 4, fig. 5

Distribution in core: 1 specimen at depth 14.88 m

Description: Test unilocular, conical in outline, circular in cross-section; twice as long as broad; 0.60 mm in length, 0.28 mm in diameter at the widest part near the base of the chamber; wall calcareous, ornamented with 7-8 prominent (high) longitudinal costate, in which one out of three costae reaches the neck of the test; spaces between longitudinal costae roughened by granular shell growth, circular punctae in the form of chains at the base of costae where they merge with the roughened chamber surface. Aperture is rounded, terminal at the end of a distinct, funnel-shaped, narrow and short neck, bordered by thickened collar.

Remarks: *Cushmanina striatopunctata* from the Bering Sea is similar to *C. striatopunctata* illustrated from the southwest Pacific described by Clark and Patterson (1993: fig. 4, 19). *C. striatopunctata* differs from the superficially similar *Lagena* sp. 3 in having punctae associated with the longitudinal costae, and in the form of its neck which is funnel-shaped. The punctae associated with the longitudinal costae are the primary distinguishing character of this species.

Distribution: *Cushmanina striatopunctata* is a cosmopolitan species recorded from the Atlantic and Pacific Oceans (Loeblich and Tappan, 1987; Clark and Patterson 1993), the Mediterranean Sea (Zenetos et al., 2010; Pećarević et al., 2013), and the Gulf of Mexico (Sen Gupta and Smith, 2010). Its stratigraphical range is from Pleistocene to Recent (Patterson and Richardson, 1987).

Genus *Oolina* d'Orbigny, 1839
Type species *Oolina laevigata* d'Orbigny, 1839

Oolina hexagona (Williamson, 1848)
Plate 5, figures 1-3.

Entosolenia squamosa (Montagu) var*. hexagona* WILLIAMSON, 1848, p. 20, pl. 2, fig., 23.
Lagena hexagona (Williamson). – BRADY, 1884, p. 472, pl. 58. Fig. 33. – CUSHMAN and TODD, 1945, p. 33, pl. 5, fig. 14. – CUSHMAN, p. 24, pl. 4, fig. 6 [cop. Williamson, 1848, fig. 23].
Oolina hexagona (Williamson). – BARKER, 1960, pl. 58, fig. 33. – TODD and LOW, 1967, p. A 29, pl. 3, fig. 28. – VILKS, 1969, p. 55, pl. 2, fig. 28. – CRONIN, 1979, p. 795, pl. 3, figs. 7, 11. – HERMELIN and SCOTT, 1985, p. 214, pl. 2, fig. 10.
Favulina hexagona (Williamson). – PATTERSON and RICHARDSON, 1988, p. 250, figs. 32, 33. – LOEBLICH and TAPPAN, 1987, p. 120, pl. 463, figs. 1, 2. – CIMERMAN and LANGER, 1991, p. 55, pl. 58, figs. 8, 9.
Oolina hexagona (Williamson). – HERMELIN, 1989, p. 56, pl. 10, fig. 5. – JONES, 1994, p. 66, pl. 58, fig. 33. – ROBERTSON, 1998, p. 100, pl. 37, fig. 2. – RASMUSSEN, 2005, p. 76, pl. 8, fig. 10.
Favulina hexagona (Williamson). – Chendeş et al., 2004, p. 76, pl. 1, fig. 16. – MILKER and SCHMIEDL, 2012, fig. 19, 4.
Oolina hexagona (Williamson). – HOLBOURN et al., 2013, p. 382.

Distribution in core: 2 specimens from depths 18.55 and 18.67 m.

Description: Test is ovate and unilocular, cross-section circular. Wall calcareous, finely perforate, ornamented with raised polygonal ridges, arranged in a honeycomb pattern, giving rise to hexagonal reticulae pattern, 11-12 stout longitudinal costae together with continuous transverse costae forming numerous hexagonal pits on the test. Average length of the test is 0.60 mm and diameter is 0.48 mm at the widest; test reticulae are arranged in slightly oblique rows. Aperture is rounded, terminal, produced on a short neck.

Remarks: *O. hexagona* from the Bering Sea shows distinctive hexagonal reticulation. *Oolina hexagona* (Williamson) differs from *Oolina melo* d'Orbigny by these hexagonal reticulae: *Oolina melo* d'Orbigny has quadrate reticulae. *O. hexagona* is superficially similar to *Favulina epibathra* described from the Pacific Ocean (by Patterson and Richardson, 1988: p. 250, figs. 30, 31), but this has only 8-10 stout longitudinal costae, which together with the discontinuous transverse costae form rectangular pits on the test. Todd & Low's (1967) specimens from Gulf of Alaska are similar to the Bering Sea specimens.

Distribution: *O. hexagona* (Williamson) is recorded from the Pacific and Arctic Oceans (Vilks, 1969; Jones, 1994) and the Caribbean (Robertson, 1998). It has a bathymetric range from neritic to abyssal, from a water depth extending from 50 m in the Canadian Arctic (Vilks, 1969) to ~4438 m in the 'Challenger'

Station in the south Pacific (Jones, 1994). Cronin (1979) noted that *O. hexagona* is common in Recent Arctic assemblages. The stratigraphic range of *O. hexagona* is Miocene to Recent (Holbourn et al., 2013).

Genus *Fissurina* Ruess 1850
Type species *Fissurina laevigata* Reuss, 1850

Fissurina crebra (Matthes, 1939)
Plate 5, figures 4-11.

Lagena crebra MATTHES 1939, p. 72, pl. 5, figs. 66-70.
Fissurina crebra (Matthes). – BARKER, 1960, p. 122, pl. 59, fig. 6. – BOLTOVSKOY and de KAHN 1983, p. 1, p. 305, figs. 1-2. – ANDERSON 1975, p. 85, pl. 6, fig. 5. – MAJEWSKI, 2005, p. 202, fig. 21, 8. – MILKER and SCHMIEDL, 2012, fig. 19, 7.

Distribution in core: 29 specimens in 12 samples; first occurrence at 1.13 m, intermittent but low abundance occurrences from intervals 5.25 to 18.95 m, highest abundance at 19.22 m.

Description: Test unilocular, ovate in outline, biconvex in cross-section, extended keeled periphery; average length of test is 0.60 mm, and diameter is 0.50 mm at the middle of the test, with thickness of 0.15 mm. Wall calcareous, hyaline, finely perforate and smooth; early part of the chambers sometimes with non-distinct aboral projection (basal spine). Aperture is a curved terminal slit, within a slightly depressed fissure at the test apex.

Remarks: Boltovskoy and Kahn (1983) report that some specimens from the South Atlantic show weak ornament on the aboral part of the test, but this is not present in the Bering Sea specimens. In some of the Bering Sea specimens the keeled periphery is poorly developed.

Distribution: *Fissurina crebra* is found in the Atlantic, Arctic, and Indian Oceans (Boltovskoy and de Kahn, 1983; Anderson, 1975; Majewski, 2005), Japan Sea (Sharma and Takayanagi, 1982) and other regions (Corliss, 1979; Gaby and Sen Gupta, 1985; Milker and Schmiedl, 2012). Its water depth ranges from 235 m in the Japan Sea (Sharma and Takayanagi, 1982) extending to 982 m and 4,600 m in the Indian and Atlantic Oceans respectively (Corliss, 1979; Boltovskoy and de Kahn, 1983; Majewski, 2005; Wilson and Costelloe, 2011; Milker and Schmiedl, 2012). The stratigraphical range of *F. crebra* is from Oligocene to Recent (Boltovskoy and Kahn, 1983).

Fissurina minima Aoki, 1964
Plate 5, figures 12-16.

Fissurina minima AOKI, 1964, pl. 25, figs. 1a, b.

Distribution in core: 8 specimens from 6 samples; absent in the top 14.87 m of the core, intermittent occurrence down core afterwards to depth 20.44 m.

Description: Test small, unilocular, average length 0.175 mm, width 0.15 mm, thickness 0.10 mm, compressed, almost circular in side view, slightly longer than broad, lenticulinar in apertural view, rounded to ovate in outline, oval to biconvex in cross-section, thickness about two-thirds of the test, periphery acute, rounded, not keeled. Wall calcareous, finely perforate; aperture a short ovate to lens-shaped terminal slit at the test apex.

Remarks: *Fissurina minima* are morphologically similar to specimens illustrated from the Boso Peninsula, Japan, by Aoki (1964). It is different from *Fissurina* sp. nov. Illustrated by Jones (1994: pl. 59. Figs. 5 a-c) from the ‘Challenger’ station 241, North Pacific, by its ovate to lens-shaped aperture. It also differs from the similar species illustrated as *Parafissurina caledoniana* McCulloch from the Bering Sea (Setoyama and Kaminski, 2015: fig. 8, 32), which has unequal sides of the curved and more elongated aperture. One of the illustrated specimens of *Fissurina minima* reproduced in the Ellis and Messina catalogue (1940) has close resemblance with the Being Sea material by having its periphery not keeled.

Distribution: *Fissurina minima* have been reported in the Japan Sea (Aoki, 1964). The holotype was reported from Upper Miocene Sasa River exposure, Boso Peninsula (Aoki, 1964).

Subfamily SIPHOLAGENINAE Patterson and Richardson, 1987
Genus *Moncharmontzeiana* Patterson, 2010
Non Pytine Fortey, 1975 (= Trilobite)
Pytine Zei and Sgarrella, 1978
Type species *Pytine parthenopeia* Moncharmont Zei and Sgarrella, 1978

Moncharmontzeiana petaloskelts (Patterson and Richardson, 1988)
Plate 5, figure 16

Pytine petaloskelts PATTERSON AND RICHARDSON, 1988, p. 252, figs. 37-39.
Moncharmontzeiana PATTERSON, 2010 p. 2, figs. 1-5

Distribution in core: 1 specimen from 19.44 m.

Description: Test unilocular, flask shaped, ovate, circular in cross-section; twice as long as broad; 0.55 mm in length (including the neck), 0.27 mm in diameter at the widest part of the chamber; wall is calcareous, translucent, ornamented with 12-13 broad, flattened longitudinal ribs (from the side view) with narrow hollow between each costae; connected together and forming a smooth surface just below the base of the neck; aperture is a small, round opening on a long, narrow terminal tubular neck which makes up about one-third of the length of the test.

Remarks: Patterson (2010) noted that the genus name of the foraminifera *Pytine* Moncharmont Zei and Sgarrella (1978, p. 2), which has its type species as *Pytine parthenopeia* Moncharmont Zei and Sgarrella (1978), is preoccupied by the trilobite genus name *Pytine* Fortey 1975, (type species *Pytine graia*, Fortey, 1975), and therefore proposed *Moncharmontzeiana* as a replacement.

Distribution: *M. petaloskelts* has been recorded from the Quaternary sediments of western Philippine Basin, in the western Pacific Ocean (Patterson and Richardson, 1988).

Family EPISTOMINIDAE Wedekind, 1937
Genus *Hoeglundina* Brotzen, 1948
Type Species *Hoeglundina elegans* (d’Orbigny, 1826)

Hoeglundina elegans (d’Orbigny, 1826)
Plate 6, figures 1, 2.

Rotalia (*Turbinulina*) *elegans* D’ORBIGNY, 1826, p. 276.
Rotalia partschiana D’ORBIGNY, 1846, p. 153, pl. 7, figs. 28 – 30; pl. 8, figs. 1-3.
Rotalia flosculiformis SCHWAGER, 1866, p. 262, pl. 7, fig. 109.
Epistomina bradyi GALLOWAY and WISSLER, 1927, p. 60, pl. 10, fig. 1.
Epistomina flinti GALLOWAY and WISSLER, 1927, p. 61, pl. 9, fig. 16.

Epistomina elegans (d'Orbigny). – CUSHMAN and JARVIS, 1930, p. 365, pl. 34, figs. 1a-c. – LEROY, 1941, p. 40, pl. 1, figs. 5-7.– BERMÚDEZ, 1949, p. 250, pl. 17, figs. 34-36. – PHLEGER and PARKER, 1951, p. 22, pl. 12, figs. 1a, b. – BELFORD, 1966, p. 190, pl. 36, figs. 8-13. – WRIGHT, 1978, p. 723, pl. 5, figs. 15, 16. – VAN MORKHOVEN et al., 1986 , p. 97, pl. 29, figs. 1a, b, 2a, b. – LOEBLICH and TAPPAN, 1987, p. 446, pl. 478, figs. 1-5. – JONES, 1994, p. 104, pl. 105, figs. 3-6. – BOLLI et al., 1994, p. 361, figs. 55; 6-8, 9a-e. – ROBERTSON, 1998, p. 114, pl. 44, fig. 2. – SEN GUPTA et al. 2009, p. A-79, pl. 77, fig. 1-3. – MILKER and SCHMIEDL, 2012, p. 79, figs. 15-16. – HOLBOURN et al., 2013, p. 289, figs. 1-3.– FINGER, 2013, p. 430, pl. 13, fig. 9.

Distribution in core: 6 specimens in 5 samples; first occurrence at 2.44 m, intermittent occurrence down core from this level to 118.95 m.

Description: Test trochospiral, closely coiled, biconvex in cross section and sub-circular in outline, with a sub-acute and keeled periphery. Test medium to large, average dimension is 0.60 mm at the longer diameter, 0.42 mm at the shorter diameter, average thickness 0.30 mm. Chambers about seven to eight in the last whorl, increasing gradually in size, being separated by thick, slightly depressed or flush sutures, curved backwards at the periphery on the spiral side, may be straight and / or oblique on the umbilical side. Chamber walls are calcareous, smooth and finely perforate. Aperture is an elongate, arched latero-marginal slit, parallel to the peripheral keel and opening on the umbilical side.

Remarks: *Hoeglundina elegans* specimens illustrated from the 'Challenger' station in West Indies by Holbourn et al. (2013) are morphologically similar to the Bering Sea specimens. Holbourn et al. (2013) recognise two different apertures on their specimens: a primary and a supplementary aperture. However, it was noted that the primary aperture, which is small and interiomarginal, may be absent in some specimens. All specimens examined from the Site U1342, Bering Sea, do not have this aperture type, but do possess the supplementary aperture type, being an elongate latero-marginal slit, parallel to the peripheral keel and opening on the umbilical side. Kaiho (1994) described *H. elegans* as an indicator of sub-oxic conditions.

Distribution: *Hoeglundina elegans* is a cosmopolitan species, except in the highest latitudes (Holbourn et al. 2013). Its bathymetric range is from neritic to bathyal (<2000 m; van Morkhoven et al., 1986). It has been recorded at a water depth between 182 to ~382 m in the Atlantic (Jones 1994), and the Pacific Oceans (Jones 1994), 245 m in the Northern Gulf of Mexico (Sen Gupta et al. 2009) and 709 m from a 'Challenger' station in the West Indies (Holbourn et al. 2013). *H. elegans* ranges from the Late Eocene to Recent.

Order BULIMINIDA Saidova, 1981
Superfamily BOLIVINACEA Saidova, 1981
Family BOLIVINIDAE Glaessner, 1937
Subfamily BOLIVININAE Glaessner, 1937
Genus *Bolivina* d'Orbigny, 1843
Type species *Bolivina plicata* d'Orbigny, 1839

Bolivina spissa (Cushman, 1926)
Plate 6, figures 3-14.

Brizalina spissa Cushman, 1926, pl. 6, figs. 8a-b.
Bolivina spissa Cushman. – BANDY, 1953, pl. 24, figs. 5 a-b. – BERGEN, 1979, p. 1273, pl. 3, fig. 25; p. 1275, pl. 4, figs. 30, 31. – INGLE et al., 1980, p. 137, pl. 3, figs. 13, 14. – WHITTAKER, 1988, p. 102, pl. 11, figs 17- 20. – MALMGREN and FUNNELL, 1991, p. 157, pl. 1, fig. 9. – BERNHARD et al., 2001, p. 2243, fig. 4, M.

***Distribution in core**:* 444 specimens in 55 samples; relative high occurrence at the top part of the core between depths 0–0.51 m, and moderately abundant between 18.43–19.22 m.

Description: Test elongate, slightly flattened, chambers initially uniserial, later biserially arranged forming alternate pairs, width broadened as new chambers are added, last two chambers weakly inflated, oval in cross-section, periphery is sub-acute; average test dimension is between 0.25 and 1.18 mm in length, 0.13 and 0.43 mm in width, 0.08 mm in thickness; while the average test length / width ratio is 2.7 (0.70/0.26). Wall is calcareous, perforate; striae on the early portion of the test runs longitudinally on the first and other early chambers. An apical spine is usually present, later part of the chambers smooth (near the aperture); pores are conspicuously absent near to, and on, the sutures. Chambers numerous (microspheric form has more chambers than the megalospheric form), six to eleven pairs in adult, last three pairs making up half of the test. Sutures slightly depressed, forming a groove towards the last chamber, often wide, curved and tangential to the edge of the chamber, making an angle of about 45 degrees with the edge of the test. Average proloculus diameter is 0.016-0.018 mm in microspheric form, 0.05-0.12 mm in megalospheric form. Aperture is a loop-shaped slit, bordered by a narrow lip. Species is strongly dimorphic: megalospheric form having a large proloculus with fewer numbers of chambers.

Remarks: *Bolivina seminuda* Cushman is differentiated from *B. spissa* by its slightly depressed and narrow sutures on the chambers that are almost normal to the median line (Scripps, 1940); *B. seminuda* also has more pointed chambers in the initial part of the test. Pore density in *B. seminuda* is more than double that of *B. spissa,* with the pore diameter slightly smaller than that of *B. spissa* (Glock et al. 2011). Generally, the number of pores varies in *B. spissa* within a single test; there are more pores on the later chambers than on the earlier chamber. The pore-densities on the test vary from 013 P/μm^2 to 0.0104 P/μm^2; while pore diameter varies randomly within a chamber and across the chambers with an average diameter of 4.11 µm.

About 85% of the specimens examined are megalospheric (the product of sexual reproduction), having a pronounced proloculus. The number of chambers increases with increase in length of the test (fig. 1: $r^2 = 0.7374$). There is a wide range of intraspecific variations in the size of *B. spissa* within assemblages: the length varies randomly from 0.25 to 1.18 mm, while width ranges from 0.13 to 0.43 mm down core. Assessment of *B. spissa* pore density shows random variation across intervals, which include horizons determined to signal different levels of water column oxygenation based on sedimentary characteristics (laminated and non-laminated intervals), and associated benthic foraminifera (deep infaunal species).

Distribution: *Bolivina spissa* has a geographical distribution that extends from the Pacific Ocean (Bandy 1953; Kennett, 1995; Schönfeld and Spiegler, 1995; Bernhard et al., 2001; Ohkushi et al., 2003; Bubenshchikova et al., 2010), and includes the Weddell and Japan Seas (Mackensen et al., 1990; Sharma and Takayanagai, 1982; Kitazato and Ohga, 1995; Nomaki et al., 2008; Noda et al., 2008) and other seas (Bergen, 1979; Bergen, 1979; Ingle et al., 1980; Nomaki et al., 2008). Its water depth ranges from 135 m in Japanese waters (Sharma and Takayanagai, 1982; Kitazato and Ohga, 1995) to between 595 and 1174 m in the Gulf of Alaska (Ohkushi et al., 2003), to a greater water depth of 4500 m in the Pacific Ocean (Smith, 1963; Bergen, 1979; Ingle et al., 1980; Bernhard et al., 2001; Ohkushi et al., 2003; Nomaki et al. 2008; Bubenshchikova et al., 2008, 2010). *B. spissa* is a deep infaunal species and has been considered an indicator of dysoxic conditions (Kaiho, 1994; Ohkushi et al., 2003; Bubenshchikova et al., 2008; 2010). *B. spissa* has been recorded in the Pleistocene to Recent (Smith, 1963).

***Bolivina* sp. 1**
Plate 6, figure 16-20; Plate 7, figures 1-3.

Distribution in core: 110 specimens in 15 samples: consistent occurrence at the top of the core between depth interval 0 and 0.25 m, highest abundance occurrence between depth 6.11 and 6.37 m, few intermittent occurrence down core.

Description**:** Test small, elongated biserial, tapered, twice as long as wide, average length ranges between 0.20 and 0.32 mm, width 0.15 and 0.22 mm at the widest. Wall calcareous, slightly lobulate at the periphery, chambers indistinct, and typically between 8 to 10, increasing gradually in size as added; first chamber slightly rounded; surface rugose; sutures sinuous may be oblique and depressed; aperture a basal opening surrounded by a small lip; apertural face slants at about 45^0.

Remarks**:** *Bolivina* sp. 1 is similar to *Bolivina variabilis* (Williamson) recorded from the western Mediterranean Sea (see Milker and Schmiedl 2012: figs. 19, 25, 26), which has pronounced pores on the rugose test. *Bolivina lutea* Sliter, illustration reproduced in the Ellis and Messina catalogue (1940), has a rugose test surface and differs from this species in being smaller and less robust. *Bolivina subreticulata* Parr, illustrated from the Holocene of the Indian Ocean and the Red Sea by Gupta (1994), is similar to *Bolivina* sp. 1 having a rugose test and an apertural face that slants at about 45^0, but differs with the suture being raised along the median line.

Morphologically similar *Bolivina substriatula* was described by Keller (1980) from the Japan Trench area, but can be differentiated from *Bolivina* sp. 1 by the prominent pores on the rugose surface of the chamber. About 20% of the specimens described here have a lobulate periphery, the degree of roughness in the ornamentation on the chambers varies; depressed areas are somewhat smooth in some specimens. There is intraspecific variation in the number of chambers on the specimens within the assemblage; the average number of chambers per specimen varies randomly from 8 to 10, this seems not related to different levels of water column oxygenation, based on the low percentage of associated species (i.e deep infaunal) recorded at these intervals and on absence or reduced sedimentary lamination.

***Bolivina* sp. 2**
Plate 7, figure 4.

Distribution in core**:** 1 specimen from depth 1.38 m; absent otherwise.

Description**:** Test small, elongate biserial, gradually tapering, average test length ranges between 0.22 and 0.37 mm, 0.15 and 0.30 mm at the widest in the last two chambers. Wall calcareous, slightly lobulate at the periphery; chambers number 10 to 12, having basal projections, adjacent to the depressed central axis of the test, becoming pronounced in the middle chambers. Chambers irregular, first chamber weakly rounded, increasing gradually in size as added; surface rugose, sutures sinuous, not distinct, may be oblique and depressed; aperture a basal opening surrounded by a small lip; apertural face slants at about 45^o.

Remarks**:** *Bolivina* sp. 2 is similar to *Bolivina* sp. 1 recovered from Site U1342, but differs in being longer in length, having more inflated chambers with a lobulate periphery; also differs from *Bolivina lutea* Sliter described from the Recent of Santa Monica Bay, California (reproduced in Ellis and Messina, 1940) which has more chambers, and *Bolivina palantia* Poag from the continental shelf of Texas (Gulf of Mexico) which is coarsely perforate at the sides of the chambers, but non-perforate in the later chambers. Only one specimen of *Bolivina* sp. 2 is recorded, this is not enough for any meaningful identification

***Bolivina* sp. 3**
Plate 7, figures 5-16.

Distribution in core: 25 specimens in 22 samples; first occurrence at the top of the core 0 to 0.10 m, intermittent occurrence down core to 19.44 m.

Description: Test initially uniserial, rapidly becoming biserial, elongate, forming alternate pairs of chambers, weakly flattened, oval in cross-section; width broadened as new chambers are added; average dimension of *Bolivina* sp. 2 is between 0.22 and 0.92 mm in length, 0.13 and 0.37 mm in width, 0.08 mm in thickness; average length / width ratio of *Bolivina* sp. 2 is 2.8 (0.62/0.22). Wall calcareous, smooth, finely perforate (visible with high magnification on the SEM); two distinct striae on the early portion of the test, run longitudinally through the middle of the test at various lengths to later chambers of the specimens; chambers six to eight pairs in adults. Sutures slightly depressed, forming a groove towards the last chamber where longitudinal striae are weakly developed. Aperture a loop shaped slit on the last chamber.

Remarks: *Bolivina* sp. 3 is similar to *B. spissa* but differs by having striae on the early portion of the test, which run longitudinally through the middle of the test to the later chambers at various lengths. Pores are conspicuously present on the chambers *of B. spissa*; this can only be spotted under a high magnification (i.e SEM) on *Bolivina* sp. 3. *Bolivina* sp. 3 has fewer chambers when compared with *B. spissa* described from the Pacific Ocean (Bergen, 1979: p. 1273, pl. 3, fig. 25; p. 1275, pl. 4, figs. 30 and 31; Ingle et al., 1980: p. 137, pl. 3). *Bolivina* sp. 3 differs from *Bolivina seminuda* Cushman illustrated by Glock et al. (2011) from the Pacific coast off Peru, which are conspicuously perforate. There is intraspecific variation in the number of chambers on the specimens, but circa 80% have seven to eight pairs of chambers, irrespective of the size.

Genus *Brizalina* Costa, 1856
Type species *Brizalina aenariensis* Costa, 1856

Brizalina earlandi Parr, 1950
Plate 7, figures 17-21.

Brizalina earlandi PARR, 1950, pl. 12, figs. 16 a-c.
Bolivina punctata d'Orbigny. – BRADY, 1884, pl. 52, figs. 18-19; pl. II, fig. g.
Brizalina earlandi Parr. – BARKER, 1960. pl. 52, figs. 18-19. – JONES, 1994, pl. 52, figs. 18-19. – HUGHES and GOODAY, 2004, pl. 2, fig. g. – ABU-ZIED, 2012, p. 7, pl. 4, fig. 14.

Distribution in core: 480 specimens in 35 samples; intermittent occurrence from the top of the core down to 20.18 m; highest abundance between depth intervals 0 to 0.38 m and at 10.87 m.

Description: Test elongate, biserial throughout, initial end of the test rounded in outline; wall calcareous, distinctly perforate, pores at the distal part of each chamber near the preceding, coarser pores concentrated at the top of the sutures, last chamber (near the aperture) without pores. Ten to fourteen chambers which broaden slightly in the later stages, slightly inflated as added. Average length of the test ranges between 0.20 and 0.90 mm, width 0.22 and 0.30 mm, average length / width ratio is 1.75 (0.42/0.24); sutures oblique, slightly depressed; aperture a slit-like opening extending up the apertural face, bordered with a thick lip in the form of the letter 'U'.

Remarks: About 95% of specimens described here have their test rounded in shape, whilst others are slightly ovate. *B. earlandi* illustrated by Hughes and Gooday (2004: p. 1479, pl. II, fig. g) from the North Atlantic are more ovate to flattened in shape. The specimens from Site U1342 are very similar to those from the Red sea (Abu-Zeid, 2012: fig. 4, 14). Apart from slight variation in test shape, specimen morphology is very uniform in the Bering Sea assemblages.

Distribution: *Brizalina earlandi* was originally described from the seas around Heard Island in the Southern Ocean (Jones, 1994). It is a cosmopolitan species, which has a geographical distribution in the Atlantic and Pacific Oceans (Jones, 1994; Hughes and Gooday, 2004; Jorissen et al., 2009), the Red Sea (Abu Zeid, 2012; Ramadan, 2012). Its water depth ranges from ~70 to 5087 m (Jones, 1994, Hughes and Gooday, 2004; Jorissen et al., 2009; Abu-Zeid, 2012). The stratigraphical age of *B. earlandi* beyond the Quaternary is not known (this study).

Brizalina alata (Seguenza, 1862)
Plate 8, figures 1-10

Vulvulina alata SEGUENZA, 1862, p. 115, pl. 2, figs. 5, 5a.
Bolivina alata (Seguenza). – CUSHMAN, 1937, p. 106, pl. 13, figs. 3-11. – RENZ, 1948, p. 116, pl. 6, fig. 26; pl. 12, fig. 12. – INGLE et al., 1980, p. 137, pl. 2, fig. 12. – CIMERMAN and LANGER, 1991, p. 59, pl. 61, figs. 12–14. – BOLLI et al., 1994, p. 339, figs. 78, 4-5, 73. – MERIC et al., 1995, pl. 6, figs. 8a-c. – den DULK et al., 1998, pl. 2, fig. 6. – ABU-ZIED, 2008, p. 51, pl. 1, fig. 25. – SEN GUPTA et al., 2009, p. A-16, pl. 14, figs. 1-3.
Brizalina alata (Seguenza). – BARKER, 1960, p. 108, pl. 53, figs. 2-4. – POAG, 1981, p. 43, 44, pl. 23, fig. 2, pl. 24, figs. 2a-c. – DENNE, 1990, pl. 2, fig. 2. – VAN MARLE, 1991, p. 166, pl. 17, figs. 1-2. – JONES, 1994, p. 58, pl. 53, figs. 2-4. – AKINMOTO, 1994, p. 289, pl. 2 figs. 1a, 1b. – CHENDEŞ et al., 2004, p. 78, pl. 2, fig. 1. – POPESCU and CRIHAN, 2005, p. 391, pl. 1, figs. 17, 18. – HOLBOURN et al., 2013, p. 76.

Distribution in core: 199 specimens in 30 samples; relatively abundant at the top of the core between depths 0 to 0.51 m, 10.78 to 11.63 m and at 19.22m; intermittent occurrence down core at other levels to 19.22 m.

Description: Test is biserial, flattened, sub-triangular and elongate in shape, lobulate in outline, elliptical in cross-section; average length ranges between 0.45 and 0.98 mm, width 0.22 and 0.40 mm, average length / width ratio is 2.3 (0.71/0.31), test periphery sharp, acute to carinate, serrate with an imperforate carina, extending into a spinose (relatively sharp downward-pointing) carina that merges into the peripheral keel projection at the edge of each chamber. Walls calcareous, finely perforate, imperforate around the early chambers and peri-apertural area; chambers distinct and perforate, arranged adjacent to each other, average of ten to thirteen, increasing broadly in size as added rather abruptly in early chambers, early chambers compressed, weakly inflated and separated by curved, slightly depressed sutures which are oblique and distinct; aperture an elongate, lens-shaped terminal opening with a bordering lip and an internal toothplate.

Remarks: The Bering Sea specimens are similar to specimens illustrated by Chendeş et al., (2004; p. 2, fig. 1) and Kaminski et al., (2002: pl. 2, fig. 12) from the Sea of Marmara in shape, size, number of chambers, and the form of perforations on chambers. Based on morphological comparison, *Brizalina alata* is likely to be the species reported from the Mediterranean Sea and Arabian Sea as *Bolivina alata* (Seguenza) by Abu-Zied (2008: p. 51, pl. 1, fig. 25); and den Dulk et al. (1998: pl. 2, fig. 6). Generally, *B. alata* differs from the superficially similar *Bolivina pisciformis* (Galoway and Morrey) and *Bolivina alazanensis* (Cushman) in possessing fewer chambers that are slightly more inflated, and by having a relatively sharp, downwards pointing carina; *B. alata* also differs from *Brizalina barbata* (Phleger & Parker) which has a wider carina that extends along the entire periphery of the final chamber, forming an apertural lip; *Brizalina spathulata* (Williamson) is morphologically similar, but differs by its more flattened shape. Despite the relatively low abundance of this species in the Bering Sea samples, intraspecies variation is noticed; about 12% of the specimens examined have their first few chambers compressed, while others are elongate.

Distribution: *Brizalina alata* is recorded from the Pacific Ocean (Jones, 1994), European waters and the Mediterranean Sea (Gross, 2001; Kaminski, 2002), the Gulf of Mexico (Sen Gupta et al., 2009), Arabian

Sea (den Dulk et al, 2000) and other seas (Akimoto, 1994; Kuhnt et al., 2007; Jones, 1994; Popescu and Crihian, 2005). *B. alata* occurs at depths extending from 91 m in the Pacific (Jones, 1994) to 350 m in the Sea of Marmara (Chendeş et al., 2004); to between 1265 and 1470 m in the Arabian Sea (den Dulk et al, 2000) and Okhotsk Sea (Bubenshchikova et al., 2010). *B. alata* is considered a deep infaunal species, characteristic of oxygen-depleted sediments (Kaiho, 1994; den Dulk et al, 2000; Bubenshchikova et al. 2010). The stratigraphical age of *B. alata* is from Early Miocene to Recent (Van Marle, 1991; Jones, 1994).

Superfamily CASSIDULINACEA d'Orbigny, 1839
Family CASSIDULINIDAE d'Orbigny, 1839
Subfamily CASSIDULININAE d'Orbigny, 1839
Genus *Cassidulina* d'Orbigny, 1826
Type species *Cassidulina laevigata* d'Orbigny, 1826

Cassidulina teretis Tappan, 1951
Plate 8, figures 11-15

Cassidulina teretis TAPPAN, 1951, p. 7, figs. 30 a-c. – LOEBLICH and TAPPAN, 1953, p. 121. – BARKER, 1960, p. 110, pl. 54, fig. 1. – LAGOE, 1977, pl. 5, figs. 15, 16. – RODRIGUES et al., 1980, pl. 5, figs. 1, 4, 7; pl. 6, figs. 7, 10. – FEYLING-HANSSEN, 1980, p. 184, pl. 1, figs. 22. 9, 10. –MACKENSEN and HALD, 1988, p. 19, pl. 1, figs. 8-15; pl. 1, figs. 6-8. – GOODAY and LAMBSHEAD, 1989, fig. 1H, I, pl. 2, fig. e. – SEIDENKRANTZ, 1995, pl. 1, figs. 12-13, pl. 2, figs. 15-18. – JONES, 1994, p. 59, pl. 54, fig. 1. – WOLLENBURG and MACKENSEN, 1998, p. 3, figs. 12, 13. – GOODAY and HUGHES, 2002, pl. 2, fig. E; - HOLBOURN et al., 2013, p. 138. – CRONIN, 2019, p. 118, pl. 1, figs. 6-13; pl. 2, figs. 1-10, 12.

Distribution in core: 363 specimens in 52 samples; consistent occurrence at intervals between 0 to 2.78 m, followed by intermittent occurrence down core from this interval; highest abundance between intervals 15.69 to 17.09 m.

Description: Lenticular, planispiral test that is biconvex in cross-section, with an average diameter between 0.25 and 0.75 mm and thickness between 0.10 and 0.25 mm; the test possesses a clear umbilical boss on each side, and an acute, keeled periphery. Wall is calcareous and perforate, surface smooth, composed of clear calcareous material; sutures weakly developed on the surface, gently curved. Chambers are coiled and biserially arranged, alternating on the two sides of the peripheral keel, about eight to ten weakly inflated chambers, oval to sub-triangular shaped. Aperture is narrow, elongate, slit-like, extending from the base of the final chamber to the peripheral keel.

Remarks: This species was originally described from the Gubik Formation (Pleistocene) of Alaska by Tappan (1951). *C. teretis* is morphologically close to *C. laevigata* (Mackensen and Hald, 1988). In the Bering Sea material, *C. teretis* is differentiated from *C. laevigata* by its larger size; *C. laevigata* is between 0.20 and 0.45 mm in diameter, 0.10 and 0.15 mm in thickness, while *C. teretis* is between 0.25 and 0.75 mm diameter; 0.10 and 0.25 mm thickness. *C. laevigata* has well developed pores and a ridge near the aperture, while this is absent in *C. teretis* (Mackensen and Hald, op. cit., pl. 1 fig. 1-15). The major difference between these two species aside their size, is the possession of a boss-like umbilical structure on each side of the test of *C. laevigata*, which is absent in *C. teretis. C. teretis* has a peripheral edge which is not carinate, and an aperture that is not as elongated as in *C. laevigata.*

Cassidulina teretis differs from *C. limbata* Cushman and Hughes by its wider chambers, which are more elongate in shape, and by its slit-like aperture. *C. teretis* differs from superficially similar *Islandiella helenae* on the basis of apertural features and the radial wall structure. *I. helenae* has a relatively short and broad apertural slit with a free apertural tongue, whereas *C. teretis* has a narrow apertural slit with a lip (Feyling-Hanssen and Buzas, 1976). *C. teretis* and *C. neoteretis* Seidenkrantz differ in the shape of their apertural lip, and by the smaller size of *C. neoteretis* (see Seidenkrantz, 1995: pl. 1, figs. 12-13; pl. 2, figs. 15-18).

Distribution: The geographical distribution of *C. teretis* ranges through the Atlantic, Arctic and Pacific Oceans (Butt, 1980; Jones, 1994; Seidenkrantz, 1995; Wollenburg and Mackensen, 1998; Seidenkrantz, 1995; Gooday and Hughes, 2002; Hughes and Gooday, 2004; Cronin, 2019) and other seas (Mackensen and Hald, 1988; Gross, 2001). *C. teretis* has a water depth from 50 to 2000 m in the Arctic Ocean (Seidenkrantz, 1995) to 2982 m in the North Atlantic (Jones, 1994). *C. teretis* may be an indicator of sub-oxic conditions (Kaiho, 1994), and has been shown to increase in abundance after phytoplankton blooms (Gooday and Lambshead, 1989). The known stratigraphical range of *C. teretis* is Pliocene to Recent (Jones, 1994).

Cassidulina laevigata d'Orbigny, 1826
Plate 8, figures 16-19; Plate 9, figure 1

Cassidulina laevigata D'ORBIGNY, 1826, p. 282, no. 1 pl. 15, figs. 4, 5. – BRADY, 1884, p. 428, pl. 54, figs. 1-3. – FEYLING-HANSSEN et al., 1976, pl. 7, figs. 20-21; pl. 18, fig. 12. – SEJRUP et al., 1981, p. 291, pl. 1, fig. 5. – SCOTT, 1987, p. 327, pl. 2, fig. 10. – MACKENSEN and HALD, 1988, pl. 1, figs. 1-7. – JONES, 1994, pl. 54, figs. 2, 3. – POPESCU and CRIHAN, 2005, p. 391, pl. 3, figs. 6-9. – MENDES et al., 2012, fig. 3, nos. 4a and 4b.
Cassidulina laevigata carinata Cushman. – COLOM, 1952, pl. 4, figs. 25, 26.
Cassidulina carinata Silvestri. – MURRAY, 1971, pl. 7. –RODRIGUES, HOOPER and JONES, 1980, pl. 5, figs. 3, 6, 9.
Cassidulina neocarinata Thalmann. – RODRIGUES, HOOPER and JONES, 1980, pl. 5, figs. 2, 5, 8.

Distribution in core: 1353 specimens in 35 samples; first occurrence at 1.98 m, consistent occurrence between 5.26 and 6.52 m; highest abundance between depths 5.41 and 5.74 m.

Description: Small lenticular and flattened test, ovoid to nearly circular in lateral shape, with acute periphery; average test dimensions are between 0.20 mm and 0.45 mm in diameter, 0.10 mm and 0.15 mm in thickness. Test wall calcareous, perforate, surface smooth; chambers sub-triangular, biserially arranged, tend to become strongly carinate; sutures pronounced and depressed, radial to oblique, straight to curved in some specimens, acute periphery which is variable, may become strongly carinate, chambers taper towards the umbilicus, distinct non-perforate, umbilical region consisting of clear test material. Aperture is an elongate slit-like opening with a lip or a flap formed by the infolded chamber walls, situated at the base of the apertural face, almost parallel to the peripheral margin.

Remark: Differences between *C. laevigata* and *C. teretis* have been described above (see 'Remarks' for *Cassidulina teretis*).

The Bering Sea material is very similar to Middle Miocene *C. laevigata* illustrated from Romania by Popescu and Crihan (2005: pl. 3, figs. 6-9), and Sejrup et al. (1981: p. 291, pl.1, fig.5), in having depressed sutures, pronounced pores and an elongate slit-like aperture at the apertural face which is parallel to the peripheral margin. The Bering Sea specimens are similar to those from the northern North Sea (Mackensen and Hald 1988: pl. 1, figs. 1-7). No significant intraspecies variation is noticed in the Bering Sea assemblages.

Distribution: *Cassidulina laevigata* is cosmopolitan, being recorded from the Atlantic, Pacific and Indian Oceans (Keller, 1980; Ingle et al., 1980; Schönfeld and Spiegler, 1995; Bubenshchikova et al., 2010; Lutze, 1980; Mackensen et al., 1985; Levy et al. 1998; Austin and Evans, 2000; Asteman and Nordberg, 2013, Mazumder et al., 2003; Jian et al., 1999; Corliss, 1979), the North Sea (Mackensen and Hald 1988), and other seas (Kurbjeweit et al., 2000; Kuhnt et al., 2007; Wilson and Costelloe 2011; Mendes et al., 2012; Erbs-Hansen et al., 2012). *C. laevigata* is found mostly in boreal environments (Phleger et al., 1953; Murray, 1971; Lutze and Coulbourn, 1984).

Cassidulina laevigata has a depth range extending from 270 to 3300 m in the Atlantic (Sejrup et al., 1981; Mackensen et al., 1985; Levy et al., 1998; Jian et al., 1999; Mazumder et al., 2003; Bubenshchikova et al., 2010), to 5600 m in the Indian Ocean (Mazumder et al., 2003; Corliss, 1979). *C. laevigata* is described as an indicator of suboxic conditions and as a shallow infaunal species (Kaiho, 1994, Bubenshchikova et al., 2010; Asteman and Nordberg, 2013). The stratigraphical range of *C. laevigata* is from Middle Pleistocene to Recent (Bergamaschi, 2012).

Cassidulina reniforme Nørvang, 1945
Plate 9, figures 6-14.

Cassidulina crassa d'Orbigny var. *reniforme* NØRVANG, 1945, p. 41, fig. 6 c-h.
Cassidulina crassa d'Orbigny. – KNUDSEN 1975, pl. 1, figs. 5-6.
Cassidulina barbara BUZAS, 1965, p. 25-26, pl. 25, figs 2a, b, 3.
Cassidulina reniforme Nørvang. – SEJRUP and GUILBAULT, 1980, p. 79, fig. 2 F-K. – FEYLING-HANSSEN 1980, p. 184, pl. 1, figs. 9, 10. – RODRIGUES et al., 1980, p. 58, pl. 2, figs. 2, 4, 6; pl. 3, figs. 3, 6, 9, 11, 12; pl. 5, figs. 10-12. – SEJRUP et al., 1981, p. 291, pl. 1, fig.7. – VILKS et al., 1982, p. 227, fig. 22a, 22b. – SCOTT, 1987, p. 327, pl. 2, figs. 11-12. – WOLLENBURG and MACKENSEN, 1998, p. 179, pl. 3, figs. 14, 15. – GUSTAFSSON and NORDBERG, 2001, pl. 1, fig. 8. – PATTERSON and KUMAR, 2002, p. 122, pl. 2, figs. 12, 18. – POLYAK et al., 2002, p. 261, pl. 2, fig. 12.

Distribution in core: 2063 specimens in 188 samples; relatively consistent occurrences down core to 20.59 m, highest abundance at depths 1.58 m and 5.87 m.

Description: Test sub-globular, average dimension of between 0.37 and 0.92 mm at the maximum diameter, 0.35 and 0.62 mm thickness (~80% of the specimen have average dimension of their test diameter between 0.60 and 0.92 mm); rounded in cross-section, thick and rounded periphery. Wall calcareous with fine pores; opaque-white, chambers indistinct, inflated and biserially connected; number of chambers is between 4 and 6 with sutural lines that are nearly flush with the chambers and sometimes not visible; peripheral edge shows no lobulation. Aperture is an elongate to fairly wide, curved, slit-like opening, situated in a depression on the apertural face, having a flap attached to the upper edge of the apertural opening, surrounded by a lip on the outer margin.

Remarks**:** *Cassidulina reniforme* is distinguished from the closely related species *C. obtusa* (Williamson) by the position of its apertural face. *C. obtusa* has a characteristic depression, or fold, which may develop in the apertural face, perpendicular to the aperture itself (Sejrup et al., 1980). The Bering Sea material is morphologically similar to *C. reniforme* from the Norwegian continental margin described by Sejrup et al. (1981: p. 291, pl.1, fig. 7), Sejrup and Guilbault (1980: p. 79, fig. 2F-K) in having nearly flush sutural lines, and an elongated to fairly wide slit-like opening, situated in a depression on the apertural face that is surrounded by a lip on the outer margin. The Bering Sea specimens differ from those illustrated by Gustafsson and Nordberg (2001: pl. fig. 8) and Davidsson et al, (2013: pl. 1, fig. 10) as *C. reniforme* from the Swedish Baltic coast, which has pronounced pores on the test. Most of the materials recovered from the Bering Sea are well preserved (probably because they are thick-walled) except near the aperture in some specimens, where parts of the tests are broken. Circa 80% of the specimens have average dimension of their test diameter between 0.60 and 0.92 mm.

Morphological assessment of *C. reniforme* specimens recovered from Bering Sea Site U1342 (the top 20.59 m), which incorporates horizons determined to signal different levels of water column oxygenation (based on sedimentary characteristics and associated benthic foraminifera), show slight but random variations in the test sizes: this variation seems to be related to maturity rather than ecological factors.

Distribution: *Cassidulina reniforme* has a geographical range from the North Atlantic, Pacific and Arctic Oceans (Rodrigues et al., 1980, Vilks et al., 1982; Scott and Vilks, 1991; Wollenburg and Mackensen, 1998; Polyak et al., 2002; Ohkushi et al., 2003, Khusid et al., 2005; Rasmussen et al., 2007; Ovsepyan et al., 2013), the Gulf of Mexico (Konradi, 1996; Sen Gupta and Smith, 2010) and other seas (Konradi, 1996; Patterson and Kumar, 2002). *C. reniforme* has a water depth range from 40 m on the Labrador Shelf, Canada (Vilks et al., 1982) down to 4427 m in the Arctic Ocean (Rodrigues et al., 1980; Wollenburg and Mackensen, 1998; Sejrup et al. 1981; Vilks et al., 1982; Scott and Vilks, 1991; Polyak et al., 2002; Ohkushi et al., 2003; Khusid et al., 2005; Rasmussen et al., 2007). This species has been reported as abundant in cold-water areas (temperatures below 2°C) with seasonal sea-ice cover; it is common in glaciated Fjords (Sejrup and Guilbault, 1980). The stratigraphic range of *C. reniforme* is Quaternary to Recent (Hesemann, 2013).

Genus *Cassidulinoides* Cushman, 1927
Type species *Cassidulina parkeriana* Brady 1881

Cassidulinoidies parkerianus (Brady, 1881)
Plate 9, figures 2-5.

Cassidulina parkeriana BRADY, 1881, p. 432, pl. 54, figs. 11–16.
Cassidulinoides parvus (Earland). – NOMURA, 1984, p. 498, pl. 90, fig. 10, pl. 91, figs. 1–5. – IGARASHI et al., 2001, p. 156, pl. 10, fig. 12.
Cassidulinoides parkerianus (Brady). – PARR, 1950, p. 344, pl. 12, fig. 25. – FILLON, 1974, p. 146, pl. 4, fig. 5. – KELLER, 1980, pl. 2, fig. 13. – WEBB et al., 1986, p. 117. – ISHMAN and WEBB, 1988, p. 534, pl. 6, fig. 1. – HIRVAS et al., 1993, pl. 1, fig. 7. – GAZDZICKI and WEBB, 1996, p. 161, pl. 35, figs. 4–6. – MAJEWSKI, 2005, p. 204, fig. 23, 1-2. – QUILTY, 2010, p. 198, fig. 3, no. 13. – HOLBOURN et al., 2013, p. 140.

Distribution in core: 156 specimens in 38 samples; first occurrence at 2.94 m, consistent down core occurrence, relative abundance increases at 9.65, 10.98, 17.09 and 19.76 m.

Description: Test elongate, coiled in early stage, cylindrical in cross-section, later chambers uncoiling, initially planispiral, becoming straight through the later chambers; somewhat compressed in outline, size typically between 0.42 mm and 1.05 mm in length, 0.18 mm and 0.20 mm in widest diameter, test robust, weakly inflated, periphery cylindrical. Wall calcareous, radial, slightly perforate; chambers not quite distinct, about 3 to 4 pairs of biserial chambers in adults; sutures slightly depressed, forming simple zigzag pattern on the inner and outer area of uncoiled biserial section; rounded periphery. Aperture is sub-terminal, loop-shaped to ovate opening with small folded toothplate.

Remarks: The direction of coiling in the early stage of the test of *C. parkerianus* specimens examined varies; about 85% of the specimens have their early chambers coiled towards the right side, when viewed from the apertural face, others are either straight, or coiled slightly towards the left. Our specimens are similar to specimens illustrated from the Japan Trench by Keller (1980: pl. 2, fig. 13), from Recent sediments in the Indian Ocean (Nomura 1995), and from east Antarctica (Igarashi et al. (2001; specimens illustrated as *C. parvus* Earland). *C. parkerianus* differs from *C. bradyi* Norman which has a wider aperture surrounded by thick lip. Our specimens differ from those illustrated by Majewski (2005: fig 23, 1-2) as *C. parkerianus* both in coiling style and sutures. Some of the Bering Sea specimens are delicate, with a smaller diameter than *Cassidulinoidies porrectus* (Heron-Allen and Earland). Generally, the Bering Sea material has more chambers in the later portion, which is uncoiled.

Morphological assessment of *C. parkerianus* specimens recovered from Bering Sea Site U1342 (top 20.59 m), which incorporates horizons determined to signal different levels of water column oxygenation (based on sedimentary characteristics and associated benthic foraminifera), show no significant relationship between specimens with coiled early chambers and the sediment type (i.e. laminated / non-laminated intervals).

Distribution: *C. parkerianus* is cosmopolitan, recorded from low to high latitudes (Holbourn et al., 2013); having a geographical distribution extending through the Pacific and the Atlantic Oceans (Keller, 1980; Jones, 1994; Levy, 1998), the Gulf of Mexico (Sen Gupta and Smith, 2010) and the Antarctic (Fillon, 1974; Anderson, 1975; Majewski 2005; Quilty, 2010). Its depth range is from 82 to 520 m in Pacific (Fillon, 1975; Keller, 1980; Jones, 1994) and Antarctic waters (Majewski, 2005). The stratigraphical range of *C. parkerianus* is from the Late Miocene to Recent (Holbourn et al., 2013).

Genus *Globocassidulina* Voloshinova, 1960
Type species *Cassidulina globosa* Hantken, 1876

Globocassidulina subglobosa (Brady, 1881)
Plat 9, figures 15-17; Plate 10, figure 1.

Cassidulina subglobosa BRADY 1881, p. 60. – BRADY, 1884, p. 430, pl. 54, fig. 17. – CUSHMAN, 1911, p. 98, text-fig. 152. – CUSHMAN and TODD, 1945, p. 61. 10, fig. 8. – RENZ, 1948, p. 125, pl. 9, figs. 11-12. – PHLEGER et al., 1953, p. 45, pl. 10, fig. 4. – BARKER, 1960, p. 112, pl. 54, fig. 17.
Globocassidulina subglobosa (Brady). – PARKER, p. 272, pl. 4, fig. 13. – BELFORD, 1966, p. 149, pl. 25, figs. 11-16. – LeROY and LEVINSON, 1974, p. 14, pl. 7, fig. 8. – LOHMANN, 1978, p. 26, pl. 2, figs. 8,9; – CORLISS, 1979, p. 14, pl. 3, figs. 12-13. – INOUE, 1989, p. 156, pl. 22, figs. 9a,b. – BOLTOVSKOY, 1980, p. 165, pl. 1, fig. 8. – POAG, 1981, p. 70-71, pl. 17, fig. 3; pl. 18, figs. 3a-c. – MURRAY, 1984, pl. 2, figs. 3, 4. – LOEBLICH and TAPPAN, 1987, p. 145, pl. 557, figs. 18-23 [figs. 21-23: cop. Brady, 1884, fig. 17]. – KAHIO, 1992, p. 305, pl. 3, figs. 11-15. – JONES, 1994, pl. 54, figs. 17a–c. – GUPTA, 1994, p. 359, pl. 2, figs. 17, 18. – SCHONFELD and SPIEGLER 1994, p. 221, pl. 2, fig 15. – RASMUSSEN, 2005, p. 84, pl. 10, fig. 11. – HAYWARD et al. 2007, p. 156, pl. 1, fig. 10. – SEN GUPTA et al., 2009, p. A-70, pl. 68, figs. 1-4. – MILKER and SCHMIEDL, 2012, fig. 20, 13, 14. – HOLBOURN et al., 2013, p. 264.

Distribution in core: 761 specimens in 104 samples; consistent occurrence down core, highest abundance at depths 15.69 and 15.79 m.

Description: Test sub-globular and ovate with a rounded periphery, rounded in cross-section; chambers indistinct, inflated and biserially connected, four to five pairs of chambers, increasing gradually in size, weakly inflated, average diameter of the test is between 0.30 and 0.45 mm; average thickness 0.20 and 0.32 mm. Wall calcareous, surface smooth and finely perforate, sutures are oblique and slightly depressed; aperture sub-elliptical, elongate to rounded opening in a depression on the apertural face, surrounded by a lip on the outer margin.

Remarks: Corliss (1979) noted that *G. subglobosa* exhibits a range of test sizes; and that small test sizes are found in water depths generally greater than 3500 m, with both small and large tests found in water depths generally less than 3500 m. The latter is true of the assemblages recovered from the interval studied in the Bering Sea Site U1342. This material is similar to specimens illustrated by Milker and Schmiedl (2012: fig. 20; 13, 14) from the western Mediterranean Sea, Schönfeld and Spiegler (1994: p. 221, pl. 2, fig. 15) and Kaiho (1992: pl. 3, figs. 11-15), in having an aperture that is elongate to rounded, situated in a depression on the apertural face, and surrounded by a lip on the outer margin. *G. obtusa,* a morphologically similar species to *G. subglobosa*, is differentiated by its densely perforate test, distinct sutures and by being planispirally enrolled (Milker and Schmiedl 2012: fig. 20; 10, 11). *G. subglobosa* has been observed to increase in abundance following seasonal pulses of phytodetritus (Gooday 1988; 1993). Despite the relatively large number of specimens of this species, there is no significant intraspecific variation in the assemblage studied from Site U1342 at horizons determined to indicate different levels of water column oxygenation (based on sedimentary characteristics and associated benthic foraminifera); all major morphological features, including number of chambers and form of aperture, are quite similar.

Distribution: *G. subglobosa* is recorded from the Atlantic, sub-Arctic and Indian Oceans (Corliss, 1979; Boltovskoy, 1980; Peterson, 1984; Weston, 1985; Gupta, 1994; Schmiedl et al., 1997; Hayward et al., 2006; Sen Gupta and Smith, 2010), northwest Pacific (Inoue, 1989), Japan Sea (Kaiho, 1992), the Gulf of Mexico (Hayward et al., 2007) and other seas (Cornelius and Gooday, 2004; Jorissen, 1987; Schönfeld and Spiegler, 1994; Wilson and Costelloe, 2011). Its water depth range is 1061 to 4600 m (Corliss, 1979; Kaiho, 1992; Hayward et al., 2007; Sen Gupta et al., 2009). Hayward et al. (2007) put the dominant water depth range for *G. subglobosa* between 1500 to 4000 m in the Gulf of Mexico. Inoue (1989) recorded an anomalously shallow depth of 50–2500 m in the northwest Pacific and Sea of Japan. *G. subglobosa* has been classified as an infaunal species and as an indicator of oxic conditions (Mackensen et al., 1990; Murray, 1991; Gooday, 1993; Schmiedl et al., 1997; Hayward et al., 2007). *G. subglobosa* has a stratigraphical range from the Oligocene to Recent (Katz and Miller, 1993).

Genus *Islandiella* Nørvang, 1959
Type species *Cassidulina islandica* Nørvang, 1945, designated by Nørvang, 1959, p. 26

Islandiella norcrossi (Cushman 1933)
Plate 10, figure 2-6.

Cassidulina norcrossi CUSHMAN, 1933, p. 7, pl. 2, fig. 7; CUSHMAN, 1948, p. 75, pl. 8 fig. 12. –LOEBLICH and TAPPAN, 1953, p. 120, pl. 24, fig. 2. – TODD and LOW, 1967, p. A37, pl. 5, fig. 11. – KELLER, 1980, p. 856, pl. 2, figs. 8-9.
Cassidulina norcrossi-australis PHLEGER and PARKER, 1951, pl. 2, Fig. 11. – LESLIE, 1965, p. 158, pl. 10, fig. 3.
Islandiella norcrossi (Cushman). – KNUDSEN, 1973, p. 184, pl. 3. figs. 2-3, pl. 12, fig. 6. – CRONIN, 1979, p. 796, pl. 4, figs. 16, 17. – RODRIGUES et al., 1980, p. 55, pl. 4, figs. 1, 4, 7, 10; pl. 6, figs. 8, 9. – PATTERSON and KUMAR, 2002. p. 122, pl. 2, figs. 6. – ISHIMURA et al., 2012, p. 4355, fig. 3, f.

Distribution in core: 3566 specimens in 112 samples, making ~10% of the total benthic foraminiferal assemblage in the study interval; consistent occurrence down core, highest abundance at depths 9.50 and 9.65 m.

Description: Test sub-globular, radial, slightly biconvex in cross-section, periphery rounded, sub-acute to carinate, thickness of the test is between 0.17 and 0.37 mm, average diameter between 0.30 and 0.70 mm, with the diameter perpendicular to the aperture slightly wider; wall calcareous, surface smooth and polished, translucent to hyaline. Chambers not distinct, about five pairs of broad chambers in the final whorl, sutures flush to slightly depress; aperture an elongate marginal opening, with internal toothplate on the sides and a flat tongue, which extends slightly beyond the apertural opening.

Remarks: The flat tongue seen from the apertural opening differentiates *Islandiella norcrossi* from the species of Islandiella (i.e., *I. helenae*, *I. californica* and *I. inflata*), which have curved tongues (Rodrigues et al., 1980). There is intraspecific variation in *I. norcrossi* test size, circa 70% of the species are more biconvex in cross-section than the others, whilst the tests of some of the specimens are perforated randomly down-core; these, however, do not amount to any significant variation in the assemblage. *I. norcrossi* is one of the most abundant (~10%) species recorded from Site U1342 in this study, and has a consistently high relative abundance.

Morphological assessment of *I. norcrossi* specimens from Bering Sea Site U1342, which includes horizons determined to indicate different levels of water column oxygenation (based on sedimentary characteristics and associated benthic foraminifera), show no significant intraspecific variation.

Distribution: *Islandiella norcrossi* has a geographical distribution that includes the Atlantic, Pacific and Arctic Oceans (Cronin, 1979; Hooper and Jones, 1980; Rodrigues et al., 1980; Steinsund and Hald, 1994; Bubenshchikova et al., 2010), Bering Sea (Ovsepyan et al., 2013), and Japan Sea (Keller, 1980; Ishimura et al., 2012). *I. norcrossi* has a depth range from 839 to 1312 m in the Okhotsk Sea (Ishimura et al., 2012; Bubenshchikova et al., 2010). *I. norcrossi* has been considered to be an indicator of sub-oxic environments and a shallow infaunal species (Kaiho, 1994; Bubenshchikova et al., 2010). *I. norcrossi* ranges from the late Pleistocene to Recent (Hesemann, 2013).

Subfamily CASSIDULININAE d' Orbigny, 1839
Genus *Takayanagia* Nomura, 1983
Type species *Cassidulina delicata* Cushman, 1927, designated by Cushman, (1927), p.168

Takayanagia delicata Cushman 1927
Plate 10, figures 7-13.

Takayanagia delicata CUSHMAN, 1927*,* fig. 3e;
Cassidulina delicata Cushman, 1927, p. 168, pl. 6, Fig. 5. – NOMURA, 1983a, p. 53, pl. 1, figs. 3a-c; pl. 7, figs. 1-5. – ISHIMURA et al., 2012, p. 4355, fig. 2 f; fig. 3 e.
Takayanagia delicata (Cushman). – NOMURA, 1983a, p. 53, pl. 1, figs. 3a-c; pl. 7, figs. 1-5. – ISHIMURA et al., 2012 fig. 2, f; fig. 3, e

***Distribution in core*:** 7503 specimens in 113 samples making ~20% of the benthic foraminiferal assemblage in the core; consistent abundant occurrences down core, highest abundance at depths 16.46, 18.80, 18.95 and 19.31 m.

Description: Test lenticular, circular in outline, compressed, average size of the test is 0.28 mm at the greatest diameter, 0.25 mm at the minimum diameter, 0.05 mm thick; alternate chambers extend to the closed umbilicus. Wall calcareous, smooth, translucent, fragile, and hyaline; chambers are biserially arranged, alternate chambers extending to the closed umbilicus on one side, four pairs of chambers in the final whorl; periphery carinate; sutures curved and depressed. Aperture is a curved long interiomarginal slit, extending along the periphery of the penultimate chamber, bordered by a small carinate apertural lip.

Remarks: The Bering Sea material is very similar to the specimens illustrated from the Okhotsk Sea by Ishimura et al. (2012: fig. 3, f) and Nomura (1983a: p. 53, pl. 1, figs. 3a-c; pl. 7, figs. 1-5) in having alternate chambers that extend to the closed umbilicus, having four pairs of chambers on each side, and by the mode of apertural opening.

Morphological assessment of *T. delicata* specimens recovered from intervals which incorporate laminated and non-laminated horizons determined to indicate different levels of water column oxygenation (based on sedimentary characteristics and associated benthic foraminifera) from Bering Sea Site U1342, show no significant intraspecific variation in the assemblage studied and the sedimentology.

***Distribution*:** *Takayanagia delicata* has a geographical distribution that includes the Pacific Ocean (Ohkushi et al., 2003; Bubenshchikova et al., 2010; Ishimura et al., 2012), Bering Sea (Ovsepyan et al., 2013), Japan Sea (Noda et al., 2008), and Arabian Gulf (Mazumder et al., 2003). *T. delicata* has a water depth that ranges between 150 and 480 m off Peru, down to between 1000–3500 m in the Pacific Ocean and Japan Sea. (Ohkushi et al. 2003; Noda et al., 2008; Bubenshchikova et al. 2010; Ishimura et al. 2012).

T. delicata may be an indicator of sub-oxic conditions and/or high organic carbon flux, and is a shallow infaunal species (Kaiho, 1994; Bubenshchikova et al., 2010, 2008). Its stratigraphical range is from the Late Pliocene to Recent (Oveisi, 2013).

Subfamily EHRENBERGININAE Cushman 1927
Genus *Ehrenbergina* Ruess, 1850
Type species *Ehrenbergina serrata* Reuss, 1850

***Ehrenbergina* sp.**
Plate 10, figures 14-16; Plate 11, figures 1-10.

Ehrenbergina sp. BUTT 1980, pl. 8, Fig. 5.

Distribution in core: 1667 specimens in 86 samples; consistent occurrences down core with the exception of intervals between 3.24 to 4.58 m, and 14.14 to 18.26 m, where there are intermittent occurrences; highest abundances are at depths 0.74 m, 5.96 m, and between 18.67 and 19.07 m.

Description: Test biserial, sub-triangular in outline with fine peripheral spines, lens-shaped in cross-section, early chambers tends to uncoil, lenticulate in cross-section, shape is asymmetrically biserial, dorsal margin convex, with median ventral furrow and fine peripheral spines. Wall calcareous, densely and finely perforate, surface appears smooth; average test length is between 0.30 and 0.75 mm, width 0.27 and 0.50 mm, and thickness 0.145 mm. Chambers become broader as added, overlapping at the midline of the periphery, about 6 pairs of chambers visible on the dorsal side; dorsal sutures curved, overlapping about half their length, flush with the surface, first chamber in the form of a lobe, coiling upwards; distinct and depressed sutures. Aperture an elongate curved slit, positioned at the middle of the last chamber, nearly parallel to the peripheral margin, with almost rounded edges at both ends of the aperture; measuring up to 0.5 mm in length and 0.4 mm in width.

Remarks: *Ehrenbergina* sp. has an almost 'U'-shaped aperture, the rounded edges of the 'U' being conspicuously absent in *E. compressa* which is morphologically similar to *Ehrenbergina* sp. Whether the Bering Sea material simply represents a regional difference in this structure, or is diagnostic of a separate subspecies is not ascertainable with the available data. *E. hystrix* Brady differs from *Ehrenbergina* sp. by lacking distinct spine-like projections at the edges of the chambers. Also, the sutures in *E. hystrix* are more raised than those of *Ehrenbergina* sp.; *Ehrenbergina* sp. can be differentiated from *E. bradyi* Cushman from the deep waters of the Pacific Ocean, as the latter species is flatter, lacks spines on the periphery, and has no ornamentation along the median line. *Ehrenbergina* sp. is similar to *Ehrenbergina* sp. from the Pacific Ocean (Butt, 1980; pl. 8, Fig. 5), and to *E. glabra* from the SE Pacific (Schönfeld and Spiegler, 1995: pl. 1, Fig. 8), which has its first chamber coiled upwards in the form of a lobe, but differs by lacking the overlapping depressed dorsal sutures and the distinctive apertural form that typify *Ehrenbergina* sp. *E. caribbea* Galloway and Hemingway from the Virgin Islands, New York, USA (reproduced in Ellis and Messina, 1940) differs from *Ehrenbergina* sp. by lacking the first few chambers coiled in the form of a lobe.

More than 90% of the specimens studied from the Bering Sea have their first chamber obviously coiled upwards in form of a lobe.

Distribution: *Ehrenbergina* sp. is known only from the Bering Sea, with a similar *Ehrenbergina* sp. described from the Pacific Ocean (Butt, 1980). In contrast, *E. compressa* (a morphologically similar species to *Ehrenbergina* sp.) has a geographical distribution in the Pacific Ocean (Takayanagi, 1951; Scripps, 1940; White, 1956; Kern and Wincander, 1974), and the Gulf of Alaska (Bergen and O'Neil, 1979), where its water depth extends from 232 to 2623 m (Scripps, 1940; Resig, 1958; Bergen and O'Neil, 1979). *Ehrenbergina* spp. have been classified as suboxic, and shallow infaunal (Kaiho, 1994; Bubenshchikova et al. 2010). The stratigraphical range of *E. compressa* is Pliocene to Recent (Van Marle, 1991), but the distinctive form described here is only known from the late Pleistocene of the Bering Sea and possibly the Pacific.

Family STAINFORTHIIDAE Reiss, 1963
Genus *Stainforthia* Hofker, 1956
Type species *Virgulina concava,* Höglund, 1947

Stainforthia fusiformis (Williamson, 1858)
Plate 11, figures 11-15

Bulimina pupoides var. fusiformis WILLIAMSON, 1858, p. 63, pl. 5, figs. 129-130.
Bulimina fusiformis (Williamson). – HÖGLUND, 1947, p. 232-235, pl. 20, fig. 3; text-figs. 219-233.
Virgulinella fusiformis (Williamson). – PARKER, 1952, p.417, pl. 6, figs. 2-3. – ATKINSON, 1970, p. 395.
Fursenkoina fusiformis (Williamson). – MURRAY, 1971, p. 185, pl. 77, figs, 1-5.
Cassidella fusiformis (Williamson). – LAGOE, 1977, p. 127, pl. 4, fig. 5.
Stainforthia fusiformis (Williamson). – HAYNES, 1973, p. 124-125, pl. 5, figs. 7, 8. – ALVE, 1990, pl. 2, fig. 17. – BARMAWIDJAJA et al., 1992, pl. 3, figs. 1-4 not 5. – NORDBERG et al., 2000, fig. 3(9) 6.1.1. – GOODAY and ALVE, 2001, pl. 1, figs. H-L; pl. 3, figs. A-J, pl. II, fig. n. – ALVE, 2001, fig. 1. – DUIJNSTEE et al. 2004, pl. 1. – DIZ and FRANCES, 2008, pl. 2, figs. 11-12.

Distribution in core: 56 specimens in 9 samples; isolated occurrences at depth 0 m, and depth intervals 9.40 to 9.65 m, 15.69 to 15.79 m; few and intermittent occurrences down the core to 18.43 m.

Description: Test small, thin walled, triserial in the early stage, twisted biserial arrangement in later stage, tapering, fusiform, rounded in cross-section; wall calcareous, finely perforate; chambers elongate, stretched to near globular, obvious overlap between adjacent chambers. Average dimension of the test is 0.30 mm in length, and 0.18 mm in width (of the last chamber); sutures steeply angled, distinct and depressed, proloculus often with short apical spine, in the form of a blunt 'tail'. Aperture is ovate, wide and terminal, usually clearly defined and positioned away from the end of the chamber, in a spoon-shaped depression, becomes narrower and shallower distally with lip-like plate on its two sides; apertural lip is serrated, curved around aperture.

Remarks: *Stainforthia fusiformis* (Williamson) was first described by Williamson (1858) from samples collected around the British Isles. The Bering Sea specimens are similar to those from the Adriatic Sea (Barmawidjaja et al., 1992: pl. 3, Figs. 1-5; Duijnstee et al., 2004: pl. 1) and NE Atlantic Ocean (Gooday and Alve, 2001: pl. 3, A-J), but differ by being wider in the middle of the test. *S. fusiformis* differs from *Stainforthia* sp. described by Gooday and Alve (2001) from the N. Atlantic, which is smaller (0.04–0.15 mm in length), and has its aperture closer to the apex of the last chamber, with a non-serrated apertural lip which appears linear; *S. fusiformis* has its aperture located farther away from the apex of the last chamber, and the apertural lip is strongly serrated, and curved around the aperture. *S. fusiformis* changes aperture characteristics during growth (see Alve, 2003; Fig. 1).

Stainforthia fusiformis responds quickly to improved oxygen conditions and is the most successful re-colonizer of formerly anoxic environments; it has been designated as an opportunistic r-strategist that can withstand short periods of anoxic conditions (Alve, 1994). Approximately 10% of the specimens examined from the Bering Sea are biserial throughout and their chambers relatively shorter with less overlap.

Distribution: *S. fusiformis* is a cosmopolitan species; it is one of the most common benthic foraminiferal species in NW European marine waters (Alve, 2003). It has been recorded from the continental shelf and coastal settings (intertidal to outer shelf), around NW Europe and North America (Alve, 1994; Gooday and

Alve, 2001; Alve, 2003), the Atlantic, Arctic and Indian Oceans (Wollenburg and Mackensen, 1998; Gooday and Hughes, 2002; Mazumder et al., 2003; Erbs-Hansen et al., 2012), the Japan Sea (Kato, 1992), and other seas (Murray, 1991; Barmawidjaja et al., 1992; Gooday and Alve, 2001; Mazumder et al., 2003; Duijnstee et al., 2004). *S. fusiformis* has a depth range from 55 m in the Atlantic (Gooday and Alve, 2001; Gooday and Hughes, 2002; Erbs-Hansen et al., 2012) to between 1570 and 4217 m in the Arctic Ocean (Scott and Vilks, 1991) and 3300 to 4850 m in the Indian Ocean (Mazumder et al., 2003). Its abundance was recorded at a depth of 4000 m in the North Atlantic Ocean (Alve, 1994; Bubenshchikova et al., 2010). *S. fusiformis* is an infaunal species that flourishes in temperate, shelf and marginal marine environments independently of whether the sediments primarily consist of mud or fine sand; but it seems to require salinities >30‰ (Alve, 1994). Its stratigraphical range is from Eocene to Recent (Loeblich and Tappan, 1987).

Family BULIMINIDAE Jones, 1875
Genus *Bulimina* d' Orbigny, 1826
Type species *Bulimina marginata* d'Orbigny, 1826

Bulimina exilis Brady, 1884
Plate 11, figures 16-22; Plate 12, figure 1.

Bulimina elegans d'Orbigny var. *exilis* Brady, 1884. p. 339, pl. 50, figs. 5, 6. – CUSHMAN, 1911, p. 82, fig. 135. – CUSHMAN, 1922, pl. 3, p. 106; pl.17, figs. 7-12; pl. 19, figs. 2,3. – CUSHMAN and PARKER, 1947, p. 123, pl. 28, figs. 27-28.
Bulimina exilis Brady. – LOEBLICH and TAPPAN, 1953, p. 110, pl. 20, figs. 4, 5. – PHLEGER, PARKER and PEIRSON, 1953. – ASANO, 1958, p. 49, pl. 3, figs. 7a-7b. – PUJOS-LAMY, 1973, pl. 2, figs. 10.1, 10.2. – HAAKE, 1980, pl. 2, Fig. 23. – VAN MORKHOVEN et al. 1986, pl. 4, figs. 1–2. – OGGIONI and ZANDINI, 1987, pl. 6, fig. 11. – CARALP 1989, p. 40, figs. 1-2. – JANNINK et al., 1998, p. 1497, pl. 1, fig. 3. – LICARI and MACKENSEN, 2005, p. 213, pl. 1, figs. 17, 18. – SCHUMACHER et al., 2007, p. 62, pl. 1, fig. 15.

Distribution in core: 3222 specimens (~9% of the total count) in 119 samples; consistent occurrences down core, high abundances at depth 11.30 m, 17.57 m, and between intervals 15.97 and 16.10 m.

Description: Test elongate, slender, nearly sub-globular, inflated; wall calcareous, finely perforate, surface smooth; chambers distinct, triserially arranged, test shows a tendency to become uniserial, average length of the test is 0.75 mm, width is 0.20 mm, and average length / width ratio is 4.3 (0.65 / 0.15); average number of chambers ranges from 8-12; sutures depressed, early chambers rounded at the periphery. Aperture is loop-shaped, situated in a depression, with a tiny tongue.

Remarks: *Bulimina exilis* is distinctive because of its slender, elongate and cylindrical test; the Bering Sea material is different from that illustrated from the northern Arabian Sea by den Dulk et al. (1998: pl. 2, fig. 5), which has an aboral spine with more elongated chambers, but it is morphologically similar to the specimens illustrated by Hayward (2002: pl. 3, fig. 1, 2) and from Trinidad and Venezuela by Morkhoven et al. (1986: pl. 4, figs. 1-2), both from SW Pacific, and by Licari and Mackensen (2005: pl. 1, figs. 17, 18) from off the West Africa coast.

Intraspecific variation is noted in the assemblages from the Bering Sea: the degree of chamber inflation varies randomly across laminated / non-laminated horizons determined to indicate different levels of water column oxygenation (based on sedimentary characteristics and associated benthic foraminifera); about 75% of the specimens have their chambers more inflated, while others are weakly inflated and more enlongate; however, this does not relate significantly to different environments determined in the core. The number of chambers varies from 8 to 16, and there is variation in the size; circa 10 % of the specimens have more chambers (up to 14), but are shorter and smaller than some specimens with less chambers (i.e., 10 chambers). One specimen shows evidence of mutation (Plate 12, fig. 1), the test being significantly different in shape from other specimens of this species; the apertural opening and chamber form are the same as *B. exilis.*

Distribution: *Bulimina exilis* is a cosmopolitan species which has a geographical distribution from the Atlantic and Pacific Oceans (Levy, 1998; Rasmussen et al., 2002; Butt, 1980, Khusid et al., 2005), Japan and Arabian seas (Asano, 1958; Keller, 1980; Schumacher et al., 2007 and Jannink et al., 1998), continental slope off SW Africa, (Schmiedl et al., 1997; Licari and Mackensen, 2004) and other regions (Caralp, 1984, 1989; Oggioni and Zandini, 1987; Schmiedl et al., 1997; Jannink et al., 1998; Maas, 2000; Mazumder et al., 2003; Schumacher et al., 2007). *B. exilis* is known from upwelling and low oxygen environments, it has a water depth range from 136 m in the Arabian Sea (Schumacher et al., 2007) extending to 500 and 3300 m along the central west coast of India and northern Arabian Sea (Caralp, 1984, 1989; Jannink et al., 1998; Mazumder et al., 2003). *B. exilis* is a dysoxic and deep infaunal species (Kaiho, 1994; Jorissen, 1999; den Dulk et al., 2000). *B. exilis* ranges from late Miocene to Recent (van Morkhoven et al., 1986).

Bulimina mexicana Cushman, 1940
Plate 12, figures 2-6.

Bulimina inflata Seguenza var. *mexicana* CUSHMAN, 1922, p. 95, pl. 21, fig., 2.
Bulimina striata d'Orbigny var. *mexicana* Cushman. – CUSHMAN and PARKER, 1940, p. 16, pl. 3, fig. 9.
Bulimina striata mexicana Cushman. – PARKER, 1954, p. 511, pl. 6, fig. 24; - KOHL, 1985, pl. 20, fig. 4. – ROBERTSON, 1998, p. 147, pl. 56, fig. 7.
Bulimina mexicana Cushman. – BELANGER and BERGGREN, 1986, p. 334, pl. 2, figs. 4a-5. – VAN MORKHOVEN et al., 1986, p. 61, pl. 19, figs. 1-4. –JONES, 1994, pl. 51, figs. 10-13. – BERNHARD et al. 2001, p. 2243, fig. 4, N. – LICARI and MACKENSEN, 2005, p. 213, pl. 1, figs. 12, 13. – KENDER et al., 2008, p. 553, pl. 17, fig. 12. – SEN GUPTA et al., 2009, p. A-12, pl. 30, figs. 1- 2.

Distribution in core: 25 specimens in 11 samples; most occurrences are within the upper part of the core between depths 0 and 0.88 m, then intermittently down the core; highest occurrence at depth 15.19 m.

Description: Test triserial, conical, circular in cross-section, tapered in outline, twice as long as wide, average length of the test is 0.65 mm, width 0.15 mm; wall calcareous, finely perforate and smooth; chambers slightly inflated towards the later chambers, initial end acute, increasing in size slowly, slightly overhanging the previous chambers, about five chambers in adult. Sutures depressed and well defined five to seven longitudinal costae on the lower half of each chamber, ending in narrow spines; chambers ornamented with tooth-like crenulations which often extend into short, sharp spines at the margins. Aperture is a loop-shaped opening, positioned near the apex of the last chamber, surrounded by a lip that merges with an internal toothplate in the form of a tooth.

Remarks: *Bulimina mexicana* from the Bering Sea material is morphologically similar to specimens illustrated from the Atlantic by Belanger and Berggren (1986: pl. 2, figs. 4a-5), Antarctica by Holbourn et al. (2013: p.110, figs. 1, 2), Monterey Bay by Bernhard et al. (2001: fig. 4, N) and from off the coast of West Africa (Licari and Mackensen 2005: pl. 1, figs. 12, 13); these specimens have sharp spines at the margins, between 5 to 7 longitudinal costae, and a loop-shaped aperture containing a tooth surrounded by a lip. The Bering Sea material differs from specimens recoded from the Pacific by Jones (1994: pl. 51, figs. 10-13), in that the triserial arrangement of the last chambers in the latter are distinct. *B. mexicana* differs from *B. rostrata* Brady illustrated from the 'Challenger' Station in the Central Pacific by Holbourn et al. (2013) which is elongate and fusiform, with indistinct sutures. All *B. mexicana* specimens studied across laminated / non-laminated horizons determined to indicate different levels of water column oxygenation based on sedimentary characteristics and associated benthic foraminifera (i.e deep infaunal species) from different horizons in core U1342 reveals no fundamental change in the key morphological traits; they are morphologically similar.

Distribution: *Bulimina mexicana* is cosmopolitan, being recorded from the Pacific (Keller, 1980; Schönfeld and Spiegler, 1995; Ken'ichi, 1999), and Atlantic Ocean (Jian et al., 1999; Schmiedl et al. 1997); offshore Angola West Africa (Kender et al., 2008) and other regions (Molina-Cruz and Ayala-Lopez, 1988; Denne and Sen Gupta, 1991; Jian et al., 1999; Licari and Mackensen, 2005; Sen Gupta et al., 2009). *B. mexicana* extends from 900 m depth in Monterey Bay (Bernhard et al., 2001) to between 1200 and 2000 m off West Africa (Licari and Mackensen, 2005; Kender et al., 2008) to 3820 m in the Atlantic Ocean (Griggs et al., 1970). *B. mexicana* is considered by some studies an indicator of sub-oxic conditions, and a shallow infaunal species (Kaiho, 1994; Kender, 2008). The stratigraphical range of *B. mexicana* is Early Miocene to Recent (Holbourn et al., 2013).

Genus GLOBOBULIMINA Cushman, 1927
Type species *Globobulimina pacifica* Cushman, 1927

Globobulimina auriculata (Bailey, 1851)
Plate 12, figures 7-11.

Bulimina auriculata BAILEY, 1851, p. 12, pl. 1, figs. 25-27. – INOUE, 1989, pl. 32, figs. 25-27. – KATO, 1992, pl. 2, figs. 9a-b. – DEBENAY and REDOIS, 1997, p. 250, pl. 1, fig. 9. – HALD and KORSUN, 1997, p.1, fig. 20. – GUSTAFSSON and NORDBERG, 2001, pl. 1, fig 8. – ISHIMURA et al., 2012, p. 4355, fig. 2, b; fig. 3, g.

Distribution in core: 129 specimens in 38 samples; intermittent occurrences down core, highest abundance at depth 10.98 and 12.98 m.

Description: Test fragile, inflated, sub-globular in outline and circular in cross-section, widest towards the initial end, tends to be elongate, average dimension of the test is 0.62 – 0.75 mm in length, and 0.36 – 0.62 mm in width. Wall calcareous, thin, smooth, finely perforate and translucent; the maximum width is located in the middle portion of the test usually towards the early part; final chamber large, encompassing more than 80% of the whole test, with a fairly rounded proximal end; aperture is a loop with an internal tooth.

Remarks: *Globobulimina auriculata* was first recorded from the upper Miocene - Pliocene Quinault Formation in the USA by Cushman et al. (1949). *G. auriculata* differs from *G. affinis* (d'Orbigny, 1839) which has a rounded proximal end (Corliss, 1985), and from *G. pacifica* by possessing a more encompassing terminal chamber, which almost overlaps all of the other chambers. The Bering Sea specimens are similar to those illustrated by Hald and Korsun (1997: pl. 1, fig. 20), Debenay and Redois (1997: pl. 1, fig 9) and Vilks et al. (1982) from the Labrador Sea, Canada. All specimens of *G. auriculata* studied across laminated / non-laminated horizons from the Bering Sea core U1342, are morphologically similar, except for slight variation noticed in their size, probably related to maturity.

Distribution: *Globobulimina auriculata* has a geographical range in the North Atlantic (Asteman and Nordberg, 2013; Rasmussen et al., 2013), Pacific (Inoue, 1989; Ohkushi et al, 2005; Ovsepyan et al, 2013), Southern Ocean (Husum and Hald, 2004; Khusid et al., 2005; Jennings et al., 2006), and Japan Sea (Inoue, 1989; Noda et al., 2008). *G. auriculata* has a depth range from 425 m in the Atlantic (Rasmussen et al, 2013) to 3500 m in the Pacific (Ohkushi et al., 2005; Khusid et al., 2005; Noda et al., 2008; Bubenshchikova et al., 2008). It is common at depths of 150–800 m in the Sea of Japan (Inoue, 1989). *G. auriculata* has been classified as a dysoxic and deep infaunal species (Jones, 1994; den Dulk, 2000; Bubenshchikova et al., 2008). The stratigraphical range of *Globobulimina auriculata* is Miocene to Holocene (Kato, 1992; Hald and Korsun, 1997).

Globobulimina pacifica Cushman, 1927
Plate 12, figures 12-17; Plate 13, figures 1 to 6.

Bulimina pyrula d' Orbigny. – BRADY, 1884, p. 399, pl. 50, figs. 7-10; - POPESCU and CRIHAN, 2005, pl. 6, fig. 10.
Globobulimina pacifica CUSHMAN, 1927, p. 67, pl. 14, fig. 12. – CUSHMAN, 1927 b, p. 153, pl. 3, fig. 1. – GALLOWAY and WISSLER, 1927, p. 74, pl. 11, fig. 18. – CUSHMAN et al., 1930, p. 66, pl. 5, fig.4. – CUSHMAN and MOYER, 1930, p. 57. – CUSHMAN and LAIMING, 1931, p. 108, pl. 1a-b. – BERMÚDEZ, 1949, p. 185, pl. 12, fig. 14. – BARKER, 1960, pl. 50, figs. 7-10. – INGLE et al., 1980, p. 134, pl. 2, figs. 7, 8. – LOEBLICH and TAPPAN, 1987, p. 521, pl. 571, figs. 8-12. – JONES, 1994, p. 54, pl. 50, figs. 7-10. – GUPTA, 1994, p. 36i, pl. 3, fig. 10. – ROBERTSON, 1998, p. 150, pl. 57, fig. 1. – ORTIZ and THOMAS, 2006, p. 118, pl. 6, figs 8-11. – HOLBOURN et al., 2013, p. 260.

***Distribution in core*:** 48 specimens in 20 samples; intermittent and low occurrence down core, highest abundance at depth 2.54 m; ~34% of its total occurrence is between depths 18.43 and 19.92 m.

***Description*:** Test elongate, triserial; sub-globular, ovate in outline, circular in cross-section, about one and a half times as long as wide, widest near the lower part of test. Average length of the test ranges between 0.70 - 0.92 mm, and width between 0.32 - 0.55 mm. Wall calcareous, fragile, finely perforate, very thin with smooth surface, translucent. Chambers distinct, inflated, rapidly enlarging and strongly overlapping; last 2-3 chambers may partially overlap the preceding ones, only 2-3 chambers visible. Sutures thin, slightly depressed, oblique, nearly parallel to the margins of the test; aperture loop-shaped, with a slight border and an internal toothplate joined to the margin of the opening.

***Remarks*:** *Globobulimina pacifica* differs from *Globobulimina auriculata* (Bailey) in the arrangement of the chambers, and by the size of the final chamber that is much larger in *G. auriculata* and almost encompasses the whole test, while the proximal end is more pointed in *G. pacifica* relative to *G. auriculata.* The Bering Sea material is similar to specimens illustrated by Jones (1994: pl. 50, figs 7-10) from the Pacific and Atlantic Oceans, but differs from those recorded from SE Spain by Ortiz and Thomas (2006: pl. 6, figs 8-11), with their sutures being more depressed and prominent. All specimens of *G. pacifica* studied from different horizons from core U1342 reveal no fundamental change in the key morphological traits, except slight variation noticed in their sizes; this may be related to maturity.

***Distribution*:** *Globobulimina pacifica* has a geographical distribution that encompasses the Pacific (Ingle et al., 1980) and Indian Oceans (Gupta, 1994) and other regions (Cushman and Laiming, 1931; Mazumder et al., 2003; Sen Gupta and Smith, 2010). It has a bathymetry from ~824 m at the 'Challenger' stations, off the Azores in the Atlantic Ocean (Jones, 1994) to 2012 m in the Pacific (Ingile et al., 1980) and to 3300 m in the Arabian Sea (Mazumder et al., 2003). *G. pacifica* is a deep infaunal species characteristic of dysoxic settings (Jorissen et al., 1998; den Dulk et al., 2000). The stratigraphical range of *G. pacifica* is Miocene to Recent (Jones, 1994).

Family UVIGERINIDAE Haekel, 1894
Subfamily UVIGERININAE Haekel, 1894
Genus *Uvigerina* d'Orbigny, 1826
Type species *Uvigerina pygmaea* d'Orbigny, 1826

Uvigerina bifurcata d'Orbigny, 1839
Plate 13, figures 7-18; Plate 14, figures 1-3.

Uvigerina bifurcata D'ORBIGNY, 1839, p. 53, pl. 7, fig. 17.

Uvigerina pygmea d'Orbigny. – BRADY, 1884, pl. 74, figs. 13–14.
Uvigerina bifurcata d'Orbigny. – THALMANN, 1932, p. 306, pl. 74, figs. 13-14. – CUSHMAN, 1947, p. 279, fig. 291. – BARKER, 1960, p. 154, pl. 74, figs. 13-14. – VAN DER ZWAAN et al., 1986, p. 226, pl. 16, figs. 4-6; pl. 17, figs. 1-4. – JONES, 1994, p. 86, pl. 74, figs. 13-14. – ABU-ZIED et al., 2008, p. 52, pl. 2, figs. 17-18.

Distribution in core: One of the dominant species, with 6103 specimens in 144 samples between depths 0 and 29.59 m.

Description: Test loosely triserial, elongate, typically stout with dimensions between 0.30 to 1.05 mm for maximal length excluding apertural neck, and between 0.20 to 0.48 mm for maximum transverse diameter; average length / breadth ratio is 2 (0.63/0.32); wall calcareous, weakly perforate; initial part of the first chamber is pointed; chambers mostly inflated and robust, particularly the later chambers, number of chambers varies with maturity from 5 to 9. Costae is usually non-serrate with relatively high lamellar forming a 'vault structure' on the test, number of heavy regular costae on the second to the last chamber varies from 4 and 9; costae sometimes end in spine-like projections at the base of the chamber, which might continue over the suture, the thickness of costae reduces on the last chambers towards the neck, proloculus pointed; aperture terminal with well-developed lip on a well-developed neck, having an inward projection of the inner portion of the neck wall into the aperture in the form of a spiral tooth, lip at the flattened side of the aperture. Arrangement of chambers tends to change from triserial to biserial in later stage of the test.

***Remarks*:** The chambers are typically inflated, with the largest width above the middle of the test, often at the level of the second to last chamber. Proloculus shape and size varies in microspheric and megalospheric specimens. *U. bifurcata* is differentiated from other *Uvigerina* species by the differences in the development of spines and pustules (e.g., *U. senticosa*). *U. celtica* Schönfeld is differentiated from *U. bifurcata* by its numerous small spines between the costae and its less inflated chambers (Schönfeld 2006). Our species correlates well with *U. bifurcata* d'Orbigny illustrated from Mediterranean Sea by Abu-Zied (2008: pl. 2, figs. 17-18) in having distinct longitudinal costae that are well spaced on the chambers. However, there are variations in the thickness of costae within the assemblage; ~ 70% of the specimens have relatively heavy regular costae through all the chambers, while the strength of costae reduces on the terminal chamber of others.

***Distribution*:** *Uvigerina bifurcata* is a cosmopolitan species that has a geographical distribution in the Pacific (Schönfeld and Spiegler, 1994; Lutze, 1986; Jones, 1994); Southern Ocean (Anderson, 1975) and Atlantic (Chiessi et al., 2008; Lutze, 1986), and bordering seas (e.g., Jones, 1994; Burch and Burch, 2007; Van Leeuwen et al., 1982). This species has been recorded between 300 and 450 m water depth in the Atlantic Ocean (Lutze, 1986). *U. bifurcata* is an infaunal species (Schmiedl et al., 2000; Fontanier et al., 2002, 2006). The stratigraphical range of *U. bifurcata* is from the Pleistocene to Recent (Jones, 1994).

Uvigerina hispida Schwager, 1866
Plate 14, figures 4-12.

Uvigerina hispida SCHWAGER, 1866, p. 249, pl. 7, fig. 95. – BOERSMA, 1984, p.76, pl. 1, figs. 1-4; – VAN MORKHOVEN et al., 1986, p. 62, pl. 20, figs. 1-4. – MILLER and KATZ, 1987, p. 140, pl. 2, fig. 2. – KATZ and MILLER, 1993, pl. 4, fig. 7. – ROBERTSON, 1998, p. 154, pl. 58, fig. 3. – KUHNT et al., 2002, p. 158, pl. 14, figs. 5-7. – ORTIZ and THOMAS, 2006, p. 134, pl. 11, fig. 8. – KENDER et al., 2008, pl. 18, figs. 6-8. – HOLBOURN et al., 2013, p. 592.

Distribution in core: 209 specimens from 34 samples; intermittent occurrence down the core, highest abundance at depths 7.85 and 15.79 m.

Description: Test is elongate, triserial, mostly sub-cylindrical in shape, fusiform, tapered at the periphery, circular cross-section; approximately two times as long as broad, average length ranges between 0.22 and 0.65 mm, width 0.18 and 0.25 mm; average length / width ratio is 2.3 (0.48 / 0.21), widest in the middle. Wall calcareous, perforate, ornamentation of densely spaced spines over each chamber, the spines varying from blunt to sharp in morphology; chambers mostly inflated and robust, particularly the later chambers, separated by distinctly depressed sutures; number of chambers varies on average with maturity from 5 to 7. Aperture is a terminal, round opening at the end of a relatively short neck, bordered by a phialine lip, and an internal toothplate.

Remarks: Characters that are typical for, but not exclusive to, *U. hispida* include the stout test, compact, sub-cylindrical shape, fusiform, triserial coiling (that tends to become loose in the later chambers), and the number of chambers varying with maturity from 5 to 8 (in Bering Sea specimens, the maximum number of chambers is 7). The circular aperture is situated on a short neck and bordered by a phialine lip, and contains an internal toothplate which is another distinctive character of *U. hispida* (see also Boersma 1984; Van Morkhoven et al. 1986 and description of Holbourn et al., 2013).

The Bering Sea material is very similar to specimens illustrated as *U. hispida* in the original description (reproduced in Ellis and Messina, 1940), having depressed and distinct sutures: the Bering Sea specimens are distinct from those illustrated from the Gulf of Mexico by Holbourn et al. (2013: p. 592), which have a basal spine on the first chamber, but no apertural neck. Circa 90% of the specimens in assemblages from the Bering Sea are well preserved, but have no basal spine. Holbourn (2013) interpreted the absence of the latter to be due to preservation, but data from this study implies that the presence/absence of this character varies intraspecifically.

There is variation in the strength of spines on individual chambers (Plate 14, Figs. 4-14) and these ranges from dense and acicular (needle-shaped) to blunt and coarse ornamentations. *U. hispaniolana* Bermudez is morphologically similar to *U. hispida* but differs by having its sutures not depressed as in *U. hispida*. The chambers in *U. senticosa* are more inflated than in *U. hispida,* while the spines are not as pronounced (sharp) and high as it is in *U. hispida*.

Distribution: *Uvigerina hispida* is a cosmopolitan species that has a geographical distribution in the Atlantic, Pacific and Indian Oceans, the Gulf of Mexico and the Mediterranean Sea (van Morkhoven et al., 1986; Kender et al., 2008; Holbourn et al., 2013) and other ocean regions (Holbourn et al., 2013). *U. hispida* has a bathymetric range that includes bathyal settings (Holbourn et al., 2013); its water depth ranges from 937 to 2539 m in the Gulf of Mexico, and 2489 to 3257 m in the Peru-Chile trench (LeRoy and Levinson, 1974). *U. hispida* also occurs as a shallow infaunal species (Corliss and Emerson, 1990; Schmiedl et al., 2000; Fontanier et al., 2002; 2003a; 2006). The stratigraphical range of *U. hispida* is from Early Miocene to Recent (Boersma, 1984c; Holbourn et al., 2013).

Uvigerina senticosa Cushman, 1927
Plate 14, figures 13-17.

Uvigerina senticosa CUSHMAN, 1927, p. 159, pl. 3, fig. 14. – CUSHMAN, STEWART, and STEWART, 1930, p. 68, pl. 5, fig. 9. – CUSHMAN, STEWART, and STEWART, 1949, p. 153, pl. 17, fig. 13. – BANDY, 1953, p. 177, pl. 25, fig. 12. – PIERCE, 1956, p. 1301, pl. 139, fig. 2. – SCHÖNFELD and SPIEGLER, 1993, pl. 1, figs. 5, 6.

Distribution in core: 50 specimens from 23 samples; intermittent occurrence between intervals 1.38 and 15.23 m, highest abundance at depths 8.60, 8.72 and 15.23 m.

Description: Test robust, elongate, triserial, sub-cylindrical in shape, fusiform, circular cross-section, periphery lobate, approximately two and a half times as long as broad, average length ranges between 0.32 and 0.77 mm, width 0.20 and 0.30 mm; average length / width ratio is 1.9 (0.48 / 0.25), increasing in size, widest in the middle of the test. Wall calcareous, moderately hispid throughout, hispidity being evenly distributed over the chambers: hispids are not aligned and do not seem to follow any hidden costae (for example, as observed in more spinose forms of *U. peregrina*), except on the first chamber where the costae break into irregular hispids. Chambers are more inflated than most other *Uvigerina* species, and are evenly graduated in size from the almost rounded initial end to the broadest towards the apertural end. Sutures are straight, oblique and depressed; aperture terminal with well-developed lip, having an inward projection of (the inner portion of) the neck wall into the aperture in the form of a spiral tooth lip at the flattened side of the aperture.

Remarks: Morphological assessment of *U. senticosa* recovered from Bering Sea core U1342, which incorporates horizons determined to signal different levels of water column oxygenation (based on sedimentary characteristics and associated fauna), shows no significant change in key morphological features including maximal length without apertural neck (maxL) and maximum transversal diameter (MTD). Bering Sea material is morphologically similar to specimens recorded by Bandy (1953, pl. 25, figs. 12 a, b) from the California coast, and from the SE Pacific by Schönfeld and Spiegler (1993: pl.1, figs 5 and 6), by having the same number and arrangement of the chambers; *Uvigerina proboscidea* Schwager recorded from the California coast (Bandy 1953: pl. 25, figs. 11 a, b), which has hispids, fairly elongated chambers and slightly straight sutural lines, is also morphologically similar to *U. senticosa,* but differs in having less inflated chambers. *Uvigerina auberiana* d'Orbigny is morphologically similar to *U. senticosa*, but is differentiated by its relatively broad cylindrical neck. Material from the Bering Sea shows intraspecific variation in the length of the apertural neck of specimens in the assemblage; the average length of the neck ranges between 0.05 - 0.1 mm; about 60% of the specimens have longer necks.

Distribution: *Uvigerina senticosa* has a geographical distribution in the Pacific Ocean (Schönfeld and Spiegler, 1993), the coasts of Australia and California (Bandy, 1953; Lowry and Smith, 2003), and the Gulf of Mexico (Sen Gupta et al., 2009). Its water depth ranges from 351 - 800 m in the SE Pacific Ocean (Schönfeld and Spiegler, 1993), to 3488 m in the Pacific to the east of Australia (Lowry and Smith, 2003), up to 3657 m in the NE Pacific (Bandy, 1953) and 0–3850 m at the Gulf of Mexico (Sen Gupta et al., 2009). *U. senticosa* also occurs as a shallow infaunal species (Ovsepyan et al., 2013) and is considered by some an indicator of suboxic conditions (Kaiho, 1994). The first record of *U. senticosa* is from the Recent of the eastern Pacific (Weldon, 1970). It has since been recorded from the Miocene, Pliocene, and Pleistocene of California.

Uvigerina peregrina Cushman, 1923
Plate 15, figures 1-16.

Uvigerina peregrina CUSHMAN, 1923, p. 166, pl. 42, figs. 7-10. – PHLEGER and PARKER, 1951, p. 18, pl. 8, figs. 22, 24-26. – PARKER, 1954, p. 521, pl. 8 fig. 5. – MILLER and LOHMANN, 1982, pl. 1, Figs. 11-12. – BOERSMA, 1984, p. 124, pl. 1, figs. 1-4. – LUTZE, 1986, p. 32, pl. 1, figs. 1-6. – TIMM, 1992, p. 67, pl. 6, fig. 2. – VAN LEEUWEN, 1986, p. 59, pl. 1, figs. 1-5. p. 67, pl. 6, fig. 2. – SCHÖNFELD, 1997, p. 1, fig. 21. – LEVY et al. 1998 p. 610, pl. 1, fig. 10. – KOUWENHOVEN, 2000, p. 197, pl. 11, figs. 1-2. – SCHÖNFELD, 2006, p. 354, pl. 1, figs. 14-18.

Distribution in core: 504 specimens in 69 samples; consistent occurrences at depth intervals 0 to 3.24 m, 5.26 to 6.63 m; highest occurrences in the first 3.24 m of Site U1342.

***Description**:* Test elongate and stout, about 2 times as long as broad, widest in the middle, typically between 0.20 to 1.13 mm in maximum length (maxL) excluding neck; 0.15 to 0.45 mm maximum transverse diameter (MTD); average length / breadth ratio is 1.9 (0.62 / 0.32); later chambers inflated, more loosely triserial from side view, number of chambers varies with maturity from 4 to 11; sutures distinct and depressed. Longitudinal costae are distinct, and tend to become serrate and divide up into a series of plate-like spines or irregular short portions towards the younger chambers; wall calcareous, perforate, first and final chambers are mostly spinose, short series of pustules may be present between the costae, which may be coarse or fine. Aperture terminal, produced on a neck, which may be depressed at the base or not; aperture circular at the end of a distinct cylindrical / tubular and often spinose neck, aperture bordered with a lip having an internal projection like a toothplate at the flattened side of the aperture, with a phialine lip.

Remarks**:** *Uvigerina peregrina* was originally described by Cushman (1923) from a continental slope sample (~2100 m), off the northeastern United States. In the assemblages, the length of the apertural neck varies randomly from 0.025 to 0.05 mm. The chambers are typically inflated, with the largest width often above the middle of the test. Costae vary from strong to weak on the chambers. The number of chambers correlates weakly with the length. The final chambers are generally hispid in all the assemblages, while the aperture is situated on an elongated neck, which may or may not be spinose.

The size of the test, shape of the chambers, length / width ratio, arrangement and morphology of costae are the main diagnostic features in differentiating this species from other *Uvigerina* species. *Uvigerina akitaensis* Asano (1950) has been considered by Scott et al. (2000) as a junior synonym for *U. peregrina*. *Uvigerina peregrina parva* Lutze is differentiated from *U. peregrina* by its smaller but uniform length, which ranges between 0.40 to 0.45 mm in adults (Schönfeld 2006), but resembles *Uvigerina peregrina* with its early and final chambers often being spinose. *U. dirupta* Todd has the same variation in test size and shape, but it is more slender with an average of 0.44 mm maximum transversal diameter (Leeuwen 1986). *U. pygmea* d' Orbigny, 1826 has thin and low costae on the chambers, which may be partially serrate on the upper end of the lower chambers, and which are often smaller with few pustules between the costae. *U. peregrina* differs from *U. peregrina* var. *latalata* Stewart and Stewart in that the latter has fewer numbers of costae (usually 5 or 6) on fully grown chambers (Ellis and Messina, 1940). The Bering Sea *U. peregrina* are similar to those from the Mediterranean Sea figured by Abu-Zied et al. (2008: pl. 2, figs. 19-20) and Schönfeld (2006: pl. 1, figs. 14-18), in having serrated costae, spines on the first chambers and prominently on the last chambers.

Distribution**:** *Uvigerina peregrina* has a geographical distribution from the Pacific (Schönfeld and Spiegler, 1995; Keller, 1980; Butt, 1980; Ken'ichi 1999), Atlantic (Levy et al., 1998; Schönfeld, 2006) and Indian Oceans (Peterson, 1984; Kurbjeweit et al., 2000; Schumacher et al. 2007), the Mediterranean Sea (Fontainer et al., 2008) and other seas (e.g., Jorissen, 1987). The characteristic water depth distribution of *U. peregrina* ranges from 900 to 3200 m (Haake, 1980; Lutze, 1980; Lutze and Coulbourn, 1984). Its water depth range varies from 300 m in the Atlantic, having its shallowest reliable occurrences in the Gulf of Mexico (Pflum and Frerichs, 1976), to 2496 m in the deep Guinea Basin (Timm, 1992). A complete bathymetric succession of *Uvigerina* morphotypes from the eastern North Atlantic has been described by Lutze (1986); *U. peregrina* is replaced progressively by another *Uvigerina* morphotype with spines between the costae and an entirely spinose last chamber (*U. hollicki* Thalmann) at 2000 m depth (Lutze 1986, Williams et al., 1987). Below 3000 m, *U. peregrina* is replaced by the spinose morphotype, *U. hispida*, which became increasingly dominant (Van Leeuwen, 1986).

The test morphology within the assemblage under review does not vary substantially, given that the water depth is relatively shallow (~800 m). *U. peregrina* has been described as a shallow infaunal species (Corliss and Emerson, 1990; Schmiedl et al., 2000, Fontanier et al., 2002; 2003a; 2006), and classified by Kaiho (1994) as a suboxic indicator. The stratigraphical range of *U. peregrina* is from Eocene to Recent (Jones, 1994).

***Uvigerina* sp. 1**
Plate 15, figure 17; Plate 16, figures 1-8.

Distribution in core: 9 specimens from 7 samples; first occurrence at 0 m, intermittent occurrence down core to 20.06 m.

Description: Test small, robust, small terminal neck, broken surface carinate; average length of test 0.32 to 0.45 mm, and width 0.20 to 0.32 mm, rounded in cross-section; chamber outlines and sutures indistinct, 11 to 12 longitudinal coarse costae on the chambers, prominent costae stop abruptly before getting to the base of the apertural neck; wall coarsely calcareous, micro perforate; aperture a round opening at the end of a depressed neck bordered with a lip.

Remarks: *Uvigerina* sp. 1 is superficially similar to juvenile *U. bifurcata* in shape, coaste and rounded aperture, but is differentiated by the wall structure, which is coarsely calcareous, and its apertural opening without a spiral tooth.

Subfamily ANGULOGERININAE Galloway, 1933
Genus *Angulogerina* Cushman, 1927.
Type species *Uvigerina angulosa* Williamson 1858 original designation by Williamson 1858, p. 67

Angulogerina angulosa (Williamson, 1858)
Plate 16, figures 9-13.

Uvigerina angulosa WILLIAMSON, 1858, p. 67, pl. 5, fig. 140. – CUSHMAN 1923, p. 170, pl. 41, figs. 17-20. *Angulogerina angulosa* (Williamson). – PARKER, 1958, p. 259, pl. 2, figs. 1, 2. – FEYLING-HANSSEN, 1980, p. 184, pl. 1, figs. 9, 10. – SEJRUP et al., 1981, p. 292, pl. 2, fig. 10. – LOEBLICH and TAPPAN, 1987, p. 151, pl. 574, figs. 5-9. – CIMERMAN and LANGER, 1991, p. 63, pl. 66, figs. 3, 4. – SGARRELLA and MONCHARMONT-ZEI, 1993, p. 215, pl. 16, fig. 8. – DEBENAY et al., 2005, p. 336 pl. 3, fig. 12. – OBLAK BROWN, 2011, p. 52, pl. 2, fig. 5. – MILKER and SCHMIEDL, 2012, p. 91, pl. 21, figs. 2-4. – SCHIEBEL, 1992, p. 56, pl. 3, fig. 1. – MURRAY, 2003, p. 26, fig. 10, no. 5. – RASMUSSEN, 2005, p. 89, pl. 12, fig. 1. – ABU-ZIED et al., 2008, p. 52, pl. 2, fig. 21. – MILKER et al., 2009, p. 218, pl. 3, fig. 2.

Distribution in core: 363 specimens from 65 samples; species totally absent between depths 2.78 to 5.13 m and 10.51 to 12.24 m, intermittent occurrence down core, highest abundances are at depths 1.13 m, and 5.26 to 5.87 m.

Description: Test elongate, angled with three flattened sides, triangular in shape and cross-section, triserial, slightly inflated, about two and a half times as long as broad, average length ranges between 0.22 and 0.85 mm, width 0.18 and 0.30 mm, average length / width ratio is 2.6 (0.57 / 0.22). Wall calcareous, finely perforate, surface ornamented with a few narrow high costae; chambers triserially arranged, later tending towards uniserial arrangement; sutures curved, oblique, and slightly depressed, the three angles of the test are carinate and well developed, longitudinal costae may not be continuous over some sutures in some specimens; aperture terminal with a toothplate, bordered by a narrow lip on a short neck.

Remarks: This taxon was originally assigned to *Uvigerina*, but placed within *Angulogerina* because of its triangular shape, cross-section and triserial arrangement of chambers, tending towards being uniserial at the later chambers (Loeblich and Tappan, 1987). The material from the Bering Sea seems morphologically identical to *A. earlandi* Parr recorded from the SW Pacific Ocean by Kawagata (1999: figs. 5, 11a, b and 12a, b) in being elongate, having carinate angles, tapering at both ends and by having longitudinal costae that are not continuous over the sutures.

Morphological assessment of specimens of *A. angulosa* recovered from Bering Sea core U1342, which incorporates horizons determined to signal different levels of water column oxygenation and organic carbon flux (based on sedimentary characteristics and associated benthic foraminifera), show no significant change in number of chambers, shape of chambers, strength of costae, and position of the neck. However, there is variation in the strength of costae on the chambers; circa 5% of the specimens have costae that are limited mostly to the early chambers.

Distribution: *Angulogerina angulosa* has a wide geographical distribution in the Pacific and Southern Oceans (Brady, 1884; Dowsett and Ishman, 1995; Bubenshchikova et al., 2010); Bering, Weddell and Mediterranean Seas (Anderson, 1975; Mackensen et al., 1990; Gross, 2001; Milker and Schmiedl, 2012; Ovsepyan et al., 2013) and other regions (Bandy, 1953, Culvers and Buzas, 1980; Asioli, 1995; Eichler et al., 2012; Wilson and Costelloe, 2011). *A. angulosa* ranges from 10 to 250 m depth for the subtropical South American coast, off the California coast and in the Mediterranean Sea (Bandy, 1953; Milker and Schmiedl, 2012), down to deeper water depth from 839 to 1312 m in the Pacific Ocean and Bering Sea (Bubenshchikova et al., 2010; Ovsepyan et al., 2013). *A. angulosa* is also a shallow infaunal species (Bubenshchikova et al., 2010), and has previously been considered an indicator of sub-oxic conditions (Kaiho, 1994). The stratigraphical range of *A. angulosa* is from Eocene to Recent (Loeblich and Tappan, 1987).

Superfamily FURSENKOINACEA Loeblich and Tappan, 1961
Family FURSENKOINIDAE Loeblich and Tappan, 1961
Genus FURSENKOINA Loeblich and Tappan, 1961
Type species *Virgulina squamosa* d'Orbigny, 1826

Fursenkoina* aff. *texturata (Brady, 1884)
Plate 16, figures 14-18; Plate 17, figures 1-3.

aff. *Virgulina texturata* BRADY 1884, p. 52, fig. 6.
aff. *Virgulina subdepressa* BRADY, 1884, pl. 52, figs. 14-17. – BARKER, 1960, pl. 52, figs. 14–17.
aff. Fursenkoina texturata (Brady, 1884). – JONES, 1994, pl. 52, figs. 6, 14-17. – HAYWARD, 2002, p. 290, pl. 3, figs 4-5. – HAWARD et al., 2004, p. 154, pl. 1, fig. 15. – HAYWARD and KAWAGATA, 2005, p. 173, pl. 1, figs. 5-9. – MOHAN et al., 2011, p. 54, pl. 4, figs. 19-20.
aff. *Virgulopsis* sp. KURIHARA and KENNETT, 1986, pl. 2, figs. 15-16.

Distribution in core: 41 specimens from 4 samples; first occurrence at 0.10 m depth, other occurrences between 13.60 and 15.56 m; highest abundance at 14.28 m.

Description: Test narrow, elongate, round to ovate in cross-section, chambers high and narrow, weakly inflated and biserial, plane of biseriality twists about the test axis throughout; chamber number varies from 10 to 12, average length of test ranges between 0.55 and 0.85 mm, and width 0.18 and 0.37 mm; sutures oblique and depressed; wall calcareous, surface finely perforate and smooth; aperture oval to round, slightly elongate with apertural foramen in the form of a tongue.

Remarks: *Fursenkoina texturata* and *Virgulina subdepressa* are considered to be micro and macrospheric forms respectively (Jones, 1994); *F. texturata* was listed in the Arabian Sea database under the older name *Virgulina texturata* Brady (see Heinz and Hemleben, 2006). *F.* aff. *texturata* is morphologically similar to *F. texturata* (Brady, 1884; Hayward and Kawagata, 2005), the latter being biserial, with weakly inflated chambers having oblique sutures; and its plane of biseriality is twisted about the test axis *F.* aff. *texturata* can be differentiated from *F. texturata* by its apertural opening, which is more rounded (see Jones, 1994; Pl. 52, fig. 6, 14-17). Whether this difference represents a subspecies, or is simply a function of regional variation, cannot as yet be defined. *F. fusiformis* (Williamson) also has its chambers more inflated than in *F.* aff. *texturata* (see Mohan et al., 2011; p. 53, pl. 4, figs. 17-18; 19-20).

Distribution: *Fursenkoina* aff. *texturata* is only known from the Bering Sea. *F. texturata has a* geographical distribution in the SW Pacific Ocean (Hayward, 2002; Hayward et al., 2004), the "Challenger station" in the South Pacific (see Brady, 1884; Jones, 1994) and the Arabian Sea (Heinz and Hemleben, 2003; 2006). It has a water depth range from 200-4500 m in the South and Southwest Pacific Ocean (Jones, 1994; Hayward, 2002; Hayward et al., 2004), extending deeper than 4000 m in the NW Atlantic Ocean (Mohan et al., 2011). The stratigraphical range of *F. texturata* is from the Late Miocene to Holocene (Hayward, 2002; Mohan et al., 2011).

Family BAGGINIDAE Cushman, 1927
Subfamily BAGGININAE Cushman, 1927
Genus *Valvulineria* Cushman, 1927
Type species *Valvulineria californica* Cushman, 1926

Valvulineria araucana (d'Orbigny, 1839)
Plate 17, figures 4-12.

Rosalina araucana D'ORBIGNY, 1839, p. 44, pl. 6, figs. 16-18.
Valvulineria araucana CUSHMAN, 1927, p. 160, pl. 4, figs. 7,8. – KLEINPELL, 1938, p. 307. – CUSHMAN, STEWART and STEWART, 1947, p. 20, pl. 3, fig. 1. – CROUCH, 1952, p. 834, pl. 4, figs. 7,8.
Valvulineria araucana (d' Orbigny, 1839). – WHITE, 1956, pl. 28, fig. 3a-b.

Distribution in core: 833 specimens from 97 samples; consistent occurrence down core, high abundance at depths 10.78, 15.19, 19.07 and 19.44 m.

Description: Test rounded to elongate in outline, smooth, thin, hyaline, coarsely and densely perforate except at the umbilical region where pores are scarce; wall calcareous, chambers inflated, six chambers in the final whorl, gradually increasing in size as added; test average dimension is 0.38 mm in the longer diameter, 0.30 mm in the shorter diameter, two and a half whorls visible, spiral side slightly convex and flattened, trochospirally coiled, umbilical region involute and depressed with rounded periphery. Sutures are curved backward on the spiral side, depressed on both sides, tends towards being radial. Aperture an extraumbilical arch at the base of the final chamber provided with a large flap covering almost the entire umbilicus.

***Remarks*:** *Valvulineria araucana* is similar in morphology to *V. complanata* (d' Orbigny) recorded by Milker and Schmiedl (2012) from the Holocene of the western Mediterranean Sea, except that *V. araucana* is slightly more elongate in outline with 6 to 8 chambers, while *V. complanata* is more rounded with 5 to 6 chambers (see Milker and Schmiedl, 2012; figs. 16 and 17). Scripps (1940) considered that the specimens referred to as *V. inflata* (d'Orbigny) by Cushman (1927) are a variety of *V. araucana* (d'Orbigny) because of various morphological similarities, like the same number of chambers and the test outline which is elongate. Circa 80% of *V. araucana* from the Bering Sea have their test outline more elongated, while others tend towards being rounded in test outline; the extent of the apertural flap covering the umbilicus varies slightly, with the majority covering the whole apertural openings, while a few do not completely cover the openings (Pl. 17, fig. 7, 9, 11 and 12).

Distribution: *V. araucana* has a geographical distribution in the Atlantic and Pacific Oceans (Mackensen, 1989), Mediterranean Sea and the Gulf of Mexico (White, 1956; Molina-Cruz and Ayala- Lopez, 1988; Gross, 2001; Dorst and Schoenfeld, 2013). *V. araucana* has a depth range from 500 m in the Pacific Ocean (Mackensen, 1989), 550 m in the Atlantic Ocean, extending to a deeper water depth range between 4,001 and 6,270 m in the West coast area offshore from Central America (Bandy and Arnal, 1957; Kern and Wincander, 1974; Culver and Buzas, 1980). *V. araucana* has a stratigraphical range from the Miocene of Southern California USA (Kern and Wincander, 1974).

Family EPONIDIDAE Hofker, 1951
Subfamily EPONIDINAE Hofker, 1951
Genus *Alabaminella* Saidova, 1975
Type species *Eponides weddellensis* Earland, 1936

Alabaminella weddellensis (Earland, 1936)
Plate 17, figures 13-17.

Eponides weddellensis EARLAND, 1936, pl. 2, figs. 22-23. – SCOTT and LEGER, 1990, p. 206, pl. 1, figs. 12, 13.
Eponides pusillus PARR, 1950, pl. 14, fig. 16 a-c.
Alabaminella weddellensis (Earland). – EARLAND, 1936, pl. 14, figs. 16 a-c. – RESIG and CHEONG, 1997, p. 436, pl. 2, figs. 1-6. – BARBIERI et al., 1999. p. 52, pl. 3, fig. 3-7. – AUSTIN and EVANS, 2000. p. 684, pl. 1, figs. p, q. – OHKUSHI et al., 2000, p. 141, pl. 3, figs. 3a-c. – HAYWARD et al., 2002, pl. 1, figs. 25-27. – HAYWARD et al., 2007, p. 156, pl. 1, fig.15.

Distribution in core: 3425 specimens from 63 samples; first occurrence at 2.78 m, consistent occurrences down core afterwards, high abundance at depth 16.10 m and also intervals 16.55 to 16.90 m and 19.22 to 19.92 m.

Description: Test is small, radial, average dimensions range from 0.075 mm to 0.175 mm in diameter. Wall calcareous, chambers are perforate except at the umbilicus, eight to ten chambers in the final whorl, biconvex, umbilical side slightly depressed, spiral side more convex, with broad low chambers, mostly five to six radial whorls, periphery rounded; sutures oblique, slightly depressed. Apertural face is prolonged on the test margin; aperture a slit-like extraumbilical and interiomarginal opening, offset from the centre toward the periphery, surrounded by a denticulated lip.

Remarks: *Alabaminella weddellensis* is differentiated from *Eponides weddellensis* Earland, which is morphologically similar but has a keeled periphery, smooth to slightly pustulose wall, and a broad aperture bordered by a narrow lip. *A. weddellensis* specimens described from the Bering Sea are more perforate than specimens described as *A. weddellensis* by Barbieri et al. (1999; pl. 3, fig. 4) from the Upper Pleistocene of the Ross Sea in Antarctica. *A. weddellensis* from the Pacific and Atlantic Oceans (Resig and Cheong, 1997; Austin and Evans, 2000; Gooday and Hughes, 2002) are morphologically similar to the Bering Sea specimens in having perforate chambers, eight to ten chambers in the final whorl, five to six radial whorls, a rounded periphery, and slightly oblique and depressed sutures.

Alabaminella weddellensis has been described as a phytodetritivore, which is an opportunistic species abundant when phytodetritus deposition increases, from for instance seasonal phytoplankton blooms in the surface water (Gooday, 1993; Thomas et al., 1995). The abundance of this species has been linked to pronounced seasonality of primary production in the Bering Sea (Okazaki et al., 2005). Despite being about 10% of the total assemblage recovered from the core, amounting to the second highest abundance in core U1342; no significant trends in intraspecific variation have been noticed in the assemblage down core.

Distribution: *Alabaminella weddellensis* has a geographical distribution in the Pacific and Atlantic Oceans (Resig and Cheong, 1997; Ken’ichi, 1999; Austin and Evans, 2000; Ohkushi and Natori, 2001; Gooday and Hughes, 2002; Khusid et al., 2005; Sun at al., 2006; Bubenshchikova et al., 2010), Antarctica (Barbieri et al., 1999; Igarashi et al., 2001; Hayward et al., 2007), Bering Sea (Ovsepyan et al., 2013), and other seas

(Schmiedl et al., 1997; Cornelius and Gooday, 2004; Murray and Pudsey, 2004; Okazaki et al., 2005). *A. weddellensis* has a water depth range from 500 to 3354 m in different oceans and seas around the world (Ohkushi and Natori, 2001; Gooday and Hughes, 2002; Bubenshchikova et al., 2010; Ovsepyan et al., 2013). *A. weddellensis* is a shallow infaunal species (Bubenshchikova et al., 2010) and has been proposed to be an indicator of sub-oxic conditions (Kaiho, 1994, Hayward et al., 2007). The stratigraphical age of *A. weddellensis* is from the Pleistocene to Holocene (Resig and Cheong, 1997, Bergamaschi, 2012).

Family PARRELLOIDIDAE Hofker, 1956
Genus *Cibicidoides* Thalman, 1939
Type species *Truncatulina mundula* Brady, Parker and Jones, 1890

***Cibicidoides* sp.**
Plate 18, figures 1-5.

Distribution in core: 35 specimens from 8 samples; first and lone occurrence at 6.37 m; lone occurrence at 8.86 m, few other occurrences between 16.48 and 18. 80 m.

Description: Low trochospiral test, sub-rounded in outline, bi-umbonate, nearly biconvex in cross-section with an involute, slightly more convex umbilical side and an evolute spiral side; test average diameter is 0.45 mm, thickness is 0.15 mm; wall calcareous, coarsely perforate, periphery is imperforate; nine to twelve chambers in the last whorl, slightly inflated, increasing gradually in size, all chambers are visible on the spiral side, more perforate on the spiral side, separated by slightly curved sutures on the umbilical side, sparsely perforate on the umbilical side; sutures oblique and flush with the surface on the spiral side, aperture a narrow interiomarginal arch, bordered by a thin lip that extends onto the spiral suture.

Remark: *Cibicidoides* sp. recorded from Core 1342 is morphologically similar to *Cibicidoides mundulus* (Brandy, Parker and Jones), but with a more pronounced convex umbo at the two sides, a fewer number of chambers (up to 9 in the final whorl). *C. mundulus* is a relatively common species in Neogene deep-sea sedimentary deposits; it was recorded from the Indian Ocean as *C. kullenbergi* (Parker) by Boltovskoy (1978 a: pl. 3, figs. 9-12). *Cibicidoides* sp. and *C. kullenbergi* (Parker) are characterised by considerable size variation, but no other essential morphological difference; *C. kullenburgi* is considered to be a junior synonym of *C. mundulus* (Morkhoven et al., 1986). *Cibicidoides* sp. described from Core 1342, Bering Sea are morphologically similar to those from the Pacific and Indian Oceans, and the Red Sea (Hermelin, 1989; pl. 17, figs. 9-11; Gupta, 1994, pl. 5, fig. 7).

Distribution: Most *Cibicidoides* species are cosmopolitan (Holbourn et al., 2013) with a geographical distribution in the Pacific, Atlantic and Indian Oceans (Brady, 1884; Burke, 1981; Resig, 1981; Thomas, 1985; Kurihara and Kennett, 1986; Stott et al., 2007; Brady et al., 1888; Phleger et al., 1953; Boltovskoy, 1978a), Bering Sea (Ovsepyan et al., 2013), and offshore Angola (Kender et al., 2008). The bathymetric range of *C. mundulus* is from bathyal to abyssal, from 751 to 2000 m (Lowell et al., 2007; Kender et al., 2008; Ovsepyan et al., 2013). *C. mundulus* is an epifaunal species (Bubenshchikova, 2010), described by Kaiho (1994) as sub-oxic in the modern ocean. The stratigraphic range of *C. mundulus* is from late Oligocene to Holocene (Thomas, 1985; Morkhoven et al., 1986; Kender et al., 2008; Holbourn et al., 2013).

Superfamily PSEUDOPARRELLIDAE Voloshinova, 1952
Family PSEUDOPARRELLINAE Voloshinova, 1952
Genus *Epistominella* Husezima and Maruhasi, 1944
Type species *Epistominella pulchella* Husezima and Maruhasi, 1944

Epistominella exigua (Brady, 1884)

Plate 18, figures 6-13.

Pulvinulina exigua BRADY, 1884, p. 696, pl. 103, figs. 13, 14. – CUSHMAN, 1921, p. 340, pl. 68, figs. 3a-c.
Pseudoparrella exigua (Brady). – PHLEGER and PARKER, 1951, p. 28, pl. 15, figs. 6a-b, 7a-b. – LOEBLICH and TAPPAN, 1994, p. 146, pl. 307, figs. 1-7.
Pulvinulinella exigua (Brady). – WIESNER, 1931, p. 121. – PARR, 1950, p. 361. – HOFKER, 1951, p. 322, text figs. 219-221.
Epistominella exigua (Brady). - PHLEGER et al., 1953, p. 43, pl. 9, figs. 35, 36. – BARKER, 1960, p. 212, pl. 103, figs. 13-14. – BOLTOVSKOY, 1978, p. 156, pl. 3, figs. 37, 38. – CORLISS, 1979, p. 13, pl. 2, figs. 7, 8. – HERMELIN and SCOTT, 1985, p. 208, pl. 4, fig. 1. – BELANGER and BERGGREN, 1986, p. 337, pl. 6a-c. – MILLER and KATZ, 1987, p. 132, pl. 5, fig. 6a,b. – INOUE, 1989, p. 153, pl. 18, figs. 12 a,b; pl. 26, figs. 2a-c. – HERMELIN, 1989, p. 67, 68. – THOMAS, 1990, p. 590. – KAIHO, 1992, p. 310, pl. 8, fig. 6a-c. – NOMURA, 1995, p. 276, pl. 3, fig. 3. – KATZ et al., 2003, p. 35, pl. 2, fig. 3. – HOLBOURN et al., 2013, p. 240.
Alabaminoides exiguus (Brady). – JONES, 1994, p. 103, pl. 103, figs. 13-14.

Distribution in core: 57 specimens from 4 samples; first occurrence and highest abundance at depth 14.41 m, other few intermittent occurrences at 15.23, 16.55 and 16.65 m.

Description: Test generally small, trochospiral, slightly lenticulate, slightly biconvex in cross-section; average dimension of 0.20 mm at the maximum diameter, 0.15 mm at the short diameter, thickness of 0.08 mm; wall calcareous, chambers are finely perforate and may be smooth, about 6 to $6^1/_2$ slightly inflated chambers present in the last whorl, increasing gradually in size, separated by flush, straight and radial sutures. All chambers are visible on spiral side, only those of the last whorl on the spiral side are evolute; aperture an extraumbilical slit, extending up the face of the final chamber on the umbilical side, bordered by serrate lip.

Remarks: *Epistominella exigua* differs from *E. vitrea* Parker in having about 5 to $5^1/_2$ instead of 6 to $6^1/_2$ chambers in the last whorl and a more angled test periphery (Hermelin, 1989; Sen Gupta, 2009; pl. 60, p. A-62). *E. exigua* described from the Bering Sea is similar to the specimens illustrated by Gupta (1994; pl. 4, figs. 18, 19) from the Indian Ocean and the Red Sea, and specimens illustrated by Sen Gupta et al., (2009; pl. 59, p. A-61) from the northern Gulf of Mexico. Specimens studied here show intraspecific variation in the density of pores on their chambers; about 70% of the specimens in the assemblage have relatively high pore density, but down core this pore-density variation appears to be random.

Distribution: *Epistominella exigua* is cosmopolitan, and has a geographical distribution in the Atlantic, Pacific and Indian Oceans (Brady, 1884; Cushman, 1912; Phleger et al., 1953; Smith, 1964; Boltovskoy, 1978a; Corliss, 1979; Schnitker, 1980; Burke, 1981; Mead, 1985; Miller and Katz 1987; Inoue, 1989; Hermelin, 1989), Arctic (Lazar and Polyak, 2016), Antarctic (Thomas, 1990; Rasmussen et al., 2002), Caribbean Sea (Wilson and Costelloe, 2011), and other oceans (Belanger and Berggren, 1986, Miller and Kartz, 1987; Hermelin, 1989; Kaiho, 1992; Lecroq et al., 2009). Murray (1991) noted that *E. exigua* has not been reported from the Mediterranean. *E. exigua* has a water depth range extending from 2500 m in the southeast Indian Ocean (Corliss, 1979) to 4755 m at a 'Challenger' station in the Southern Ocean (Jones, 1994), down to the deep abyssal planes at >3.5 km in the North Atlantic (Miller and Katz 1987). Inoue (1989) reported it as abundant at depths of 500–4500 in the Philippine Sea.

Epistominella exigua has been described as an opportunistic, phytodetritus-exploiting species indicating a seasonally fluctuating input of organic matter to the sea floor (Thomas 1990; Thomas and Gooday, 1996; Smart et al., 1994; Lazar and Polyak, 2016). It has been considered as an indicator species for Northeast Atlantic Deep Water (Weston and Murray, 1984), and in the Arctic it is most common in the older interglacial intervals (Lazar and Polyak, 2016). The stratigraphical range of *E. exigua* is from the Middle Eocene to Recent, though its occurrence is rare from the middle Eocene and Late Eocene (Thomas, 1990).

Epistominella pulchella Husezima and Maruhasi, 1944
Plate 18, figures 14-16; Plate 19, figures 1-3.

Epistominella pulchella HUSEZIMA and MARUHASI, 1944, p. 398, pl. 34, figs. 10a-c. – INOUE, 1989, p. 154, pl. 33, figs. 14a,b. – VILKS, 1989, p. 540, pl. 21-IV, figs. 13-15. – KATO, 1992, pl. 3, figs. 2a-c. –SETOYAMA and KAMINSKI, 2015, fig. 5, 8a-c.

Distribution in core: 80 specimens from 16 samples; intermittent occurrences in the first 8.10 m; species absent down core thereafter.

Description: Test medium in size, average diameter is 0.45 mm, thickness is 0.35 mm; weakly lenticular on the spiral side, trochospiral, two and a half to three whorls, unequally biconvex to planoconvex in cross-section with an involute and convex umbilical side; evolute spiral side is flat to low convex with an acute carinate periphery; wall calcareous, surface smooth, six to seven chambers visible on the umbilical side; sutures are slightly depressed, and oblique, maybe straight or gently curved, nearly radial; aperture an interiomarginal opening, extending to the apertural face of the final chamber on the umbilical side, bordered with a lip.

Remarks: *Epistominella pulchella* is differentiated from *E. exigua* (Brady) in size and cross-section of the test, *E. pulchella* being bigger and planoconvex in cross-section. According to Voloshinova et al. (1970) and Ujiié et al. (1983), *E. pulchella* is a junior synonym of *E. pacifica* (Cushman). The material from the Bering Sea is morphologically similar to *E. pacifica* recorded by Figueroa et al. (2005) from the central south of Chile (adjacent to the Pacific Ocean), but *E. pacifica* is more convex to conical on the umbilical side (see also Bergen and O'Neil, 1979; Bernhard et al., 2001: figs. 4 A a-c; Figueroa et al., 2005).

Distribution: *Epistominella pulchella* has a geographical distribution in the Pacific, Arctic and Atlantic Oceans (Inoue, 1989; Echols, 2005; Setoyama and Kaminski, 2015), the Mediterranean, Japan and Bering Seas (Kato, 1992; Setoyama and Kaminski, 2015); its water depth ranges from 100 m in the Japan Sea (Kato, 1992; Compton et al., 2002), to 209 m in the North Atlantic Ocean (Echols, 2005) and 2140 m depth in the Bering Sea (Setoyama and Kaminski, 2015). In the northwest Pacific, Inoue (1989) reported it to be a common deep-water species, commonly occurring at depths from 1000 to 3800 m. *E. pulchella* occurs as an infaunal species and has been suggested to be an indicator of sub-oxic conditions (Kaiho, 1994; Bubenshchikova, 2010). The stratigraphical range of *E. pulchella* is from the Lower Miocene to Holocene (Loeblich and Tappan, 1987).

Superfamily PLANORBULINACEA Bermúdez, 1952
Family PLANULINIDAE Bermúdez, 1952
Genus *Planulina* d'Orbigny, 1826
Type species *Planulina ariminensis* d'Orbigny, 1826

Planulina ariminensis d'Orbigny, 1826
Plate 19, figures 4-6.

Planulina ariminensis D'ORBIGNY, 1826, p. 280, pl. 14, figs. 1-3. – CUSHMAN, 1931, p. 110. – PHLEGER and PARKER, 1951, p. 32, pl. 18, figs. 4a, b. – PARKER, 1954, p. 540, pl. 11, figs. 27, 30. – BARKER, 1960, p. 192, pl. 93, figs. 10, 11. – LEROY and LEVINSON, 1974, pl. 6, figs. 11-13. – POAG, 1981, p. 75, pl. 43, fig. 3; pl. 44, figs. 3a, b. – VAN MORKHOVEN et al., 1986, p. 38, 40, pl. 10, figs. 1-4, – DENNE, 1990, pl. 10, figs. 7a, b. –JONES, 1994, p. 98, pl. 93, figs. 10-11; ABU-ZIED et al. 2008, pl. 2, figs. 31-32. – SEN GUPTA et al., 2009, p. 380, pl. 127, figs. 1-2. – HOLBOURN et al., 2013, p. 402.
Anomalina ariminensis (d'Orbigny). – BRADY, 1884, p. 674, pl. 93, figs. 10, 11.

Distribution in core: 26 specimens from 6 samples; isolated occurrences at depths 0.10 m, 2.64 m and between 15.69 to 15.79 m; highest abundance at 15.69 m.

Description: Test planispiral, relatively large, sub-circular in outline, average dimension of 0.88 mm at maximum diameter, thickness of 0.15 mm; evolute on the spiral side and partially evolute umbilical side, periphery truncate, sides of the test flattened and almost parallel; acute and keeled periphery. Wall calcareous, distinctly perforate on the two sides; generally more coarsely perforate on the spiral side, ten to twelve narrow and curved chambers in the final whorl, flaring, increasing rapidly in size, overlapping, separated by strongly curved and slightly depressed sutures; aperture is an equatorial slit with a narrow lip, extending below the umbilical folium.

Remarks: *Planulina ariminensis* is differentiated from *P. weullerstorfi* (Schwager) by having both sides of the test flattened, almost parallel and evolute on both sides, the chambers being more flared, while *P. weullerstorfi* (Schwager) has a planoconvex shape and it is finely perforate on the umbilical side, coarsely perforate on the spiral side with more elongate, thick curved sutures, and a more compressed test. *P. ariminensis* is similar to *P. mexicana* but the latter is more finely perforate on both sides. Bering Sea specimens are similar to illustrated specimens from Mexico (Holbourn et al., 2013: p. 402, figs. 1-2), and also with the specimens illustrated from the Mediterranean Sea by Abu-Zied et al. (2008: pl. 2, figs. 31-32) being perforate on the two sides, and having the same number of chambers and same form of coiling.

Distribution: *Planulina ariminensis* is a cosmopolitan species which has a geographical distribution in the Atlantic Ocean (Austin and Evans, 2000; Gooday and Hughes, 2002; Sun at al. 2006), Gulf of Mexico (LeRoy and Levinson, 1974; van Morkhoven et al., 1986; Sen Gupta et al., 2009), Bering Sea (Ovsepyan et al., 2013) and other seas (Sun at al. 2006; Wilson and Costelloe, 2011). *P. ariminensis* ranges from 1061 and 2918 m in the Gulf of Mexico, the Caribbean Sea and the Atlantic Ocean (LeRoy and Levinson, 1974; Gooday and Hughes, 2002; Sun at al. 2006; Wilson and Costelloe, 2011; Ovsepyan et al., 2013). The stratigraphical range of *P. ariminensis* is Late Miocene to Recent (Holbourn et al., 2013).

Planulina wuellerstorfi (Schwager, 1866)
Plate 19, figures 7-18.

Anomalina wuellerstorfi SCHWAGER, 1866, p. 258, pl. 7, figs. 105, 107.
Planulina wuellerstorfi (Schwager). – CUSHMAN, 1929, p. 104, pl. 15, figs. 1, 2. – BERMÚDEZ, 1949, p. 293, pl. 23, figs. 37-39. – PHLEGER et al., 1953, p. 26, pl. 11, figs. 1-2. – PHLEGER et al., 1953, p. 49, pl. 11, figs. 1, 2. – BARKER, 1960, pl. 93, figs. 9a-c. – LOHMANN 1978, p. 26, pl. 2, figs. 1-4. – CORLISS, 1979, p. 7, pl. 2, figs. 13-16. – VAN MORKHOVEN et al., 1986, p. 48, pl. 14. – BELANGER and BERGGREN, 1986, p. 337, pl. 3, figs. 9a-11c. – MILLER and KATZ, 1987. p. 136, pl. 6, figs 2. – SCOTT and VILKS, 1991, p. 31, pl. 2, figs. 13, 14; pl. 4, figs. 14, 15. – ROBERTSON, 1998, p. 216, pl. 86, fig. 2.– OHKUSHI et al., 2000, p. 142, pl. 4, figs. 1a-c. – HOLBOURN et al., 2013, p. 416. – HOLBOURN et al., 2013, p. 416.
Cibicides wuellerstorfi (Schwager). – PFLUM and FRERICHS, 1976, p. 116, pl. 4, figs 2-4. – CORLISS, 1979, p. 13, pl. 2, figs. 13-16.

Distribution in core: 6 specimens from 5 samples; few and random occurrence at the top part of the core between intervals 0.74 and 2.24 m, isolated occurrence at depth 12.47 m, absent thereafter.

Description: Test calcareous, discoidal, planoconvex in cross-section, with a flattened evolute spiral side, a slightly convex, partially evolute umbilical side and a truncate, keeled periphery; average dimension is 0.73 mm in the longest diameter, thickness is 0.34 mm. Chamber walls are coarsely perforate on the spiral side, finely perforate on the umbilical side; low trochospiral chamber arrangement, nine to ten narrow chambers in the final whorl, curved, slightly inflated chambers, increasing rapidly in size, separated by thickened and strongly curved sutures which, on the spiral side, are slightly depressed, while sutures are slightly raised on the umbilical side; primary aperture is an equatorial slit with a narrow lip extending beneath the umbilical point.

Remarks: *Planulina wuellerstorfi* is differentiated from *P. ariminensis* which is parallel at both sides, and more flared in coiling. Setoyama and Kaminski (2015) referred to specimens from the Bering Sea as *Fontbotia wuellerstorfi* (Schwager), following Loeblich and Tappan (1987). We assign this species to *Planulina* because the test is discoidal, low trochospiral, and having an evolute umbilical side. *Fonthobia* usually have a compressed test, and an involute coiling on the umbilical side which is convex; a more recent description of *P. wuellerstorfi* (Holbourn et al., 2013), tallies morphologically with our specimens. Bandy (1967) observed that specimens of *P. wuellerstorfi* from depths over 1000 m from North Atlantic deep waters tend to have hooked or sigmoid sutures, whereas specimens from shallower environments have smoother, curved sutures. Specimens examined from Bering Sea Site U1342 appear to vary randomly in the coiling of their test, rate of expansion of their final chambers, width of the final whorl and the curvature of the sutures. There is also no significant intraspecific variation in the number or density of pores, mode of coiling and other morphological characteristics in the few specimens examined from U1342; occurrence of *P. wuellerstorfi* is very limited to the first half of the studied core.

Distribution: *Planulina wuellerstorfi* is a cosmopolitan species, typical of major oceans and marginal basins (van Morkhoven et al., 1986; Sen Gupta, 1989; Schnitker, 1980; Douglas and Woodruff, 1981). *P. wuellerstorfi* has its water depth range extending from 1151 m in the North Atlantic (Streeter, 1973; Lohmann, 1978; Belanger and Berggren, 1986) to between 2500 and 4600 m in the southeast Indian Ocean (Corliss, 1979)**.** *P. wuellerstorfi* is abundant mainly in lower bathyal and abyssal depths, and is generally used as a bathymetric indicator for water depths over 800 m (Holbourn et al., 2013); it constitutes a significant portion of the benthic foraminiferal assemblage in waters deeper than 2500 m (Van Morkhoven et al., 1986). *P. wuellerstorfi* was considered a low to intermediate carbon (2.5–9 g/m^2 y) flux indicator by Altenbach et al. (1999). Kaiho (1994) and Bubenshchikova (2010) classified this species as sub-oxic in the modern ocean. *P. wuellerstorfi* also occurs as an epifaunal species (Bubenshchikova et al., 2008). Its stratigraphic range is from Middle Miocene to Recent (Holbourn et al., 2013).

Family NONIONIDAE Schultze, 1854
Subfamily NONIONINAE Schultze, 1854
Genus *Nonionellina* Voloshinova, 1958
Type species *Nonionina labradorica* Dawson, 1860

Nonionellina labradorica (Dawson, 1860)
Plate 20, figures 1-5.

Nonionina labradorica DAWSON, 1860, p. 191-192, fig. 4.
Nonion labradoricum (Dawson). – LOEBLICH and TAPPAN, 1953, p. 86, pl.17, figs. 1, 2. – HANSEN and LYKKE-ANDERSEN, 1976, p. 37, pl. 21, figs. 5-8.
Nonionellina labradorica (Dawson). – BANDY, 1953, p. 66, pl. 22, fig. 1. – VOLOSHINOVA, 1958, p. 142. – KNUDSEN, 1971, p. 262, pl. 10, figs. 1-2. – CRONIN, 1979, p. 805, pl. 5, fig. 6. – KELLER, 1980, p. 859, pl. 3, figs. 9-10. – SEJRUP et al., 1981, p. 293, pl. 2, figs. 5-7. – VILKS et al., 1982, p. 227, pl. 1., figs. 24 a-b. – WILLIAMSON et al., 1984, p. 224, pl. 1, fig. 11. – LOEBLICH and TAPPAN, 1987, p. 617, pl. 689, figs. 8-17. – INOUE, 1989, p. 157, pl. 24, figs. 3a,b; pl. 32, figs. 13a,b; pl. 33, figs. 3a,b. – GUSTAFSSON and NORDBERG, 2001, p. 9, pl. 1, fig. 6. – PATTERSON and KUMAR, 2002. p. 122, pl. 2, figs. 12, 18. – POLYAK et al. 2002, p. 261, pl. 2, fig. 10. – NARAYAN et al., 2005, p. 132, pl. 4, figs. 21, 22. – ABU-ZIED et al., 2008, p. 53, pl. 3, figs. 10 -13. – HOLBOURN et al., 2013, p. 374. – SETOYAMA and KAMINSKI, 2015, fig. 6.1a, b, 8.19.

Distribution in core: 77 specimens from 22 samples; intermittent occurrences down core, abundance occurrence between intervals 17.09 to 18.55 m.

Description: Test is biconvex, trochospiral in the very early stage, planispiral in the later part, tends to be involute; wall calcareous, finely perforate, surface smooth, thin and translucent; seven to eight chambers, enlarging rapidly as added, producing a somewhat flaring test; average number of chambers is eight in the final whorl, average length of the test is 0.45 mm at the maximum diameter; chamber thickness ranges between 0.12 to 0.30 mm, thickness of the last chamber exceeding that of the first chamber by about three times; chambers enlarging rapidly as added; small, deeply depressed umbilici on both sides, slightly inflated basal lobe, periphery sub-angular to round; sutures are gently curved, thin and slightly depressed, but more incised near the umbilicus. Aperture is a low equatorial arched slit, surrounded by few pustules at the base of the apertural face; apertural face is smooth, broad, sub-triangular and slightly perforate.

Remark: *Nonionellina labradorica* is distinguished by the initial part of the test being trochoid while the later part is planispiral (Hansen and Lykke-Andersen, 1976). Bering Sea specimens closely resemble those reported by Hansen and Lykke-Andersen (1976) from east Greenland, but differ slightly from specimens illustrated by Dawson (1860), which have an outline that is non-lobulate. Keller (1980) illustrated a form with a lobulate outline from the Japan Trench (Pacific Ocean), which has an average number of eight chambers, and the degree of inflation of the chambers in the last whorl and the chamber coiling is very similar to specimens in this study. Bering Sea specimens have a smooth outline similar to specimens from the Pacific Ocean illustrated by Vázquez Riveiro and Patterson (2007), and Matoba (1967). The Bering Sea specimens are similar to *N. labradorica* Dawson described by Abu-Zied et al (2008: pl. 3, figs 10-13) from the Swedish coast, from the Mediterranean Sea by Gustafsson and Nordberg (2001: pl. fig. 6) and from Canada by Vilks et al. (1982: pl. 1, fig. 24a-b).

Distribution: *Nonionellina labradorica* is present in the NW Pacific, and the Atlantic Oceans (Cronin, 1979; Keller 1980; Inoue, 1989; Ohkushi et al., 2003; Bubenshchikova et al., 2010; Erbs-Hansen et al., 2012), the Bering Sea (Ovsepyan et al., 2013), Arctic and boreal seas bordering Alaska, Canada, Greenland, Spitsbergen, Norway and Denmark (Polyak et al., 2002; Scott et al., 2008; Holbourn et al., 2013; Pawlowska, 2015), and other regions (Gustafsson and Nordberg, 2001; Patterson and Kumar, 2002; Mazumder et al., 2003). *N. labradorica* has a bathymetric range between the neritic and abyssal (Holbourn et al., 2013). In Spitsbergen it characterises the Atlantic water mass (Pawlowska, 2015). In the northwest Pacific it was recored from depths of 100–3500 m (Inoue, 1989). Its water depth ranges from 50 to 3500 m (Keller 1980; Gustafsson and Nordberg, 2001; Polyak et al., 2002; Patterson and Kumar, 2002; Mazumder et al., 2003; Scott et al., 2008; Erbs-Hansen et al., 2012; Ovsepyan et al., 2013). *N. labradorica* has been considered a dysoxic species (Kaiho, 1994; Bubenshchikova et al., 2010). The stratigraphical range of *N. labradorica* is from Miocene to Recent (Hansen and Lykke-Andersen 1976; Inoue, 1989; Holbourn et al., 2013).

Nonionella digitata Nørvang, 1945
Plate 20, figure 6.

Nonionella turgida (Williamson) var. *digitata* NØRVANG, p. 29, text-fig. 4.
Nonionella digitata Nørvang, 1945. – PATTERSON, BURBIDGE and LUTERNAUER, p. 20, pl. 21, figs. 1-3. – TODD and LOW, 1967, pl. 5, fig. 8. – PATTERSON and KUMAR, 2002. p. 122, pl. 2, fig. 11. – RIVEIROS and PATTERSON, 2007, p. 13, fig. 12, 5. – VÁZQUEZ RIVEIROS and PATTERSON, 2008, p. 29, fig. 12.5. – SETOYAMA and KAMINSKI, 2015, fig. 5.11-c, 8.18.

Distribution in core: 4 specimens from 3 samples; first occurrence at 15.59 m, isolated occurrences at 18.67 and 19.44 m.

Description**:** Test compressed, fragile, general outline round to elongate, slightly inflated, elliptical in shape, may be ovate, periphery rounded to elongate; average length of the test is 0.52 mm at the maximum diameter, 0.32 mm in width; slightly inflated basal lobe on the umbilical side. Wall calcareous, hyaline, fragile, smooth, finely perforate, rapidly increasing in size; umbilical side involute with only 5 to 6 chambers in the final whorl visible, sutures slightly depressed towards the umbilical area; distinctive flap-like extensions of final chambers subdivided into 7 to 8 digitate projections obscuring the umbilical region. Aperture is an interiomarginal, nearly equatorial arch, covered by digitate projection extending over umbilical side.

Remarks**:** Bering Sea specimens are similar to *Nonionella digitata* Nørvang, described by Vázquez Riveiros and Patterson (2007), from northern British Columbia, Canada (NE Pacific) with distinctive finger-like projections covering the umbilical region. *N. digitata* is differentiated from other *Nonionella* by its umbilical flap with long digitate extensions, and differs especially from *N. labradorica* in the way the chambers are added: *N. labradorica* has its whorls progressively enlarging, producing a flaring final chamber, while *N. digitata* has flap-like extensions of the final chamber ending in finger-like projections. *N. digitata* is differentiated from *N. stella* Cushman and Moyer by its umbilical flap being more prominent with longer extensions. The few specimens of *N. digitata* recorded from Site U1342 do not show any significant intraspecific variation.

Distribution**:** *Nonionella digitata* has a geographical distribution in the Arctic and Atlantic Oceans (Gross, 2001), Okhotsk and Bering Seas, and the Pacific adjacent to British Columbia (Lembake et al. 2003; Vázquez Riveiros and Patterson, 2007; Ovsepyan et al., 2013), and the Gulf of Alaska (Bergen and O'Neil, 1979). Its water depth ranges from 200 to 238 m in the Gulf of Alaska and British Columbia (Bergen and O'Neil, 1979; Patterson and Kumar, 2002; Riveiros and Patterson, 2007), extending to 625 to 1752 m in the Pacific Ocean (Lembake et al., 2003; Riveiros and Patterson, 2007; Bubenshchikova et al., 2008; Ovsepyan et al., 2013). *N. digitata* has been considered a deep infaunal species and an indicator of dysoxic conditions (Bubenshchikova et al. 2008).

Subfamily PULLENIINAE Schwager, 1877
Genus *Melonis* de Montfort, 1808
Type species *Melonis etruscus* de Montfort, 1808

Melonis barleeanus (Williamson, 1858)
Plate 20, figures 7-12.

Nonionina barleeana WILLIAMSON, 1858. p. 32, pl. 3. figs. 68, 69.
Nonionina umbilicatula (Montagu). – BRADY, 1884, p. 726, pl. 109, figs. 8, 9.
Nonion barleeanum (Williamson). – PHLEGER et al., 1953, p. 30, pl. 6, fig. 4.
Gavelinonion barleeanum (Williamson). – BARKER, 1960, p. 224, pl. 109, figs. 8, 9.
Melonis barleeanum (Williamson). – WILLIAMSON, 1858, pl. 2, figs. 1-9. – PFLUM and FRERICHS, 1976, p. 122, pl. 7, figs. 5, 6. – WRIGHT, 1978, p. 715, pl. 6, fig. 4. – CORLISS, 1979, p. 10, 12, pl. 5, figs. 7, 8. – INGLE et al., 1980, p. 142, pl. 7, figs. 14-15. – O'NEILL et al., 1981, p. 1155, pl. 3, figs. 1,6. – LOUBERE and BANONIS, 1987, pl. 1, figs. 1, 2. – CARALP, 1988, figs. 3-4. – CARALP, 1989, p. 40, figs. 13-4. – GUPTA, 1994, p. 366, pl. 6, fig. 1. – DOWSETT and ISHMAN, 1995, p. 154, pl. 1, fig. 5. – JANNINK et al., 1998, p. 1497, pl. 1, fig. 7a-b. – OHKUSHI et al., 2000, p. 143, pl. 5, figs. 6a-b. – LICARI and MACKENSEN, 2005, p. 213, pl. 1, figs. 12, 13. – PANIERI, 2005, p. 253, fig. 4, 3 a-b. – ABU-ZIED et al., 2008, p. 53, pl. 3, figs. 16, 17. – SEN GUPTA et al., 2009, p. 380, pl. 103, figs. 1-2. – MILKER and SCHMIEDL, 2012, p. 115, fig. 26.11-12. – HOLBOURN et al., 2013, p. 354. – SETOYAMA and KAMINSKI 2015, figs. 6.4a-b, 6.5.

Distribution in core: 13 specimens from 7 samples; first and last occurrence at 12.98 and 19.92 m respectively; few intermittent occurrences in between this range.

Description: Test compressed, planispiral, involute and symmetrical; wall calcareous, hyaline and perforate; chambers broad, new chambers are added on the previous apertural face, enlarging gradually as added; average dimension at the longest diameter is between 0.30 and 0.37 mm; thickness between 0.12 and 0.15 mm, usually more than 10 chambers in the final whorl. Open umbilical region, sutures slightly raised, radial or straight to slightly curved, merged with thickened umbilical rim, periphery broadly rounded, peripheral outline smooth and slightly curvy; finely perforate except on the apertural face and on the sutures. Aperture an open, equatorial and interiomarginal curved slit, extending to an open umbilical region at the two sides, bordered with a pronounced lip.

Remarks: *Melonis barleeanum* has been placed by several authors in the genus *Nonion* which is morphologically similar, but a distinction from that genus is possible because the umbilical region is open rather than closed as in *Nonion*. Thus, *M. barleeanum* is differentiated from *Nonion fabum* (Fichtel and Moll) by its open umbilical region. *M. barleeanum* differs from *M. pompilioides* (Fichtel and Moll), by being thinner and more coarsely perforate (Luisa et al, 1994; Bergamin et al. 1997), with pronounced sutures that tend to be tangential to the umbilicus, in contrast to the radiate and less well defined sutures in *M. pompilioides.* Bering Sea materials are similar to *M. affinis* illustrated by Milker and Schmiedl (2012), but differ in that the latter has a less prominent apertural lip.

Van Marle (1991) noted that *Melonis barleeanum* (Williamson) is a junior synonym of *Melonis affinis* (Reuss). Schweizer (2006) synonymised *M. barleeanus* under *M. affinis* based on molecular analysis. Bering Sea specimens are similar to *M. barleeanum* (Williamson) from the Mediterranean Sea illustrated by Abu-Zied et al. (2008: pl. 3, figs. 16-17), and also similar to the specimens illustrated by Chendeş et al. (2004; p. IV, fig. 1) from the Marmara Sea, and Jannink (1998: pl. 1, figs 7a-b) from the northern Arabian Sea, and from the Pacific bordering central and southern Chile (Figueroa et al., 2005). The stratigraphical range of *M. barleeanum* in Site U1342 is restricted to 12.98 to 19.92 m.

Distribution: *Melonis barleeanum* is a cosmopolitan species which has a geographical distribution in the Atlantic, Pacific, Southern and Indian Oceans (Cushman, 1914; 1939a; Phleger et al., 1953; Corliss 1979; Ingle et al., 1980; Hermelin et al., 1985; Caralp, 1989; Schönfeld and Spiegler, 1995; Dowsett and Ishman; 1995; Labeyrie et al., 1996; Khusid et al., 2005; Panieri, 2005), the Bering Sea (Ovsepyan et al., 2013), and other seas (Kurihara and Kennett, 1986; Kuhnt et al., 2007; Wilson and Costelloe, 2011; Milker et al., 2009). *M. barleeanum* is generally considered a bathyal species; but was recorded in the Gulf of Mexico from the neritic zone to the middle bathyal zone (Pflum and Frerichs, 1976); its depth ranges between 500 and 3290 m in the northeast Atlantic (Caralp, 1989; Labeyrie et al., 1996; Panieri, 2005; Licari and Mackensen, 2005); and it is also found within the oxygen minimum zone between 500 and 1000 m depths in the northern Arabian Sea (Jannink et al., 1998; de Dulk et al., 1998; Mazumder et al., 2003; Ovsepyan et al., 2013). *M. barleeanum* was recorded from the Indian Ocean at a deeper water depth range between 2500 and 4500 m (Corliss 1979; Ovsepyan et al., 2013).

Melonis barleeanum occurs as an intermediate and shallow infaunal species (Corliss, 1985; Corliss and Emerson, 1990; Gooday, 1994; Jorissen et al., 1995; Jorissen et al., 1998; Mackensen et al., 2000; Licari et al., 2003). Kuhnt et al. (2007) reported this species as an indicator of dysoxic conditions. *M. barleeanum* is known to be rare in the Oligocene, but abundant in the Middle and Late Miocene (Miller and Katz, 1987; Katz and Miller, 1993). Its stratigraphical range is Oligocene to Recent (Thomas, 1985; Holbourn et al., 2013).

Genus *Pullenia* Parker and Jones, 1862
Type species *Nonionina bulloides* d'Orbigny, 1846

Pullenia simplex Rhumbler, 1931

Plate 20, figures 13-16.

Pullenia simplex Rhumbler 1931, p. 132, pl. 22, fig. 263. – WIESNER, 1931, p. 132, pl. 22, fig. 263. – FEYLING-HANSSEN, 1954, p. 2, fig. 6a, 6b. – ANDERSON, 1975, p. 95, pl. 11, fig. 10. – CORLISS, 1979, p. 9, pl. 4, figs. 5-6. – MACKENSEN, 1992, p. 670, pl. 2, fig. 6. – KAIHO, 1992, p. 310, pl. 8, fig. 4. – BARBIERI et al., 1999, p. 50, pl. 2, figs. 3-5. – KOHO et al., 2007, p. 43, pl. II, figs. 6a-b.

***Distribution in core*:** 257 specimens from 63 samples; occurrence is relatively consistent down core, with the exception of intervals 3.77–4.85 m, 6.80–7.71 m and 19.61–20.59 m where the species is absent; relatively abundant between intervals 1.13–1.38 m.

***Description*:** Test is medium-sized, slightly compressed, sub-circular in outline, planispiral and involute, slightly inflated, a sub-rounded periphery, having five to seven chambers in the final whorl which increases rapidly in size, the last chamber being flared; average dimension of the test ranges from 0.25 mm to 0.35 mm at the longest diameter, 0.12 mm to 0.16 mm in thickness. Wall calcareous, finely perforate with smooth surface, sutures radial, flushed to slightly depressed; aperture a narrow interiomarginal slit, extending across the periphery to the sides of the umbilicus, surrounded by a lip.

***Remarks*:** *Pullenia simplex* was originally described by Rhumbler (1931), but Wiesner (1931) published the report of the description (Corliss 1979, p. 9). *P. simplex* from the Bering Sea differ from the specimens illustrated from the Indian Ocean (Corliss, 1979; p. 9, pl. 4, figs. 5-6) in not having as rapidly enlarging chambers; but are morphologically similar to specimens from the Portuguese continental margin (Koho et al., 2007; p. 43, pl. II, figs. 6a-b) in the chamber number and coiling. *P. simplex* is morphologically similar to *P. quinqueloba* (Reuss), but the latter differs in not having rapidly enlarging chambers (Belanger and Berggren, 1986), and being more biconvex (see Holbourn, 2013; p. 448 fig. 2). In addition, *P. quinqueloba* (Reuss) has fewer chambers. *P. simplex* differs from *P. bulloides*, the latter having its chambers less undulose, whilst its umbilici are more open and its chambers enlarged more rapidly than in *P. simplex*.

***Distribution*:** *Pullenia simplex* has a geographical distribution in the Atlantic and Indian Oceans (Corliss, 1979; Belanger and Berggren, 1986; Corliss, 1991; Mackensen, 1992); the Southern Ocean (Anderson, 1974; Mackensen and Douglas, 1989; Barbieri et al., 1999) and Japan Sea (Kaiho, 1992). Its water depth ranges from 200 and 3410 m in the Atlantic and Indian Oceans, and in the Antarctic (Corliss, 1979, 1991; Belanger and Berggren, 1986; Mackensen and Douglas, 1989; Barbieri et al., 1999), this extends to 4976 m along the Portuguese continental margin in the Atlantic (Koho et al., 2007). *P. simplex* is an apparent indicator of sub-oxic conditions in the modern ocean (Kaiho, 1994). The stratigraphical range of is from Paleocene to Recent (Corliss, 1979).

Family ORIDORSALIDAE Loeblich and Tappan, 1984
Genus *Oridorsalis* Andersen, 1961
Type species *Oridorsalis westi* Andersen, 1961

Oridorsalis umbonatus (Reuss, 1851)
Plate 21, figures 1-10.

Rotalina umbonata REUSS, 1851, p. 75, pl. 5, figs. 35 a-c.
Pulvinulina umbonata (Reuss). – BRADY, 1884, p. 695-696, pl. 105, figs. 2a-c. – CUSHMAN, 1915, p. 60, pl. 27, fig. 2. – CUSHMAN, 1921, p. 339-340, pl. 71, figs. 1a-c. – HERON-ALLEN and EARLAND, 1932, p. 430, pl. 15, figs. 16-18.
Rotalia ecuadorensis GALLOWAY and MOREY, 1929, p. 26, pl. 3, fig. 13.

Eponides umbonatus (Reuss). – CHAPMAN and PARR, 1937, p. 108. – BERMÚDEZ, 1949, p. 249, pl. 17, figs. 22-24. – PARKER, 1952, p. 419, pl. 6, fig. 13. – PHLEGER et al., 1953, p. 42, pl. 9, figs. 9-10. – BARKER, 1960, p. 216, pl. 105, figs. 2a-c.
Pseudoeponides umbonatus (Reuss). – PARKER, 1954, p. 530, pl. 9, figs. 20, 21.
Oridorsalis umbonatus (Reuss). – TODD, 1965. p. 23, pl. 6, fig. 2. – PFLUM and FRERICHS, 1976, p. 106, pl. 24, figs. 4.
Oridorsalis tener tener (Brady). – PFLUM and FRERICHS, 1976, pl. 6 figs. 2-4.
Oridorsalis tener umbonatus (Reuss). – PFLUM and FRERICHS, 1976, p. 108, pl. 6, figs. 5-7.
Oridorsalis tener (Brady). – LOHMANN, 1978, p. 26, pl. 4, figs. 5-7. – CORLISS, 1979, p. 9, pl. 4. figs. 10-15. – INGLE et al., 1980, p. 142, pl. 5, figs. 5-6.
Oridorsalis umbonatus (Reuss). – WRIGHT, 1978, p. 724, pl. 6, figs. 13-14.– BOLTOVSKOY, 1980, p. 169, pl. 3, fig. 1; p. 170, fig. 8. – SAUNDERS et al. 1984, p. 408, pl. 4, fig. 10. – BELANGER and BERGGREN, 1986, p. 340, pl. 5, figs. 10a-c. – INOUE, 1989, p. 158, pl. 24, figs. 13 a-c. – HERMELIN et al., 1989, p. 141, pl. 16, figs. 1-5. – SCHRÖEDER et al., 1990, p. 34, pl. 8, fig. 13. – MACKENSEN et al., 1990, p. 261, pl. 7, figs. 4-6. – SCOTT and VILKS, 1991, p. 31, pl. 2, figs. 15, 16; p. 34, pl. 4, figs. 4-5. – JONES, 1994, p. 99, pl. 95, fig. 11. – AKIMOTO, 1994, p. 290, pl. 3, fig. 5. – BOLLI et al. 1994, p. 247, pl. 58, fig. 10-13. – SCHÖNFELD and SPIEGLER 1994, p. 220, pl. 1, fig. 9. – SEN GUPTA, 1994, p. 365, pl. 6, fig. 11. – SCHÖNFELD, p. 171, pl. 1, fig. 11. – OHKUSHI et al., 2000, p. 143, pl. 5, figs. 1a-c. – HAYWARD et al., 2001, figs. 16 R–S. – SEN GUPTA et al., 2009, p. A-118, pl. 116, figs. 1-3. – HOLBOURN et al., 2013, p. 384. – SETOYAMA and KAMINSKI, 2015, fig. 7.2a-c

Distribution in core: 142 specimens from 17 samples; a few isolated occurrences down core at 0– 0.10 m, 5.26–5.41 m, 5.46 m, 15.79 m–15.95 m and 18.95–19.22 m; relatively abundant in the interval 18.95–19.22 m.

Description: Test trochospiral, compressed, low trochospire; sub-circular to slightly lobate in outline, unequally biconvex in cross section, convex and evolute spiral side, with an involute, less convex umbilical side, keeled and sub-acute periphery. About twice as thick as wide, average dimension is 0.27 mm in diameter at the widest diameter, and 0.15 mm in thickness. Wall calcareous, finely perforate and smooth, about six to seven moderately inflated chambers in the final whorl, increasing in size gradually. Sutures slightly depressed, radial on spiral side, straight to sinuous on the umbilical side. Aperture an interiomarginal slit, extending from the closed umbilical area to the periphery, with lip and pustules surrounding it; supplementary openings on the umbilical side at the junction between the spiral side, and at the sinuous bend along the suture on the umbilical side.

Remarks: *Oridorsalis umbonatus* and *O. tener* (Brady) have been reported to be morphologically similar (Hermelin, 1989). *O. umbonatus* from the Bering Sea has straight sutures on the spiral side which differentiate it from *O. tener* (see Corliss, 1979; Mead, 1985). *O. umbonatus* from the Bering Sea shows intraspecific variation in test convexity: larger tests are more convex, and this may be related to maturity. Parker (1954) did not observe supplementary apertures in her small specimens, and Barker (1960) could not find supplementary apertures on any of his Pacific material. Supplementary apertures are difficult to see under the light microscope, but are obvious in SEM micrographs as rounded openings on the dorsal side (Plate 21, figs. 2, 4, 6 and 10)

Distribution: *Oridorsalis umbonatus* has a geographical distribution in the Pacific, Atlantic and Indian Oceans (Corliss, 1979; Butt, 1980; Boltovskoy, 1980; Keller, 1980; Boersma, 1984a, b; Murray, 1984; Mackensen et al. 1990; Kato, 1992; Akimoto 1994; Schönfeld and Spiegler, 1994; Schönfeld, 1995; Ken'ichi, 1999; Sun at al. 2006; Noda et al., 2008; Bubenshchikova et al., 2010), the Arctic (Scott and Vilks, 1991) as well as other regions (Wright, 1978; Sen Gupta et al., 2009; Kender et al., 2008). Its water depth range extends from 95 to 1708 m at the 'Challenger' stations in the Pacific Ocean (Jones, 1994), between 70 and 280 m in the Sea of Japan (Inoue, 1989), to between 289 and 5600 m in the Indian Ocean, SW and

Atlantic Oceans, Weddell and other seas (Corliss, 1979; Mackensen et al., 1990; Rasmussen et al., 2007; Kender et al., 2008; Noda et al., 2008; Sen Gupta et al., 2009; Jorissen et al., 2009).

The distribution of *O. umbonatus* in the northeast Atlantic has been linked to bottom water masses (Streeter, 1973; Schnitker, 1974, 1980; Weston and Murray, 1984; Gaydyukov and Lukashina, 1988; Lukashina, 1988). *O. umbonatus* is an indicator of sub-oxic conditions and is a shallow infaunal species (Bubenshchikova et al., 2010). The stratigraphical range of *O. umbonatus* is from Middle Paleocene to Recent (Tjalsma and Lohmann, 1983; Thomas, 1990; Bolli et al., 1994; Jones, 1994; Holbourn, 2013).

Family GAVELINELLIDAE Hofker, 1956
Subfamily GAVELINELLINAE Hofker, 1956
Genus *Gyroidina* d' Orbigny, 1826
Type species *Gyroidina orbicularis* d'Orbigny, 1826

***Gyroidina* sp. 1**
Plate 21, figures 11, 12.

Distribution in core: 2 specimens in 2 samples at 18.43 and 19.22 m

Description: Morphologically similar to *Gyroidina* sp. 2 (see *Gyroidina* sp. 2) but with the raised umbilical sutures.

Remarks: Only two specimens were recorded from the interval studied. The major difference between *Gyroidina* sp. 1 and *Gyroidina* sp. 2 is the raised umbilical sutures; which is depressed in *Gyroidina* sp. 2. The two specimens are well preserved.

***Gyroidina* sp. 2**
Plate 21, figures 13-16; Plate 22, figures 1-4.

Distribution in core: 700 specimens from 47 samples; species absent in the first 2.38 m of the core, intermittent occurrence down core, relative abundance between 5.55 - 5.46 m, 6.11 – 6.20 m and 10.87 m; highest abundance at 19.22 m.

Description: Test medium to large, average dimension is 0.52 mm at the longer diameter, 0.37 mm at the shorter diameter, average thickness 0.30 mm, slightly compressed, tightly coiled, trochospiral, surface is smooth, unequally biconvex, umbilical side more convex, spiral side slightly flat in most individuals, but occasionally weakly convex. Wall calcareous, chambers gradually increasing in size as added, six to nine chambers in the final whorl; only 1 to 1-1/2 whorls per test. Sutures are backwardly curved, depressed, slightly flush with the surface on the spiral side, radial in the umbilical side. Aperture an interiomarginal slit at the middle of the apertural face, extending toward the periphery, bordered by a lip.

Remarks: The biconvexity of most *Gyroidina* sp. 2 studied from the fauna causes it to appear like species of *Eponides*; however, the deep ventral side and the character of the aperture are features of *Gyroidina. Gyroidina* sp. 2 is morphologically close to *G. lamarckiana* (D'Orbigny), but it is differentiated by the fewer number of chambers in its final whorl; chambers in *Gyroidina* sp. 2 being more (10 to12), and also *Gyroidina* sp. 2 has an evolute coiling in the umbilical view, whilst *Gyroidina* sp. has involute coiling on the umbilical side. *Gyroidina* sp. 2 is morphologically similar to the material described as *G. lamarckiana* by Todd (1965) from the Pacific Ocean; it is thought to be conspecific with *G. lamarckiana* (D'Orbigny); but differs from *G. soldanii* d'Orbigny which has more distinct chambers from the spiral view and a greater number of chambers and whorls generally (see Bandy, 1953; p. 173, pl. 23, figs. 6a-c). *Gyroidina* sp. 2 specimens from core U1342 show slight intraspecific variation in their sizes and coiling of their test; this seems to be related to maturity as the bigger ones exhibit a wider degree of coiling.

Distribution: *Gyroidina* sp. 2 is recorded only from the Bering Sea. In contrast, *G. lamarckiana* has a geographical distribution in the Pacific and Atlantic Oceans (Todd, 1965; Boltovskoy, 1980; Sun at al. 2006), the Mediterranean, Japan and South China seas (Wright, 1978; Keller, 1980; Kuhnt et al., 1999) and other seas (Boltovskoy, 1978, 1980; Sen Gupta and Smith, 2010, Wilson and Costelloe 2011). It has a water depth range from 61 m in Norway, down to 1574 m in the Pacific Ocean (Rosoff and Corliss, 1992; Todd, 1965), and extending to approximately 2000 m in the Japan Sea (Keller, 1980) down to 4000 m in the South China Sea (Kuhnt et al., 1999). The known stratigraphical range of *G. lamarckiana* is from Oligocene to Recent (Boltovskoy, 1978).

Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIINAE Galloway, 1933
Genus *Elphidium* de Montfort, 1808
Type species *Nautilus macellus* var. ß Fitchtel and Moll, 1798

Elphidium ustulatum Todd, 1957
Plate 22, figures 5-8

Elphidium? ustulatum TODD, 1957, p. 230, pl. 28, fig. 16.
Elphidium sp. 2 VAN VOORTHUYSEN, 1958, p. 25, pl. 9, fig. 98.
Protelphidium lecticulare GUDINA, 1966, p. 55, pl. 3, figs. 7-9, pl. 9, fig. 1. – GUDINA, 1969, p. 35, pl. 12, figs. 7, 8.
Elphidium ustulatum KNUDSEN in FEYLING-HANSSEN et al. 1971, p. 283, pl. 13, figs. 12, 13; pl. 23, figs. 5-7. – KNUDSEN, 1972, p. 295, fig. 5. – KNUDSEN, 1973, p. 159, pl. 5, figs. 5-7. – HANSEN and LYKKE-ANDERSEN, 1976, p. 16, pl. 13. figs. 7-12. – GREGORY and BRIDGE, 1979, p. 72, pl. 1, figs. 1-6. – McDOUGALL, 1993, pl. 2, figs. 11, 12.

Distribution in core: 43 specimens from 17 samples; intermittent but low occurrences down core, first and last occurrence at 2.64 and 9.50 m respectively, relatively consistent occurrence from 7.71 to 9.50 m, highest abundance at 9.11 m.

Description: Test rounded to slightly elliptical, compressed, slightly bi-umbonate, average dimension is 0.33 – 0.45 mm at the longer diameter, 0.28 – 0.40 mm at the shorter diameter, average thickness is 0.16 – 0.20 mm; wall calcareous with radial structure, finely perforate. Chambers not inflated, narrow, degree of coiling increases with size, number varies from seven to eleven. Sutures distinct, incised, containing medium to fine tuberculation (granular materials) around the sutural openings; surface flush with the chambers forming a sigmoidal curvature, central section of each suture deepens, curvature swinging gently backwards from umbilical area towards the periphery, no bosses or sutures in the umbilical area; sutures are closed at both ends, occupying approximately two-thirds of the length of the chamber; specimens vary from semi-transparent to opaque. Aperture is not visible, as it is usually concealed by granular calcite at the base of the apertural face, which may be flat, slightly convex, or triangular (Gregory and Bridge, 1979). Hansen and Lykke-Anderson (1976) discussed the details of the test microstructure.

Remarks: Specimens from the Bering Sea are smaller in size to Todd's (1957) holotype, which has an average diameter of 0.45 – 0.57 mm at the longer diameter and a thickness of 0.20 – 0.26 mm. *E. ustulatum* from the Bering Sea differs from specimens recorded as *Elphidium? ustulatum* by Gudina (1966, 1969; see Gregory and Bridge, 1979; pg. 74) by being larger. *E. incertum* (Williamson) differs from *E. ustulatum* in having longer and curved sutural slits that are not incised. There is intraspecific variation among the specimens studied; more than half show medium to fine tuberculation (granular materials) around the openings.

Distribution: *Elphidium ustulatum* was originally described from the Nuwok Member at Carter Creek, northern Alaska (Todd, 1957); MacNeil (1957) determined the age of this unit to be upper Miocene or lower Pliocene. It has a modern geographical distribution in the North Sea (Gregory and Bridge, 1979; Sejrup et al., 1991; Knudsen and Asbjörnsdóttir, 1991; Knudsen and Sejrup, 1993), Norway, Denmark (Knudsen, 1971; 1972) and north Greenland (Feyling Hanssen, 1980). *E. ustulatum* occurs at 229 m depth in the central North Sea (Gregory and Bridge, 1979). It occurs as a shallow infaunal species (Bubenshchikova et al., 2010), and has been considered an indicator of sub-oxic conditions (Kaiho, 1994). The stratigraphical range of *E. ustulatum* throughout the Arctic region is from Pliocene to Pleistocene (McDougall, 1993).

***Elphidium* sp. 1**
Plates 22, figures 9-11

***Distribution* in core:** 6 specimens from 6 samples occurrences at depths 1.38, 2.38, 5.41, 6.52, 9.40 and 9.50 m.

Description: Test involute to partially evolute, robust, periphery rounded, compressed with umbilical regions slightly depressed, general outline somewhat lobate. Wall calcareous with radial structures, perforate; increasing gradually in size, about nine to ten chambers in final whorl; average dimension of 0.37 – 0.47 mm at the longer diameter, 0.30 – 0.43 mm at the shorter diameter, average thickness is 0.16 – 0.20 mm; sutures elongate, slightly curved and linking with umbilical spiral canal system, surrounded by tubercles or striae along the sutures forming an ornamentation around the umbilici; apertural face and the earliest part of the final whorl are covered by dense tuberculation. Aperture is a low interiomarginal equatorial arch, obscured by tuberculation covering the apertural face.

Remarks: *Elphidium* sp. 1 is differentiated from *E. ustulatum* by its shorter and wider sutural openings, terminating before reaching the umbilical area. *Elphidium* sp. 1 is differentiated from *E. batialis* Saidova (1961) by its greater number of chambers, demarcated by relatively large perforations aligned with the radial sutural line. *Elphidium* sp. 1 is morphologically similar to specimens illustrated and described as *Elphidium magellanicum* Heron-Allen and Earland by Hansen and Lykke-Andersen (1976; pl. 13: 2-6) from Kattegat, Denmark, by having tuberculation covering the apertural face, number and form of chambers varies, *E. magellanicum* having fewer and more inflated chambers.

***Elphidium* sp. 2**
Plate 22, figure 12, 13

Distribution in core: 9 specimens from 6 samples; random occurrences at depths 0.74, 2.64, 9.50, 12.73, 12.98 m; last occurrence at 18.43 m.

Description: Test planispiral, involute, robust, slightly compressed, periphery broadly rounded, subcircular in outline, the later part of the final whorl is slightly lobate. Chambers moderately inflated, about 9-10 chambers in final whorl, chambers increasing gradually in size, no bosses or sutures in the umbilical area; sutures are closed at both ends; closure more rounded and terminates towards the umbilical area, occupying approximately two-thirds of the length of the chamber; wall calcareous, perforate and smooth, sutures incised, depressed and covered with tuberculation, apertural face is smooth and imperforate. Aperture is not clearly seen.

Remarks: *Elphidium* sp. 2 is differentiated from *E. kugleri* (Cushman and Brönnimann, 1948) described by Hansen and Lykke-Andersen (1976: pl. 9: 4-8) which has fewer strongly embracing chambers (7-8) and fused umbilical chamber parts though the two species have perforate chamber walls.

***Elphidium* sp. 3**
Plates 22, figures 14-17.

Distribution in core: 3 specimens from depths 15.23, 16.65 and 19.44 m.

Description: Test planispiral, involute, robust, slightly compressed, periphery rounded, subcircular in outline. Wall calcareous, perforate and smooth; chambers increasing gradually in size, ten to eleven in final whorl; the later part of the test shows a slightly lobate outline. Average dimension of 0.32 – 0.47 mm at the longer diameter, 0.30 – 0.43 mm at the shorter diameter, average thickness is 0.16 – 0.20 mm; pore diameter about 0.05 mm. Sutures are gently curved and crossed by distinct ponticuli.

Remarks: *Elphidium* sp. 3 is morphologically close to *E. poeyanum* (d'Orbigny, 1839) illustrated by Hansen and Lykke-Andersen (1976: pl. 9: 9-12) from the Recent of Florida, USA, by having nine to ten chambers, a slightly compressed test, lobate outline, a rounded periphery and the same sutural form, but *Elphidium* sp. 3 differs having a more lobate outline. *Elphidium* sp. 3 is morphologically similar to *E. batialis*; having about the same number of slightly inflated chambers in their final whorls (9-10). It is differentiated from *E. batialis,* which has relatively pronounced tuberculation extending in umbilico-posterior direction onto the lateral chamber wall of the final chamber (Hansen and Lykke-Andersen: pl. 10: 6-12). *Elphidium* sp. 3 is differentiated from *E. kugleri* (Cushman and Brönnimann, 1948) described by Hansen and Lykke-Andersen (1976: pl. 9: 4-8) which has its later chambers more flared.

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Plates

Plate 1
Scale bar = 100 µm (unless indicated)
1, 2. *Eggerella* sp. 1 *(*A-2H-5-37-39 cm)
3 - **5.** *Eggerella* sp. 1 (A-2H-5-105-109 cm)
6. *Martinottiella* sp. 3 (A-3H-5-91-92 cm)
7. *Martinottiella* sp. 3 (A-2H-5-105-109 cm)
8, **9.** *Martinottiella* sp. 3 (C-2H-5-78-81 cm)
11. *Quinqueloculina* sp. (D-2H-6-17-22 cm)
12. *Quinqueloculina* sp. (C-2H-5-25-28 cm)
13. *Quinqueloculina* sp. (A-3H-5-130-133 cm)
14. *Pyrgo murrhina* (D-1H-1-104-108 cm)
15. *Pyrgo murrhina* (A-2H-3-61-64 cm)
16. *Pyrgo murrhina* (D-1H-4-77-79 cm)
17. *Pyrgo murrhina* (D-1H-4-92-94 cm)

Plate 2
Scale bar = 100 µm (unless indicated)
1, 2. *Triloculina frigida* (D-1H-2-129-133 cm)
3. *Triloculina frigida (*A-2H-3-39-42 cm*)*
4. *Dentalina ittai* (D-1H-1-129-133 cm)
5. *Dentalina ittai* (C-2H-5-78-89 cm)
6, 7. *Dentalina ittai* (D-1H-2-89-93 cm)
8. *Dentalina ittai* (A-3H-5-12-16 cm)
9. *Dentalina ittai* (D-1H-2 105-109)
10. *Lotostomoides calomorphus* (D-1H-1-11-13 cm*)*
11. *Lotostomoides calomorphus* (D-H-4-106-108 cm)
12, 13, 15. *Lenticulina rotulata* (D-1H-1-11-13 cm)
14. *Lenticulina rotulata* (D-1H-1-129-133 cm)
16. *Lenticulina rotulata* (D-1H-2-25-29 cm)
17. *Lenticulina gibba* (C-2H-6-124-128 cm)
18. *Lenticulina gibba* (A-3H-3-134-138 cm)

Plate 3
Scale bar = 100 µm (unless indicated)
1 - **3.** *Lenticulina gibba* (A-3H-3-134-138 cm)
4 - **5.** *Lenticulina gibba* (A-3H-3-134-138 cm)
6 - **7.** *Lenticulina gibba* (A-3H-5-36-39 cm)
8, 9, 11, 12. *Lagena hispida* (A-2H-5-65-67 cm)
10. *Lagena hispida* (A-2H-5-25-27 cm)
13, 14. *Lagena hispida* (A-2H-5-90-94 cm)
15. *Lagena hispida* (C-2H-6-98-100 cm)
16. *Lagena sulcata* (D-1H-1-139-141 cm)
17, 18. *Lagena sulcata* (D-1H-3-78-82 cm)
19. *Lagena nebulosa* (A-2H-5-76-79 cm)
20. *Lagena* sp. 1 (C-2H-5-50-53 cm)
21-**22.** *Lagena* sp.1 (C-2H-5-9-13 cm)

Plate 4
Scale bar = 100 µm (unless indicated)

1 - **2.** *Lagena* sp.1 (C-2H-5-9-13 cm)
3 - **4.** *Lagena* sp. 1 (D-2H-6-17-22 cm)
5, 6. *Lagena* sp. 2 (C-2H-6-114-115 cm)
7 - **11.** *Lagena* sp. 3 (D-2H-6-17-22 cm)
12. *Procerolagena gracilis* (A-2H-3-102-104 cm)
13. *Procerolagena gracilis* (C-2H-7-0-2 cm)
14. *Procerolagena gracillima* (A-2H-51-53 cm)
15. *Procerolagena gracillima* (A-3H-5-145-147 cm)
16 - **17.** *Reussoolina apiculata* (D-1H-1-11-13 cm)
18. *Reussoolina apiculata* (D-1H-2-89-93 cm)
19. *Reussoolina apiculata* (A-2H-5-115-119 cm)
20. *Cushmanina striatopunctata* (D-2H-6-17-22 cm)

Plate 5
Scale bar = 100 µm (unless indicated)
1, 2. *Oolina hexagona* (A-3H-5-24-27 cm)
3. *Oolina hexagona* (A-3H-5-36-39 cm)
4 - **6.** *Fissurina crebra* (D-1H-1-114-118 cm)
7. *Fissurina crebra* (A-2H-5-115-119)
8. *Fissurina crebra* (A-2H-5-65-67 cm)
9. *Fissurina crebra* (A-2H-6-81-84 cm)
10, 11. *Fissurina crebra* (A-3H-5-76-78 cm)
12, 13. *Fissurina minima* (D-2H-6-17-22 cm)
14, 15. *Fissurina minima* (C-2H-7-0-2 cm)
16. *Moncharmontzeiana petaloskelts* (A-3H-5-11-117 cm)

Plate 6
Scale bar = 100 µm (unless indicated)
1, 2. *Hoeglundina elegans* (D-1H-2-65-69 cm)
3. *Bolivina spissa* (D-1H-1-0-2 cm)
4**.** *Bolivina spissa* (D-1H-1-0-2 cm)
5, 6. *Bolivina spissa* (D-1H-1-0-2 cm)
7. *Bolivina spissa* (D-1H-1-0-2 cm)
8, 9, 10, 15. *Bolivina spissa* (D-1H-1-0-2 cm)
11. *Bolivina spissa* (D-1H-1-11-13 cm)
12 - **14.** *Bolivina spissa* (D-1H-1-11-13 cm)
16. *Bolivina* sp. 1 (D-1H-1-0-2 cm)
17, 18. *Bolivina* sp. 1 (D-1H-1-0-2 cm)
19, 20. *Bolivina* sp. 1 (D-1H-1-26-28 cm)

Plate 7
Scale bar = 100 µm (unless indicated)
1-3. *Bolivina* sp.1 (D-1H-1-0-2cm)
4. *Bolivina* sp. 2 (D-1H-1-139-141 cm)
5. *Bolivina* sp. 3 (D-1H-1-0-2 cm)
6. *Bolivina* sp. 3 (D-1H-1-139-141 cm)
7. *Bolivina* sp. 3 (D-1H-1-139-141 cm)
8, 9. *Bolivina* sp. 3 (D-1H-2-9-13 cm)
10. *Bolivina* sp. 3 (D-1H-2-75-80 cm)
11. *Bolivina* sp. 3 (D-1H-3-99-101 cm)
12, 13. *Bolivina* sp. 3 (D-1H-4-115-117 cm)

14. *Bolivina* sp. 3 (D-1H-4-92-94 cm)
15. *Bolivina* sp. 3 (A-2H-5-12-14 cm)
16. *Bolivina* sp. 3 (A-2H-6-40-46 cm)
17, 18. *Brizalina earlandi* (D-1H-1-0-2 cm)
19. *Brizalina earlandi* (D-1H-1-0-2 cm)
20. *Brizalina earlandi* (C-2H-7-25-27 cm)
21. *Brizalina earlandi* (D-1H-1-0-2 cm)

Plate 8
Scale bar = 100 µm (unless indicated)
1. *Brizalina alata* (D-1H-1-0-2 cm)
2. *Brizalina alata* (D-1H-1-26-28 cm)
3. *Brizalina alata* (D-1H-1-0-2 cm)
4 - **6.** *Brizalina alata* (D-1H-1-0-2 cm)
7. *Brizalina alata* (D-1H-1-11-13 cm)
8, 9. *Brizalina alata* (D-1H-1-26-28 cm)
10. *Brizalina alata* (A-24-6-102-105 cm)
11, 12. *Cassidulina teretis* (D-1H-1-0-2 cm)
13. *Cassidulina teretis* (D-1H-1-39-41 cm)
14, 15. *Cassidulina teretis* (D-1H-1-39-41 cm)
16. *Cassidulina laevigata* (D-1H-2-49-53 cm)
17, 18. *Cassidulina laevigata* (D-1H-2-49-53 cm)
19. *Cassidulina laevigata* (D-1H-4-77-79 cm)

Plate 9
Scale bar = 100 µm (unless indicated)
1. *Cassidulina laevigata* (A 2H-5-115-119 cm)
2. *Cassidulinoidies parkerianus* (A-2H-3-99-101 cm)
3, 4. *Cassidulinoidies parkerianus* (D-1H-2-145-150 cm)
5. *Cassidulinoidies parkerianus* (A- 2H-3-61-64 cm)
6. *Cassidulina reniforme* (D-1H-39-41 cm)
7, 8, *Cassidulina reniforme* (D-1H-114-118 cm)
9, 10. *Cassidulina reniforme* (D-1H-114-118 cm)
11 - **14.** *Cassidulina reniforme* (D-1H-39-41 cm)
15. *Globocassidulina subglobosa* (D-1H-1-39-41 cm)
16. *Globocassidulina subglobosa* (C-2H-6-108-112 cm)
17. *Globocassidulina subglobosa* (D-1H-1-39-41 cm)

Plate 10
Scale bar = 100 µm (unless indicated)
1. *Globocassidulina subglobosa* (D-1H-1-75-79 cm)
2. *Islandiella norcrossi* (D-1H-1-39-41 cm)
3. *Islandiella norcrossi* (A-3H-3-124-128 cm)
4. *Islandiella norcrossi* (D-1H-1-39-41 cm)
5. *Islandiella norcrossi* (D-1H-2-105-109 cm)
6. *Islandiella norcrossi* (D-1H-2-129-133 cm)
7. *Takayanagia delicata* (D-1H-1-0-2 cm)
8. *Takayanagia delicata* (D-1H-1-11-13 cm)
9. *Takayanagia delicata* (D-1H-2-105-109 cm)
10. *Takayanagia delicata* (A-2H-6-128-130 cm)
11, 12. *Takayanagia delicata* (D-1H-1-26-28 cm)

13. *Takayanagia delicata* (A-2H-3-76-78)
14. *Ehrenbergina* sp. (D-1H-1-0-2 cm)
15. *Ehrenbergina* sp. (D-1H-1-11-13 cm)
16. *Ehrenbergina* sp. (D-1H-1-75-79 cm)

Plate 11
Scale bar = 100 µm (unless indicated)
1. *Ehrenbergina* sp. (D-1-H-1-26-28)
2. *Ehrenbergina* sp. (D-1-H-1-26-28 cm)
3. *Ehrenbergina* sp. (D-1H-1- 75-79 cm)
4. *Ehrenbergina* sp. (A 2H-5-37-39 cm)
5. *Ehrenbergina* sp. (D-1H-1- 75-79 cm)
6 - **9.** *Ehrenbergina* sp. (A-2H-5-37-39)
10. *Ehrenbergina* sp. (D-1H-1-0-2 cm)
11. *Stainforthia fusiformis* (D-1H-1-0-2 cm)
12. *Stainforthia fusiformis* (A-2H-5-105-109 cm)
13. *Stainforthia fusiformis* (A-2h-6-130-134 cm)
14, 15. *Stainforthia fusiformis* (A-2h-6-130-134 cm)
16. *Bulimina exilis* (D-1H-1-0-2 cm)
17. *Bulimina exilis* (D-1H-1-0-2 cm)
18 - **20.** *Bulimina exilis* (D-1H-2-26-28 cm)
21. *Bulimina exilis* (D-1H-2-89-93)
22. *Bulimina exilis* (D-1H-2-105-109 cm)

Plate 12
Scale bar = 100 µm (unless indicated)
1. *Bulimina exilis* (D-1H-1-0-2 cm)
2 - **4.** *Bulimina mexicana* (D-1H-1-11-13 cm)
5. *Bulimina mexicana* (D-1H-1-89-93 cm)
6. *Bulimina mexicana* (D-1H-1-89-93 cm)
7. *Globobulimina auriculata* (D-1H-3-10-13 cm)
8. *Globobulimina auriculata* (D-1H-3-10-13 cm)
9. *Globobulimina auriculata* (A-2H-5-115-119 cm)
10, 11. *Globobulimina auriculata* (A-2H-6-113-117 cm)
12. *Globobulimina pacifica* (D-1H-1-26-28 cm)
13. *Globobulimina pacifica* (D-1H-1-26-28 cm)
14. *Globobulimina pacifica* (D-1H-1-1-39-41)
15. *Globobulimina pacifica* (D-1H-2-105-109 cm)
16. *Globobulimina pacifica* (D-1H-2-105-109 cm)
17. *Globobulimina pacifica* (D-1H-2-105-109 cm)

Plate 13
Scale bar = 100 µm (unless indicated)
1, 3, 4, 5. *Globobulimina pacifica* (D-1h-2-1050109 cm)
2. *Globobulimina pacifica* (D-1H-2-105-109 cm)
6. *Globobulimina pacifica* (C-2H-5-25-28 cm)
7. *Uvigerina bifurcata* (D-1H-1-0-2 cm)
8. *Uvigerina bifurcata* (D-1H-1-0-2 cm)
9, 10. *Uvigerina bifurcata* (D-1H-1-0-2 cm)
11. *Uvigerina bifurcata* (C-2H-4-102-106 cm)
12. *Uvigerina bifurcata* (C-2H-4-102-106 cm)

13, 14. *Uvigerina bifurcata* (C-2H-4-102-106 cm)
15. *Uvigerina bifurcata* (C-2H-5-25-28 cm)
16. *Uvigerina bifurcata* (C-2H-5-25-28 cm)
17. *Uvigerina bifurcata* (C-2H-5-25-28 cm)
18. *Uvigerina bifurcata* (C-2H-5-25-28 cm)

Plate 14
Scale bar = 100 µm (unless indicated)
1. *Uvigerina bifurcata* (C-2H-6-46-52 cm)
2. *Uvigerina bifurcata* (C-2H-6-46-52 cm)
3. *Uvigerina bifurcata* (C-2H-6-46-52 cm)
4. *Uvigerina hispida* (D-1H-4-77-79 cm)
5. *Uvigerina hispida* (D-1H-4-77-79 cm)
6. *Uvigerina hispida* (D-1H-4-77-79 cm)
7, 8. *Uvigerina hispida* (D-1H-4-77-79 cm)
9. *Uvigerina hispida* (D-1H-4-77-79 cm)
10. *Uvigerina hispida* (D-1H-1-0-2 cm)
11, 12. *Uvigerina hispida* (A-2H-3-117-119)
13. *Uvigerina senticosa* (D-1H-1-139-141 cm)
14. *Uvigerina senticosa* (D-1H-3-67-69 cm)
15. *Uvigerina senticosa* (D-1H-3-67-69 cm)
16, 17. *Uvigerina senticosa* (D-1H-4-77-79 cm)

Plate 15
Scale bar = 100 µm (unless indicated)
1. *Uvigerina peregrina* (D-1H-1-75-79 cm)
2. *Uvigerina peregrina* (D-1H-1-75-79 cm)
3. *Uvigerina peregrina* (D-1H-1-75-79 cm)
4. *Uvigerina peregrina* (D-1H-1-75-79 cm)
5. *Uvigerina peregrina* (D-1H-1-0-2 cm)
6 - **9.** *Uvigerina peregrina* (D-1H-1-0-2 cm)
10. *Uvigerina peregrina* (D-1H-1-0-2 cm)
11. *Uvigerina peregrina* (D-1H-2-115-120 cm)
12. *Uvigerina peregrina* (D-1H-1-75-79 cm)
13. *Uvigerina peregrina* (D-1H-1-52-56 cm)
14. *Uvigerina peregrina* (A-2H-3-102-104 cm)
15. *Uvigerina peregrina* (D-1H-1-139-141 cm)
16. *Uvigerina peregrina* (D-1H-2-115-120 cm)
17. *Uvigerina* sp. 1 (D-1H-1-0-2 cm)

Plate 16
Scale bar = 100 µm (unless indicated)
1 - **4.** *Uvigerina* sp.1 (D-1H-1-0-2 cm)
5, 6. *Uvigerina* sp.1 (D-1H-3-99-101 cm)
7. *Uvigerina* sp.1 (D-1H-3-99-101 cm)
8. *Uvigerina* sp.1 (A-2H-3-117-119 cm)
9. *Angulogerina angulosa* (D-1H-1-114-118 cm)
10. *Angulogerina angulosa* (D-1H-1-114-118 cm)
11, 12. *Angulogerina angulosa* (D-1H-1-0-2 cm)
13. *Angulogerina angulosa* (D-1H-1-114-118 cm)
14. *Fursenkoina* aff. *texturata* (D-1H-1-11-13 cm)

15. *Fursenkoina* aff. *texturata* (C-2H-5-39-42 cm)
16 - **18.** *Fursenkoina* aff. *texturata* (C-2H-5-107-108 cm)

Plate 17
Scale bar = 100 µm (unless indicated)
1 - **3.** *Fursenkoina* aff. *texturata* (C-2H-5-107-108 cm)
4. *Valvulineria araucana* (C-2H-4-102-108 cm)
5, 6. *Valvulineria araucana* (C-2H-4-102-106 cm)
7. *Valvulineria araucana* (C-2H-4-102-106 cm)
8. *Valvulineria araucana* (C-2H-6-48-52 cm)
9, 10. *Valvulineria araucana* (C-2H-6-48-52 cm)
11. *Valvulineria araucana*: apertural view (C-2H-4-127-131 cm)
12. *Valvulineria araucana* (C-2H-7-0-2 cm)
13. *Alabaminella weddellensis* (A-2H-5-65-67 cm)
14, 15. *Alabaminella weddellensis* (A-2H-6-93-97 cm)
16. *Alabaminella weddellensis* (A-2H-6-113-117 cm)
17. *Alabaminella weddellensis* (C-2H-5-9-13 cm)

Plate 18
Scale bar = 100 µm (unless indicated)
1, 2. *Cibicidoides* sp. (A-2H-3-102-104 cm)
3, 4. *Cibicidoides* sp. (C-2H-7-25-27 cm)
5. *Cibicidoides* sp. *(*A-3H-5-24-27 cm)
6 - **8.** *Epistominella exigua* (C-2H-5-120-121 cm)
9 - **11.** *Epistominella exigua* (C- 2H-5-120-121 cm)
12, 13. *Epistominella exigua* (C-2H-6-114-115 cm)
14, 15. *Epistominella pulchella* (D-1H-3-99-101 cm)
16. *Epistominella pulchella* (D-1H-1-0-2 cm)

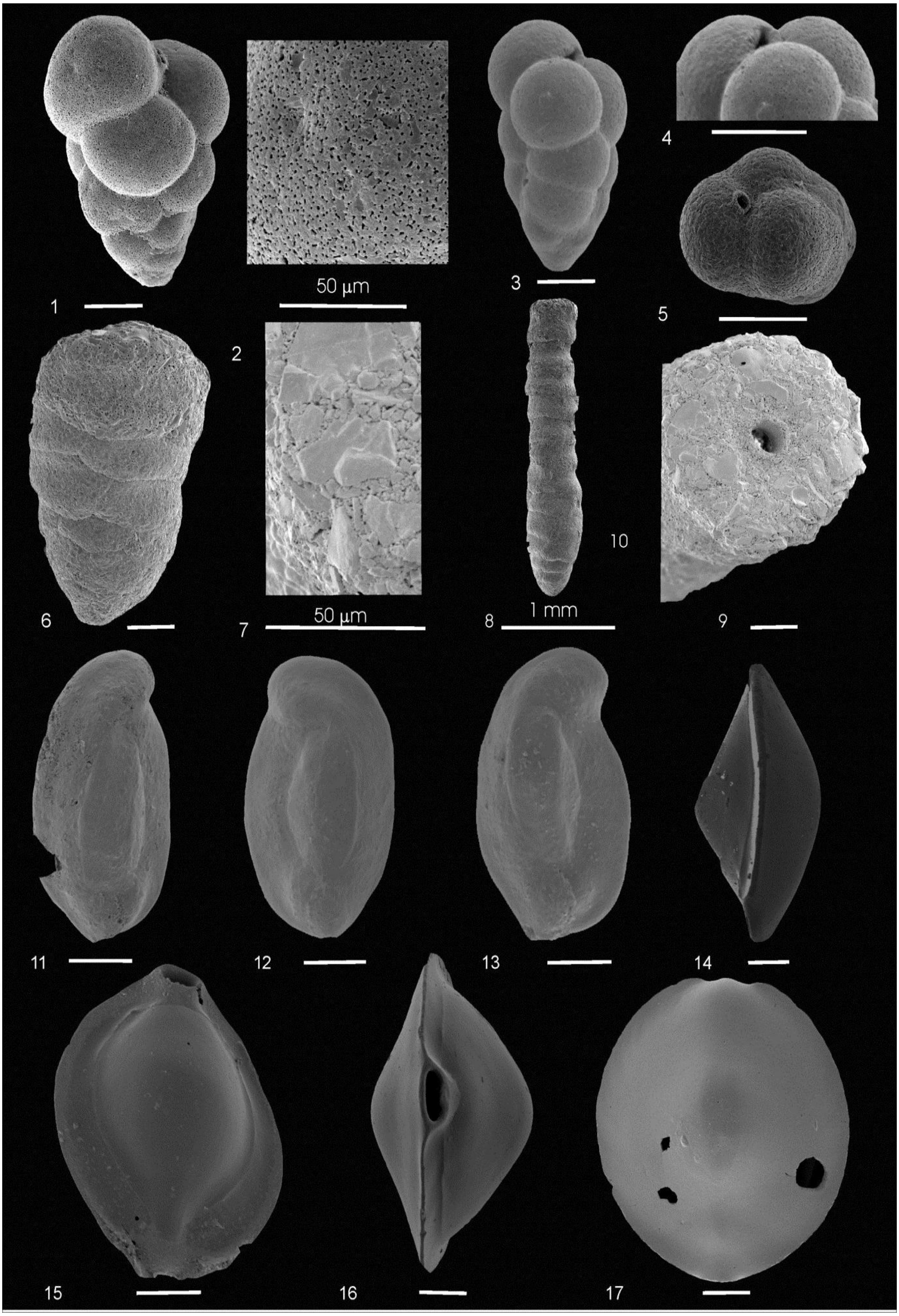
Plate 19
Scale bar = 100 µm (unless indicated)
1 - **3.** *Epistominella pulchella* (D-1H-3-67-69 cm)
4. *Planulina ariminensis* (D-1H-1-11-13 cm)
5, 6. *Planulina ariminensis* (C-2H-6-98-100 cm)
7, 8. *Planulina wuellerstorfi* (D-1H-1-75-79 cm)
9, 10. *Planulina wuellerstorfi* (D-1H-2-75-79)
11, 12, *Planulina wuellerstorfi* (D-1H-2-49-53 cm)
13. *Planulina wuellerstorfi* (C-2H-6-108-112 cm)
14 - **16.** *Planulina wuellerstorfi* (C-24-6-108-112 cm)
17. *Planulina wuellerstorfi* (C-2H-6-108-112 cm)
18. *Planulina wuellerstorfi* (A-3H-3-134-138 cm)

Plate 20
Scale bar = 100 µm (unless indicated)
1, 2. *Nonionella labradorica* (D-1H-1-39-41 cm)
3. *Nonionella labradorica* (D-1H-1-39-41 cm)
4, 5. *Nonionella labradorica* (A-2H-3-90-92 cm)
6. *Nonionella digitata* (C-2H-6-98-100 cm)
7. *Melonis barleeanus* (C-2H-4-127-131)
8. *Melonis barleeanus* (C-2H-5-120-121 cm)
9 - **12.** *Melonis barleeanus* (C-2H-5-120-121 cm)

13. *Pullenia simplex* (D-1H-1-39-41 cm)
14. *Pullenia simplex* (D-1H-1-39-41 cm)
15. *Pullenia simplex* (1H-1-129-133 cm)
16. *Pullenia simplex* (D-1H-3-67-69)

Plate 21
Scale bar = 100 µm (unless indicated)
1, 2. *Oridorsalis umbonatus* (D-1H-1-0-2 cm)
3, 4. *Oridorsalis umbonatus* (D-1H-1-0-2 cm)
5 - **8.** *Oridorsalis umbonatus* (D-1H-1-11-13 cm)
9. *Oridorsalis umbonatus* (D-1H-1-11-13 cm)
10. *Oridorsalis umbonatus* (D-1H-4-77-79 cm)
11. *Gyroidina* sp. 1 (A-3H-5-12-15 cm)
12. *Gyroidina* sp. 1(A-3H-5-91-92 cm)
13. *Gyroidina* sp. 2 (D-1H-2-75-80 cm)
14. *Gyroidina* sp. 2 (D-1H-4-106-108 cm)
15. *Gyroidina* sp. 2 (A-2H-6-102-105 cm)
16. *Gyroidina* sp. 2 (A-2H-6-102-105 cm)

Plate 22
Scale bar = 100 µm (unless indicated)
1 - **3.** *Gyroidina* sp. 2 (C-2H-4-102-106 cm)
4. *Gyroidina* sp. 2 (A-2H-6-102-106 cm)
5. *Elphidium ustulatum* (D-1H-4-92-94 cm)
6. *Elphidium ustulatum* (D-1H-4-92-94 cm)
7, 8. *Elphidium ustulatum* (D-1H-4-92-94 cm)
9. *Elphidium* sp. 1 (D-1H-1-139-141 cm)
10. *Elphidium* sp. 1 (D-1H-1-139-141 cm)
11. *Elphidium* sp. 1 (D-1H-4-92-94 cm)
12. *Elphidium* sp. 2 (C-2H-4-102-106 cm)
13. *Elphidium* sp. 2 (C-2H-4-102-106 cm)
14. *Elphidium* sp. 3 (C-3H-6-114-115 cm)
15. *Elphidium* sp. 3 (A-3H-5-H3-117 cm)
16, 17. *Elphidium* sp. 3 (A-3H-3-134-138 cm)



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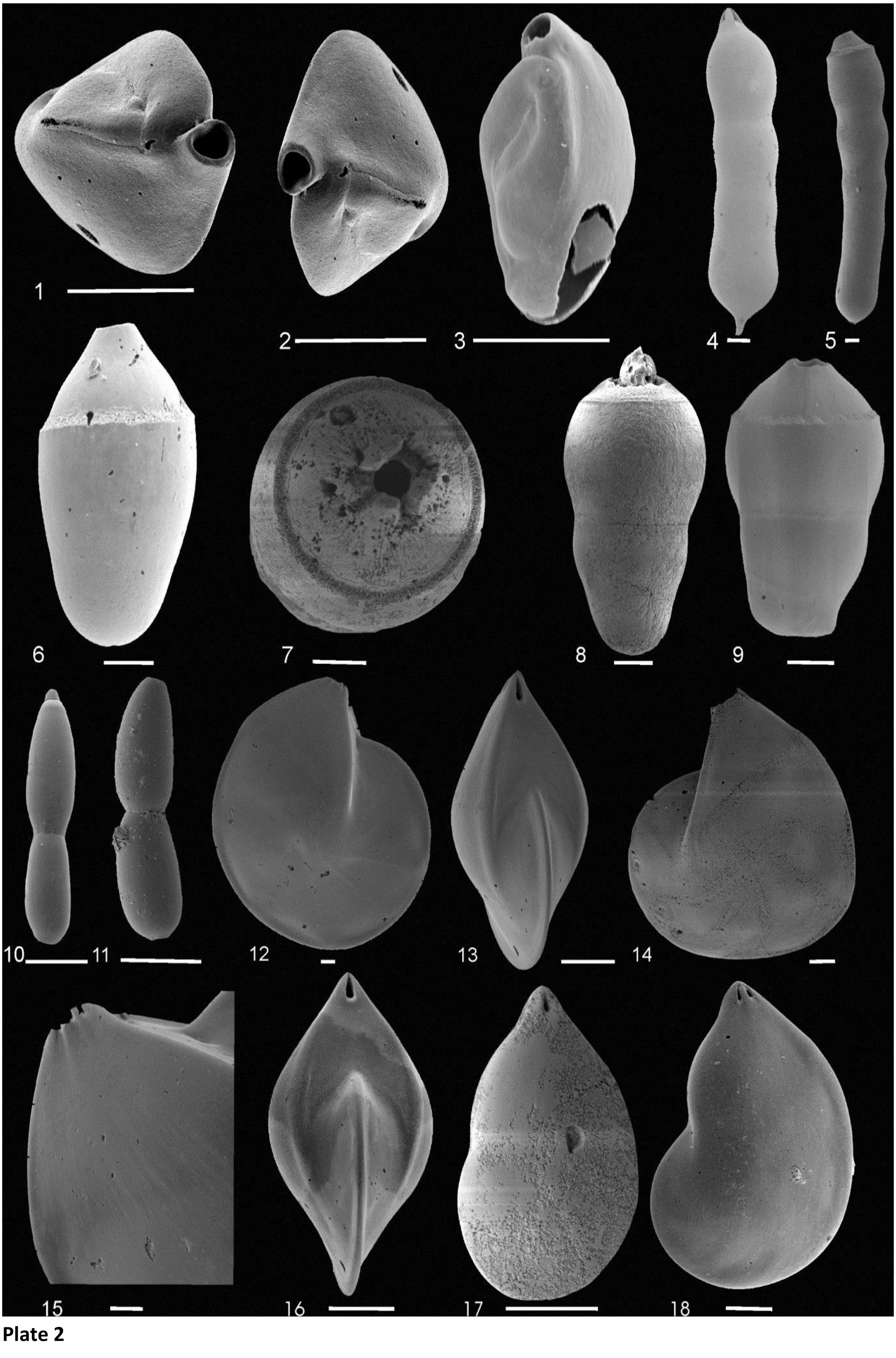

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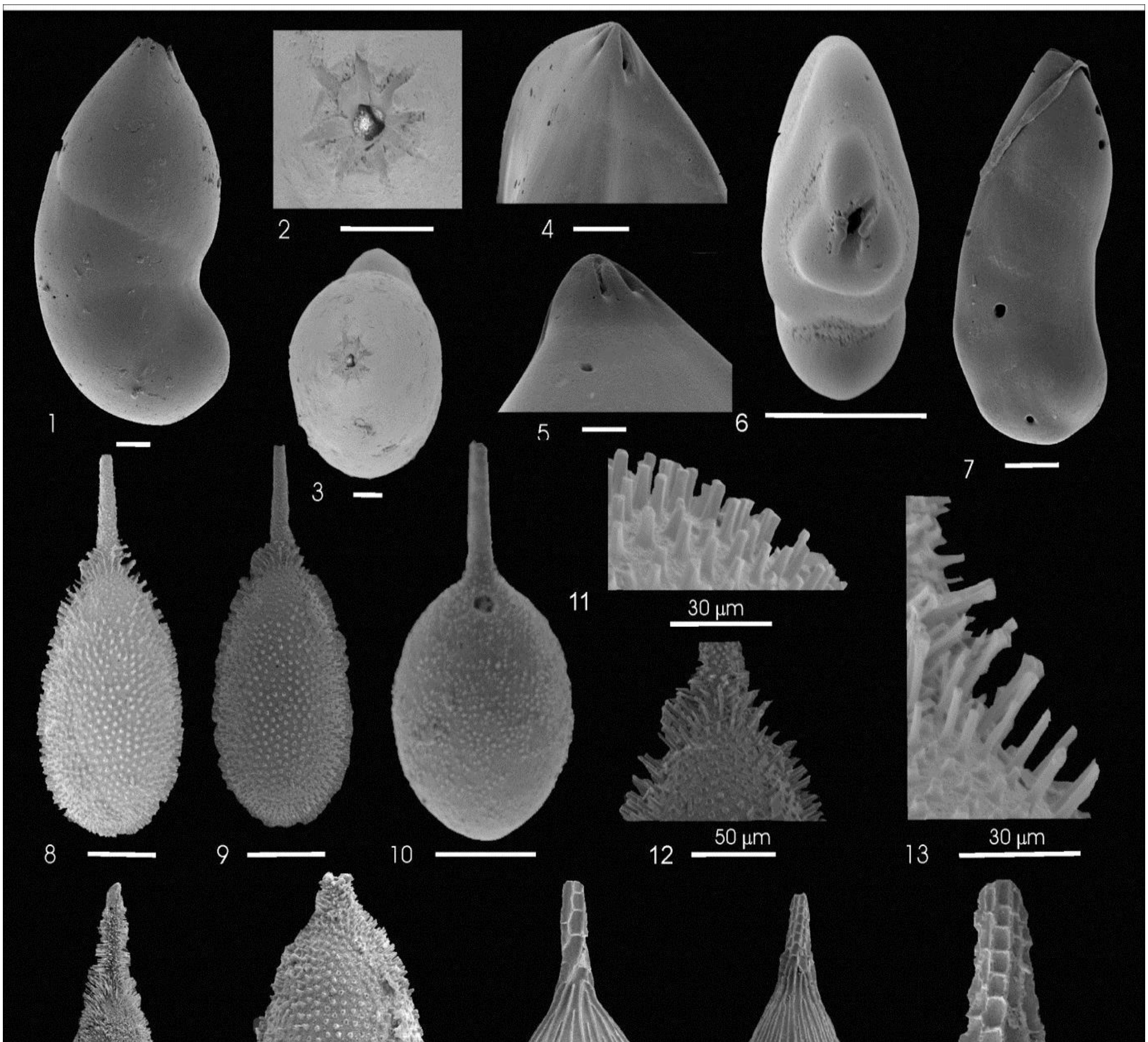

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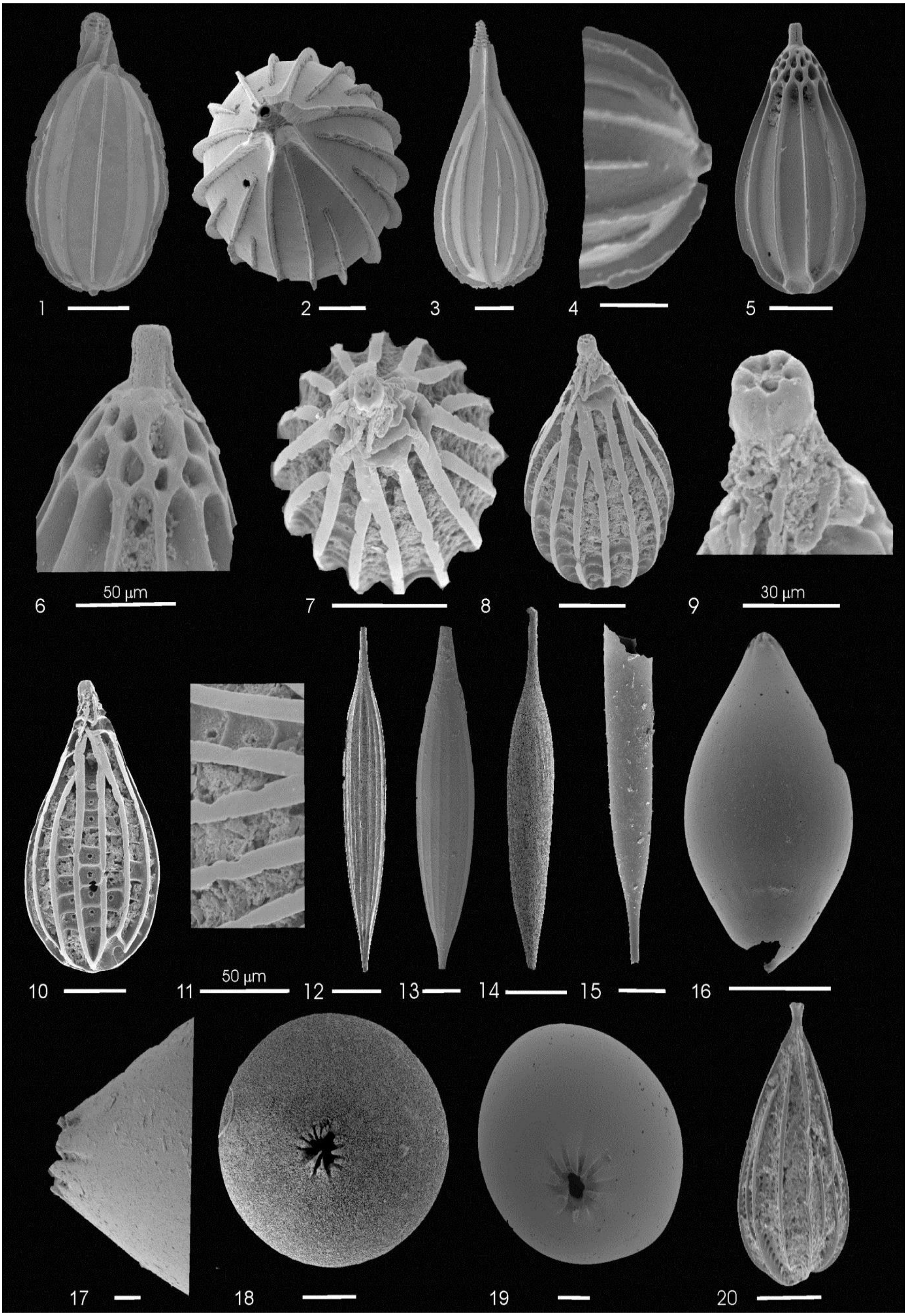

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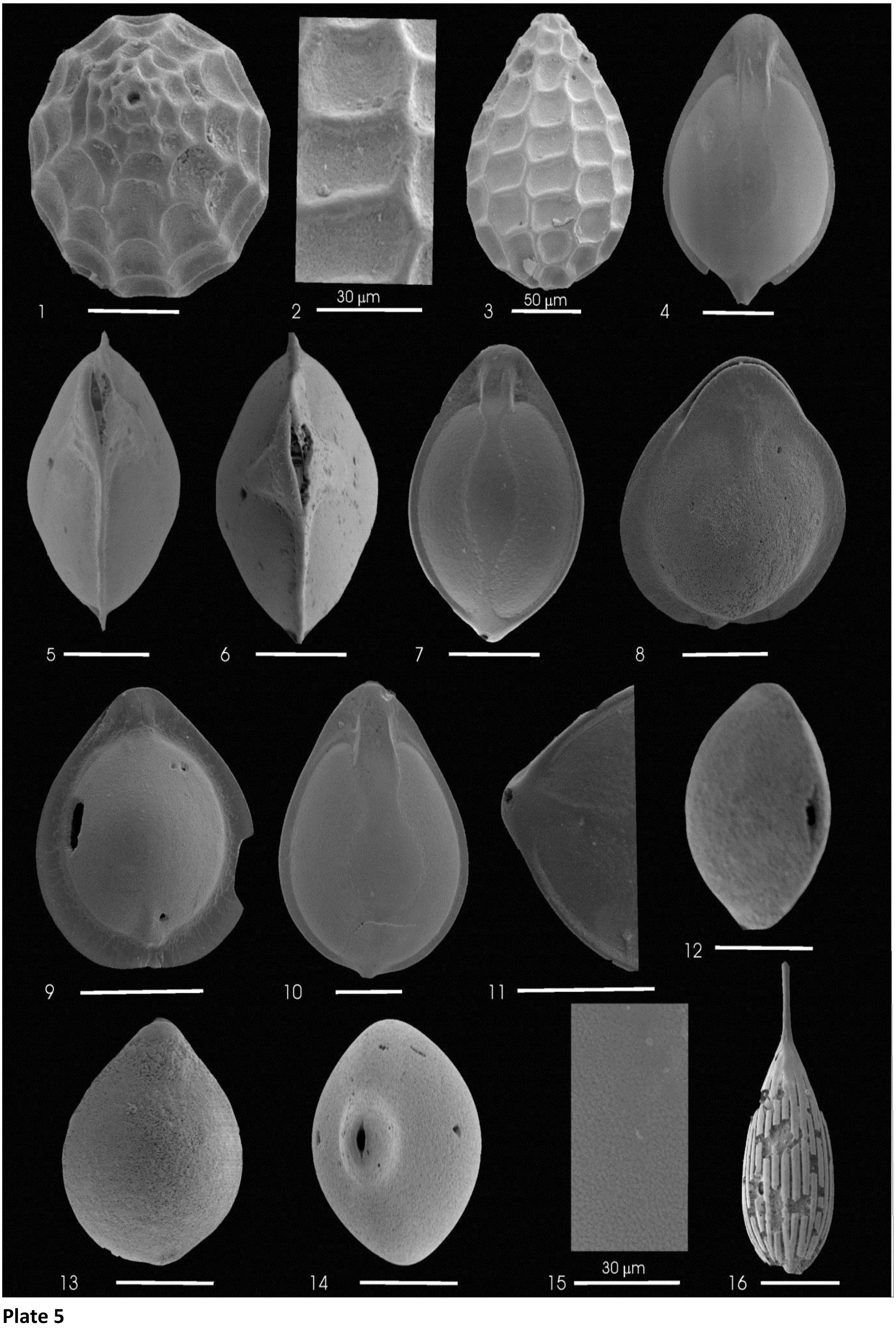

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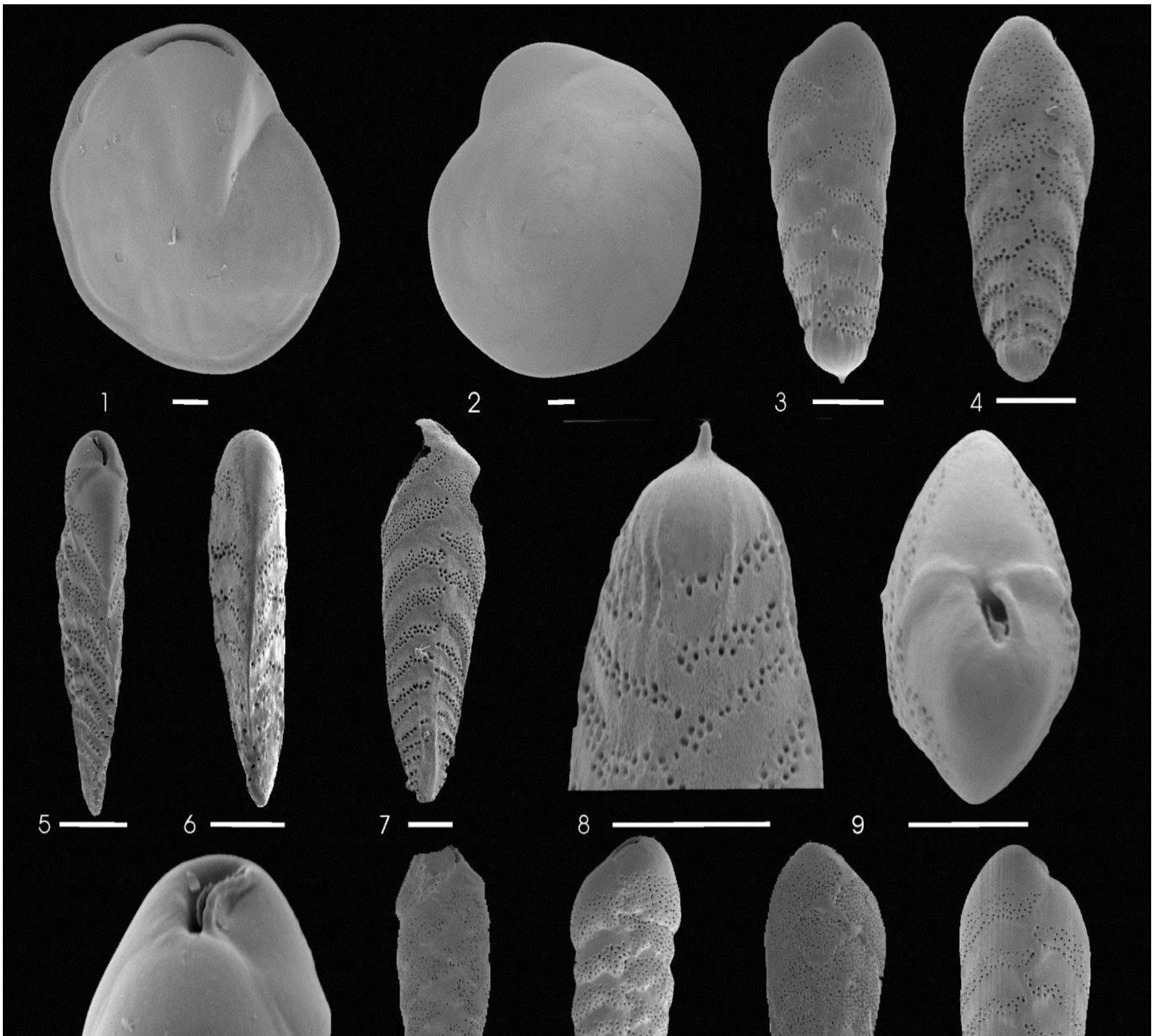

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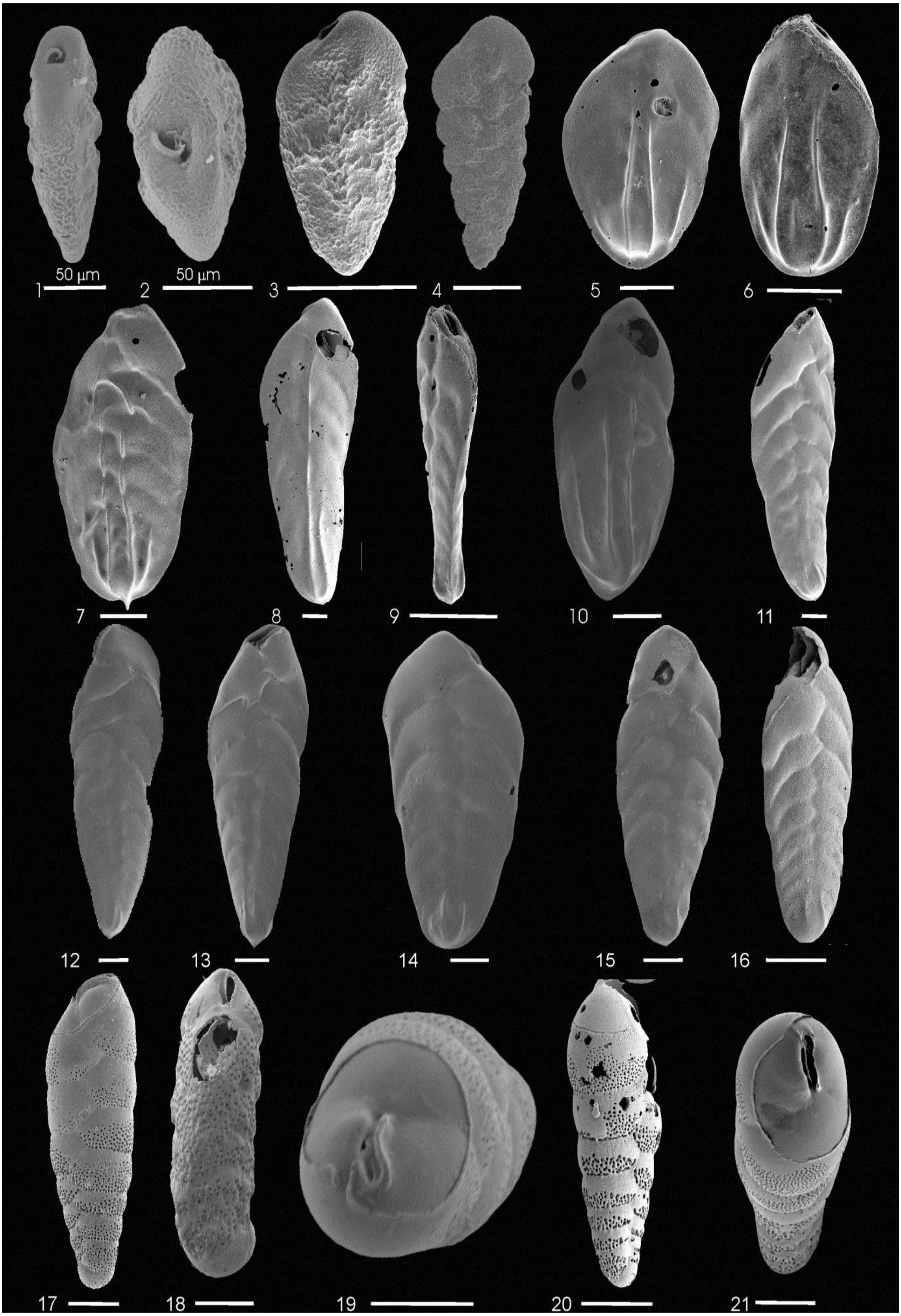

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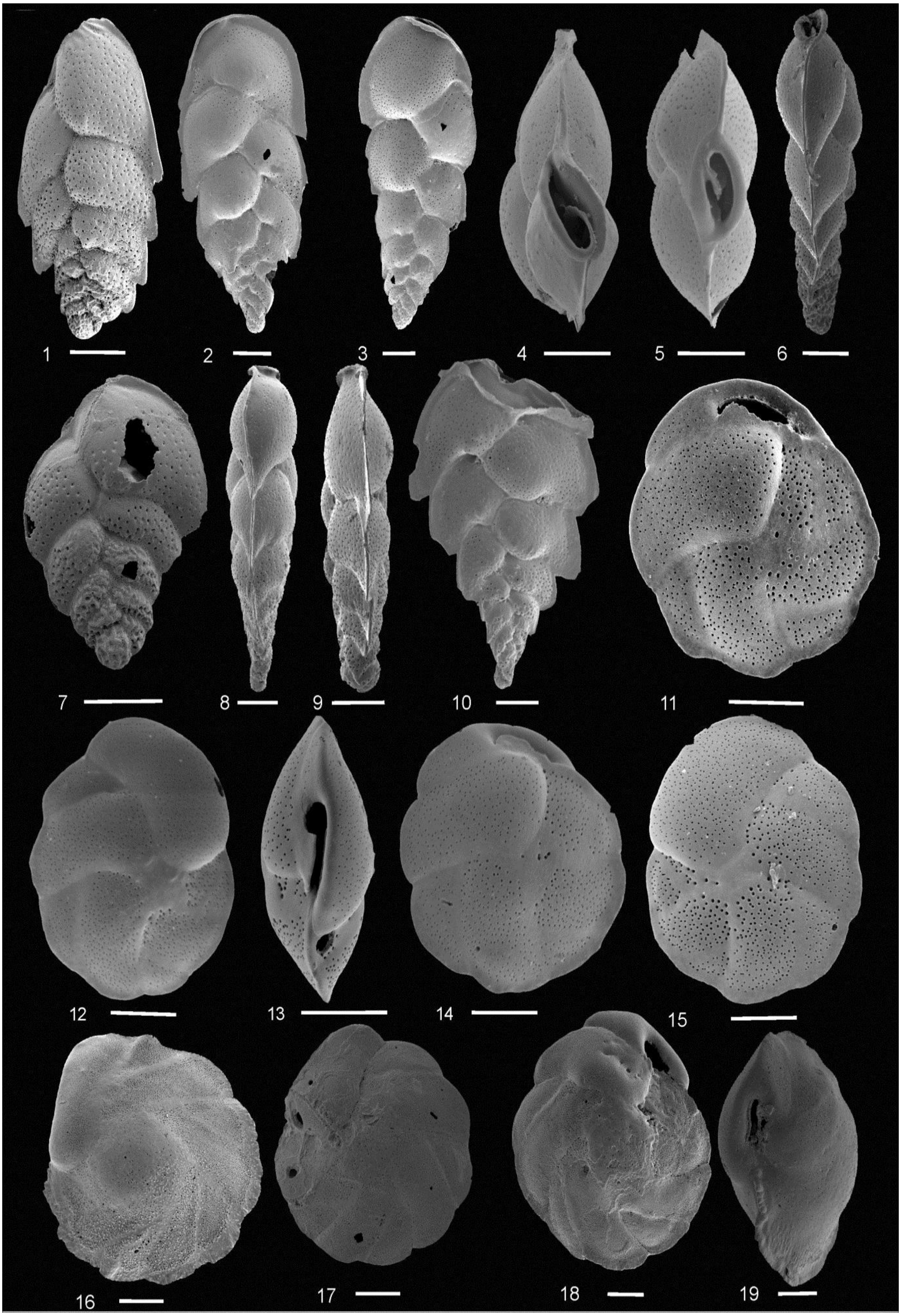

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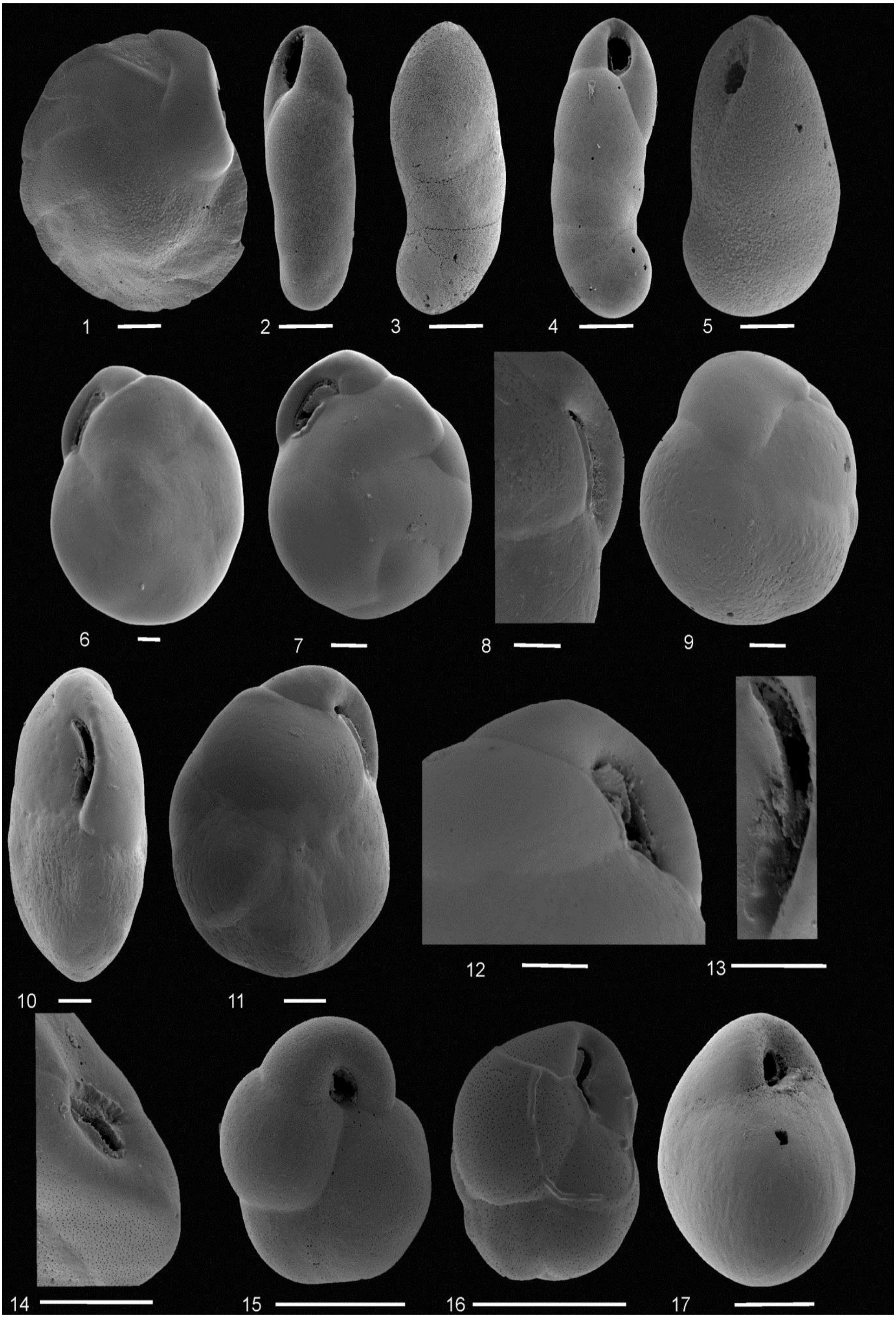

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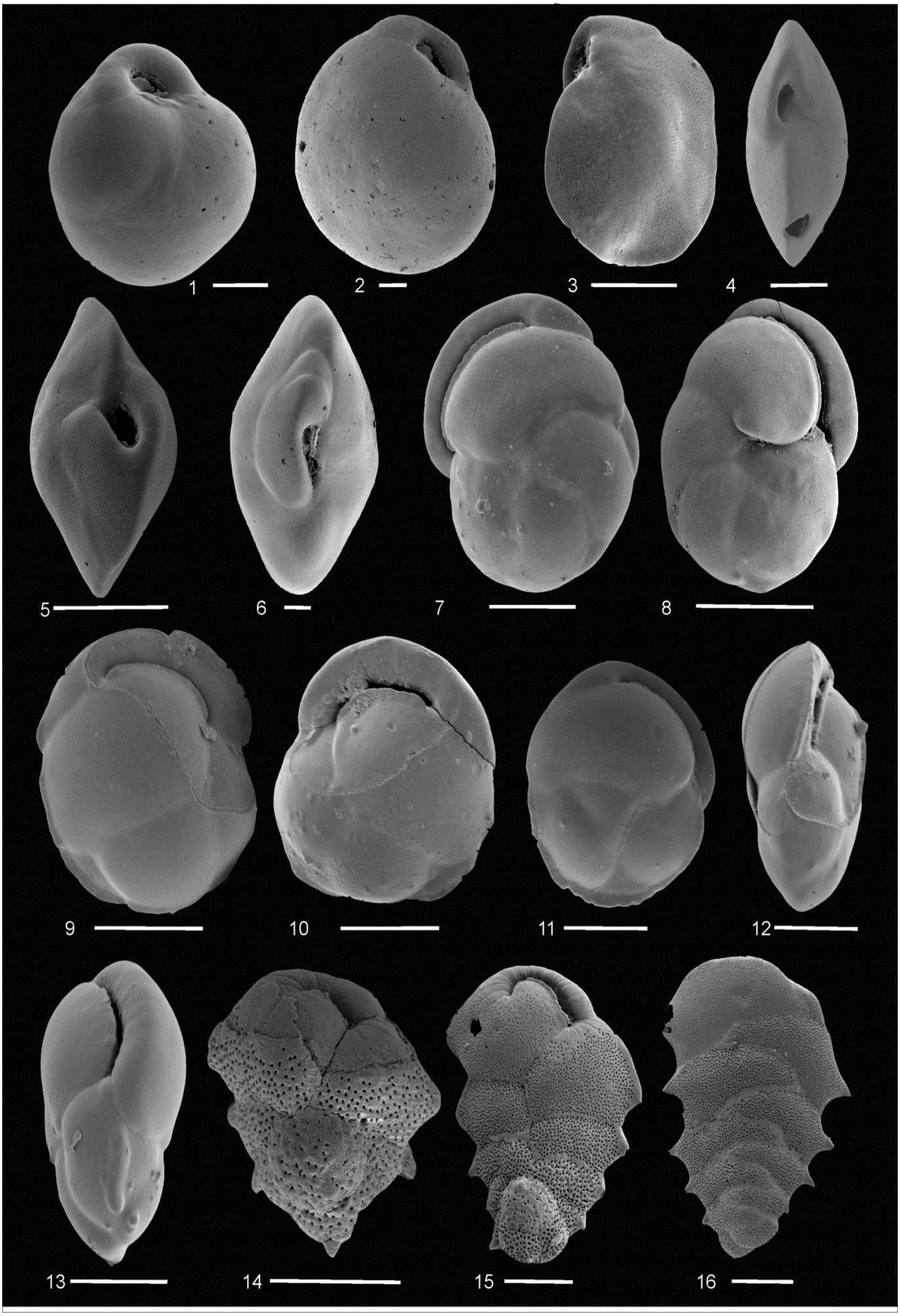

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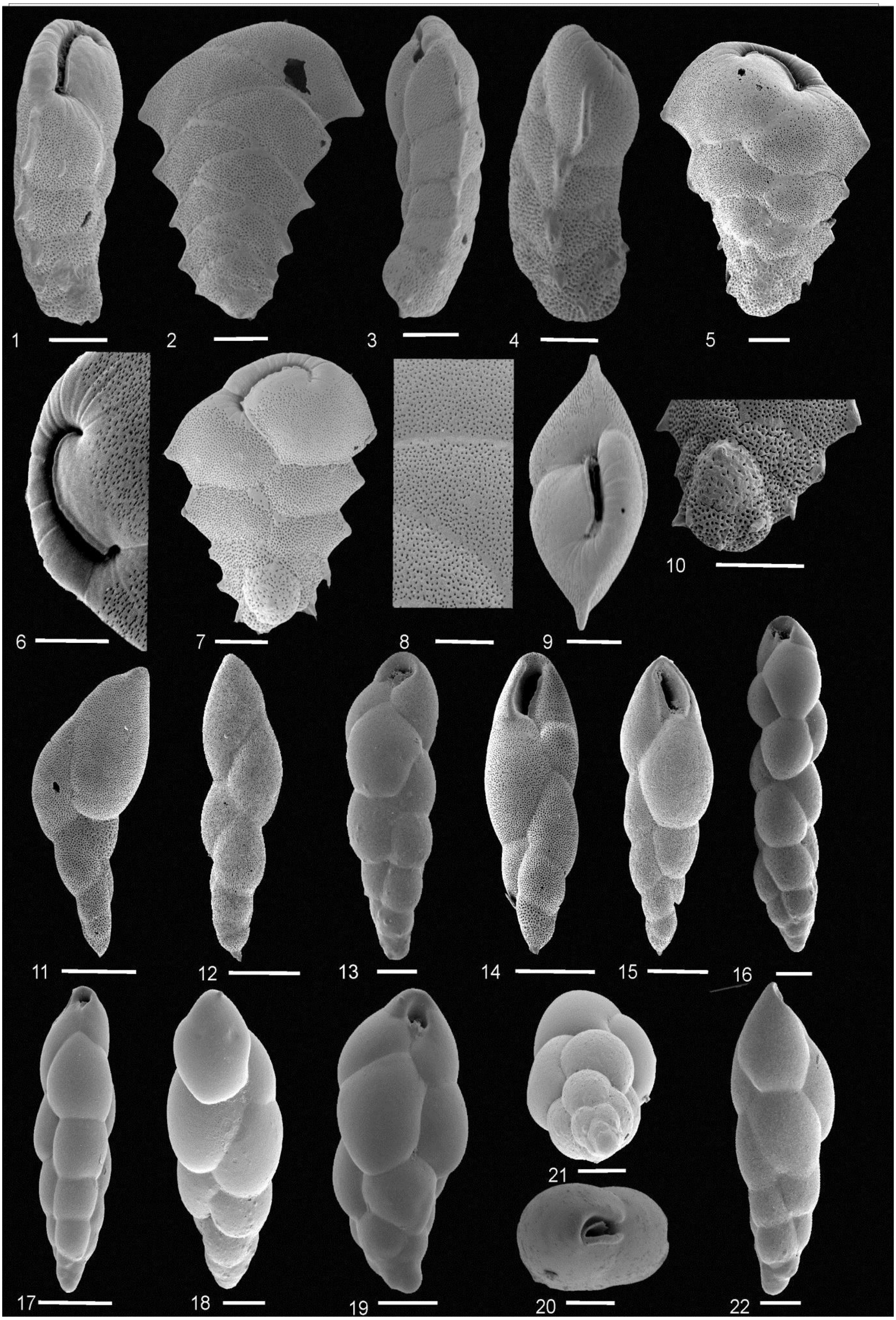

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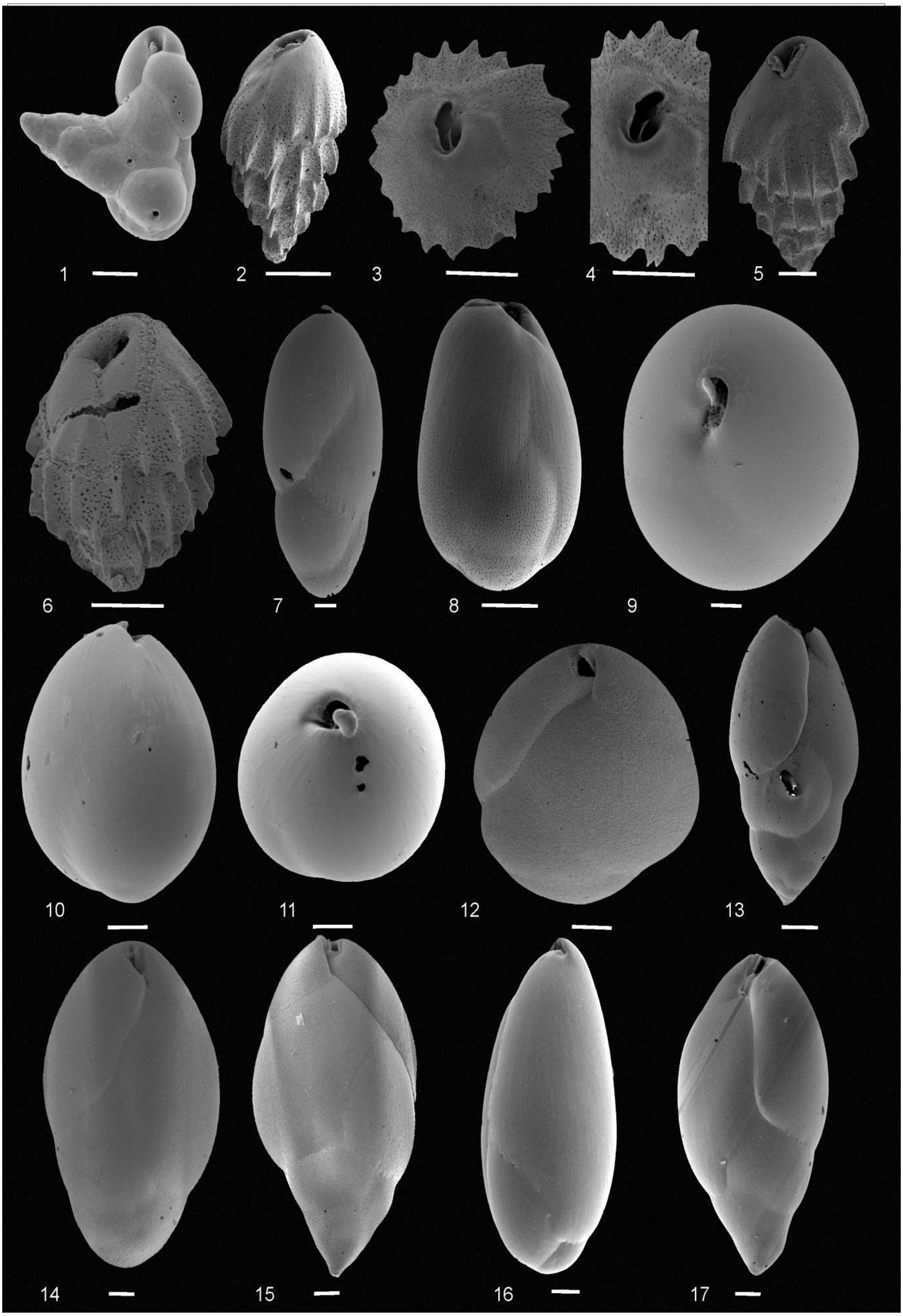

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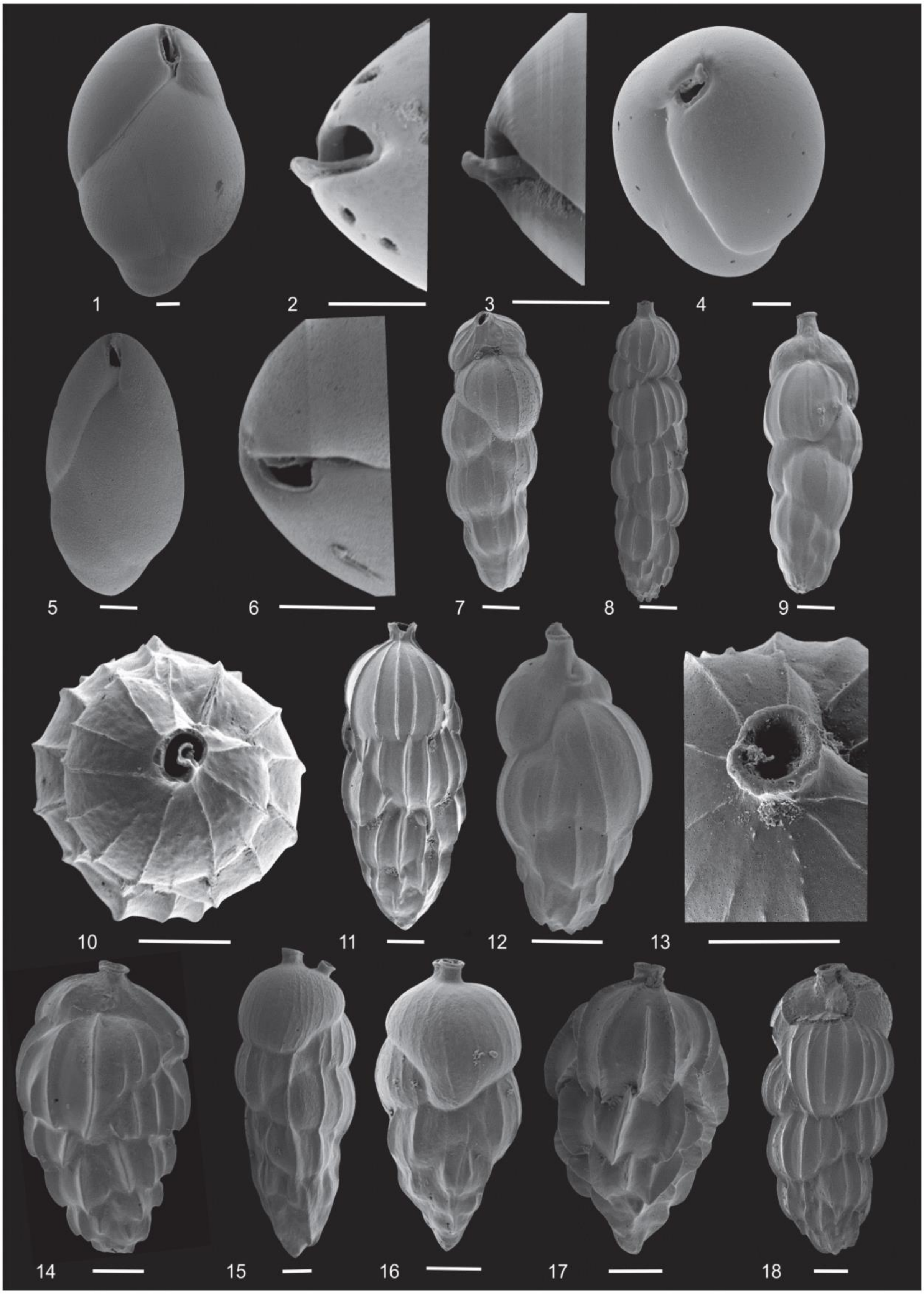

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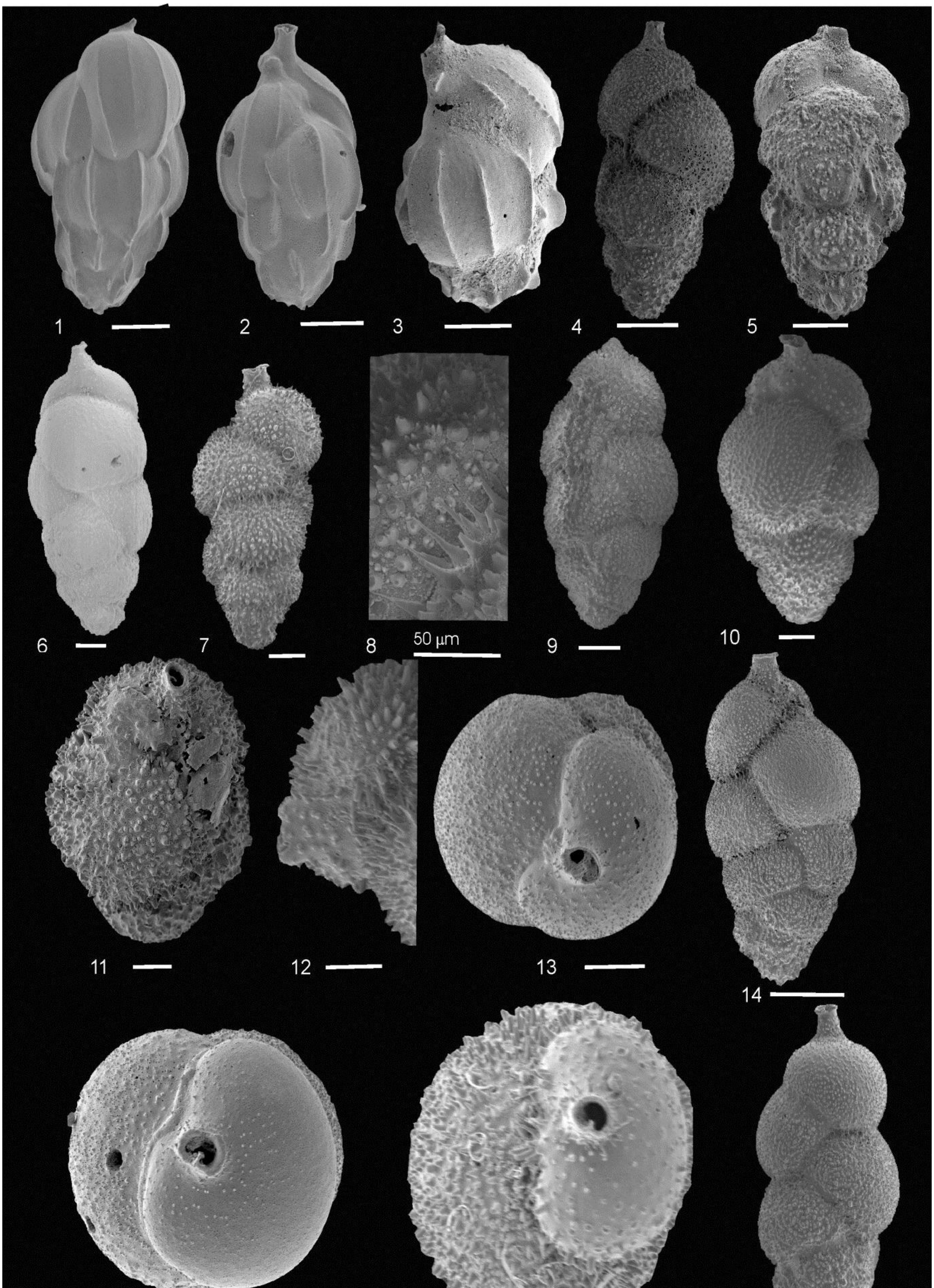

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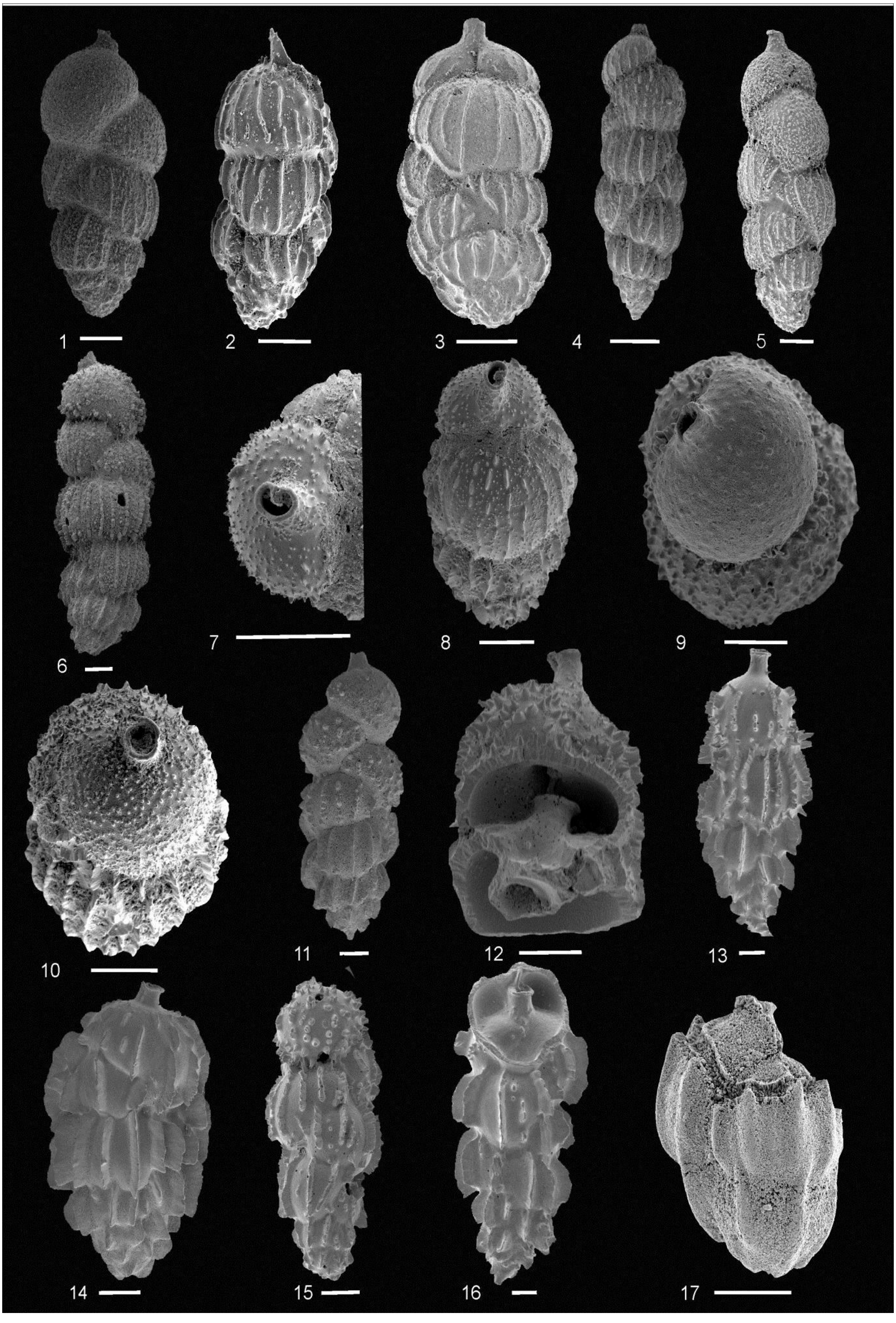

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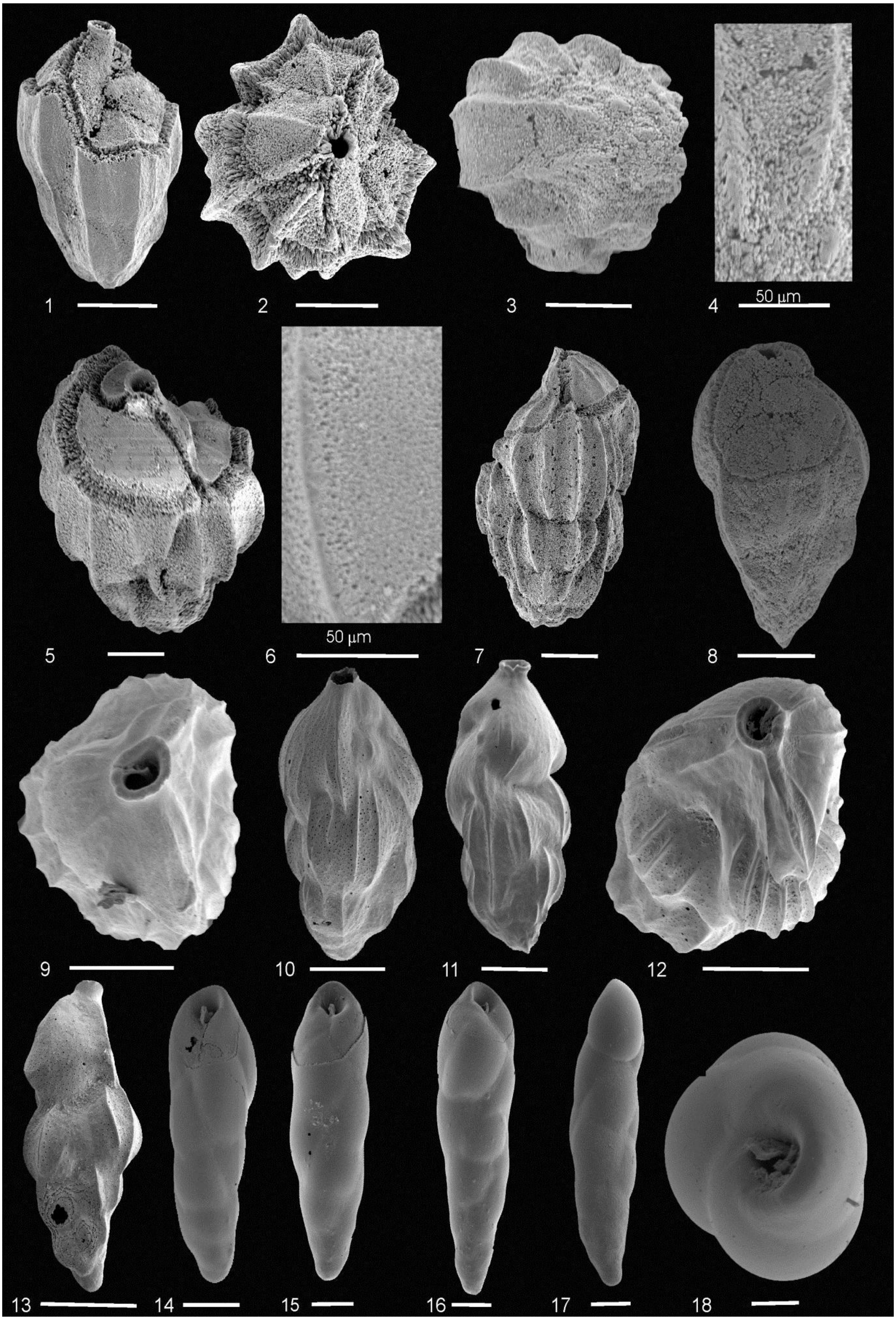

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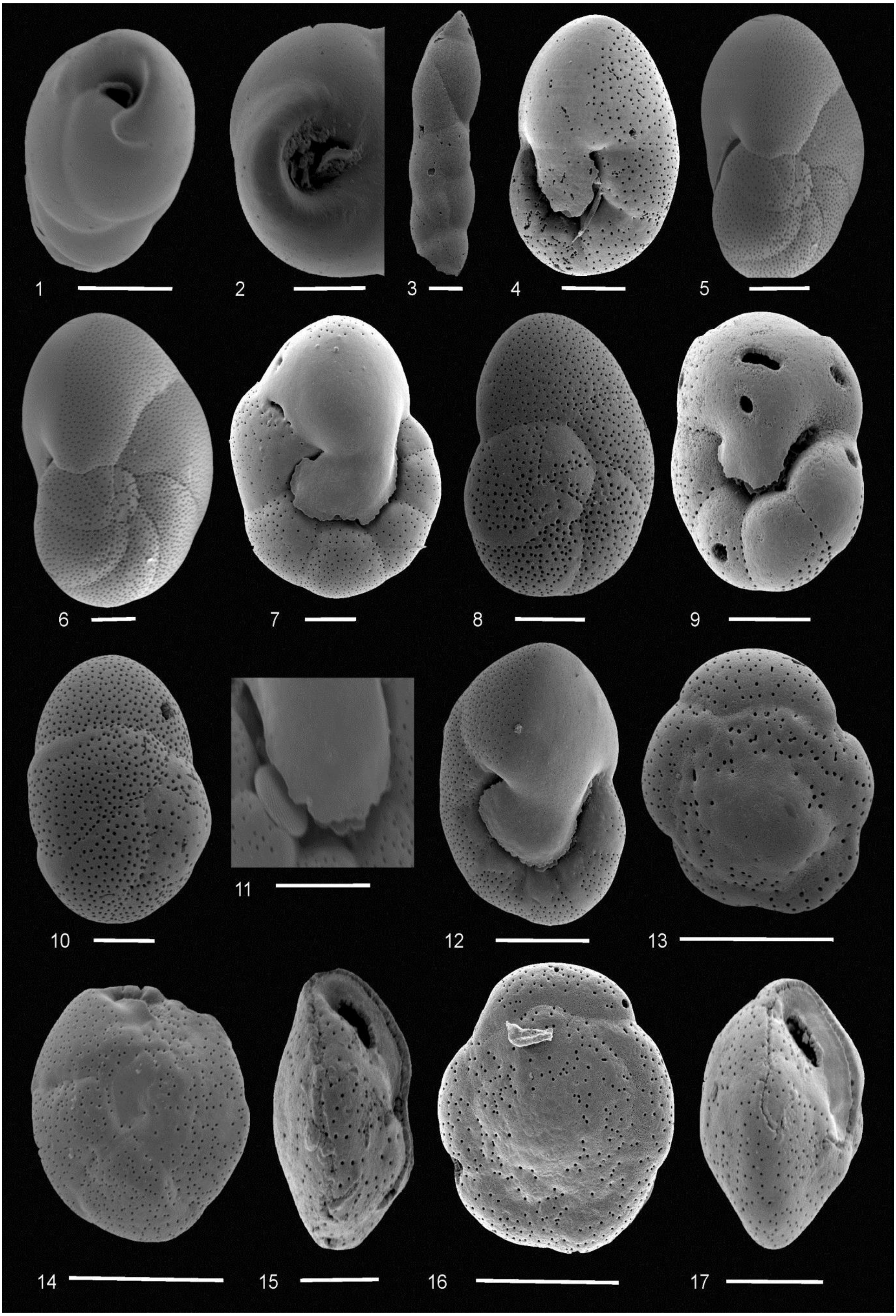

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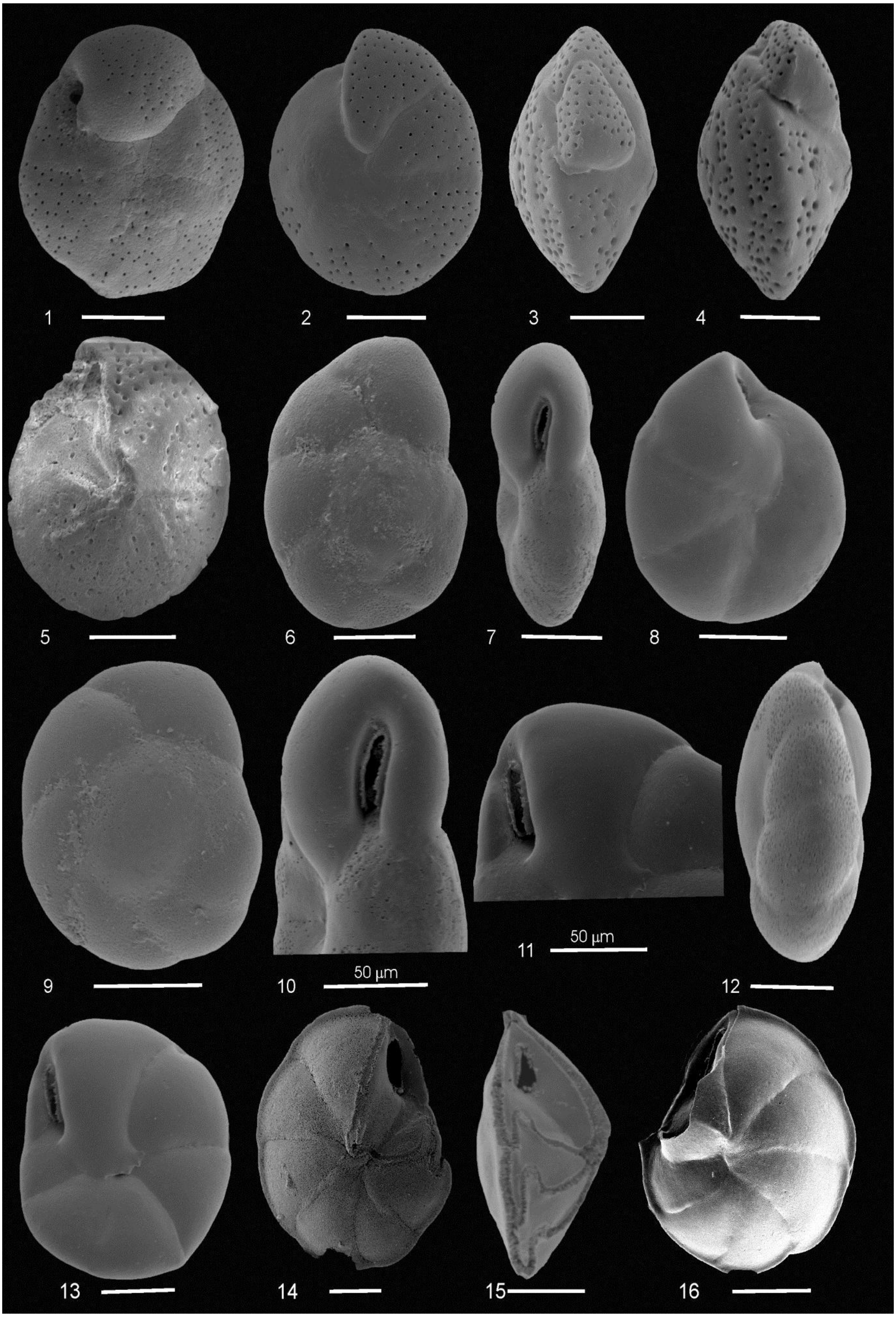
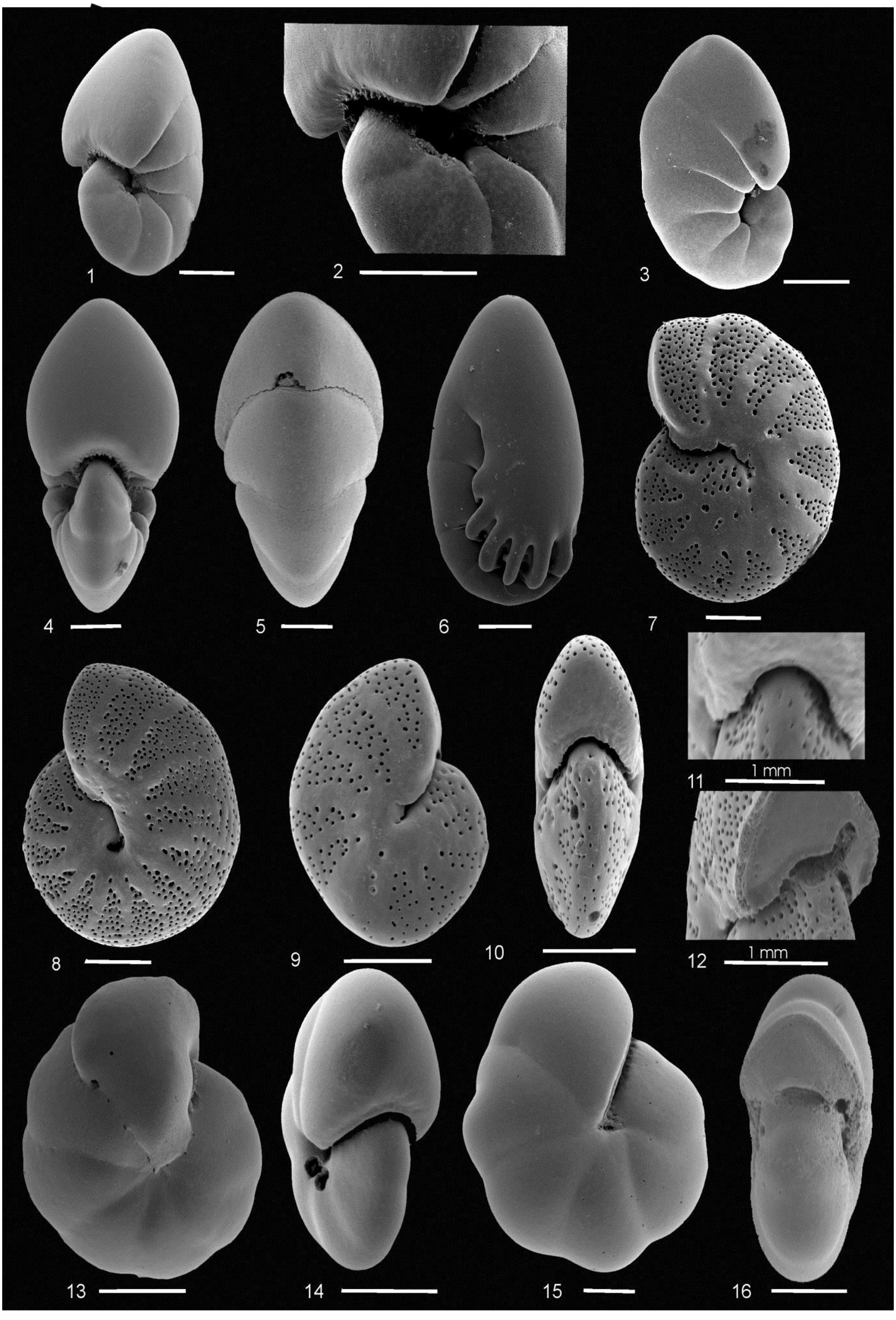


Plate 18

Plate 19



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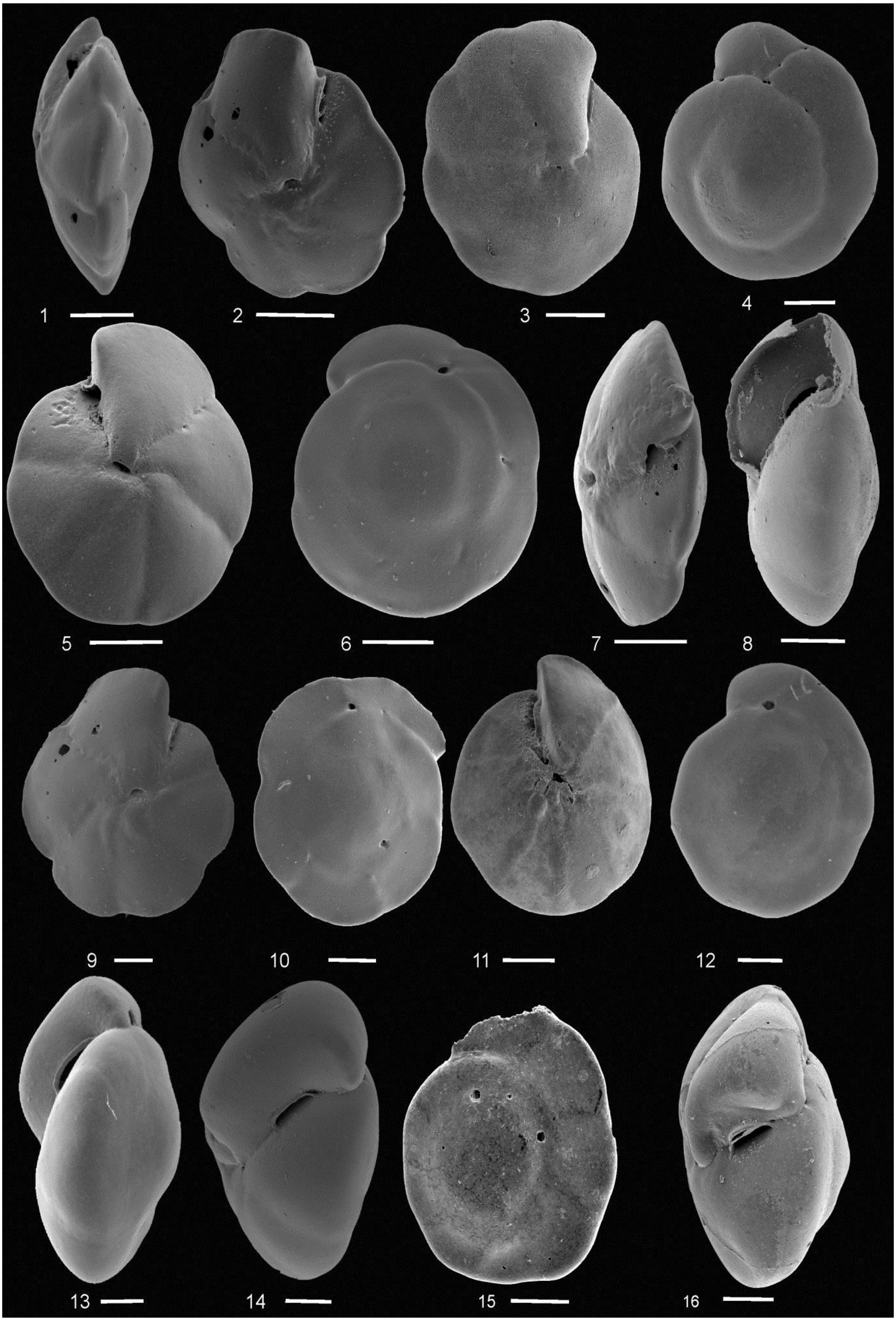

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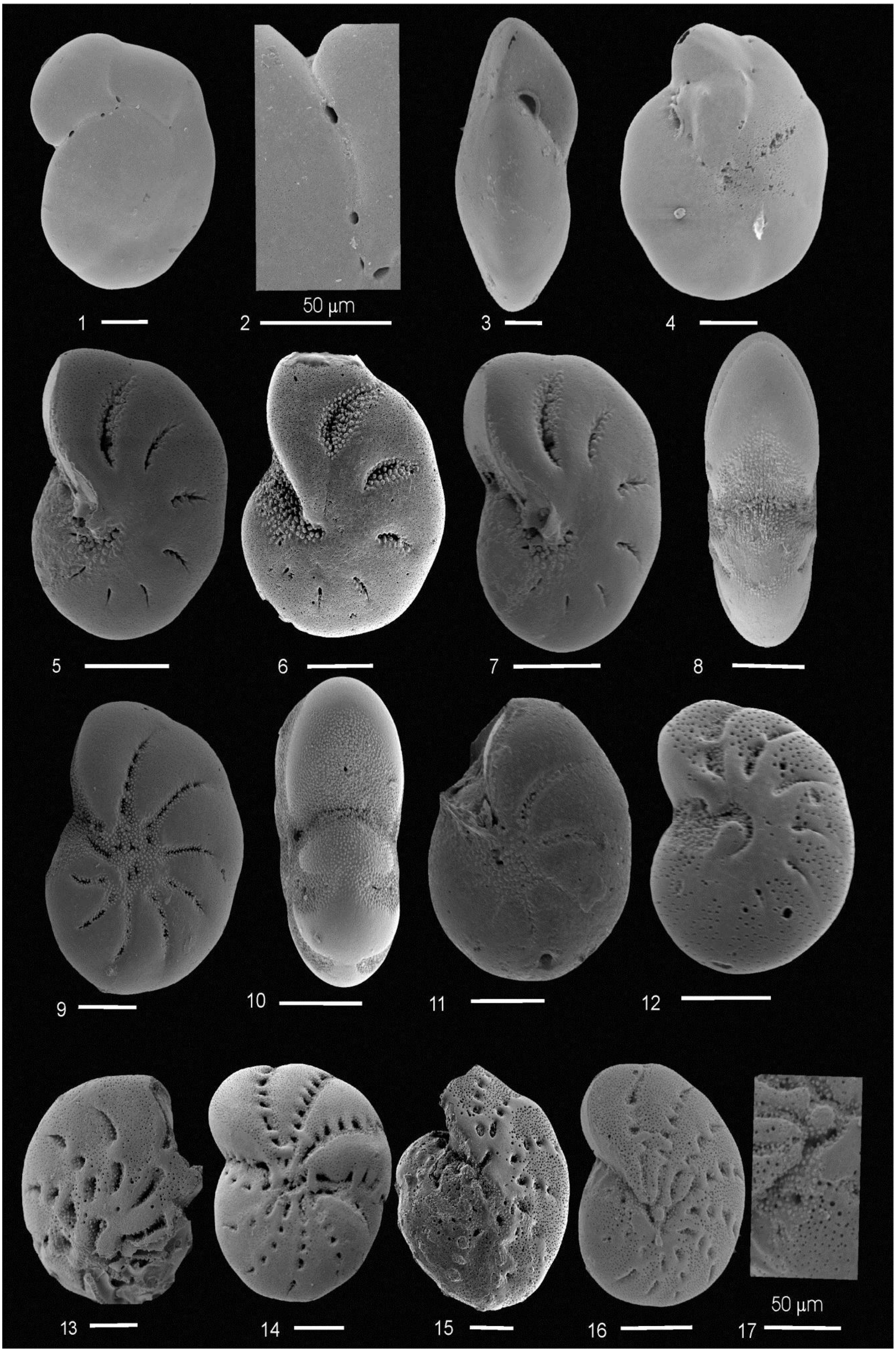

Plate 22

Supplementary Figures

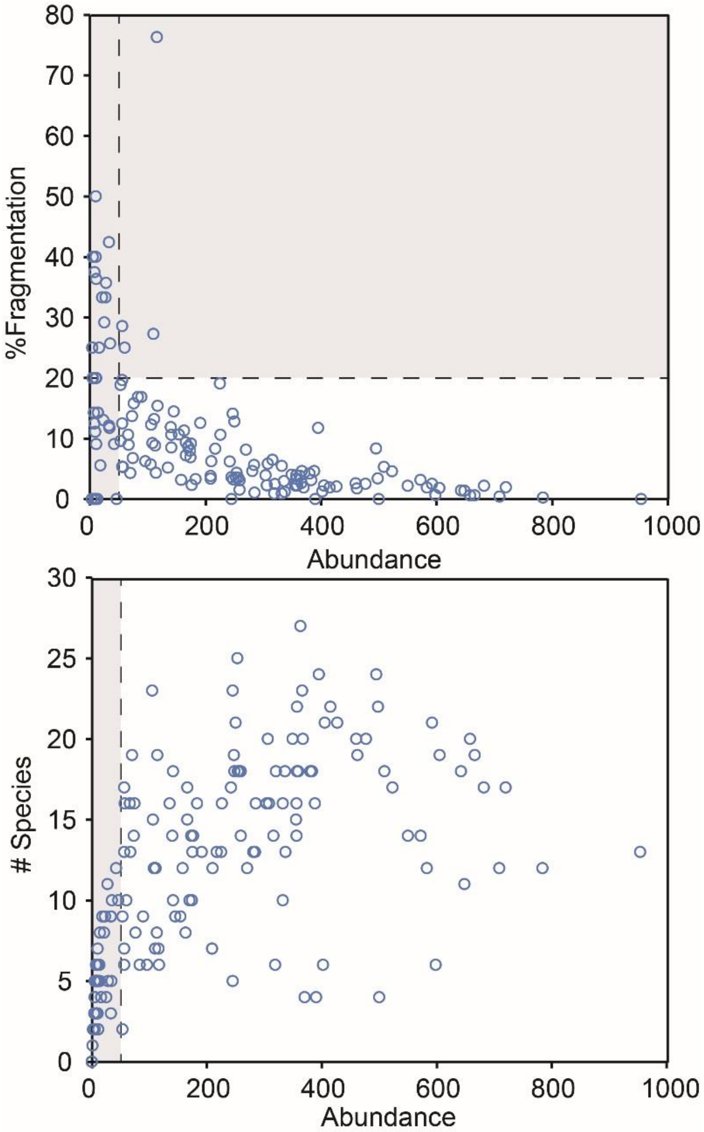

Figure S1. The foraminiferal abundance of each sample against %fragmentation (top) and the number of species in each sample (bottom). Samples with fewer than 50 specimens were removed from Correspondence Analysis as the reduced number of species was not deemed representative, and fragmentation was higher in some of these samples signifying dissolution. Samples with >20% fragmentation were also removed.

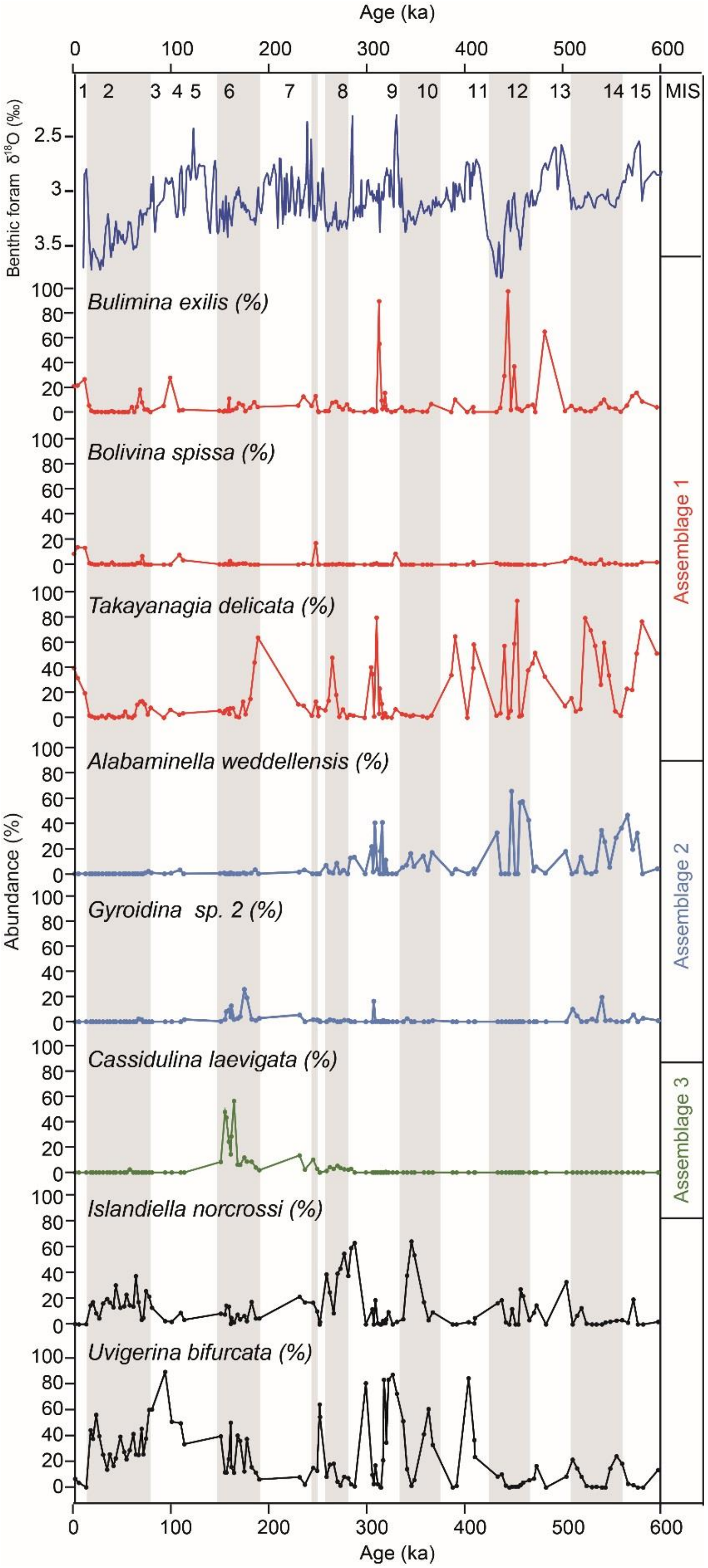

Figure S2. Relative abundance per sample of some of the most abundant species encountered, and important species that make up the assemblages defined with Correspondence Analysis. Glacial maxima are marked as grey bars.

Supplementary Table 1. Benthic foraminiferal census counts.

IODP Site	Hole	Core	Section	Top depth (cm)	Bottom depth (cm)	Depth CCSF (m)	# specimens	# species	*Uvigerina bifurcata*	*Cassidulina reniforme*	*Alabaminella weddellensis*	*Islandiella norcrossi*	*Ehrenbergina sp.*	*Uvigerina peregrina*	*Angulogerina angulosa*	*Globocassidulina subglobosa*	*Pullenia simplex*	*Bulimina exilis*	*Cassidulina teretis*	*Bulimina mexicana*	*Valvulineria araucana*	*Ephidium sp. 1*	*Elphidium sp. 2*	*Elphidium sp. 3*	*Elphidium ustulatum*	*Globobulimina pacifica*	*Planulina weullerstorfi*	*Moncharmontzeiana sp.*	*Quinqueloculina sp.*	*Bolivina spissa*	*Takayanagia delicata*	*Fursenkonia aff texturata*	*Brizalina earlandi*	*Uvigerina hispida*	*Uvigerina sp. 1*	*Epistominella pulchella*	*Bolivina sp. 1*	*Bolivina sp. 3*	*Bolivina sp. 2*
U1342	D	1H	1	0	2	0	493	23	33	1		1	13	4	2	1		102	2	4										42	194		47	2	2	9	14	1	
U1342	D	1H	1	11	13	0.1	403	21	14				13	20				86		5										56	127	2	48	1		4	8	1	
U1342	D	1H	1	26	28	0.25	583	12	1			1	5	2				154								2				78	114		181				1		
U1342	D	1H	1	39	41	0.38	320	18	141	15		47	9	31	4	14	6	17	9	1	1					1				4	6					4			
U1342	D	1H	1	52	56	0.51	285	16	107	11		49	57	16	10	9	7	3	6		2									2	3		1						
U1342	D	1H	1	64	68	0.63	209	7	117	18		18	18	26	2	10																							
U1342	D	1H	1	75	79	0.74	356	14	141	36		16	91	30		20	2	1	13	1	1		1			2	1												
U1342	D	1H	1	89	93	0.88	210	12	53	30		34	34	23		10	1		16	3						1				2	3								
U1342	D	1H	1	104	108	1.03	102	9	14	24		20	12		12	8	3		8																				
U1342	D	1H	1	114	118	1.13	270	12	69	53		46	13	11	26	15	15		14												6								
U1342	D	1H	1	129	133	1.28	114	19	19	11		15	5	8	9	7	14	1	9								1			2	1		1	1		2	1		
U1342	D	1H	1	139	141	1.38	192	14	43	34		58	5	5	11	7	16		6			1																2	1
U1342	D	1H	2	9	13	1.58	225	13	88	75		29	2	4	1	14			6		1										1					2		1	
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U1342	D	1H	2	35	40	1.84	83	6	18	30		19			1	11															4								
U1342	D	1H	2	49	53	1.98	175	13	50	63		26	8	2		8			6		1						1				1					1			
U1342	D	1H	2	65	69	2.14	175	16	72	16		24	25	1		6	3	7	8		3									1					0	5			
U1342	D	1H	2	75	80	2.24	166	15	42	24		62	15	3		2	2		3		3						2				3							1	
U1342	D	1H	2	89	93	2.38	251	22	63	50		43	10	3		12	4	11	1		7	1				1				3	26					1			
U1342	D	1H	2	105	109	2.54	226	16	102	5		8	5	7		3	3	41	1		2					11				3	29								
U1342	D	1H	2	115	120	2.64	395	24	101	40		20	23	12	1	19	3	31	1		11		1		1	1				27	52		28			1	6		
U1342	D	1H	2	129	133	2.78	245	18	92	24	2	63	3	4		7	2	5	6							1				1	26		3						

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U1342	D	1H	3	78	82	3.77	5	5	1	1		1				1																							
U1342	D	1H	3	89	92	3.88	28	5	12	13																				1	1								
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U1342	A	2H	5	76	79	9.11	139	17	2	12	1	60		1		24	1	6			2				11					1	1			7					
U1342	A	2H	5	90	94	9.25	243	22	20	15	7	133	4		7	12	1	5	2		2				1					1	16			1					
U1342	A	2H	5	105	109	9.4	96	23	7	9		36			3	2		6	1		5	1				2								2					
U1342	A	2H	5	115	119	9.5	353	27	9	7	44	208		3	3	9	1	7	1		3	1	1		2	4					8			1					
U1342	A	2H	6	130	134	9.65	356	17	3	4	47	224	1	1	2	6	9	2			9									1	6								
U1342	A	2H	6	7	11	9.92	36	11	8	11		4				2		1		1											4			1					
U1342	A	2H	6	12	16	9.97	0	0																															
U1342	A	2H	6	25	29	10.1	8	3	4			2				2																							
U1342	A	2H	6	40	43	10.25	28	12	5	11		2			1	2		1							1						1			1	1			1	

U1342	A	2H	6	51	55	10.36	76	8	61	8					1	2					1													1					
U1342	A	2H	6	66	70	10.51	111	8	69	28		5						1			3																		
U1342	A	2H	6	81	84	10.66	59	9	37	4		6		1		1					5																		
U1342	A	2H	6	93	97	10.78	567	13	55	20	122	66				23	3	7			31										227			1					
U1342	A	2H	6	102	105	10.87	337	13	9	1	5		1			1	2	8			17										117		85						
U1342	A	2H	6	113	117	10.98	317	15	54	7	128	59	1			4		1			17									2	3		1					1	
U1342	A	2H	6	128	130	11.13	356	16	9	3	13	3	1	1		3		3			22									4	283		2						
U1342	C	2H	3	97	99	11.18	34	5	4		2							24			1										3								
U1342	A	2H	7	145	147	11.3	402	6	1									360			3										13								
U1342	C	2H	3	112	114	11.33	319	6			57			2			2	176			8										74								
U1342	A	2H	7	12	15	11.47	182	15	38	8	74	5				1	4	17		1	5										20								
U1342	C	2H	3	131	134	11.52	117	6	97	14		1						3			1																		
U1342	A	2H	7	28	32	11.63	308	16	192	42	1	3	1			12		13			17										7								
U1342	A	2H	7	33	36	11.68	174	10	60	38	19	7	3	1				27			10										6								
U1342	C	2H	4	10	13	11.81	170	10	141			16	1			1		3			3										1			2					
U1342	C	2H	4	25	28	11.96	5	4	1							1																							
U1342	C	2H	4	38	41	12.09	53	2	46	7																													
U1342	C	2H	4	53	56	12.24	33	3	29	3			1																										
U1342	C	2H	4	64	67	12.35	104	11	75	3		2	2			2		1			1									9	7		1						
U1342	C	2H	4	76	79	12.47	13	6	7					1				1									1												
U1342	C	2H	4	89	91	12.6	102	12	52	10	5	4	2		14	1	1	4			1										3								
U1342	C	2H	4	102	106	12.73	326	15	46	45	22	123	40		2	10		2			15		3								7								
U1342	C	2H	4	117	119	12.88	156	11	2	6	25	100	6		1	1		1			11										2								
U1342	C	2H	4	127	131	12.98	348	15	20	32	20	186	22			6	2	5			27		2								7								
U1342	C	2H	5	9	13	13.3	285	14	117	27	40	49	13		10	3		1			15										3				1				
U1342	C	2H	5	25	28	13.46	218	14	131	22	6	7	9		1	4		1			27					3			1										
U1342	C	2H	5	39	42	13.6	107	16	35	9	18	10	1		2	4		7			6										2	3							
U1342	C	2H	5	50	53	13.71	9	6	2									1	1																				
U1342	C	2H	5	65	68	13.86	14	3	8									3																			3		
U1342	C	2H	5	78	81	13.99	7	5	2									1																					

U1342	C	2H	5	93	95	14.14	34	10	15	1		2	3			1		1			2									6	2							1	
U1342	C	2H	5	107	108	14.28	71	5													4										24	34	8						
U1342	C	2H	5	120	121	14.41	332	10	4		12					1	6	33			9										214								
U1342	C	2H	5	133	136	14.54	8	3	3	4																													
U1342	C	2H	6	11	13	14.82	113	8	95	5		2			2	1					6																		
U1342	D	2H	6	17	22	14.88	23	11	10	4		1			1														1										
U1342	D	2H	6	101	102	15.1	35	9	2		6	5			3																12		2				2		
U1342	C	2H	6	48	52	15.19	551	15	201		21	4		2			10	22		6	41									10	217	2	4					1	
U1342	C	2H	6	114	115	15.23	124	9	29	3		6									3			1							72								
U1342	C	2H	6	58	62	15.29	0	0																															
U1342	C	2H	6	73	75	15.44	0	0																															
U1342	C	2H	6	85	87	15.56	116	7	13	81						13		5	2		1																		
U1342	C	2H	6	98	100	15.69	416	23	35	26	135	68	3	14	2	42	2		13		11					1				6	7		3	12			1		
U1342	C	2H	6	108	112	15.79	461	21	47	45		86		34	2	38		16	56		9									2	16			76			2	1	
U1342	C	2H	6	124	128	15.95	721	18	11	14		12	7	4	1	6		210	2		10									3	412			1					
U1342	C	2H	6	139	141	16.1	500	4										488			8									2									
U1342	C	2H	7	0	2	16.21	473	22	3	1	309	56		4	4	7		8	3		14								1		26		3				21		
U1342	C	2H	7	14	16	16.35	390	4	2									144			15										229								
U1342	C	2H	7	25	27	16.46	709	12	5							2	1	22			2										658		12						
U1342	A	3H	3	124	128	16.55	524	18	10	5	295	142		4	4	3	4	12	14		12										5			1			5		
U1342	A	3H	3	134	138	16.65	607	21	22	2	347	133		8		1	2	6	38		13			1							12		3				7		
U1342	A	3H	4	9	13	16.9	648	11	36	5	275	21			7	4		31			16										244		7						
U1342	A	3H	4	28	32	17.09	134	15	9	1	3	12		2	1			8	9		9										58		1						
U1342	A	3H	4	38	42	17.19	109	10	18		6	16		1					2		2										56		2						
U1342	A	3H	4	49	53	17.3	15	3	10									1																					
U1342	A	3H	4	64	66	17.45	25	4	19							3		1			2																		
U1342	A	3H	4	76	78	17.57	601	8			2							390			2										197		2	1					
U1342	A	3H	5	91	95	17.72	9	3	3									2																					
U1342	A	3H	5	103	108	17.84	17	6	6		1							1													1								
U1342	A	3H	5	126	130	18.07	21	9	4	2						1		2	2																				

U1342	A	3H	5	145	147	18.26	119	13	10	11	21	39	2			6		1	2											3	11								
U1342	A	3H	5	12	15	18.43	360	24	77	35			30	8	2	11	13	18	4		23		1			2				20	56							1	
U1342	A	3H	5	24	27	18.55	258	25	38	23	4	17	32	9	8	7	6	4	6		36					2				12	13								
U1342	A	3H	5	36	39	18.67	366	23	30	32	49	46	103	5	2	21	2	10	7											12	25						4	1	
U1342	A	3H	5	49	52	18.8	682	17	8	24	6	4	59		1	6	3	4	2		9									7	540								
U1342	A	3H	5	64	67	18.95	662	18	2	12			131			3	5	4	1		9					1				5	459							1	
U1342	A	3H	5	76	78	19.07	644	19	4		11		139	1			6	17			51					3				4	368							1	
U1342	A	3H	5	91	92	19.22	764	14			263							54			14									32	200		8					2	
U1342	A	3H	5	100	101	19.31	812	11			206	12				7	2	80			4										483								
U1342	A	3H	5	113	117	19.44	582	22	85	9	30	12	94	16		7	7	22	24		42			1				1		6	196							1	
U1342	A	3H	5	130	133	19.61	383	17	92	10	109	11	57	21	3			11	11		18								1	5	20		3						
U1342	A	3H	5	145	148	19.76	502	17	92	68	181	16	34	16	3	9		2	12		28					6					8			2			2		
U1342	A	3H	6	11	13	19.92	639	17	18	8	297	8	62	17		9		34	8		16					2					147								
U1342	A	3H	6	25	27	20.06	109	13	2	7	21	21			2	3		14			1				1						24		6		1				
U1342	A	3H	6	37	39	20.18	243	4			78							38													124		3						
U1342	A	3H	6	50	54	20.31	106	10		2			2		2			9	1											2	81								
U1342	C	3H	3	63	67	20.44	1	1																															
U1342	C	3H	3	78	83	20.59	104	17	14	7	4	2	3		2			4			4									2	53								

Table 1, part a.

Depth CCSF (m)	*Brizalina alata*	*Bolivina aff. mexicana*	*Oridorsalis umbonatus*	*Hoeglundina elegans*	*Epistomella pacifica*	*Planulina arimenensis*	*Cibicidoides sp.*	*Procerolagena gracilis*	*Procerolagena gracillima*	*Lagena sulcata*	*Legena hispida*	*Lagena nebulosa*	*Lagena sp. 1*	*Lagena sp. 2*	*Lagena sp. 3*	*Lenticulina rotundata*	*Stainforthia fusiformis*	*Nonionella labradorica*	*Nonionella digitata*	*Fissurina crebra*	*Uvigerina senticosa*	*Globocassidulina sp*	*Gyroidina sp. 2*	*Gyroidina sp. 1*	*Dentalina ittai*	*Triloculina frigida*	*Cassidulinoides parkerianus*	*Globobulimina auriculata*	*Cassidulina laevigata*	*Lotostomoides calomorphus*	*Martinoitella sp. 3*	*Cushmanina striatopunctata*	*Pyrgo murrhina*	*Eggerella sp. 1*	*Reussoolina apiculata*	*Fissurina minima*	*Epistominella exigua*	*Melonis barleeanus*	*Lenticulina gibba*	*Oolina hexagona*
0	11	2	4		1												1																							
0.1	5	3	4		1	1										2														1					1					
0.25	43	1																																						
0.38	2																	8																						
0.51	1																	1																						
0.63																																								
0.74																																								
0.88																																								
1.03																																	1							
1.13	1																			1																				
1.28																6									1															
1.38										1											2																			
1.58																1																								
1.74																9																								
1.84																																								
1.98																4													4											
2.14				2												1						1																		
2.24					1											2						1																		
2.38					4						1											1	6		1					1					1					
2.54	1																						4		1															
2.64	11				1	2												1				1																		
2.78	3																	1				1				1														
2.94																											1													

3.09	1																				1							2												
3.24	1																											2												
3.38																						1																		
3.48					1																	1						1												
3.66																2					2							1												
3.77										1																														
3.88																						1																		
3.98																1		1									1	2												
4.11	1																					1	1					1							1					
4.24																							1																	
4.37																																								
4.47																																								
4.58																																								
4.74																																								
4.85				1																	1																			
4.97																																	1							
5.13																																								
5.26			5																	1	2	5	1						29				1							
5.41			5																	1		3	9						238				1							
5.46	1		8															1				1	39						206											
5.55																						2	28						74	1										
5.62																							11						40											
5.64																							48					2	108											
5.74																							7			2	1		202				1							
5.87	1				2													1					11				1		26											
5.96																		2					14				8		20				1							
6.11																							79				3		36											
6.2	7																	2			1		63				3		28											
6.37							1	1		1												1	5						21											
6.52																					1		3						10											

6.63																					1		5						3											
6.8																					1		1																	
6.94																																			1					
7.06																													1											
7.21																										1			3											
7.3																										1			8											
7.44																																								
7.59																													2											
7.71				1																	2		4						10											
7.85																					4								3											
7.99																							1						4											
8.1																							1						6											
8.25																					2		1						2											
8.34																						9	1				3													
8.36																						8																		
8.47																													1											
8.6	1										1									1	4								3											
8.72																					5		6				1		15					1						
8.86							1		1	1													3						7											
9											2									2	1								12											
9.11												2									2						1		5											
9.25										1	2										2		3				1	1	6											
9.4		1						1		1							3			1	1		1				8	1	2		1			1						
9.5										2							7			3						3	9	4	10	1				1	1					
9.65																	13									4	19	5												
9.92																										1	2	1												
9.97																																								
10.1																																								
10.25																											1													
10.36																					1						1													

10.51																						3							1						1					
10.66																				1		2					2													
10.78	3																										8	1												
10.87	35																						55					1												
10.98																							1				21	17												
11.13	2																	1					1					5												
11.18																																								
11.3	24																	1																						
11.33																																								
11.47	2																					1	2				3	1												
11.52																											1													
11.63	3																				2	8	1				1	4	1											
11.68																						3																		
11.81	1			1																																				
11.96																										2								1						
12.09																																								
12.24																																								
12.35																												1												
12.47																						2						1												
12.6																						5																		
12.73																						1	8				1	1												
12.88																						1																		
12.98																												16		1	1							1		
13.3													1									1						4												
13.46																					4							1												
13.6											1											5	1					1										2		
13.71													1								1	3																		
13.86																																								
13.99																									1		1				2									
14.14																																								

14.28													1																											
14.41																						1															48	4		
14.54																																		1						
14.82																						1				1														
14.88											1		1		1																	1				1				
15.1	1																														2									
15.19																		3										7												
15.23														1							7																2			
15.29																																								
15.44																																								
15.56																1																								
15.69						14					1						16		2	1										1										
15.79			3			7				1							12			3						2		3												
15.95			24									1				1												1											1	
16.1																																						2		
16.21						1		1		5							1										1								1	2				
16.35																																								
16.46							2			1										2							1	1												
16.55							1																			1		2									4			
16.65							1									1	2										2										3	1	2	
16.9																											2													
17.09											2							5									12	2												
17.19																		2									4													
17.3																		4																						
17.45																																								
17.57	5																	2																						
17.72																		4																						
17.84																		7																1						
18.07							1											7								1	1													
18.26			4															8										1												

18.43	4		6														1	7					36	1	1	1		2												
18.55	2		6				3			2								7					12				1	6											1	1
18.67			7							1									1								4			1						1			1	1
18.8			4				2			2													1																	
18.95	1		11	1						1										1			14																	
19.07	6		12			1				2										11			4					2								1				
19.22	18		19					1		1													150	1							1									
19.31			2							1													8					7												
19.44			10							3									1				7					7										1		
19.61																											6	4												
19.76																											17	6												
19.92										5													3					1								2		2		
20.06																							6																	
20.18																																								
20.31																							3				1							3						
20.44																																				1				
20.59										2													1			1	2			1				1	1					

Table 1, part b.