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Benthic foraminifera associated to cold-water coral ecosystems

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There are three kinds of lies: lies, damned lies and statistics.

Mark Twain

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ABSTRACT

Cold-water coral reef ecosystems occur worldwide and are especially developed along the European margin, from northern Norway to the Gulf of Cadiz and into the Western Mediterranean Sea. The dominant reef builder in these areas is the scleractinian coral *Lophelia pertusa*, often associated with the scleractinian coral *Madrepora oculata*. These species settle on suitable hard substrates, in environments characterized by elevated currents and high food availability. Along the European margin cold-water coral reefs developed during different times and with different morphologies. In particular, on the Norwegian shelf and upper slope, extended active/living reefs have developed on elevated hard substrata. Along the Irish margin on the Rockall Bank, on the Porcupine Bank, and in the Porcupine Seabight, *L. pertusa* has built large fossil and/or active carbonate mounds. In the Gulf of Cadiz and in the Alboran Sea buried reefs and patch reefs with often strongly fragmented coral rubble are generally found in association with mud volcanoes below a (hemi-) pelagic sediment cover.

Cold-water corals have been known since the eighteenth century but the development of new technologies has resulted in the discovery of huge cold-water coral ecosystems and carbonate mounds during the last few decades. Their widespread occurrence presents a challenge to understand their development, preservation and possible importance in the geologic record.

In modern oceans, they provide important ecological niches for the marine benthic fauna in the deep-sea. In comparison to the macrofauna the microfauna, particularly the foraminifera associated with these systems, are poorly known. The present study focuses on the foraminiferal assemblages associated with cold-water coral ecosystems from the European continental margin. Samples were collected in three key regions: surface sediments along the Norwegian margin and in the Porcupine-Rockall region, gravity cores were taken on the top of two mud volcanoes in the Alboran Sea. Planktonic and benthic foraminiferal assemblages were quantitatively analyzed. Since patterns of community structures are often not readily apparent, hierarchical cluster analysis, multidimensional scaling (nMDS), and diversity analysis were applied to emphasize differences in the foraminiferal assemblages.

Planktonic foraminiferal assemblages provide information about the conditions in surface waters. The assemblage of planktonic foraminifera in the coral-rich layer of two sediment cores in the Alboran Sea and in surface sediments from the Norwegian margin indicate similar conditions in the uppermost waters of both regions: nutrient-rich with enhanced phytoplankton blooms. At the transition from the coral-rich layer to the overlying (hemi-)pelagic sediments in the Alboran Sea a main shift in the planktonic foraminiferal assemblage indicate a reorganization of water masses towards more oligotrophic conditions. Low food availability could be the main reason for the decline of the cold-water coral reefs in this area.

The benthic foraminiferal assemblages in the Porcupine/Rockall region on the Irish margin are strictly related to the distribution of different sedimentary facies. On the Norwegian margin, benthic foraminiferal assemblages show a clear separation of cold-water coral reef associated fauna and off-reef associated fauna. However, different assemblages for each facies are only weakly defined and grade one into the other preventing a strict facies attribution as that observed along the Irish margin. The benthic assemblages from coral-rich layers in the Alboran Sea and those from cold-water coral reefs associated to carbonate mounds in the Porcupine/Rockall and cold-water coral reefs along the Norwegian margin also show remarkable similarities. In particular, the assemblages are dominated by epifaunal-attached species such as *Discanomalina coronata*, *Cibicides refulgens*, and *Lobatula lobatula* but also infaunal foraminifera such as *Globocassidulina* spp., *Epistominella* spp., *Cassidulina* spp. are highly abundant. The benthic fauna provide information on currents, oxygenation and organic matter content. In particular, the benthic fauna associated with cold-water coral ecosystems indicates an environment characterized by high energy, well oxygenated waters and high organic matter supply derived from phytoplankton blooms and reaching the sea floor. In the investigated areas *D. coronata* is restricted to living cold-water coral reefs facies only and/or in co-occurrence with coral fragments. Based on these observations *D. coronata* is interpreted to require similar ecological conditions to cold-water corals and, therefore, proposed as an indicator species for healthy cold-water coral ecosystems on the European continental margin.

In conclusion, our data suggest that although cold-water coral ecosystems occur at different latitudes, the associated foraminiferal assemblages are consistent from Norway to the Western Mediterranean. Thus they can be used to identify these ecosystems even in the geologic record, when the corals are often strongly dissolved like in the Alboran Sea.

ZUSAMMENFASSUNG

Kaltwasserkorallenriffe treten weltweit auf, sind aber am stärksten verbreite entlang des europäischen Kontinentalabhangs zwischen Nordnorwegen und dem Golf von Cadiz. Sie kommen aber auch im Mittelmeer vor. Die Steinkoralle *Lophelia pertusa* ist die dominierende riffbildende Art und wird oft von einer zweiten Steinkorallenart, *Madrepora oculata*, begleitet. Die Larven dieser Arten besiedeln ausschliesslich Hartsubstrat. Starke bodennahe Strömungen und ein hohes Nahrungsangebot sind weitere Voraussetzungen für Kaltwasserkorallenwachstum. Entlang des europäischen Kontinentalabhangs etablierten sich Kaltwasserkorallenriffe während verschiedenen geologischen Zeiträumen und mit unterschiedlichen Erscheinungsbildern. Seit Beginn des Holozäns entwickelten sich grossflächige Riffe auf dem norwegischen Schelf und dem oberen Kontinentalabhang. Am irischen Kontinentalabhang, auf der Rockall Bank, Porupine Bank und in der Porcupine Seabight, hat hauptsächlich *L. pertusa* seit dem späten Pliozän riesige fossile und teilweise noch aktive wachsende Karbonat-Hügel aufgebaut. Im Golf von Cadiz und in der Alboransee (westliches Mittelmeer) sind lebende Kaltwasserkorallenriffe sehr selten, begrabene fossile Riffe und „Patch“-Riffe aber häufig. Sie bestehen aus mehr oder weniger stark verwitterten Korallenbruchstücken und sind häufig mit Schlammvulkanen assoziiert.

Die Existenz von Kaltwasserkorallen ist schon seit dem achtzehnten Jahrhundert bekannt. Aber erst die Entwicklung von neuen Technologien in der Ozeanforschung in den letzten zwanzig Jahren hat zur Entdeckung der weitläufigen Kaltwasserkorallen-Ökosysteme und der riesigen Karbonat-Hügel geführt. Die grosse Verbreitung der Kaltwasserkorallen wirft viele Fragen auf, z.B. was sind die ökologischen Bedingungen für Kaltwasserkorallenwachstum, wie gut bleibt das Korallenskelett in der Tiefsee erhalten oder wie verbreitet waren die Kaltwasserkorallen in der Vergangenheit.

Heutzutage sind Kaltwasserkorallen-Ökosysteme wichtige Nischen in der Tiefsee mit einer hohen Diversität an mariner benthischer Fauna. Im Vergleich zur Makrofauna ist über die Mikrofauna und speziell über die Foraminiferenvergesellschaftungen assoziiert mit Kaltwasserkorallen fast nichts bekannt. Die vorgelegte Studie befasst sich mit der Foraminiferenvergesellschaftung von Kaltwasserkorallenökosystemen entlang des europäischen Kontinentalabhangs. Planktonische und benthische Foraminiferen wurden in Sedimentoberflächenproben entlang des irischen und norwegischen Kontinentalabhangs und in Schwerelotkernen von Schlammvulkanen quantitative analysiert. Da einzelne Vergesellschaftungen in einem grossen Datensatz oft nicht gleich sichtbar sind wurden statistische Methoden wie Hierarchical Cluster Analysis, Multidimensional Scaling (nMDS) und Diversitätsanalysen angewandt.

Die planktonische Foraminiferenvergesellschaftung in den korallebruchreichen Schichten von zwei Sedimentkerne aus der Alboransee und in den Oberflächensedimenten von norwegischen Korallenriffen weisen auf hohe Nährstoffkonzentrationen in den oberflächennahen Wasserschichten und damit verbundenen hohe Primärproduktion hin. Beim Übergang von den korallenreichen Schichten zu den darüberliegenden (hemi-)pelagischen Schichten in den Alboransee-Bohrkernen verändert sich die planktonischen Foraminiferenvergesellschaftung dramatisch und weist auf eine Reorganisation der Wassermassen zu nährstoffärmeren Bedingungen mit geringer Primärproduktion hin. Die dadurch geringere

Nährstoffverfügbarkeit für die Korallen mag der Hauptgrund für das Absterben der Riffe sein.

Die benthische Foraminiferenvergesellschaftung in der Porcupine/Rockall Region am irischen Kontinentalabhang ist stark abhängig von der Fazies in der sie leben. Auf dem norwegischen Schelf und Kontinentalabhang unterscheidet sich die benthische Foraminiferenfauna zwischen der Vergesellschaftung, die im Riff lebt von derjenigen die ausserhalb lebt. Die starke Faziesabhängigkeit der einzelnen Vergesellschaftungen wie in der Porcupine/Rockall Region, ist in Norwegen nur schwach definiert. Der Grund dafür dürfte in Faziesunterschieden liegen, die sich auf kleinstem Raum ändern und sich stark überlappen. Die benthische Foraminiferenvergesellschaftung von den korallereichen Schichten der Alboransee-Sedimentbohrkernen, den Oberflächensedimenten von den Karbonat-Hügeln in der Porcupine/Rockall Region sowie den norwegischen Korallenriffen zeigen grosse Ähnlichkeiten. Speziell epifaunale Arten wie *Discanomalina cornata*, *Cibicides refulgens* und *Lobatula lobatula* dominieren die Korallenriff-Vergesselschaftung. Aber auch infaunal lebende Foraminiferen wie *Globocassidulina* spp., *Epistominella* spp. und *Cassidulina* spp. sind häufig. Einzelne Arten benthischer Foraminiferen geben Auskunft über Strömungsgeschwindigkeiten, Sauerstoff- und Nährstoffgehalt des Wassers. Diese Arten zeigen auf, dass starke bodennahe Strömungen, sauerstoffreiche Wassermassen und ein hoher Eintrag an Nährstoffen, hauptsächlich von Phytoplanktonblüten, charakteristisch für dieses Ökosystem sind. Ebenfalls kennzeichnend für das Kaltwasserkorallenökosystem ist die Art *Discanomalina coronata*. Sie kommt nur in den lebenden Korallenriffen vor und lebt hauptsächlich auf abgestorbenen Korallenästen und anderem vorhandenen Hardsubstrat. Ausserhalb der Korallenriffe kommt *D. coronata* hingegen nicht vor. Es scheint, dass *D. coronata* die gleichen ökologischen Ansprüche wie die Kaltwasserkorallen und im speziellen *L. pertusa* hat. Aus diesem Grund kann *D. coronata* als Indikator-Art für gesunde Kaltwasserkorallenökosysteme des europäischen Kontinentalabhangs definiert werden.

Zusammenfassend kann gesagt werden, dass Kaltwasserkorallenökosysteme entlang des europäischen Kontinentalabhangs in verschiedenen geografischen Breiten vorkommen. Die Foraminiferenvergesselschaftung für diese Ökosysteme stimmen von Nordnorwegen bis ins westlich Mittelmeer überein. Diese kaltwasserkorallenassozierten Foraminiferen können in Zukunft zur Identifikation dieser Ökosysteme in der geologischen Abfolge genutzt werden auch wenn die Korallenbruchstücke, wie in der Alboransee, stark aufgelöst.

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1 - INTRODUCTION

1.1 COLD-WATER CORALS

For most people corals are marine animals living in the tropics, thriving in well-illuminated surface waters and may build up enormous coral reefs which host a very high biodiversity like the Great Barrier Reef on the north east coast of Australia. These ecosystems are known since hundreds of years and are very well investigated. Only a few people are presently aware that coral reefs from warm latitudes have a cold-water counterpart.

Cold-water corals were first discovered by Norwegian fisherman in the eighteen century and first described by Pontoppidan (1755), and Gunnerus (1768). However their potential to build up huge carbonate mounds is a very recent discovery and they are under investigation since a couple of decades only. Thanks to the development of new technologies and tools in deep-sea exploration such as manned and robotic submersibles, and sophisticated camera systems we are now able to investigate these fascinating ecosystems.

Comprehensive reviews about cold-water corals are given in the books “Cold-water Corals and Ecosystems” edited by Freiwald and Roberts (2005), “Deep-water Coral Reefs: Unique Biodiversity Hot-spots” (Hovland, 2008) and “Cold-water Corals: The Biology and Geology of Deep-Sea Coral Habitats” (Roberts et al., 2009). Additionally, the United Nations Environmental Program (UNEP) – World Conservation Monitoring Centre (WCMC) has published an overview about cold-water corals: “Cold-water Coral Reefs” (Freiwald et al., 2004) and short summary about the state-of-the-art is given in an article published by Roberts et al., 2006. However, the functioning of these ecosystems is far away to be fully understood and their global distribution is not mapped as yet as it is for warm water reefs. However, we can assume that almost all oceans and seas worldwide may host cold-water corals when their ecological requirements are met. To the present they have been documented in Fjords and on the continental shelf of Norway (Fosså et al., 2002; Freiwald et al., 2002), along the upper continental slope from the Faroe-Shetland Channel south to central Africa, in the northwest Atlantic from Canada, Gulf of Mexico down to Brasil but also in the Indian and Pacific Oceans (Stetson et al., 1962; Freiwald et al., 1999; Paull et al., 2000; Heifetz, 2002; Reed, 2002; Freiwald et al., 2004; Gass and Willison, 2005; Mortensen and Buhl-Mortensen, 2005; Schroeder at al., 2005; Reyes et al., 2005). On deep-sea banks cold-water corals have been documented on the Rockall Bank in the northeast Atlantic, Galicia Bank close to Spain and the Chatman Rise and Champbell Plateau bear New Zealand and on several seamounts in the Atlantic and Pacific Oceans (Jaques, 1972; Grigg, 1984; Wilson and Kaufman, 1987; Richer de Forges, 1990; Grigg, 1993; Richer de Forges, 1993; Probert et al., 1997; Koslow et al., 2001; Andrews et al., 2002; Gubbay, 2003; Baco and Shank, 2005), and on mud volcanoes in the Gulf of Cadiz and in the Mediterranean (Van Rensbergen et al., 2005; Foubert et al., 2008; Freiwald et al., 2009; Wienberg et al., 2009). Peculiar and spectacular cold-water coral settings are the scleractinian coral reef build-ups, allowing the European margin from northern Norway down to the Mediterranean.

Lophelia pertusa is the main reef forming scleractinian cold-water coral (Freiwald et al., 2004). Minor components are *Madrepora oculata* and *Desmophillum* spp. *Lophelia pertusa* may form white, orange or red bush-like colonies often of several meter heights. Its distribution is cosmopolitan but it occurs very frequently in the NE Atlantic Ocean (Zibrowius, 1980; Freiwald, 2004). Nevertheless, the full extend of its present geographical distribution is still unknown

(Freiwald et al., 2004). The shallowest occurrence has been recorded at 39 m depth in the Trondheimsfjord, the deepest from the New England Seamount chain in the North Atlantic, at 3383 m, and off Morocco, at 2775 m (Zibrowius, 1980).

The most significant environmental factors for cold-water coral distribution and growth are temperature, salinity, and nutrient supply. *Lophelia pertusa* tolerates a temperature range between 4 and 14 °C (Freiwald et al., 1997; Freiwald et al., 2002), and a salinity range between 32 psu and 38.8 psu (Strømgren, 1971; Taviani et al., 2005a). A combination of these two parameters is expressed in the density gradient sigma-theta (σ_θ). Recent studies show that *L. pertusa* coral reefs within a density gradient of sigma-theta (σ_θ) = 27.35 to 27.65 kg m^{-3} in the NE Atlantic Ocean (Dullo et al., 2008) and sigma-theta (σ_θ) = 29.08 and 29.13 kg m^{-3} in the Mediterranean (Freiwald et al., 2009). Hard substratum is required for initial attachment of the larvae. These factors are more important than specific depth range (Freiwald et al., 2004).

Lophelia pertusa is a suspension feeder (Messing et al., 1990; Jensen and Frederiksen, 1992) and needs to be supplied by a diverse range of food from live zooplankton to particle aggregates of marine snow and resuspended material (Mortensen et al., 2001; Freiwald, 2002; Kiriakoulakis et al., 2004; 2005; Duineveld et al., 2007). In regions where *L. pertusa* is abundant, high primary productivity by surface phytoplankton is observed (Duineveld et al., 2004). This is important to trigger the zooplankton blooms. Bottom current patterns also provide the cold-water corals with food, remove the waste products and limits sediment smothering (Klitgaard et al., 1997; Duineveld et al., 2004; Freiwald et al., 2004; White et al., 2007; Thiem et al., 2006).

The exploration of cold-water coral ecosystems with sophisticated camera systems and manned submersible dives has showed that these ecosystems can undergo serious damage e..g., habitat losses. The main threats are caused by commercial bottom trawling and other bottom fishing techniques, hydrocarbon exploration and production, cable and pipeline placement, bioprospecting and destructive scientific sampling, waste disposal and dumping, which are documented in the UNEP-WCMC report "Cold-water Coral Reefs" (Freiwald et al., 2004). It will be important for the future of these unique and diverse ecosystems, that scientist and policy makers put some effort to protect them.

1.2 COLD-WATER CORAL REEFS

Scleractinian cold-water corals can form biogenic reef frameworks, very similar in morphology to their warm-water counterpart, through complex interaction between biological and geological processes under suitable hydrodynamic conditions. A cold-water coral reef starts with the settlement of coral larvae on suitable hard substratum such as pre-existing height, moraine ridges, iceberg plough mark levees (Freiwald et al., 1999; Mortensen et al., 2001), mud breccia extruded from mud volcanoes (Chapter 4), and skeletal debris (Roberts et al., 2005). Under favourable environmental conditions like permanently or episodically strong currents and food supply, small coral colonies are able to grow (Dons, 1944; Frederiksen et al., 1992). Under stable physical oceanographic conditions in terms of temperature, salinity, food supply and strong currents, the colonies may continue their growth, colonize larger areas to form coral thicket (Dons, 1944; Freiwald, 2002). These thickets provide support and protection for other organisms, which form together a complex reef biocoenosis (Dons, 1944; Burdon-Jones and Tambs-Lyche, 1960; Jensen and Frederiksen, 1992, Fosså and Mortensen, 1998; Rogers, 1999; Fosså et al., 2000; Freiwald et al., 2004). The continuous growth of the reef results in a separation between the live reef and the dead framework providing different habitats resulting in distinct faunal zonation. Bioeroders, dominantly sponges and fungi, attack the dead corals (Beuck and Freiwald, 2005). This process produce the formation of extended fields of coral rubbles, which provide additional different habitat for distinct fauna but also the substrata for renewed coral settlement supporting horizontal reef growth. The bottom circulation pattern may produce a facies zonation, which can be identified by the presence of abundant exposed glacial dropstones in the northern regions. This facies harbour distinct communities, different from the more sheltered areas (Mullins et al., 1981; Messing et al., 1990).

Several reef complexes have been described along the Norwegian margin. The largest reefs are the Sula Reef at 64°N and the Røst Reef at 67° N. The Sula Reef is located on the continental shelf at around 290 m water depth measuring 14 km by 350 m with a hight of around 25 m (Freiwald et al., 2002). The Røst Reef is located on the continental shelf break between 300 and 400 m water depth, is 35 – 40 km long, and up to 3 km wide (Føssa et al., 2005). Cold-water coral reefs also often settle on the sill at fjord entrances like in the Stjernsundet at a water depth around 260 m (Freiwald et al., 1997). The northernmost coral reef "Korallen" is located at almost 71° N on the Norwegian continental shelf at around 210 m water depth (Chapter 3).

1.3 COLD-WATER CORAL CARBONATE MOUNDS

Cold-water coral can also colonize structural high and form carbonate mounds. The known occurrence of cold-water coral carbonate mounds is generally confined to the upper and mid-slope of continental margins like the Porcupine Seabight, the Gulf of Cadiz, the Moroccan and Mauritanian margins, the Florida-Hatteras Straight, the Blake Plateau (Florida), the eastern USA and the Gulf of Mexico (e.g., Newton et al., 1987; Colman et al., 2005; De Mol et al., 2005; Grasmueck et al., 2006, Foubert and Henriet, 2009). The growth rate of coral carbonate mounds is high (up 0.05 mm yr^{-1} under favourable conditions for cold-water corals) in comparison to off-mound sedimentation rates (Freiwald et al., 1999; Lindberg et al., 2007). For this reason cold-water coral carbonate mounds can be also called "carbonate factories" (Tucker and Wright 1990; James and Bourque 1992) although most of them occur in mixed carbonatic – siliciclastic domains.

These mounds are interpreted to be formed by cyclic development of cold-water coral, which includes a number of processes acting in different ranges of temporal and spatial scales as described in several models (De Mol et al., 2002; Kenyon et al., 2003; De Mol et al., 2005; Dorschel et al., 2005; Huvenne et al., 2005; Kozachenko et al., 2005; Roberts et al., 2006; Rüggeberg et al., 2007; Huvenne et al., 2009). All these models have a common point, which is the widely accepted mechanism of cold-water coral mound initiation from a cold-water coral reef (Roberts et al., 2009). According to this theory, mounds develop from extended cold-water coral reefs (Williams et al., 2006; Kano et al., 2007) by vertical coral growth on accumulated coral rubble, sediment accumulation of biogenic and authigenic carbonate and sediment baffled in the coral framework. The majority of these models show also that climatic changes from interglacial to glacial causes fundamental changes in the environmental conditions and in the sedimentation rates, thus in the corals development.

Rüggeberg et al. (2007) showed that the decrease in temperature, nutrient supply, current speed and increase in sediment input during glacial times produces unfavourable conditions for cold-water coral growth. They show that the return to interlacial/interstadial conditions is marked by the return to relatively warmer temperatures and by the re-establishment of high speeds in the circulation patterns with consequent removal of the glacio-marine deposits, thus producing again the favourable conditions for cold water coral growth. In the northern hemisphere glacial/interglacial cycles occurred many times over the last 2.7 Ma (Bartoli et al., 2005). Consequences of this cyclicity are the typical mound sequences with fine grained sediments accumulated during glacial times and coarser deposits accumulated during interglacial/interstadial (Dorschel et al., 2005; Rüggeberg et al., 2007; Huvenne et al., 2009).

Cyclic sedimentation is also responsible for the accumulations of thick mound deposits. When mounds reach a relevant size, their top may become isolated from bedload transport, thus they cannot longer expand and they may result embedded within sediment drifts whose accumulation rate is higher than the mound growth rate (Van Rooji et al., 2003, 2007a, b). In some case large mounds can shape their own hydrodynamics with the establishment of a circulation pattern that erodes the mound itself (Wheeler et al., 2005; White et al., 2005; Dorschel et al., 2007a; Wheeler et al., 2007) until it is completely buried (Huvenne et al., 2003, 2007; Van Rooij et al., 2008).

1.4 FORAMINIFERA

Foraminifera are unicellular amoeboid protists distributed worldwide and mainly restricted to marine environments. They constitute one of the most diverse groups of shelled organisms in modern oceans and are a major component of marine communities. Around 10,000 living foraminiferal species are presently known (Vickerman, 1992). The majority of them are benthic, e.g., they live on the sea floor or in the sediment from the seashore to the deep-sea (e.g., Murray, 2006). Only about 40-50 species are planktonic (floating in the water mass; Kennet and Srinivasan, 1983). Most foraminifera produce a mineralized shell, generally calcitic, which can have either one or multiple chambers, and can be fossilized.

Shells of foraminifera have been noticed in shore sands since the 17th century but the first modern description of foraminifera were made by Beccarius in 1731. In the 18th and 19th century foraminiferal research was only based on taxonomical work and the discovery of new species (e.g. Fichtel and Moll, 1798, d'Orbigny, 1826). In the 20th century foraminiferal studies intensified with the requirements of oil companies for dating and correlating sediments (e.g. Cushman, 1928) and first paleoceanographic and ecological applications were made in the middle of the 20th century. For example, Emiliani (1955) introduced the study of stable oxygen and carbon isotopes from foraminiferal shells to reconstruct paleoclimates and Boltovskoy (1956) and Phleger (1960) did pioneer works on foraminiferal ecology. Since then, foraminifera have been one of the most important tools for geologic, biostratigraphic and paleoceanographic reconstructions because as pointed out in Spezzaferri and Spiegler (2005):

- They are highly diversified, numerous, easily recognizable, and often their shell is well preserved.
- They occur in high numbers in all marine environments from the Polar region in both hemispheres to the Equator, in marginal to deep basins, floating in surface waters down to living within the sediments.
- Benthic foraminifera first occur in the Cambrian, whereas planktonic foraminifera exist since the Jurassic.
- Some genera and species appear, evolve and become extinct in a very short time and, therefore, represent excellent marker fossils.
- The composition of assemblages reflects ecological conditions and is highly sensitive to environmental influences.
- Several species of planktonic and benthic foraminifera build their shells in equilibrium with seawater and can be used to trace variations occurring in the chemistry of the water masses.

Benthic foraminiferal taxonomy is primarily based on the morphology of the tests, whereas the taxonomy of planktonic foraminifera is based on the characteristic of the wall textures and the function and significance of structures. Spines, pustules, keels have been unraveled as evolutionary-driven life strategies and adaptation to changing paleoecological settings (e.g., Hemleben et al. 1989). A relatively new field in systematics started with genetic studies on foraminifera (e.g., Pawlowski et al., 1994; Darling et al., 1996), which will have a major impact on foraminiferal taxonomy in future.

The criteria and the rules on which the taxonomy of foraminifera is based are formulated by the "International Commission on Zoological Nomenclature" and reported in the "International Code of Zoological Nomenclature (ICZN)" (Ride et al., 2000). The code fixes the criteria of selection and naming of holotypes of each known taxon. The holotype is a single physical example or illustration of an organism, known to have been used when the species was formally described. Holotypes are listed and illustrated in the Ellis and Messina catalogues (Ellis and Messina (1940 and later). At genus level the recent foraminiferal taxonomy is based on Loeblich and Tappan (1987) "Foraminiferal Genera and their Classification". The taxonomic concepts from both the ICZN, Ellis and Messina (1940 and later) as well as Loeblich and Tappan (1987) are applied to foraminiferal species reported in the photographic appendix (Plate 1 to 42).

1.4.1 Deep-sea benthic foraminiferal ecology

Benthic foraminifera are an important component of the deep-sea biomass in the present oceans. They are adapted to cold, dark and often extremely oligotrophic environments. The benthic foraminiferal fauna is highly diverse and many species have a cosmopolitan distribution. These organisms convey a remarkable amount of information about the present and past ecological conditions at the ocean seafloor and have played an important role to understand the functioning of the marine systems.

Many investigations have so far proved and documented the relationship between foraminiferal species and different ecological parameters (including physico-chemical) and how these parameters control spatial and temporal dynamics of foraminiferal communities (e.g. Van der Zwaan, 1999; Gooday, 2003; Murray, 2006; Jorissen et al., 2007).

Foraminifera can be considered as reliable indicators for the origin, quality, quantity, and periodicity of organic matter reaching the seafloor (Lutze and Coulbourn, 1984; Altenbach and Sarnthein, 1989; Herguera and Berger, 1991; Gooday, 1994; Altenbach et al., 1999; Loubere and Fariduddin, 1999). One of the major environmental parameter structuring deep-sea benthic foraminiferal faunas is the organic matter flux mainly derived from primary production at the sea surface. In eutrophic environmental settings, the organic particles cannot be consumed directly by benthic organisms, the organic matter can accumulate and thus, sediment pore waters become anoxic. In these cases the limiting variable for benthic foraminiferal distribution become the oxygen (Koutsoukos et al., 1990; Hermelin, 1992; Alve, 1995; Jorissen et al., 1995; Bernhard and Sen Gupta, 1999).

Additional limiting environmental parameters for benthic foraminiferal are sediment grain size and current velocity (e.g. Miller and Lohmann, 1982; Lutze and Coulbourn, 1984; Mackensen et al., 1990, 1995; Schmiedel et al., 1997, Schönfeld, 2002b). Water mass properties such as salinity and temperature and bathymetry play only a minor role in their distribution (Jorissen et al., 2007).

1.5 Motivation and main objectives

Only recently scientists have started to understand the complex interaction of ecological variables contolling cold-water coral ecosystems. Further investigations are still needed to obtain a complete picture of cold-water coral reefs and their ecology. It is known that these ecosystems are "hot-spots" for marine life and host thousands of species of sponges, hydrozoans, mollusks, bryozoans, echinoderms, polychaetes, crustaceans, and fishes with a comparable biodiversity as observed for their warm-water analogues (Dons, 1944; Burdon-Jones and Tambs-Lyche, 1960; Jensen and Frederiksen, 1992, Fosså and Mortensen, 1998; Rogers, 1999; Fosså et al., 2000; Freiwald et al., 2004). Until now, studies on cold-water coral associated faunas mainly focused on the mega- and macrofauna (e.g., Jensen and Frederiksen, 1992; Costello et al., 2005; Henry and Roberts, 2007) or microfauna (e.g., Penn et al., 2006; Neulinger et al., 2008; Schrötter et al., 2009).

Studies on foraminifera associated to cold-water corals are very few. Freiwald and Schönfeld (1996) focused on the single parasitic foraminifera *Hyrrokkin sarcophaga,* (Hawkes and Scott, 2005) investigated the benthic foraminifera associated to an "octocoral garden" on the east coast of Canada and (Rüggeberg et al., 2007) focused on benthic foraminiferal assemblages in sediment cores on a carbonate mound in the Porcupine Seabight.

Since 2005 the micropaleontology group of Fribourg and the marine geologists of the GEOMAR-Kiel and Renard Center of Marine Geology of Ghent started a collaboration to study these organisms in detail. The goal of this thesis, founded by the Swiss National Foundation Project Ref. 200020-117928, is to present an extensive picture about recent and sub-recent benthic foraminifera associated to scleractinian cold-water coral ecosystems along the European margin from northern Norway down to the Mediterranean.

Three key regions for cold-water coral carbonate mounds and reefs were investigated:

Chapter 2: **The Porcupine Seabight-Rockall region.** Surface sediment samples from different facies and different coral carbonate mounds in the Porcupine Seabight, on the Porcupine Bank, and on the Rockall Bank were investigated using multivariate statistical methods on quantitative benthic foraminiferal census. The results indicate that different benthic foraminiferal assemblages characterize different facies along cold-water coral carbonate mounds and are related to the different environmental conditions and available substrate. Therefore benthic foraminiferal assemblage analysis provides an independent tool to identify the different facies, which characterize cold-water coral mounds in this region. The *Off-mound Facies* is dominated by infaunal species indicating high organic matter flux to the seafloor. The *Dropstone Facies* is dominated by *Cibicidoides* sp., living attached to dropstones and thriving in well-oxygenated high-energy environment. The *Dead Coral Facies* is characterized by epifaunal and infaunal species indicating strong bottom currents. The *Living Coral Facies* is dominated by opportunistic infaunal species indicating low food supply on the seafloor. Cold-water corals may consume the major part of the food and only a small amount passes through the coral thicket to the seafloor. The *Sandwave Facies* is characterized by high abundances of epifaunal species. *Discanomalina coronata* is only highly abundant in the *Living Coral Facies* and *Sandwave Facies*, where living cold-water corals thrive and is completely absent in adjacent sediments/facies. Therefore, *D. coronata* is proposed to be a indicator species for living/healthy cold-water coral mounds in this area.

Chapter 3: **Norwegian Margin.** On the Norwegian shelf and on the upper continental slope, extensive reefs settle on post-glacial structures. Surface sediment samples were taken from different reefs from the Skagerrak to northern Norway. Planktonic and benthic foraminifera were quantitatively analyzed, and the different assemblages characterized using multivariate statistics. Two different planktonic foraminiferal assemblages reflect the two major surface current systems on the Norwegian margin: *Neogloboquadrina incompta* dominates the North Atlantic Current whereas very small specimens of *Globigerinita glutinata*, *Turborotalita quinqueloba*, and *Globigerinita uvula* dominate the Norwegian Coastal Current. The benthic foraminifera show different assemblages for on-reef and off-reef samples but also regional differences related to the different environmental conditions. In particular, the foraminiferal assemblage associated to the healthy reefs on the mid Norwegian slope and northern Norwegian shelf are typical of environments with high energy, well-oxygenated waters and high amount of labile organic matter, derived from seasonal phytoplankton blooms. The benthic foraminifera associated to the coral reefs from the Skagerrak indicate that the amount of organic matter input to the sea floor is high but the labile components usable for corals are low. The low amount of labile organic matter may explain the extensive occurrence of dead corals in this area.

In the Norwegian reefs benthic foraminiferal habitats are only weakly defined and grade one into the other preventing sharp facies separation as observed on the cold-water coral carbonate mounds in the Rockall/Porcupine region (Chapter 2). The gradual changes in the assemblages observed on the Norwegian margin can be attributed to the changes in the reef facies, which are restricted within tens of meters, whereas the facies on the carbonate mounds in the Porcupine/Rockall region occur over long distance. *Discanomalina coronata* is only abundant in healthy cold-water coral reefs indicating that this species require similar ecological conditions as cold-water corals. Therefore *D. coronata* is proposed as an indicator species for living cold-water coral ecosystems on the Norwegian margin.

Chapter 4: **The Alboran Sea – Western Mediterranean.** Samples from sediment cores of two Mud Volcanoes (Maya and Dakha) in the Alboran Sea - Western Mediterranean were investigated using facies description and multivariate statistical methods on quantitative planktonic and benthic census. These investigations were carried out to test if there is a causal link between *D. coronata* and cold-water coral ecosystems during the Holocene. *Discanomalina coronata* was observed only in those layers containing partly dissolved cold-water coral fragments. The co-occurrence of these elements shows a striking similarity to their common distribution pattern observed in the Porcupine/Rockall Region (Chapter 2) and on the Norwegian margin (Chapter 3), thus suggesting that the ecosystems in the Alboran Sea are in-situ. Coral growth on the two mud volcanoes are observed in two phases, on the Dakha MV between 2230 ± 59 years BP and slightly older than 4175 ± 62 years BP. On the Maya MV cold-water corals occur between 7616 ± 38 years BP and slightly older than15583 ± 185 years BP. On both mud volcanoes cold-water corals occur on the top of the extruded mud breccia, which provides the nucleation point for colonization and development of the corals. The period of cold-water coral development on both mud volcanoes is characterized by planktonic foraminifera like *Neogloboquarina incompta*, indicating high nutrient availability, triggered by upwelling and/or strong currents that mobilized horizontal nutrient fluxes. The decline of the cold-water corals on both mud volcanoes co-occurs with a shift of *N. incompta* dominated period to a *Globorotalia inflata* dominated period, which reflects more oligotrophic conditions observed in the modern Western Mediterranean.

2 - BENTHIC FORAMINIFERA AS BIOINDICATOR FOR COLD-WATER CORAL REEF ECOSYSTEMS ALONG THE IRISH MARGIN

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ABSTRACT

Cold-water coral ecosystems building cold-water carbonate mounds occur worldwide and are especially developed along the European margin, from northern Norway to the Gulf of Cadiz. A remarkable mound province is documented southwest of Ireland along the Porcupine and Rockall Banks. In this area carbonate mounds are formed in water depths between 500 and 1200 m and are often densely settled by cold-water coral ecosystems offering many ecological niches for benthic foraminifera. We investigated total (unstained) benthic foraminiferal assemblages from surface sediments (0-1 cm, >63 µm size fraction) of this region with the aim to trace their distribution patterns and to test if they can be used as bioindicators for facies characterization in the different parts of carbonate mound systems. Our quantitative data were further statistically treated with non-metric multidimensional scaling (nMDS) based on Bray-Curties similarity matrix to highlight community patterns that were not readily apparent. Our results indicate that different benthic foraminiferal assemblages characterize different facies along cold-water carbonate mounds and are related to the environmental conditions and available substrates. The following facies can be described: (1) the *Off-Mound Facies* is dominated by uvigerinids and other infaunal species; (2) the *Dropstone Facies* is characterized by infaunal *Globocassidulina subglobosa* and attached-epifaunal *Cibicidoides* sp.; (3) the *Dead Coral Facies* is characterised by epifaunal species (e.g., *Planulina ariminensis*, *Hanzawaia boueana)* and infaunal species (*Spiroplectinella wrightii*, *Angulogerina angulosa*, *Epistominella vitrea*); (4) the *Living Coral Facies* includes both infaunal and epifaunal species, but is dominated by the epifaunal *Discanomalina coronata*; (5) the *Sandwave Facies* contains high abundances of epifaunal species including *D. coronata*. Based on this distribution, we propose *D. coronata*, as an indicator species to identify active mounds and/or living cold-water coral ecosystems. Our results also emphasise the importance of studying the small size fractions that yield many infaunal species. A causal link exists between distribution patterns of benthic foraminifera and cold-water coral facies, thus providing an independent tool to identify and describe the different facies in this setting.

2.1 INTRODUCTION

Cold-water coral ecosystems occur worldwide and are developed along the European margin, from northern Norway (Fosså et al. 2002; Freiwald et al. 1997, 1999; Hovland et al. 1998; Lindberg and Mienert 2005; Mortensen et al. 1995) along the Irish margin (De Mol et al. 2002; Hovland et al. 1994; Kenyon et al. 2003; Van Rooij et al. 2003) down to the Gulf of Cadiz (Pinheiro et al. 2003; Somoza et al. 2003), and in the Mediterranean Sea (Taviani et al. 2005; Zibrowius, 1980). These ecosystems have been known since the last century. Cold-water corals were collected and successively studied by Duncan (1879, 1873, 1878), Gravier (1915, 1920), and mapped by Joubin (1922a, b, 1923). The investigation of these ecosystems proceeded more quickly in Norway where cold-water corals were more easily accessible. However, research accelerated only in the last two decades after Hovland et al. (1994) described a group of seabed mounds, suspected to be modern bioherms off western Ireland. Since then, research has progressed quickly within the framework of several European and international projects (ECOMOUND, GEOMOUND, ACES, MOUNDFORCE, MICROSYSTEM, HERMES).

On the Rockall and Porcupine Banks, cold-water corals, particularly the scleractinians *Lophelia pertusa* and *Madrepora oculata*, build up carbonate mounds. These mounds considerably differ in size and some are partially or fully buried (De Mol et al. 2002; Huvenne et al. 2003). Recent investigations in this area revealed that successive phases of coral growth might be superimposed on fossil coral debris building mounds up to a few hundred meters in height (Wheeler et al. 2007). The amount of living corals is presently used

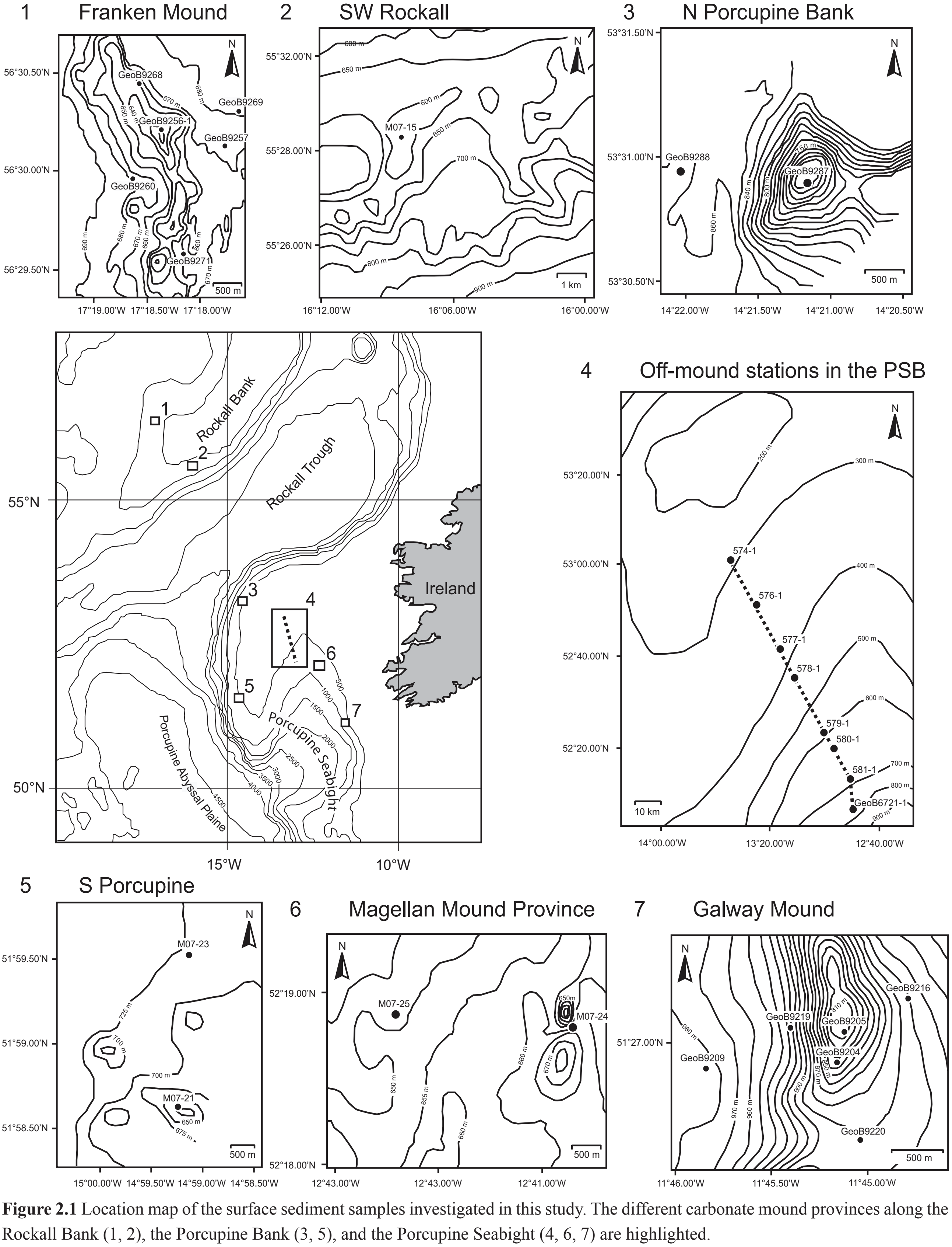

Figure 2.1 Location map of the surface sediment samples investigated in this study. The different carbonate mound provinces along the Rockall Bank (1, 2), the Porcupine Bank (3, 5), and the Porcupine Seabight (4, 6, 7) are highlighted.

as the main parameter for "activity" of cold-water carbonate mounds. If living corals are abundant, the mound is considered to be in a growing state - a so-called "active" or "active growing" mound (Henriet et al. 2002; Rüggeberg et al. 2007). If living corals are absent and pelagic sediment covers the mound, it is then defined as a "buried" mound and is only visible on seismic sections (De Mol et al. 2002; Freiwald 2002).

Presently, cold-water coral mounds are described and classified based on their sedimentary facies and type of coral coverage. Foubert et al. (2005) introduced 12 different facies for seabed classification and used them for interpreting ROV video surveys in the Belgica Mound Province. The study of Dorschel et al. (2007a), focused on Galway Mound, reduced the number of the different facies to seven from mound top down to the basin: (1) dense coral coverage (mostly alive); (2) dense coral coverage (mostly dead); (3) sediment clogged dead coral framework and/or coral rubble; (4) patchy distribution of mostly live (or dead) coral on un-rippled seabed; (5) patchy distribution of mostly dead coral on rippled seabed; (6) sandwaves covered with corals (overgrown sandwaves); (7) patchy distribution of dropstones. Dorschel et al. (2007a) also demonstrated that the spatial distribution of the different facies correlates with different small-scale environmental settings and in particular, with local hydrodynamic regimes.

However, until now only a few studies targeted foraminiferal assemblages and their relation to cold-water coral ecosystems along the European continental margin (e.g., Freiwald and Schönfeld 1996; Hawkes and Scott 2005; Rüggeberg et al. 2007). The present study focuses on the distribution patterns of total (unstained) benthic foraminiferal assemblages that are associated with different cold-water coral mounds on the Rockall and Porcupine Bank area (Fig. 2.1). The aims of this study are to: (a) identify the distribution patterns of benthic foraminifera on cold-water coral mounds in the investigated area; (b) relate these to the different facies; and (c) propose a model for assemblage versus facies distribution that can be applied to other carbonate mounds in similar settings.

2.2 STUDY AREA

The Porcupine and the Rockall Banks are situated in the Northeast Atlantic west of Ireland (Fig. 2.1). Steep flanks characterize the Rockall Trough, a deep-sea channel between the Porcupine Bank to the east and the Rockall Bank to the west. The Porcupine Bank and the Irish Mainland Shelf delimit a small basin, the Porcupine Seabight, which opens to the west onto the Porcupine Abyssal Plain. Along the flanks of the Porcupine Bank and Porcupine Seabight numerous carbonate mounds of different sizes are documented (e.g., De Mol et al. 2002; Foubert et al. 2007; Huvenne et al. 2002, 2003; Mienis et al. 2006). In particular, three carbonate mound provinces are located along the margin of the Porcupine Seabight: (a) the Belgica Mound Province, which is located along the steep eastern slope, (b) the Hovland Mound Province along the margin of the central Porcupine Seabight and (c) the Magellan Mound Province north of the Hovland Mound Province (De Mol et al. 2002; Henriet et al. 1998; Huvenne et al. 2003; Van Rooij et al. 2003).

Several mounds from the Porcupine and Rockall Bank region have been investigated for the present study (Fig. 2.1). (1) The Franken Mound is situated on the steep western slope of the Rockall Bank. Its summit rises up to 600-675 m water depth. It is 2.5 km long and 600-700 m wide. It has a more irregular shape compared to the ovate shape of the Galway and the Propeller mounds in the Porcupine Seabight (Wienberg et al. 2007). (2) Single mounds on the southeastern Rockall margin, up to 1-2 kilometres in diameter and 50-100 m of elevation. They are all located in a water depth between 650 and 900 m (Akhmetzhanov et al. 2003; Mienis et al. 2006; Rogers, 1999; Van Weering et al. 2003). (3) The Connaught Mound located on the steep slope of the Northern Porcupine Bank. It is orientated north-south, about 3 km long and 1.7 km wide with an elevation above the seafloor of 180 m and a water depth at the summit of 680 m. (4) The Propeller Mound is situated in the Hovland Mound Province. Its summit is at a water depth of 680 m, its elevation above the surrounding seafloor is 140 m (Dorschel et al. 2005, 2007b; Rüggeberg et al. 2005, 2007). (5) Unnamed mound from the western Porcupine Bank discovered in 2008 during the 'Pelagia' cruise M07II. (6) Unnamed half buried mounds from the Magellan Mound Province (De Mol, 2002; Huvenne et al. 2003). (7) The Galway Mound, which is part of the Belgica Mound Province. Its summit is at 782 m water depth and its elevation above the seafloor is 160 m (Dorschel et al. 2007a). It belongs to an "active" and "growing" mound chain with a dense coverage of living corals (De Mol et al. 2002; Foubert et al. 2005; Huvenne et al. 2005; Wheeler et al. 2005).

2.3 MATERIAL AND METHODS

During four different cruises (RV ‘Meteor’ cruise M61-3, RV ‘Poseidon’ cruises P265, and P292, and RV ‘Pelagia’ cruise M07II) carbonate mounds and pelagic sediments were sampled at 27 stations in the Rockall and Porcupine Bank region (Tab. 2.1). A giant box corer with a sampling area of 50x50 cm allowed a maximum 50 cm penetration into the sediments. All retrieved samples were taken from cold-water coral mounds and/or the adjacent pelagic sediments. Samples P292/564-1, P292/576-1, P292/577-1, P292/578-1, P292/579-1, P292/580-1, P292/581-1, and GeoB6721-1 were retrieved along a bathymetric transect from the Porcupine Bank at ~200 m down to the Porcupine Seabight at ~750 m (Fig. 2.1). A sample from the uppermost two centimetres of each box core was taken with a teflon spatula and stored in plastic containers. Additionally, video records obtained by an underwater video camera or a Remotely Operated Vehicle (ROV ‘Quest’ and ‘Cherokee’ of MARUM, University Bremen) were used to characterize the seafloor, together with descriptions of cores from unpublished cruise reports (De Haas, 2007; Freiwald et al. 2000; Freiwald et al. 2002; Ratmeyer et al. 2004).

Sediment samples for micropaleontological analyses were processed at the University of Fribourg following Spezzaferri and Coric (2001). Samples were washed through a set of 250 µm, 125 µm and 63 µm mesh sieves to obtain three size fractions. The obtained residues were dried at room temperature and weighted. If the residue contained more than 400 foraminiferal specimens in one fraction, the volume was reduced by splitting. A maximum of 200 benthic specimens per fraction (600 specimens per sample) were picked, collected in Plummer cell-slides, sorted at species level, fixed with glue, and counted. In the case of samples containing less than 100 specimens per fraction, all specimens were counted. The 124 benthic foraminiferal species identified are listed in Appendix A.

Multivariate statistical treatment on the compositional faunal data was performed with the software PRIMER 5 (Clarke, 1993; Clarke and Warwick, 2001). Data were double-square root transformed in order to limit the contribution of most abundant, ubiquitous species (Field et al. 1982). Bray-Curtis (dis-)similarities were calculated following Clifford and Stephenson (1975). The resulting similarity matrix was used to obtain the nMDS plot (non-metric MultiDimensional Scaling; Kruskal 1964; Kruskal and Wish 1978). The nMDS plot has no dimensions and no axes and can be arbitrarily scaled, rotated, located or inverted as it gives simply the relationship of samples relative to each other (Clarke and Warwick 2001; Warwick and Clark 1991). Based on the clusters given in the nMDS plot, the Similarity Percentage Analysis (SIMPER) was obtained to highlight the contribution of each species to the total average (dis-) similarity between different groups and

Table 2.1 Sample number, geographical position, water depth, region, mound region and facies of the investigated samples.

Station	Latitude	Longitude	Depth [m]	Region	Mound Region	Facies
GeoB 9220	51°26.69'N	11°45.04'W	892	Porcupine Seabight	Belgica	sandwave
GeoB 9209-2	51°26.89'N	11°45.81'W	982	Porcupine Seabight	Belgica	sandwave
GeoB 9204-1	51°26.94'N	11°45.16'W	838	Porcupine Seabight	Belgica	living coral
GeoB 9205-1	51°27.04'N	11°45.12'W	810	Porcupine Seabight	Belgica	living coral
GeoB 9219-1	51°27.05'N	11°45.40'W	920	Porcupine Seabight	Belgica	living coral
GeoB 9216-1	51°27.09'N	11°44.81'W	890	Porcupine Seabight	Belgica	living coral
M07-21	51°58.65'N	14°59.18'W	627	Porcupine Seabight	SW Porcupine Bank	dead coral
M07-23	51°59.54'N	14°59.05'W	721	Porcupine Seabight	SW Porcupine Bank	off-mound
GeoB 6721-1	52°09.22'N	12°46.31'W	696	Porcupine Seabight	Hovland	off-mound
P292/581-1	52°13.40'N	12°50.24'W	736	Porcupine Seabight		off-mound
M07-24	52°18.86'N	12°40.78'W	663	Porcupine Seabight	Magellan	dead coral
Mo7-25	52°18.87'N	12°42.42'W	647	Porcupine Seabight	Magellan	off-mound
P292/580-1	52°20.46'N	12°56.72'W	630	Porcupine Seabight		off-mound
P292/579-1	52°23.62'N	13°01.56'W	554	Porcupine Seabight		off-mound
P292/578-1	52°35.67'N	13°10.74'W	450	Porcupine Seabight		off-mound
P292/577-1	52°41.78'N	13°16.43'W	356	Porcupine Seabight		off-mound
P292/576-1	52°51.40'N	13°25.39'W	249	Porcupine Seabight		off-mound
P292/574-1	53°00.80'N	13°34.04'W	202	Porcupine Seabight		off-mound
GeoB 9287	53°30.91'N	14°21.16'W	696	Porcupine Bank	N Porcupine Bank	living coral
GeoB 9288	53°31.06'N	14°21.77'W	870	Porcupine Bank	N Porcupine Bank	dropstones
M07-15	55°29.18'N	16°08.24'W	552	Rockall Bank	SE Rockall Trough	living coral
GeoB 9271	56°29.58'N	17°18.16'W	664	Rockall Bank	SW Rockall Bank	dropstones
GeoB 9260	56°29.98'N	17°18.63'W	683	Rockall Bank	SW Rockall Bank	dropstones
GeoB 9257	56°30.13'N	17°17.77'W	678	Rockall Bank	SW Rockall Bank	dropstones
GeoB 9256-1	56°30.20'N	17°18.37'W	629	Rockall Bank	SW Rockall Bank	dead coral
GeoB 9269	56°30.28'N	17°17.63'W	686	Rockall Bank	SW Rockall Bank	dropstones
GeoB 9268	56°30.44'N	17°18.62'W	656	Rockall Bank	SW Rockall Bank	dead coral

within one group (e.g., Basso and Spezzaferri 2000; Clarke and Warwick 2001; Kruskal 1964; Kruskal and Wish 1978;). Taxonomic notes, census data, and compositional data of the benthic foraminiferal taxa used for multivariate statistic are given in Appendix A.

2.4 RESULTS

2.4.1 Facies description

Field observations (video images taken on board with underwater video camera, ROV camera, and core description) and sediments recovered in core samples allowed to identify five different facies types (Tab. 2.1):

1) *Off-Mound Facies*: the distal parts of the cold-water carbonate mounds, the fine-grained pelagic sediments contain sand-sized benthic and planktonic foraminifera, echinoids, molluscs, and terrigenous components.

2) *Dropstone Facies*: large mounds (e.g., Galway Mound) are flanked by erosional moats formed by bottom currents (De Mol et al. 2002). These moats consist of sandy and silty sediments, sometimes rippled, containing dropstones up to 10 cm in diameter. Fragments of bryozoans, molluscs, and corals, generally characterize this facies.

3) *Dead Coral Facies*: this facies consists mainly of dead coral debris accumulating at the lower flanks and/or base of the mounds. Fine-grained sediments, mud and silt, trapped by the coral debris, are deposited to form a soft-sediment substratum containing pieces of molluscs and echinoids. The amount of coral debris decreases towards the distal parts of this facies.

4) *Living Coral Facies*: mainly developed on the upper flanks of the mounds and partially on their summits, this facies consists of a dense cover of living cold-water corals, mainly *Lophelia pertusa* and *Madrepora oculata*. Corals may colonize a hard substratum composed of dead coral debris or coarse sand. Also in this facies, muddy and silty sediments are trapped by the coral build-ups. However, the trapped sediments can be finer than in the *Dead Coral Facies*.

5) *Sandwave Facies*: the sandwave facies can co-exist with all the other facies. However, this facies is generally developed on the mound flanks (e.g., Galway and Franken Mounds) or close to the summit (Propeller Mound) within or close to the *Living Coral Facies* (Rüggeberg et al. 2007). Single branches or small patches of living cold-water corals colonize the sandy sediments and/or fragments of dead corals.

2.4.2 Benthic foraminiferal assemblages in surface sediments

A total of 124 total (unstained) benthic foraminiferal species belonging to 75 genera were identified in the studied region (Appendix A). The samples collected along the bathymetric transect (water-depths between 202 and 736 m) from the Porcupine Bank into the Seabight document the variation of benthic foraminiferal assemblages with depth in this area (Fig. 2.1, 2.2; Tab. 2.1).

In the shallowest part of the Porcupine Bank (202 m, 249 m, and 356 m) *Cassidulina carinata* dominates the assemblage (50 % at 202 m, 24.9 % at 249 m, and 10.7 % at 356 m, respectively). The accompanying species at 202 m include abundant *Globocassidulina subglobosa* (up to 14.9 %), and at 249 m abundant *Cibicidoides pachyderma* (20.5 %). The abundances of uvigerinids increase with increasing depth reaching a maximum of 40.6 % at 554 m, but they show abundances still around ~30 % down to 736 m. *Hyalinea balthica* and *Bulimina marginata* are abundant in the whole transect with a maximum between 356 and 630 m water depth. Below 450 m water depth *Melonis barleeanum*, *Epistominella vitrea* and *Epistominella exigua* are important representatives of the community. Other deep-water taxa are present in lower amounts. For example, the highest abundance of *Angulogerina angulosa* (9.3 %) is recorded at 356 m. Sample GeoB6721-1 is located within the Hovland mound region on the summit of a cold-water coral mound. In comparison to other mounds in this region the sediment does not contain coral rubble, dropstones or sandwaves, indicating no recent settling of *Lophelia pertusa*. Therefore we classify it as off-mound sediment but relatively close to cold-water corals. Transport could be the reason for the abundance of epifaunal attached foraminiferal species like *Planulina ariminensis*, *Discanomalina coronata*, *Cibicidoides ungerianus*, and *Fontbotia wuellersdorfi*.

2.4.3 Statistical treatment

Since patterns of community structures are often not readily apparent (Clark and Warwick, 2001), we have applied the Bray-Curtis Similarity clustering to our data, which is an excellent method to treat community data in order to highlight patterns in benthic foraminiferal distribution (Kenkel and Orloci, 1986). At the 100% of Bray-Curtis similarity, 5 clusters (1 to 5) can be distinguished. On the basis of the same similarity matrix samples are ordinated by non-metric MultiDimensional - nMDS - (Kruskal, 1964; Kruskal and Wish, 1978), with a stress value of 0.19 (Fig. 2.3, Tab. 2.3).

Cluster 1 groups samples 574-1, 576-1, 577-1, 578-1, 579-1, 580-1, 581-1, GeoB6721-1, M07-23, and M07-25 (Bray-Curtis Similarity 49 %). Eleven species and/or groups account for 90.4 % of the average similarity of this cluster (Tab. 2.3). Cluster 2 combines samples 9257, 9269, 9260, 9271, and 9288 (Bray-Curtis Similarity 58 %). Ten species and/or groups account for 91.1 % of the average similarity of this cluster (Tab. 2.3). Cluster 3 groups samples M07-21, M07-24, 9256-1, and 9268 (Bray-Curtis Similarity 51.1 %). Eleven species and/or groups account for 90.2 % of the average similarity of this cluster (Tab. 2.3). Cluster 4 assembles samples 9204-1, 9205-1, 9216-1, 9219-1, 9287, and M07-15 (Bray-Curtis Similarity 51.1 %). Fourteen species and/or groups account for 90.9 % of the average similarity of this cluster (Tab. 2.3). Cluster 5 combines only two samples, 9209-2 and 9220 (Bray-Curtis Similarity 49.5%). Eleven species and/or groups account for 90.4 % of the average similarity of this cluster (Tab. 2.3).

2.5 DISCUSSION

2.5.1 Potential indicator species

We investigated total (unstained) assemblages from surface sediments recovered in the Porcupine Seabight and Rockall Bank carbonate mound systems. A total assemblage may result from complex interaction of environmental parameters, including the original microhabitat of the living forms, reworking, winnowing, dissolution, and bacterial decomposition of organic test components, which create differences between the live and dead components (Licari and Mackensen, 2005; Loubere, 1989; Mackensen and Douglas, 1989). For this reason we probably miss some of the monothalamous and soft-shelled foraminiferal species (Gooday and Hughes, 2002). Nevertheless, the aim of this study is to define benthic foraminiferal assemblages that can help to identify different mound facies in the paleo-record. We therefore exclude soft-shelled species since they are rarely preserved in the

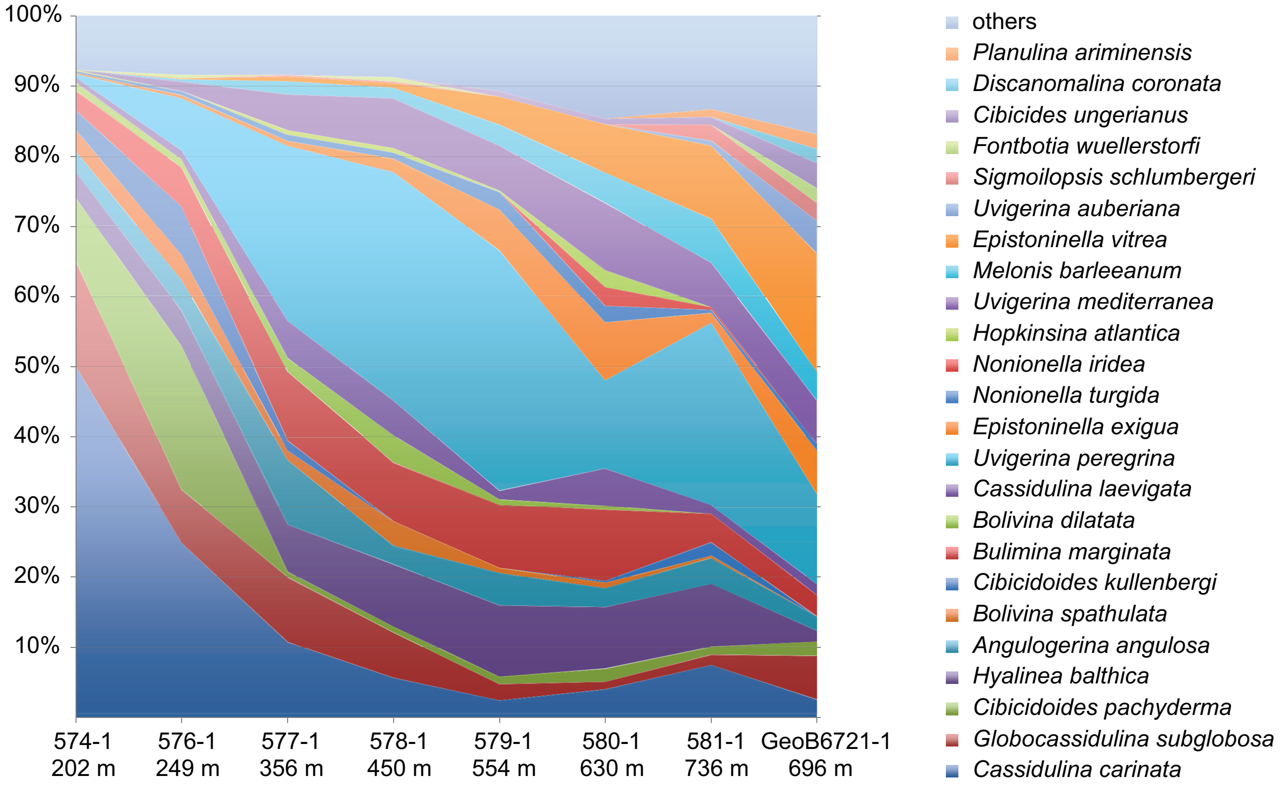

Figure 2.2 Percent distribution of the most abundant species (>2%) along a bathymetric transect comprising 8 off-mound-station in the Porcupine Seabight.

fossil record. Therefore, although, monothalamous and soft-shelled species are very important components of cold-water coral ecosystems, they are rarely preserved in the fossil record and are not treated in the present study.

2.5.2 Environmental interpretation

The spatial distribution of benthic foraminifera is controlled by a combination of environmental parameters (e.g., Gooday 2003; Grimsdale and Van Morkhoven 1955; Gupta 1999; Jorissen et al. 2007; Lutze and Coulbourn 1984; Murray 1991, 2006; Natland 1933; Pflum and Frerichs 1976; Schönfeld 2002a, b; Van der Zwaan et al. 1999; Tab. 2.2). Among the most important parameters controlling the distribution of these organisms in the deep sea are the organic flux to the seafloor and the bottom water oxygenation (e.g. Jorissen 1988; Lutze and Coulbourn 1984; Mackensen et al. 1990, 1995; Miller and Lohmann 1982; Schmiedl and Mackensen 1997). The quality of the organic matter, and the degree of seasonality in its delivery to the seafloor, are also important (Fontanier et al. 2002, 2005). Where current velocities are high, bottom flow, together with substrate characteristics, play a central role in the distribution of benthic foraminiferal assemblages (Schönfeld 1997, 2002a, b).

Weston (1985) compared living and dead foraminiferal assemblages (>125 µm) from surface samples south of 51° 50’ N in the Porcupine Seabight, the area where big cold-water coral mounds on elevated substrates were originally discovered (Hovland et al. 1994; Rüggeberg et al. 2007). The assemblages of Weston (1985) show zonation with respect to water-depth. In particular, Weston found high numbers of *Bulimina marginata* and *Cassidulina carinata* above 700 m water depth and attached living species, e.g. *Lobatula lobatula*, *Cibicides refulgens*, below this depth. In the area that we investigated, benthic foraminiferal assemblages are dominated by infaunal species. In particular, *Globocassidulina subglobosa*, *Uvigerina peregrina*, *Uvigerina mediterranea*, *Epistominella*

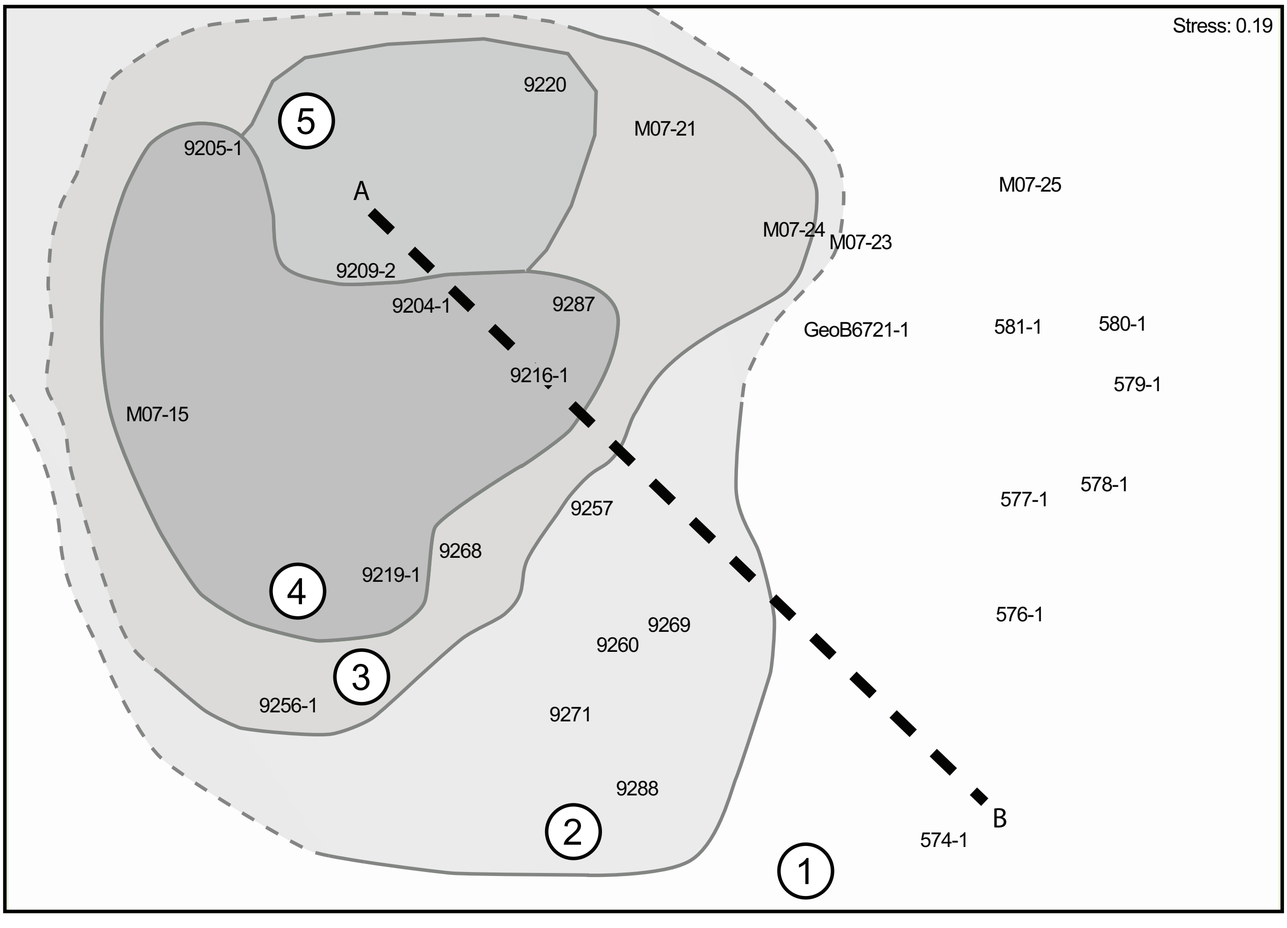

Figure 2.3 Non-metric MultiDimensional Scaling (nMDS) plot obtained from Bray-Curties similarity matrix of benthic foraminifera compositional data. The different clusters (1 to 5) are illustrated in different greyscales. The cluster arrangement corresponds to the facies distribution of an active cold-water coral mound. Transect A–B is illustrated in figure 2.4. The stress represents the distortion involved in compressing the data from a multidimensional space into a smaller number of dimensions (Field et al. 1982).

Table 2.2 Living strategy, preferred substratum and other ecological attributes of selected benthic foraminifera according to the literature. The five facies identified in this study are also plotted.

Species	facies	Living strategy	Preferred substratum	Comments	Reference
Hyalinea balthica	off-mound	epifaunal	mud to silt		Murray, 2006
Epistominella exigua	off-mound	epifaunal, shallow infaunal	mud	opportunistic, phytodetritus feeder, seasonal food fluxes, large tolerance to varying organic flux	Gooday, 1988, Gooday et al. 1993; Loubere and Fariduddin, 1999; Murray, 2006; Smart, 2008; Smart et al. 1994; Thomas et al. 1995; Thomas and Gooday, 1996
Cibicidoides kullenbergi	off-mound	epifaunal, shallow infaunal		passive suspension feeder, deep sea habitat, oligotrophic environment, oxic, stable physico-chemical conditions	Fariduddin and Loubere, 1997;Jorissen et al. 1998; Morigi et al., 2001; Murray, 2006; Schmiedl et al. 2000; Woodruff et al. 1980
Uvigerina mediterranea	off-mound	shallow infaunal	mud	rich supply on labile organic matter, superior competitor in food- and oxigen-rich sediments, less tolerant to suboxic conditions then *U. peregrina*	Altenbach et al. 1999; De Stigter et al. 1998; Fontanier et al. 2002; Murray, 2006
Uvigerina peregrina	off-mound	shallow infaunal	mud	rich supply on labile organic matter and high concentration of bacteria	Altenbach et al., 1999; Altenbach and Sarnthein, 1989; Fontanier et al. 2002
Nonionella iridea	off-mound	infaunal	mud	opportunistic, suboxic, reacts fast to phytodetritus blooms	Duchemin et al. 2007; Murray, 2006
Nonionella turgida	off-mound	infaunal	mud	suboxic, disoxic	Kaiho, 1994; Murray, 2006
Bulimina spp.	off-mound	infaunal	mud to fine sand	high carbon flux rates; tolerates low oxigen	Brüchert et al. 2000; Mackensen et al. 1993; Mackensen et al. 1990; Mullins et al. 1985; Murray, 2006; Seidenkrantz et al. 2000
Hanzawaia boueana	dead coral facies	epifaunal attached	hard substrates	oxic	Murray, 2006; Spezzaferri and Goric, 2001
Planulina ariminensis	dead coral facies	epifaunal attached		suspension feeder	Lutze and Thiel, 1987; Schönfeld, 2002a
Spiroplectinella wrightii	dead coral facies	epifaunal, attached			Gross, 2000
Angulogerina angulosa	dead coral facies	infaunal	sand	high energy areas, can withstand permanent winnowing and redeposition	Hald and Vorren, 1984; Jarke, 1960; Mackensen et al. 1985; Murray, 1971; Qvale and Van Weering, 1985; Schönfeld, 2002a; Sejrup et al. 1981
Epistominella vitrea	dead coral facies	infaunal	mud	opportunist, high food availability, low water energy, hypoxic	Jorissen et al. 1992; Murray, 2006; Osterman et al. 2005
Gavelinopsis praegeri	living coral facies	epifaunal attached, mobile	hard substrates		Murray, 2006
Lobatula lobatula	living coral facies	epifaunal, attached	hard substrates, coarse sediments	suspension feeder, high energy areas	Lutze and Thiel, 1989; Murray, 1971; Murray, 2006; Schönfeld, 2002a
Cassidulina carinata	living coral facies, off-mound	shallow infaunal, epifaunal		opportunistic, moderate to high carbon flux rates, preferance for high quality food	Altenbach et al. 1999; Gupta and Thomas 1999; Hess et al. 2005; Jorissen et al. 2007; Nomura 1983a, b
Cassidulina laevigata	living coral facies, off-mound	infaunal	sand	high carbon flux rates, tolerates low oxigen	Mackensen and Hald, 1988; Murray, 2003; Murray, 2006
Bolivina spp.	living coral facies	infaunal	mud	high carbon flux rates; tolerates low oxigen	Loubere, 1996; Mackensen et al. 1995; Mullins et al. 1985; Murray, 2006; Seidenkrantz et al. 2000
Pullenia spp.	living coral facies	infaunal	mud	high carbon flux rates, low oxigen, variable food flux	Corliss and Chen, 1988; Gupta and Thomas, 1999; Loubere, 1998; Murray, 2006
Trifarina brady	living coral facies	infaunal		facultative anaerob	Gupta, 1997
Globocassidulina subglobosa	living coral facies, dropstone facies	infaunal	mud	phytodetritus feeder, preferentially ingest fresh diatoms, oligotrophic	Corliss, 1979; Fariduddin and Loubere, 1997; Gooday, 1994; Mackensen et al. 1995; Murray, 2006; Suhr et al. 2003
Discanomalina coronata	sandwave facies, living coral facies	epifaunal attached		strong bottom currents	Hawkes and Scott, 2005; Schönfeld, 1997, 2002a, b
Cibicides refulgens	sandwave facies	epifaunal attached	hard substrates	passive suspension feeder, high energy, oxic, stable physico-chemical conditions	Kaiho, 1994, 1999; Kouwenhoven, 2000; Murray, 2006; Van der Zwaan, 1982
Astrononion spp.	sandwave facies	epifaunal attached, infaunal	mud		Murray, 2006
Cibicides ungerianus	sandwave facies	epifaunal, shallow infaunal	mud	passive suspension feeder, high energy, oxic, stable physico-chemical conditions	Jorissen et al. 2007; Kaiho, 1994, 1999; Kouwenhoven, 2000 Murray, 2006; Van der Zwaan, 1982
Cibicidoides pachyderma	sandwave facies	epifaunal, shallow infaunal		passive suspension feeder, preferentially ingest fresh diatoms, oligotrophic environment, high energy, oxic, stable physico-chemical conditions	Almogi-Labin et al. 2000; Miao & Thunell, 1993; Murray, 2006; Schmiedl et al. 2000
Eggerella scabra	sandwave facies	infaunal	fine sand	eutrophic environments, does not depend on labile organic matter	De Nooijer et al. 2008; Duijnstee et al. 2003; Ernst 2002; Ernst et al. 2005
Karreriella brady	sandwave facies	epifaunal	mud to silt		Murray, 2006
Melonis barleeanum	sandwave facies, off-mound	infaunal	mud to silt	<10°C, high POM, lives in high productiv waters, lives on the redox front	Caralp, 1989; Corliss, 1985; Gooday, 1986; Koho et al. 2008; Loubere, 1991; Murray, 2006
Gyroidina soldanii	sandwave facies	epifaunal	mud	suboxic, disoxic	Mullins et al. 1985; Murray, 2006

vitrea, *Cassidulina carinata*, *Cassidulina laevigata*, *Angulogerina angulosa*, and *Buliminia marginata* are generally very abundant (Appendix A). Clear depth-related patterns in these assemblages, of the kind observed by Weston (1985), are not obvious (Fig. 2.1, Appendix A). Instead, benthic foraminiferal distribution patterns reveal a link between assemblages and facies. In particular, the infaunal uvigerinids and cassidulinids display the highest abundance in off-mound surface sediments, whereas *G. subglobosa* and *E. vitrea* dominate on-mound. The most remarkable feature is the high occurrence of the epibenthic species *Discanomalina coronata* in on-mound sediments and its absence in the off-mound sediments.

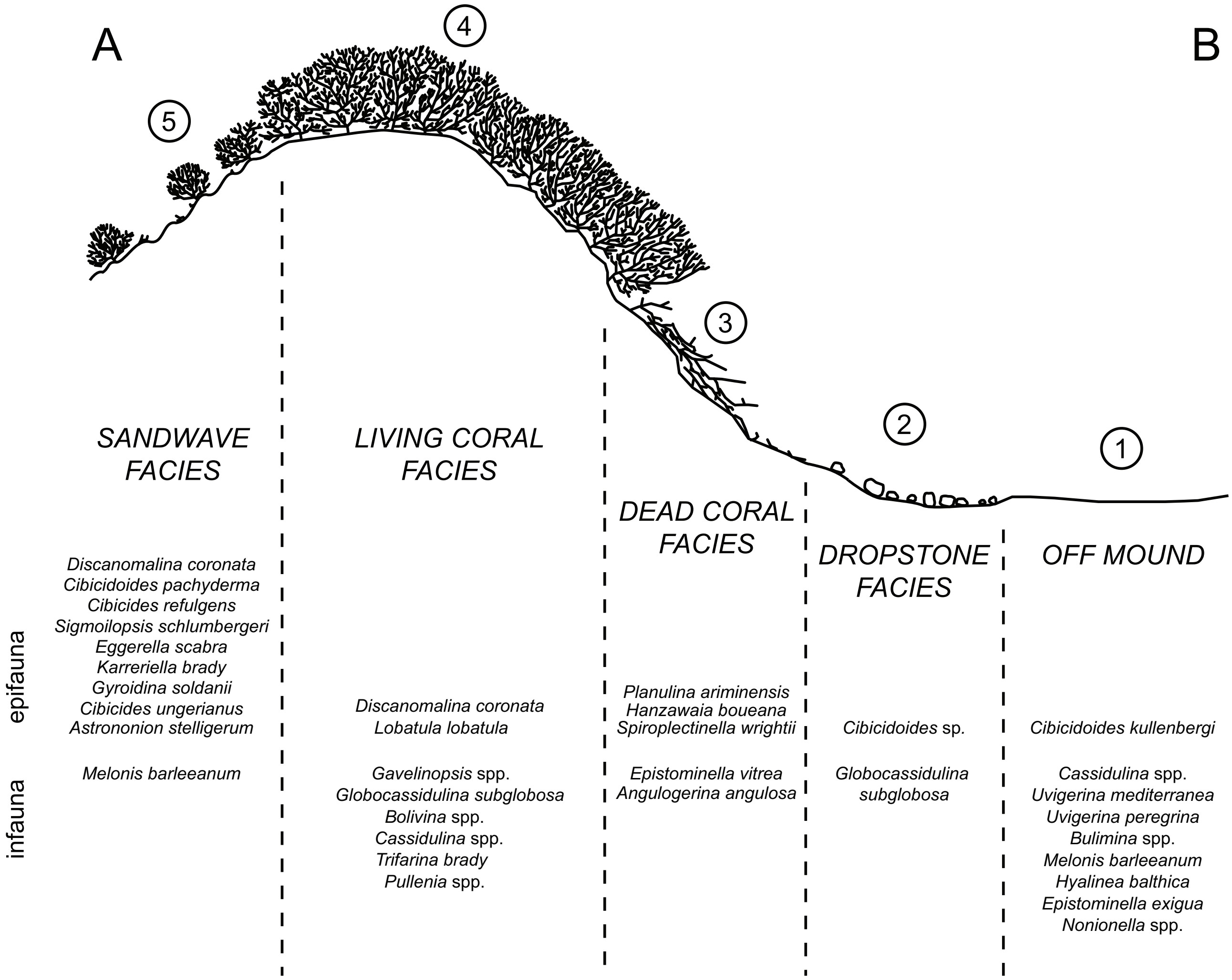

Figure 2.4 Model representing the distribution of benthic foraminiferal assemblages, based on the nMDS ordination, along the A-B transect. Numbers 1 to 5 refer to the five clusters estimated in the nMDS and representing the different facies on an active cold-water coral mound. For each cluster the most important benthic foraminifers are listed according to their living strategy and preference (Tab. 2.3).

The nMDS plot provides an overview of the similarities between assemblages (Clarke and Warwick, 2001; Everitt, 1978). This method is particularly suitable for the analysis of coral mound faunas, where the boundaries between different facies are often gradual (Clarke and Warwick, 2001). Our samples have been collected from different mounds at different water depth and from different facies in the Porcupine-Rockall Bank region (Tab. 2.1). The clustering of samples in the nMDS plot based on species corresponds to the distribution of facies on a typical mound in this area (e.g., Galway Mound, Fig. 2.4). The nMDS ordination (Fig. 2.3) and SIMPER analysis (Tab. 2.3; 2.4), together with information about the ecology of individual species and species groups (e.g., Tab. 2.2), leads to the following interpretations of the five clusters.

Cluster 1 groups 10 samples from the *Off-Mound Facies* (Fig. 2.3; Tab. 2.2; 2.3; 2.4). The sediment

Table 2.3 List of species and statistical parameters associated with the similarity in cluster 1 to 5. Average similarity within the group of station, average abundance, average similarity, contribution (%), and cumulative contribution (%) are given for each species with respect to the total similarity for each cluster.

Group 1	**Average similarity: 49.49%**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
U. peregrina	17.69	11.04	22.31	22.31
Cassidulina spp.	14.51	7.55	15.26	37.56
Bulimina spp.	7.18	4.97	10.04	47.6
H. balthica	6.49	4.6	9.29	56.89
U. mediterrannea	10.09	4.52	9.12	66.01
A. angulosa	4.05	2.9	5.87	71.88
G. subglobosa	5.39	2.8	5.67	77.55
E. vitrea	5.92	2.26	4.56	82.11
Bolivina spp.	3.45	1.94	3.92	86.03
M. barleeanum	2.53	1.29	2.6	88.63
C. pachyderma	3.73	0.87	1.75	90.38
Group 2	**Average similarity: 57.80%**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
G. subglobosa	29.74	25.51	44.14	44.14
E. vitrea	10.25	6.34	10.97	55.1
Cibicidoides sp.	7.47	4.98	8.62	63.72
Cassidulina spp.	8.13	3.99	6.9	70.62
Bulimina spp.	4.55	3.37	5.83	76.45
A. angulosa	4.92	2.97	5.13	81.59
C. pachyderma	2.46	1.67	2.89	84.48
U. peregrina	4.44	1.45	2.51	86.99
L. lobatula	1.56	1.26	2.18	89.16
P. ariminensis	2.24	1.1	1.91	91.07
Group 3	**Average similarity: 51.10%**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
E. vitrea	16.88	13.16	25.75	25.75
G. subglobosa	20.52	12.88	25.21	50.97
A. angulosa	9.16	4.79	9.38	60.35
Cassidulina spp.	6.37	4.08	7.99	68.34
P. ariminensis	4.62	2.46	4.81	73.15
H. boueana	2.54	1.93	3.78	76.93
Discanomalina spp.	2.64	1.62	3.16	80.09
U. peregrina	4.65	1.59	3.12	83.21
U. mediterrannea	3.14	1.51	2.96	86.17
Bulimina spp.	2.89	1.06	2.08	88.25
L. lobatula	1.44	0.99	1.94	90.19
Group 4	**Average similarity: 51.10%**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
G. subglobosa	19.67	15.51	30.36	30.36
Bolivina spp.	10.15	7.47	14.62	44.98
Cassidulina spp.	11.09	7.33	14.35	59.33
Discanomalina spp.	9.03	4.28	8.38	67.71
P. ariminensis	3.02	1.89	3.71	71.41
L. lobatula	2.14	1.3	2.55	73.96
Cibicidoides sp.	2.13	1.29	2.53	76.49
E. vitrea	4.27	1.29	2.52	79.01
A. stelligerum	2.11	1.18	2.31	81.32
Bulimina spp.	2.48	1.17	2.28	83.61
A. angulosa	3.32	1.09	2.14	85.75
U. peregrina	2.13	0.91	1.79	87.53
T. bradyi	1.47	0.87	1.69	89.23
Gavelinopsis spp.	1.88	0.86	1.67	90.9
Group 5	**Average similarity: 49.19%**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
G. subglobosa	12.1	11.29	22.95	22.95
Discanomalina spp.	14.11	10.48	21.31	44.26
Cassidulina spp.	10.08	5.65	11.48	55.74
E. vitrea	6.05	4.03	8.2	63.93
A. stelligerum	4.44	2.42	4.92	68.85
Bolivina spp.	3.63	2.42	4.92	73.77
U. mediterrannea	4.84	1.61	3.28	77.05
K. brady	2.42	1.61	3.28	80.33
L. lobatula	2.42	1.61	3.28	83.61
M. barleeanum	2.02	1.61	3.28	86.89
H. boueana	1.61	1.61	3.28	90.16

Table 2.4 List of species and statistical parameter associated with the dissimilarity between each pair of clusters 1 to 5. For each pair of clusters the average dissimilarity is shown. For each species the average abundance, average dissimilarity, contribution (%), and cumulative contribution (%) to the total similarity is also given.

	Average dissimilarity = 68.0				
	Group 1	**Group 4**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib %**	**Cum.%**
U. peregrina	17.7	2.1	8.0	11.8	11.8
G. subglobosa	5.4	19.7	7.3	10.8	22.5
Cassidulina spp.	14.5	11.1	5.1	7.4	29.9
Discanomalina spp.	0.2	9.0	4.4	6.5	36.4
U. mediterrannea	10.1	2.0	4.4	6.5	42.9
Bolivina spp.	3.5	10.2	3.6	5.3	48.2
E. vitrea	5.9	4.3	3.1	4.5	52.7
H. balthica	6.5	0.9	2.9	4.2	57.0
Bulimina spp.	7.2	2.5	2.7	3.9	60.9
C. pachyderma	3.7	0.0	1.9	2.8	63.6
A. angulosa	4.1	3.3	1.7	2.5	66.1
P. ariminensis	0.3	3.0	1.4	2.1	68.1
E. exigua	2.5	0.0	1.3	1.9	70.0
Nonionella spp.	2.5	0.1	1.2	1.8	71.8
M. barleeanum	2.5	0.7	1.1	1.7	73.4
C. kullenbergi	2.0	1.3	1.1	1.6	75.0
Cibicidoides spp.	0.1	2.1	1.0	1.5	76.5
A. stelligerum	0.9	2.1	1.0	1.5	78.0
L. lobatula	0.3	2.1	1.0	1.4	79.5
Gavelinopsis spp.	0.3	1.9	0.8	1.2	80.7

	Average dissimilarity = 58.9				
	Group 3	**Group 5**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Discanomalina spp.	2.6	14.1	5.8	9.8	9.8
E. vitrea	16.9	6.1	5.4	9.2	19.0
G. subglobosa	20.5	12.1	5.1	8.7	27.7
A. angulosa	9.2	0.0	4.6	7.8	35.5
C. pachyderma	0.0	8.9	4.5	7.6	43.1
Cassidulina spp.	6.4	10.1	2.8	4.8	47.9
U. peregrina	4.7	0.4	2.2	3.8	51.7
C. refulgens	1.5	4.4	1.9	3.3	54.9
A. stelligerum	0.6	4.4	1.9	3.3	58.2
U. mediterrannea	3.1	4.8	1.8	3.1	61.3
P. ariminensis	4.6	2.4	1.8	3.0	64.3
S. schlumbergeri	0.0	3.2	1.6	2.8	67.0
S. wrightii	2.6	0.0	1.3	2.3	69.3
Bulimina spp.	2.9	1.2	1.3	2.1	71.4
Bolivina spp.	2.0	3.6	1.1	1.9	73.3
K. brady	0.3	2.4	1.1	1.8	75.1
E. scabra	1.4	2.0	1.0	1.7	76.9
G. soldanii	0.4	1.6	0.8	1.4	78.2
C. kullenbergi	1.6	0.0	0.8	1.4	79.6
L. lobatula	1.4	2.4	0.6	1.0	80.6

	Average dissimilarity = 64.0				
	Group 1	**Group 3**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
G. subglobosa	5.4	20.5	7.8	12.2	12.2
U. peregrina	17.7	4.7	7.0	11.0	23.2
E. vitrea	5.9	16.9	5.9	9.2	32.4
Cassidulina spp.	14.5	6.4	4.9	7.6	40.0
U. mediterrannea	10.1	3.1	4.0	6.3	46.3
A. angulosa	4.1	9.2	3.3	5.1	51.5
H. balthica	6.5	0.5	3.0	4.7	56.2
Bulimina spp.	7.2	2.9	2.6	4.0	60.2
P. ariminensis	0.3	4.6	2.2	3.4	63.6
C. pachyderma	3.7	0.0	1.9	2.9	66.6
Bolivina spp.	3.5	2.0	1.3	2.1	68.7
S. wrightii	0.6	2.6	1.3	2.1	70.7
E. exigua	2.5	0.0	1.3	2.0	72.7
Discanomalina spp.	0.2	2.6	1.3	2.0	74.7
C. kullenbergi	2.0	1.6	1.2	1.9	76.5
Nonionella spp.	2.5	0.2	1.2	1.9	78.4
H. boueana	0.4	2.5	1.1	1.7	80.1

	Average dissimilarity = 64.3				
	Group 1	**Group 2**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
G. subglobosa	5.4	29.7	12.2	19.0	19.0
U. peregrina	17.7	4.4	7.2	11.1	30.1
U. mediterrannea	10.1	5.7	5.5	8.5	38.6
Cassidulina spp.	14.5	8.1	5.4	8.4	47.0
E. vitrea	5.9	10.3	3.9	6.1	53.1
Cibicidoides spp.	0.1	7.5	3.7	5.7	58.8
H. balthica	6.5	0.2	3.1	4.9	63.7
C. pachyderma	3.7	2.5	2.0	3.1	66.8
Bulimina spp.	7.2	4.6	1.9	3.0	69.8
Bolivina spp.	3.5	1.6	1.4	2.2	72.0
A. angulosa	4.1	4.9	1.4	2.1	74.1
E. exigua	2.5	0.0	1.3	2.0	76.1
Nonionella spp.	2.5	0.2	1.2	1.9	77.9
P. ariminensis	0.3	2.2	1.1	1.6	79.6
C. kullenbergi	2.0	1.7	1.0	1.6	81.1

	Average dissimilarity = 55.3				
	Group 4	**Group 3**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
E. vitrea	4.3	16.9	6.4	11.6	11.6
G. subglobosa	19.7	20.5	5.2	9.4	21.1
Bolivina spp.	10.2	2.0	4.2	7.6	28.7
A. angulosa	3.3	9.2	3.7	6.8	35.4
Discanomalina spp.	9.0	2.6	3.4	6.2	41.6
Cassidulina spp.	11.1	6.4	3.2	5.7	47.3
U. peregrina	2.1	4.7	2.2	4.0	51.3
P. ariminensis	3.0	4.6	1.5	2.7	54.0
Bulimina spp.	2.5	2.9	1.5	2.7	56.6
S. wrightii	0.1	2.6	1.3	2.4	59.0
U. mediterrannea	2.0	3.1	1.3	2.4	61.4
C. kullenbergi	1.3	1.6	1.0	1.9	63.3
Cibiciodoides sp.	2.1	0.2	1.0	1.8	65.1
A. stelligerum	2.1	0.6	1.0	1.7	66.8
C. refulgens	1.2	1.5	0.9	1.5	68.4
H. boueana	1.1	2.5	0.8	1.5	69.9
Gavelinopsis spp.	1.9	0.6	0.8	1.4	71.3
M. barleeanum	0.7	1.8	0.8	1.4	72.7
E. scabra	0.0	1.4	0.7	1.3	74.0
L. lobatula	2.1	1.4	0.7	1.3	75.3
T. bradyi	1.5	0.3	0.7	1.2	76.5
C. tenellus	1.3	0.0	0.6	1.2	77.7
Fissurina spp.	0.8	0.8	0.6	1.0	78.7
Pullenia spp.	1.4	0.5	0.6	1.0	79.7
H. balthica	0.9	0.5	0.5	0.9	80.6

	Average dissimilarity = 53.6				
	Group 4	**Group 2**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
G. subglobosa	19.7	29.7	5.4	10.0	10.0
Discanomalina spp.	9.0	0.2	4.4	8.3	18.3
Bolivina spp.	10.2	1.6	4.4	8.2	26.5
E. vitrea	4.3	10.3	4.0	7.4	33.9
Cassidulina spp.	11.1	8.1	3.7	6.8	40.7
U. mediterrannea	2.0	5.7	3.1	5.8	46.5
C. lopjanicus	2.1	7.5	2.8	5.1	51.6
U. peregrina	2.1	4.4	2.2	4.0	55.6
A. angulosa	3.3	4.9	2.0	3.6	59.2
Bulimina spp.	2.5	4.6	1.6	2.9	62.1
C. pachyderma	0.0	2.5	1.2	2.3	64.4
P. ariminensis	3.0	2.2	1.0	1.9	66.3
C. kullenbergi	1.3	1.7	1.0	1.8	68.1
A. stelligerum	2.1	1.2	0.9	1.6	69.7
C. refulgens	1.2	0.6	0.8	1.4	71.1
T. bradyi	1.5	0.0	0.7	1.4	72.5
M. barleeanum	0.7	1.6	0.7	1.4	73.8
Gavelinopsis spp.	1.9	1.3	0.7	1.3	75.2
Pullenia spp.	1.4	0.0	0.7	1.3	76.5
L. lobatula	2.1	1.6	0.7	1.3	77.7
C. tenellus	1.3	0.3	0.6	1.2	78.9
S. schlumbergeri	0.9	1.0	0.6	1.1	80.0
H. boueana	1.1	0.5	0.5	1.0	81.0

Table 2.4 (continued)

	Average dissimilarity = 68.5				
	Group 1	**Group 5**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
U. peregrina	17.7	0.4	8.7	12.7	12.7
Discanomalina spp.	0.2	14.1	7.0	10.2	22.8
Cassidulina spp.	14.5	10.1	4.9	7.1	29.9
C. pachyderma	3.7	8.9	4.6	6.7	36.6
U. mediterrannea	10.1	4.8	3.9	5.7	42.3
G. subglobosa	5.4	12.1	3.6	5.3	47.6
H. balthica	6.5	0.4	3.0	4.4	52.0
Bulimina spp.	7.2	1.2	3.0	4.4	56.4
E. vitrea	5.9	6.1	2.7	3.9	60.3
C. refulgens	0.5	4.4	2.1	3.1	63.4
A. angulosa	4.1	0.0	2.0	3.0	66.4
A. stelligerum	0.9	4.4	1.9	2.8	69.2
S. schlumbergeri	0.7	3.2	1.6	2.4	71.5
E. exigua	2.5	0.0	1.3	1.9	73.4
Nonionella spp.	2.5	0.0	1.2	1.8	75.2
P. ariminensis	0.3	2.4	1.2	1.8	76.9
Bolivina spp.	3.5	3.6	1.1	1.6	78.6
K. brady	0.3	2.4	1.1	1.6	80.2

	Average dissimilarity = 49.5				
	Group 3	**Group 2**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
G. subglobosa	20.5	29.7	6.5	13.1	13.1
E. vitrea	16.9	10.3	4.2	8.4	21.5
Cibicidoides sp.	0.2	7.5	3.7	7.4	28.8
A. angulosa	9.2	4.9	3.3	6.6	35.5
U. mediterrannea	3.1	5.7	3.2	6.5	42.0
Cassidulina spp.	6.4	8.1	2.9	5.9	47.9
U. peregrina	4.7	4.4	2.4	4.9	52.8
P. ariminensis	4.6	2.2	1.6	3.3	56.1
Bulimina spp.	2.9	4.6	1.5	3.1	59.2
S. wrightii	2.6	0.0	1.3	2.7	61.8
C. pachyderma	0.0	2.5	1.2	2.5	64.3
Discanomalina spp.	2.6	0.2	1.2	2.5	66.8
C. kullenbergi	1.6	1.7	1.1	2.2	69.0
H. boueana	2.5	0.5	1.0	2.1	71.1
Bolivina spp.	2.0	1.6	1.0	1.9	73.0
C. refulgens	1.5	0.6	0.8	1.6	74.6
M. barleeanum	1.8	1.6	0.7	1.5	76.0
E. scabra	1.4	0.0	0.7	1.5	77.5
A. stelligerum	0.6	1.2	0.6	1.2	78.6
Fissurina spp.	0.8	0.8	0.6	1.2	79.8
S. schlumbergeri	0.0	1.0	0.5	1.1	80.8

	Average dissimilarity = 52.4				
	Group 4	**Group 5**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Discanomalina spp.	9.0	14.1	4.8	9.1	9.1
C. pachyderma	0.0	8.9	4.5	8.5	17.6
G. subglobosa	19.7	12.1	4.4	8.4	26.0
Bolivina spp.	10.2	3.6	3.5	6.6	32.6
Cassidulina spp.	11.1	10.1	3.0	5.8	38.4
E. vitrea	4.3	6.1	2.5	4.7	43.1
U. mediterrannea	2.0	4.8	2.0	3.9	46.9
C. refulgens	1.2	4.4	2.0	3.9	50.8
A. angulosa	3.3	0.0	1.7	3.2	54.0
S. schlumbergeri	0.9	3.2	1.6	3.1	57.1
A. stelligerum	2.1	4.4	1.4	2.7	59.8
P. ariminensis	3.0	2.4	1.3	2.4	62.2
E. scabra	0.0	2.0	1.0	1.9	64.1
U. peregrina	2.1	0.4	1.0	1.9	66.0
K. brady	0.5	2.4	1.0	1.9	67.9
Cibicidoides sp.	2.1	0.8	0.9	1.7	69.6
Bulimina spp.	2.5	1.2	0.8	1.6	71.2
G. soldanii	0.0	1.6	0.8	1.5	72.7
Gavelinopsis spp.	1.9	0.8	0.8	1.5	74.2
M. barleeanum	0.7	2.0	0.8	1.4	75.6
M. pompilioides	0.9	0.8	0.7	1.3	77.0
L. lobatula	2.1	2.4	0.7	1.2	78.2
C. kullenbergi	1.3	0.0	0.6	1.2	79.4

	Average dissimilarity = 61.6				
	Group 5	**Group 2**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
G. subglobosa	12.1	29.7	8.8	14.3	14.3
Discanomalina spp.	14.1	0.2	7.0	11.3	25.6
C. pachyderma	8.9	2.5	4.4	7.2	32.8
U. mediterrannea	4.8	5.7	3.7	6.0	38.8
Cassidulina spp.	10.1	8.1	3.4	5.6	44.4
Cibicidoides sp.	0.8	7.5	3.3	5.4	49.8
E. vitrea	6.1	10.3	3.2	5.2	55.0
A. angulosa	0.0	4.9	2.5	4.0	59.0
C. refulgens	4.4	0.6	2.1	3.5	62.4
U. peregrina	0.4	4.4	2.1	3.4	65.8
Bulimina spp.	1.2	4.6	1.7	2.7	68.6
S. schlumbergeri	3.2	1.0	1.6	2.6	71.2
A. stelligerum	4.4	1.2	1.6	2.6	73.8
Bolivina spp.	3.6	1.6	1.2	2.0	75.8
P. ariminensis	2.4	2.2	1.2	2.0	77.8
E. scabra	2.0	0.0	1.0	1.6	79.4
K. brady	2.4	0.5	1.0	1.5	80.9

varies from sandy silt to coarse sand. The water depths at which samples were taken range between 202 and 736 m (Tab. 2.1). Cluster 1 is represented by the infaunal species *U. peregrina*, *U. mediterranea*, *H. balthica*, *M. barleeanum*, *E. exigua* and *Cassidulina* spp. (*C. carinata* and *C. laevigata*), *Bulimina* spp. (*B. aculeate*, *B. marginata*, and *B. striata*), and *Nonionella* spp. (*N. iridea*, *N. labradorica*, and *N. turgida*). These species are known to be typical for muddy/silty to sandy substrata, to prefer high organic matter input, and to thrive under suboxic-dysoxic conditions (e.g., Fontanier et al. 2002; Jorissen et al. 2007; Murray, 2006; Schönfeld and Altenbach, 2005). In particular, uvigerinids require high quantity and quality of nutrients supplied to the seafloor (Jorissen et al. 1988, Schönfeld and Altenbach, 2005).

Cluster 2 combines 5 samples from the *Dropstone Facies*. Sediment consists of a sandy fraction with dropstones indicating strong bottom currents (De Mol et al. 2002). *Globocassidulina subglobosa* is highly abundant in these samples. This infaunal species (e.g., Fariduddin and Loubere, 1997; Murray, 2006) is characteristic for oligotrophic areas with high bottom current velocities (Jorissen, 1988; Mackensen et al. 1995). *Cibicidoides* sp., the dominant epibenthic species, appears to be specialised to this high-energy environment.

Clusters 3, 4, and 5 represent the facies types typical of cold-water carbonate mounds. The boundaries between these facies types are gradual. Some species are represented in all of them, although their relative

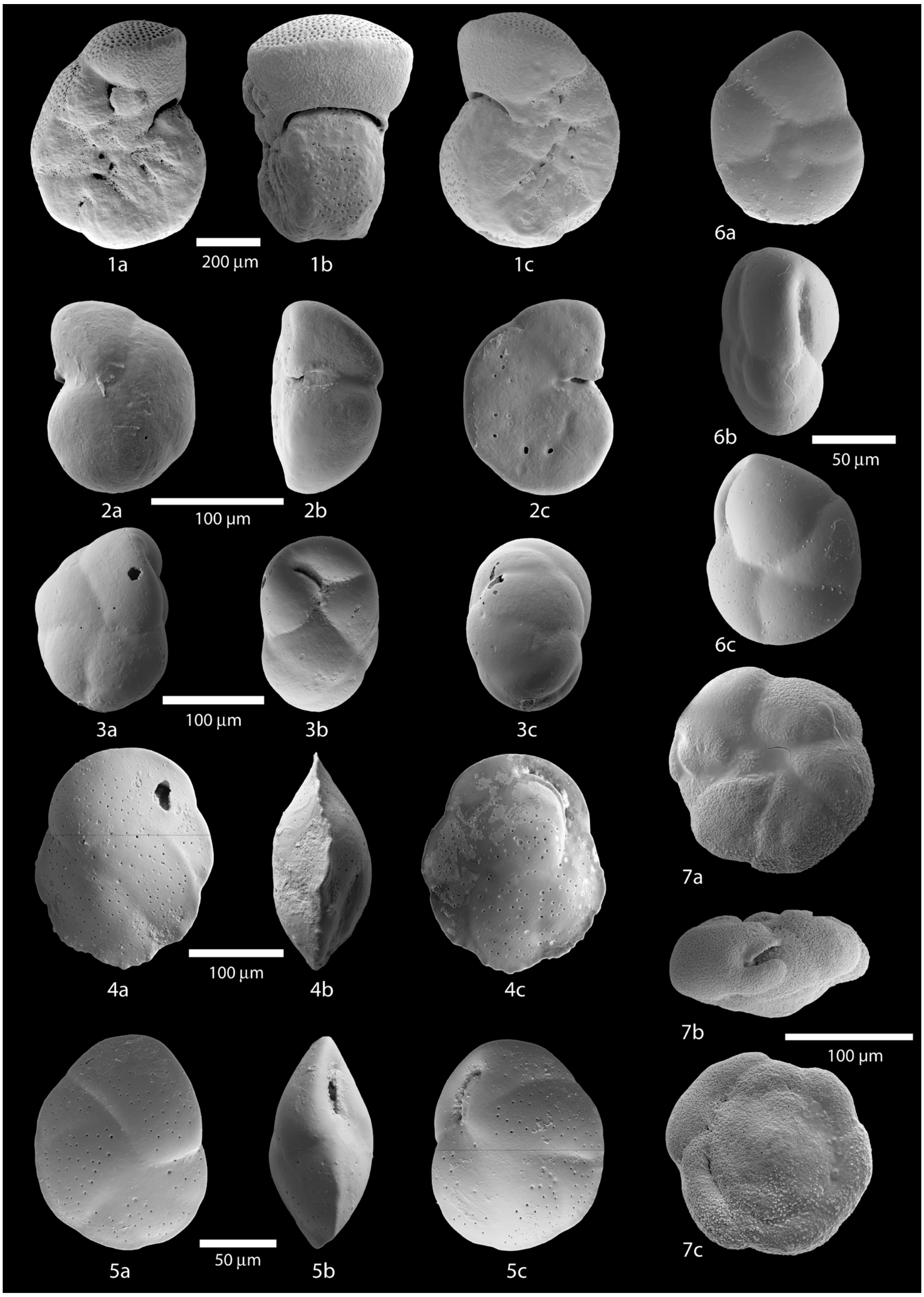

Figure 2.5 Important species collected on cold-water coral mounds at the Rockall and Porcupine Bank: (1a-c) *Discanomalina coronata* (Parker and Jones, 1857), sample M07-15. (2a-c) *Cibicidoides* sp., sample 9260. (3a-c) *Globocassidulina subglobosa* (Brady, 1881), sample 9260. (4a-c) *Cassidulina* carinata (Silvestri, 1896), sample 574-1. (5a-c) *Cassidulina laevigata* (d'Orbigny, 1826), sample 577-1. (6a-c) *Epistominella exigua* (Brady, 1884), sample 580-1. (7a-c) *Epistominella vitrea* (Parker, 1953), sample 9256-1. a = spiral views, b = side views, c = umbilical views.

abundance varies. Attached epifaunal foraminiferal species are considerably more abundant on- than off-mound.

Cluster 3 groups 4 samples from the *Dead Coral Facies*. A variety of different sediment types are associated with this facies. The framework created by the coarse coral debris traps fine sediment. Coral debris offers substrates favourable for the proliferation of epifaunal-attached species such as *Planulina* *ariminensis*, *Hanzawaia boueana*, and *Spiroplectinella wrightii* (Gross 2000; Lutze and Thiel 1989; Murray 2006). *Angulogerina angulosa* and *Epistominella vitrea* are very abundant in this facies. *Angulogerina angulosa*, a small infaunal species often associated with strong bottom currents, is typical for coarse grained sediments (Mackensen et al. 1985; Schönfeld 2002a). *Epistominella vitrea* is an opportunistic species that responds to high food availability and occurs in muddy sediments under hypoxic conditions (e.g., Jorissen et al. 1992; Murray 2006; Osterman et al. 2005). It dominates in microhabitats that are more protected from high current velocities (Mackensen et al. 1995).

Cluster 4 groups 6 samples from the *Living Coral Facies*. Living corals grow on debris and/or pebbly mud that is clogged by fine-grained sediments (mud and silt). Foraminiferal assemblages from this facies mainly comprise *G. subglobosa*, *Bolivina* spp., *Cassidulina* spp., *Trifarina brady*, and *Pullenia* spp., species that are generally considered to be infaunal (e.g, Gooday, 2003; Murray 2006; Jorissen et al. 2007). According to Jorissen (1988), *G. subglobosa* prefers more oligotrophic environments than the uvigerinids. Since *G. subglobosa* dominates the *Living Coral Facies* on-mound and uvigerinids dominate the *Off-Mound Facies* we can interpret this distribution pattern as related to the current hydrography. In particular, the higher current energy probably keeps the organic particles in suspension in the water column, and therefore unavailable to the infaunal species *G. subglobosa*. On the other hand corals feed on high amounts of fresh organic matter (Duineveld et al. 2007), which may influence the quantity and/or quality of the flux material reaching the sea floor.

The epifaunal-attached species in the *Living Coral Facies* consist of *Discanomalina coronata*, *Lobatula lobatula*, and *Gavelinopsis praegeri*, which are characteristic for active mounds (Rüggeberg et al. 2007). *Discanomalina coronata* lives attached to dead biogenic fragments that make up the substratum in the *Living Coral Facies*. The high density of *L. pertusa* in this facies offers wide habitats for *D. coronata*.

Cluster 5 groups 2 samples from the *Sandwave Facies*. In this facies sandwaves are the result of bottom currents. The sandwaves are colonized by patches of living corals and a highly diverse fauna, including hydroids, sponges, soft corals, and bivalves (Wienberg et al. 2007). Typical for this facies are high abundances of epifaunal species such as *Cibicidoides pachyderma*, *Karreriella brady*, *Gyroidina soldanii*, *Cibicidoides ungerianus*, *Astrononion stelligerum* and epifaunal-attached forms like *Cibicides refulgens* (e.g., Miao and Thunell 1993; Murray 2006; Schmiedl et al. 2000). *Discanomalina coronata* is a very abundant component of this cluster and dominates the epifaunal group (Rüggeberg et al. 2007; Schönfeld 1997, 2002a). Infaunal species are dominated by *Globocassidulina subglobosa*, *Cassidulina* spp., *Melonis barleeanum* and *Eggerella scabra*.

In summary, cold-water carbonate mounds generally develop in environments with high current velocities (e.g., De Mol et al. 2002, White 2005) and high nutrient flux (Kiriakoulakis et al. 2004). Various types of elevated substrata provide different ecological niches for epifaunal foraminifera. The epifauna in the *Living Coral Facies* has a distinctive composition compared to other facies. In particular, *D. coronata* is the dominant epifaunal species in the *Living Coral Facies* and in the *Sandwave Facies* and seems to occupy the ecological niches made available by dead fragments of cold-water corals (Jensen and Frederiksen 1992).

2.6 Conclusion

(1) Benthic foraminiferal assemblages provide an independent tool to identify different facies of cold-water coral mounds in the Porcupine-Rockall Bank region. The *Off-Mound Facies* is dominated by uvigerinids and other infaunal species. The *Dropstone Facies* is characterized by both infaunal (*G. subglobosa*) and epifaunal-attached (*Cibicidoides* sp.) species. The *Dead Coral Facies* is characterized by a combination of infaunal (*A. angulosa*, *E. vitrea*) and epifaunal (*P. ariminensis*, *H. boueana*, *S. wrightii*) species. The *Living Coral Facies* is characterized by epifauna and infauna. The species typical of this facies is *D. coronata*. The *Sandwave Facies* contains high abundances of epifauna and *D. coronata*.

(2) A potential problem in environmental interpretation is the fact that most of the indicator species (e.g., phytodetritus feeders) are small-sized (63-125 µm) and therefore have not been studied very often (Jorissen et al. 2007). Our results underline the importance of studying the small fraction to highlight the contribution of small-sized species.

(3) *Discanomalina coronata* is present and abundant only in sediments associated with cold-water coral mounds and is not present off-mound. The

fact that it is mainly found in the *Living Coral* and *Sandwave Facies* makes this species useful as an indicator for active cold-water coral mounds.

(4) Foraminiferal species associated with cold-water coral carbonate mounds provide potentially useful indicators for these environments in the fossil record.

3 - Benthic foraminifera associated to Norwegian cold-water coral reefs: towards the assessment of regional bioindicators

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submitted to Marine Micropaleontology

Abstract

Cold-water coral ecosystems have a worldwide occurrence. Along the European margin the species *Lophelia pertusa* in particular, forms widespread reefs. On the Norwegian shelf and upper slope from the Skagerrak (Oslofjord), mid Norwegian slope (Sula Reef, Røst Reef, Trænadjupet) to the northern coral-reef areas (Korallen, Lopphavet, Stjernsundet, Sveinsgrunnen), extensive reefs have settled on post-glacial structures. These ecosystems offer many ecological niches for benthic foraminifera. In this study we quantitatively investigated the total (unstained) planktonic and benthic foraminiferal assemblage from surface sediments (0–2 cm, > 63 µm size fraction) from the Norwegian cold-water coral reefs. Aim of the study is to highlight their distribution pattern and to identify and trace possible indicator species for these ecosystems in different regions. Based on diversity analysis, hierarchical cluster analysis, and multidimensional scaling (nMDS), discrete patterns in the planktonic and benthic foraminiferal distribution could be identified. Planktonic foraminifera can be grouped into two assemblages. One occurring on the shelf and slope, influenced by the North Atlantic Current and by seasonal phytoplankton blooms, the other one is influenced by the low salinity Norwegian Coastal Current and possibly also by seasonal phytoplankton blooms. The total (unstained) benthic species can be grouped into six different assemblages: I) deep-sea below 1800 m water depth; II) deep-sea between 1800 and 800 m water depth; III) off-reef Skagerrak; IV) on-reef Skagerrak; V) mid-Norwegian coral reefs, and VI) northern Norwegian coral reefs. This study reveals that benthic foraminifera associated with cold-water coral reefs indicate an environment characterized by high energy, well oxygenated waters and high organic matter supply, derived from seasonal phytoplankton blooms and reaching the sea floor. The benthic fauna associated with the coral reefs in the Skagerrak (Oslo Fjord) is depleted of phytodetritus-feeding species. This datum suggests that probably a low amount of labile organic matter and/or nutrients reached the sea floor making the environmental setting unfavourable for coral growth, thus explaining the high amounts of dead corals in this area. High diversity of benthic foraminifera characterizes "on-reef", especially in the central reef parts, whereas the "off-reef" diversity is lower.

This study reveals that the relation of benthic foraminiferal assemblages with different sedimentary facies is not well expressed for Norwegian coral reefs as it is for cold-water coral reefs on the carbonate mounds along the Irish margin. This difference possibly results from small-scale facies changes within tens of metres in the Norwegian reefs. The abundance of the benthic species Discanomalina coronata is restricted to cold-water coral reefs and absent off-reef. A similar distribution has been observed for cold-water coral reefs associated to carbonate mounds along the Irish margin, thus D. coronata is here interpreted to have ecological requirement similar to cold-water corals.

3.1 Introduction

Cold-water corals (CWCs) were first described from Norway in the eighteenth century (Pontoppidan, 1755; Gunnerus, 1768). Since these pioneering investigations many CWC ecosystems have been reported from around the world and especially from along the European margins. Cold-water coral reefs occur in the Mediterranean Sea (Zibrowius, 1980; Taviani et al., 2005, Margreth et al. in review.), the Gulf of Cadiz (e.g., Pinheiro et al., 2001; Somoza et al., 2001; Foubert et al., 2008; Wienberg et al. 2009), along the Irish margin (e.g., Hovland et al., 1994; De Mol et al., 2002; Kenyon et al., 2003; Van Rooij et al., 2003) up to northern Norway (e.g., Mortensen et al., 1995; Freiwald et al., 1997; Hovland et al., 1998;

Freiwald et al., 1999; Fosså et al., 2002; Lindberg and Mienert, 2005).

Lophelia pertusa is the dominant species in these ecosystems. It is a colonial, reef forming scleractinian coral (Roberts et al., 2009). Along the Irish margin *L. pertusa* forms large coral carbonate mounds, which originated in the late Pliocene/early Pleistocene (De Mol et al., 2002; Kano et al., 2007, Raddatz et al., in review.). On the Norwegian continental shelf the *L. pertusa* colonies are of Holocene age and have been developing since the end of the last glacial stage (e.g., Freiwald et al., 1997, 1999; Lindberg et al., 2007). In this region the corals build elongated reef-like structures on elevated hard substrates and can reach heights of 40 m and lengths of several kilometres (Freiwald et al., 1999; Freiwald et al., 2002). Their distribution is controlled by pre-existing topographical heights on the sea floor, such as moraine ridges and iceberg plough mark levees (Freiwald et al., 1999; Mortensen et al., 2001; Freiwald et al., 2002; Fosså et al., 2005). Living corals colonize the top and the upper slopes of these structures and preferentially occur at water depths between 150 and 400 m with the exception of a few shallower occurrences in fjord settings. The steep flanks of the reefs are generally characterized by *in situ* dead corals, while bio-eroded coral rubble accumulates around the base. These reefs provide abundant and diverse microhabitats for benthic organisms (Mortensen et al., 1995).

The biodiversity in CWC-reefs is high compared to that of the surrounding pelagic environments (Henry and Roberts, 2007). This is especially the case for suspension and filter feeders such as sponges, molluscs, brachiopods, cnidarians, bryozoans, ophiuroids, and crinoids, which are typical for these ecosystems (Mortensen et al., 2001). A high diversity foraminiferal population occurs in these ecosystems. In particular, recent studies on CWC-mounds in the Rockall Bank and the Porcupine Seabight have shown that a characteristic benthic foraminiferal community with a high number of epifaunal-attached species colonizes these habitats (Rüggeberg et al., 2007; Margreth et al., 2009). Furthermore, the benthic species *Discanomalina coronata* is generally associated with living CWC-reefs in this region (Margreth et al., 2009).

The present study focuses on the foraminiferal assemblages associated with CWC-reefs from northern Norway down to the Oslofjord (Fig. 3.1). The aims of this study are (1) to compare on- and off-reef total (unstained) planktonic and benthic foraminiferal assemblage from different CWC-reefs; (2) to compare the foraminiferal assemblages from the Rockall Bank and the Porcupine Seabight with those from the Norwegian margin; and (3) to identify foraminiferal indicator species for CWC-reefs along the Norwegian margin.

3.2 OCEANOGRAPHIC SETTINGS AND CORAL REEF OCCURRENCE

Along the Norwegian coast, surface water flow is controlled by two northward-trending current systems, the Norwegian Coastal Current (NCC) and further off the shelf the North Atlantic Current (NAC; Mork, 1981). The primary origins of the NCC are freshwater discharge from the Baltic Sea and freshwater runoff from Norway (Mork, 1981). The waters are low saline with a high temperature gradient between summer and winter (Sætre, 1999; Mitchelson-Jacob and Sundby, 2001). The core of the NAC flows along the shelf break and is characterized by the northward transport of warm water (6–14°C) to high latitudes. During winter the mixing of these two current systems, combined with the effects of wind and topography are responsible for seasonal upwelling and eddies. In summer the two current systems flow parallel and the differences in their respective salinities prevent mixing (Sætre, 1999; Mitchelson-Jacob and Sundby, 2001). Blindheim (1990) groups the NCC and the NAC current systems into the Norwegian Atlantic Current (NwAC), which flows above the Arctic Intermediate Water (AIW). The AIW is characterized by a salinity minimum at depths of ~ 600 m. The Norwegian Sea Deep Water (NSDW) and the Norwegian Sea Bottom Water (NSBW) currents with temperatures below 0°C govern the water masses on the deep continental slope (Peterson and Rooth, 1976).

Along the Norwegian margin CWC-reefs occur at different water depths. In the Oslofjord CWCs develop between 90 and 140 m. They thrive in the saline and well-oxygenated oceanic Atlantic Water Inflow (AWI), only a few tens of meters beneath the permanently brackish surface water layer of the Baltic Waters (Svansson, 1975; Wisshak et al., 2005). At Sula Reef they occur at depths of 240–315 m, at Røst Reef at 300–400 m, and at the northern-most reefs near the Nordkapp they thrive in the NwAC at 140–320 m (Fosså et al., 2002; Freiwald et al., 2004; Rüggeberg et al., in review.; Tab. 3.1; Fig. 3.1).

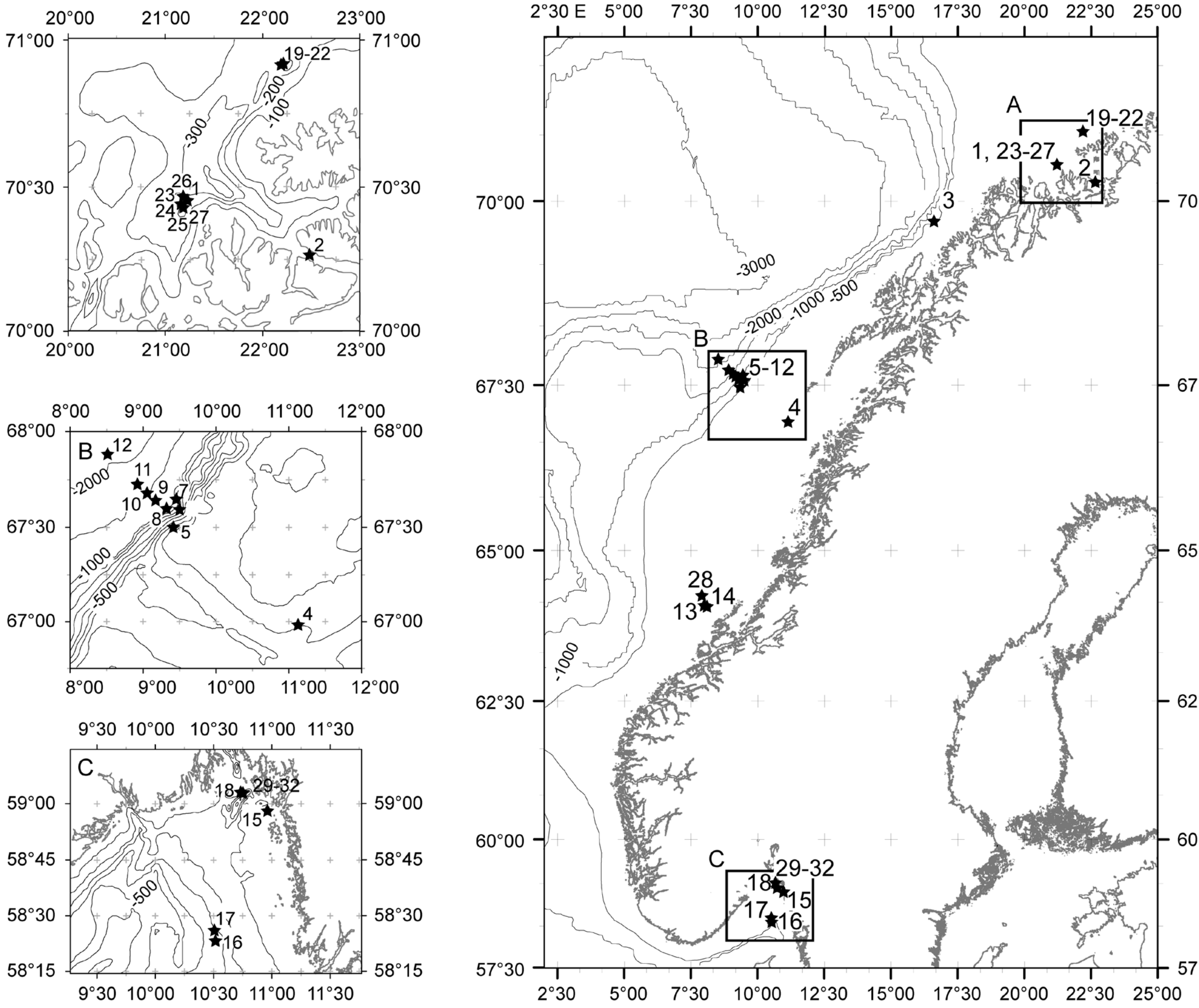

Figure 3.1 Bathymetry and location map of the surface sediment samples investigated in this study.

3.3 Material and methods

Surface sediments were taken along the Norwegian margin (Fig. 3.1) using a grab sampler operated by the submarine JAGO, a Giant Box corer and a Van-Veen grabber during six different cruises (Tab. 3.1). Dead coral frameworks from steep reef flanks (inclinations >40°) were not sampled. From the living coral reefs samples were taken only by submarine operated grab samplers to avoid damaging the reef. A few samples between the coral branches could be taken with a special submarine operated small sampler especially developed on board for this purpose. Surface sub-samples from the uppermost 2 cm were transferred to plastic bottles. Sediment samples for micropaleontological analyses were processed at the University of Fribourg following the method described in Spezzaferri and Coric (2001). Thirty-two samples were dried at room temperature, weighed, washed through a set of sieves (63µm, 125µm, 250µm), dried again at room temperature, and weighed. The samples were split to obtain at least 300 dead (unstained) benthic and 900 planktonic specimens for each sample. In the case of samples containing less than these amounts, all specimens were counted. The 19 planktonic and the 213 benthic foraminiferal species identified are listed in Appendix B and C. Video records obtained by Remotely Operated Vehicle (ROV) or images taken with the submersible JAGO were used to characterize the seafloor, together with the descriptions of the cores, which are published in the cruise reports.

To identify significant differences in foraminiferal assemblages, univariate and multivariate statistical analysis were performed on the foraminiferal assemblage data (Appendix A) with the PRIMER software (version 6.1.9; Clarke, 1993, Clarke and Warwick, 2001). The diversity of the benthic foraminiferal faunas is expressed by the species richness S and by the Fisher's α index (Fisher et al., 1943). To highlight similarities among assemblages, the Bray-Curties similarity matrix was calculated using square-root transformation (Clifford and Stephenson, 1975). The resulting similarity matrix was used for the hierarchical clustering analysis including the similar profile analysis (SIMPROF test, with $\rho = 0.05$) and the non-metric multidimensional scaling (nMDS) ordination plot (Kruskal, 1964; Kruskal and Wish, 1978). The SIMPROF was used to test the significance of the clusters. The null hypothesis of no internal group structures in the full set of samples was rejected when the significance level ρ was < 0.05. For the foraminiferal assemblages the percentages of similarity (SIMPER) were calculated to highlight the contribution of each species to the total average (dis)similarity between different groups and within one group (e.g., Kruskal, 1964; Kruskal and Wish, 1978; Basso and Spezzaferri, 2000; Clarke and Warwick, 2001). Census data of the benthic foraminiferal taxa used for multivariate statistic is provided in Appendix B.

Abundance curves for each functional group of benthic foraminifera (indicators for phytodetritus flux, organic carbon flux, oxygen level and current strength) were constructed by calculating the abundances of species displaying similar ecological preferences following Murray (2006) and Margreth et al. (2009). These are listed in Appendix D.

3.4 Results

3.4.1 Surface sediments

The surface sediment samples collected along the Norwegian continental margin were obtained from a relatively wide range of water depths. Between 170 and 330 m at the northern coral reefs (Korallen, Stjernsundet, Lopphavet, and Sveinsgrunnen), between 300 m and 2100 m on- and off-reef at the mid-Norwegian margin (Sula Reef, Røst Reef, Trænadjupet), and between 90 m and 300 m in the northern Skagerrak close to the Norwegian-Swedish border (Tab. 3.1; Fig. 3.1). Field observations made during manned submersible JAGO missions and from underwater imaging material obtained by ROV as well as from the sediments recovered in the core samples, contributed to differentiate five sedimentary facies as also identified and described in Mortensen et al. (1995; 2001), Freiwald et al. (2002) and Rüggeberg et al. (in review). Facies characteristics are subsequently summarized and represented in Fig. 3.2:

(1) *Living coral framework facies:* This facies occurs at the top of the CWC-reefs. It consists

Table 3.1 Sample number, geographical position, water depth, region, mound region and facies of the investigated samples.

Nr.	Campaign label	Event label	Device	Latitude	Longitude	Depth (m)	Region	Facies
1	G.O.Sars Hermi-1	Hermi-1_1	Grab	70°27.71	21°12.77	300	Lopphavet	*coral rubble facies*
2	POS 325	POS325 455	Giant box corer	70°16.13	22°29.46	270	Stjernsundet	*coral rubble facies*
3	ARK-XXII/1a	PS70/011-1	Giant box corer	69°44.21	16°33.27	327	Sveinsgrunnen	*coral rubble facies*
4	ARK-XXII/1a	PS70/023-3	van Veen Grab	66°58.12	11°07.79	324	Trænadjupet	*coral rubble facies*
5	ARK-XXII/1a	PS70/002-2	Giant box corer	67°30.40	9°25.55	304	Røst Reef	*sediment clogged coral framework*
6	ARK-XXII/1a	PS70/029-3	Giant box corer	67°35.23	9°28.92	604	Røst Reef	*pebbly sand facies*
7	ARK-XXII/1a	PS70/028-2	Giant box corer	67°38.05	9°26.98	761	Røst Reef	*pebbly sand facies*
8	ARK-XXII/1a	PS70/037-2	Giant box corer	67°35.15	9°19.22	889	continental slope	*mud facies (deep)*
9	ARK-XXII/1a	PS70/038-2	Giant box corer	67°37.77	9°10.30	1214	continental slope	*mud facies (deep)*
10	ARK-XXII/1a	PS70/039-2	Giant box corer	67°40.15	9°03.00	1514	continental slope	*mud facies (deep)*
11	ARK-XXII/1a	PS70/033-2	Giant box corer	67°43.00	8°55.00	1824	continental slope	*mud facies (deep)*
12	ARK-XXII/1a	PS70/032-2	Giant box corer	67°52.22	8°30.72	2098	continental slope	*mud facies (deep)*
13	AL 316	AL316-320	van Veen Grab	64°06.30	8°04.80	296	Sula Reef	*pebbly sand facies*
14	AL 316	AL316 321	van Veen Grab	64°05.88	8°05.35	278	Sula Reef	*coral rubble facies*
15	AL 232	AL 232 1022	Giant box corer	58°59.88	10°57.80	91	Oslo Fjord	*coral rubble facies*
16	AL 232	AL 232 1025	Giant box corer	58°25.88	10°31.05	326	Oslo Fjord	*mud facies (shallow)*
17	AL 232	AL 232 1026	Giant box corer	58°27.75	10°30.31	287	Oslo Fjord	*mud facies (shallow)*
18	AL 232	AL 232 1155	Giant box corer	59°04.71	10°43.90	106	Oslo Fjord	*sediment clogged coral framework*
19	POS 391	POS 391 534-1	van Veen Grab	70°55.26	22°10.71	214	Korallen	*pebbly sand facies*
20	POS 391	POS 391 535-1	van Veen Grab	70°55.14	22°11.26	201	Korallen	*coral rubble facies*
21	POS 391	POS 391 539-1	van Veen Grab	70°56.09	22°11.00	247	Korallen	*pebbly sand facies*
22	POS 391	POS 391 544-2	van Veen Grab	70°56.03	22°12.35	172	Korallen	*coral rubble facies*
23	POS 391	POS 391 550-1	JAGO Grab	70°26.72	21°10.36	233	Lopphavet	*living coral framework facies*
24	POS 391	POS 391 555-1	van Veen Grab	70°26.58	21°10.01	232	Lopphavet	*coral rubble facies*
25	POS 391	POS 391 556-2	van Veen Grab	70°26.64	21°11.61	320	Lopphavet	*coral rubble facies*
26	POS 391	POS 391 558-1	van Veen Grab	70°28.29	21°11.48	330	Lopphavet	*pebbly sand facies*
27	POS 391	POS 391 559-1	van Veen Grab	70°26.93	21°11.10	230	Lopphavet	*pebbly sand facies*
28	POS 391	POS 391 562-1	van Veen Grab	64°04.40	08°01.20	287	Sula Reef	*coral rubble facies*
29	POS 391	POS 391 567-1	JAGO Grab	59°06.78	10°47.46	140	Oslo Fjord	*sediment clogged coral framework*
30	POS 391	POS 391 570-2	van Veen Grab	59°05.62	10°47.95	110	Oslo Fjord	*coral rubble facies*
31	POS 391	POS 391 571-1	JAGO Grab	59°05.96	10°47.67	117	Oslo Fjord	*living coral framework facies*
32	POS 391	POS 391 584-1	Giant box corer	59°03.96	10°48.37	290	Oslo Fjord	*mud facies (shallow)*

of large deposits of dead *Lophelia pertusa* (up to 2 m thick) with the living parts at their periphery. The living corals appear pristine white or orange and are covered by the translucent mucus produced by *L. pertusa*. This permanent mucus film actively prevents most organisms from attaching to the living polyps. Samples 23 and 31 represent this facies.

(2) *Sediment-clogged coral framework:* this facies is found on the slopes. The construction of both *in situ* and dislocated coral framework is filled with silty clay or sandy deposits enriched by skeletal elements of bivalves and bio-eroded sponge chips. The facies could only be sampled where the dip of the slope was gentle (Tab. 3.1). Samples 5, 18, and 29 represent this facies.

(3) *Coral rubble facies:* this external reef facies consists mainly of dead coral debris, which accumulates on the lower flanks and/or at the base of the living reefs. Fine-grained sediments, mud and silt, trapped by the coral debris form a soft-sediment substratum containing skeletal remains of molluscs and echinoids. The amount of coral debris decreases away from the reef. The inclination of the slope where this facies occurs is generally between 5° and 25°. Samples 1 to 4, 14 to 15, 20, 22, 24 to 25, 28, and 30 represent this facies.

(4) *Pebbly sand facies:* the transitional zone from the external reef facies to the “off-reef” habitats, is characterized by sandy and silty sediments, sometimes rippled and containing dropstones. Fragments of bryozoans, molluscs, and corals, may also be present. Samples 6 to 7, 13, 19, 21, 26, and 27 represent this facies. Sample 26 is in the transition zone between *pebbly sand facies* and *mudfacies*, indicated by fine-grained sediment including coarser clasts.

(5) *a) Mud facies (deep):* this facies occurs at water depths deeper than 800 m under the influence of the NSDW in the very distal and deep parts off the mid-Norwegian shelves. Sediments consist of fine-grained (hemi-) pelagic sediments with benthic and planktonic foraminifera, echinoids, molluscs, and various terrigenous components. Samples 8 to 12 represent this facies.

b) Mud facies (shallow): This facies is represented by fine-grained sediments containing skeletal elements of foraminifera, echinoids and molluscs as well as various terrigenous components. The hemipelagic sediments from the northern Skagerrak are very fine-grained and a colour change marks the boundary from a thin oxygenated surface layer to the dysoxic sediments below. Planktonic foraminifera are almost absent. Samples 16 to 17, and 32 represent this facies.

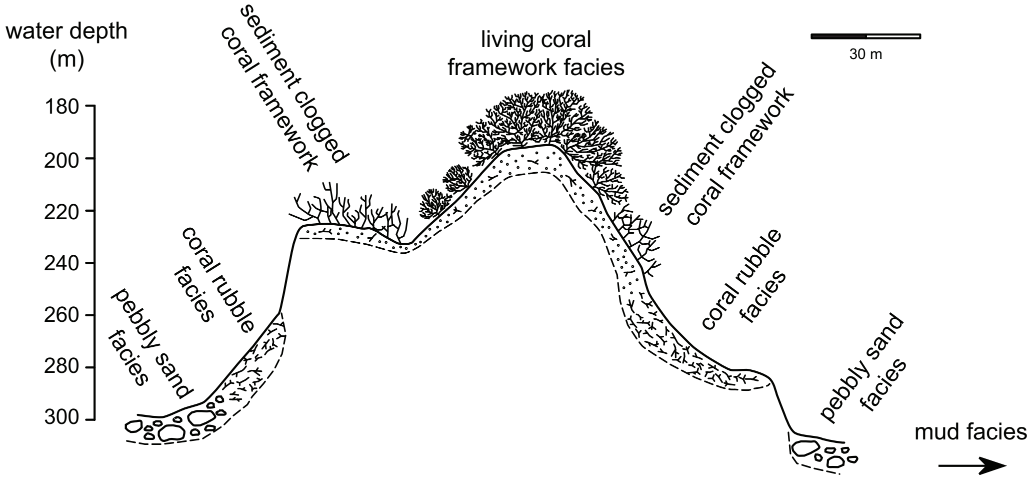

Figure 3.2 Sketch of *Lophelia*-reef facies pattern on a typical cold-water coral reef at Lopphavet. The data presented are derived from multibeam maps (Institute of Marine Research, Bergen, Norway) and direct observation with the manned submersible JAGO, IFM-GEOMAR, Kiel, Germany. Facies after Freiwald et al. (2002)

3.4.2 Planktonic foraminifera

Nineteen planktonic foraminiferal species were identified in twenty samples (Appendix C). Samples containing less than 30 planktonic specimens were not considered for cluster analysis and are not listed in Appendix C.

At the 62% level of the Bray-Curties Similarity (Fig. 3.3A) two clusters can be distinguished. Cluster I comprises samples from the outer shelf and continental slope environments, including: Sveinsgrunnen (327 m), Trænadjupet (324 m), Røst Reef (304 m, 604 m, 761 m), Mid Norwegian continental slope (889 m, 1214 m, 1514 m, 1824 m, 2098 m), and Sula Reef (296 m, 278 m). Six species and/or groups account for 95.1% of the average similarity (Tab. 3.2; Fig. 3.3B). Cluster II groups samples from Korallen (172 m, 201 m), and Lopphavet (230 m, 232 m, 233 m, 320 m, 330 m) on the inner shelf close to the shore. Four species and/or groups of species account for 93.44% of the average similarity (Tab. 3.2; Fig. 3.3B). The dissimilarities between the two groups are given in Table 3.3.

3.4.3 Benthic foraminifera

In total, 213 (unstained) benthic foraminiferal species were identified in the studied samples (Appendix B). Assemblages are generally well preserved and show a high diversity. They are characterized by epibenthic species such as *Cibicidoides pachyderma, Fontbotia wuellerstorfi, Cribrostomoides subglobosum,*

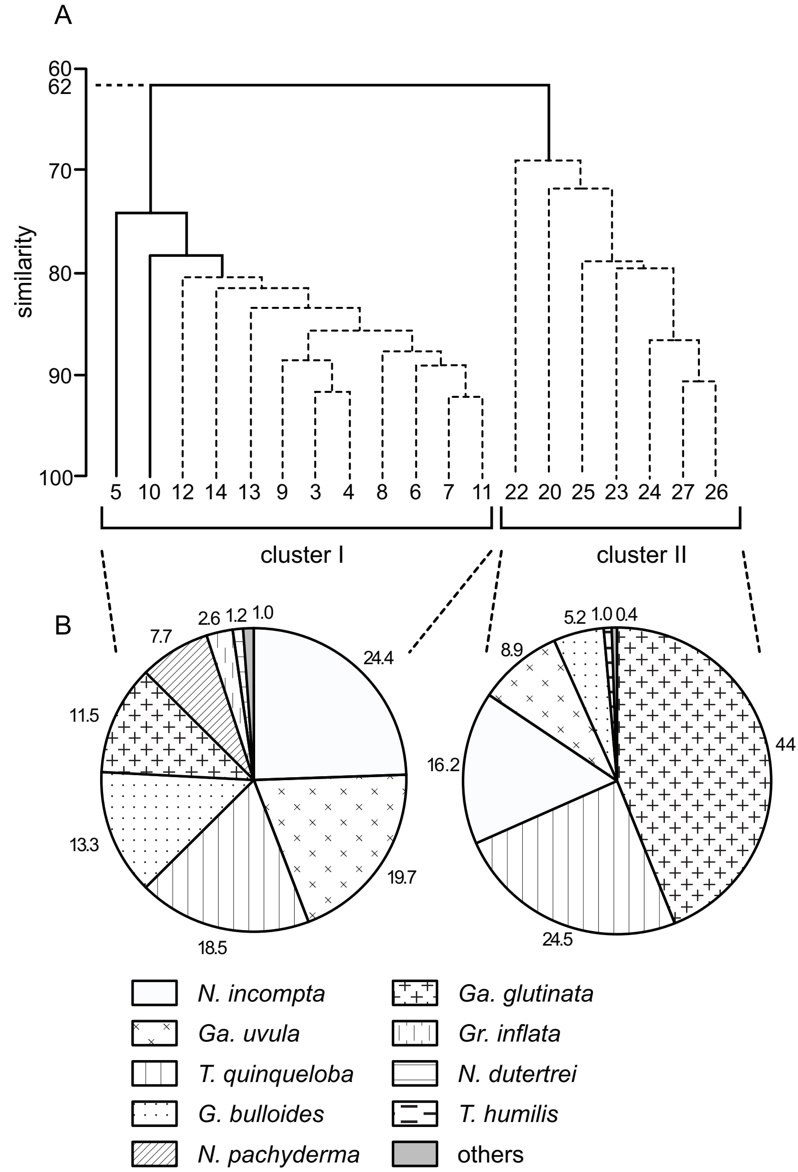

Figure 3.3 A: Hierarchical Cluster Analysis based on the Bray-Curties similarity matrix of planktonic foraminifera compositional data. Dashed lines indicate non-significantly differing samples (SIMPROF ρ > 0.05). B: Contribution (%) of planktonic foraminiferal species to the two separated groups I and II.

Lobatula lobatula, and *Discanomalina coronata*, and infaunal species such as *Angulogerina angulosa, Melonis barleeanum, Uvigerina peregrina*, and *Globocassidulina* spp*., Cassidulina* spp*., Epistominella* spp.

3.4.3.1. Depth zonation of benthic foraminifera

During the R/V Polarstern Cruise ARK-XXII/1a samples were retrieved along a bathymetric transect. The investigations along this transect revealed a zonation in the distribution pattern of the benthic foraminifera from the shelf area of Trænadjupet and Røst Reef down the slope to the abyssal area at 2098 m water depth (Fig. 3.4). In the shallowest part *A. angulosa* and *C. pachyderma* dominate the assemblages (Fig. 3.4). *Uvigerina peregrina* and *Hyalinea balthica* show their highest abundance at 327 m water depth at Trænadjupet, while *D. coronata* is more abundant at the Røst Reef at 304 m. Further downslope the numbers of *C. pachyderma* decrease. *Angulogerina angulosa* displays a similar decreasing trend with increasing water depth. *Melonis barleeanum* and the *Cassidulina laevigata* group is very abundant on the midslope. At a water depth of 1214 m the agglutinated species *Reophax scorpiurus* and *Reophax difflugiformis* are highly abundant. In the deepest part of the transect *Epistominella exigua*, *C. subglobosum*, and *F. wuellerstorfi* dominate the assemblage. *Pyrgo sarsi* is only abundant at 2098 m (Fig. 3.4).

3.4.3.2. Diversity

To compare the diversity patterns of the thanatocoenoses (unstained) of benthic foraminifera from different sediment facies, the species richness S and the Fisher's α were calculated (Tab. 3.4). These univariate statistical parameters were calculated for the species and groups of species listed in the Appendix B. The benthic species richness (S) has values between 19 (sample 21) and 59 (sample 31). Fisher's α has a minimum value of 4.83 in sample 21, and a maximum value of 21.05 in sample 5 (Tab. 3.4).

3.4.3.3. Assemblages

The hierarchical clustering based on the Bray-Curties Similarity matrix (Fig. 3.5A) and nMDS (Fig 3.5B) is used to highlight potential patterns in the benthic foraminiferal assemblages, since they are not often readily apparent (Clark and Warwick, 1994). The hierarchical cluster analysis shows two high-level clusters A and B separated at 28% of the Bray-Curties Similarity (Fig. 3.5). The two clusters are bathymetrically distinct. Cluster A includes bathyal and abyssal samples from depths between 889 and 2098 m. Cluster B includes shelf and upper bathyal samples from depths between 91 to 761 m. Six sub-clusters separate at the lower level of 49% of the Bray-Curties Similarity (Fig. 3.5). Cluster I includes the deepest bathyal and abyssal samples from the mid Norwegian continental slope (1824 m, 2098 m; Bray-Curties Similarity 66.6%). Nine species and/or groups account for 80.7% of the average similarity (Tab. 3.5). Cluster II includes shallower bathyal samples from the mid Norwegian slope (889–1514 m; Bray-Curties Similarity 61.6%). Thirteen species and/or groups account for 81.6% of the average similarity (Tab. 3.5). Cluster III includes "off-reef" samples from the Skagerrak (287–326 m; Bray-Curties Similarity 58.1%). Sixteen species and/or groups account for 82.0% of the average similarity (Tab. 3.5). Cluster IV includes "on-reef" samples from the Skagerrak

Table 3.2 List of planktonic species and statistical parameters associated with the similarity in Clusters I and II. Average similarity within the group of stations, average abundance, average similarity, contribution (%), and cumulative contribution (%) are given for each species with respect to the total similarity for each group.

Cluster I	**Average similarity: 81.64**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
N. incompta	5.51	19.92	24.4	24.4
Ga. uvula	4.55	16.12	19.74	44.14
T. quinqueloba	4.3	15.1	18.49	62.63
G. bulloides	3.17	10.85	13.29	75.92
Ga. glutinata	2.88	9.4	11.52	87.44
N. pachyderma	2.2	6.25	7.66	95.1
Cluster II	**Average similarity: 75.82**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Ga. glutinata	7.18	33.34	43.97	43.97
T. quinqueloba	4.29	18.55	24.46	68.44
N. incompta	3.74	12.25	16.15	84.59
Ga. uvula	2.17	6.71	8.85	93.44

Table 3.3 List of planktonic species and statistical parameter associated with the dissimilarity between each pair of Clusters I and II. For each pair of groups the average dissimilarity is shown. For each species the average abundance, average dissimilarity, contribution (%), and cumulative contribution (%) to the total similarity are also given.

	Average dissimilarity = 38.30				
	Cluster I	**Cluster II**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Ga. glutinata	2.88	7.18	9.79	25.55	25.55
Ga. uvula	4.55	2.17	5.53	14.44	39.99
N. incompta	5.51	3.74	5.46	14.27	54.26
G. bulloides	3.17	1.07	4.73	12.35	66.61
N. pachyderma	2.2	0.48	4.13	10.79	77.39
T. quinqueloba	4.3	4.29	2.58	6.73	84.12
Gr. inflata	0.86	0	1.93	5.04	89.16
N. dutertrei	0.55	0	1.21	3.16	92.31
T. humilis	0	0.53	1.17	3.05	95.36

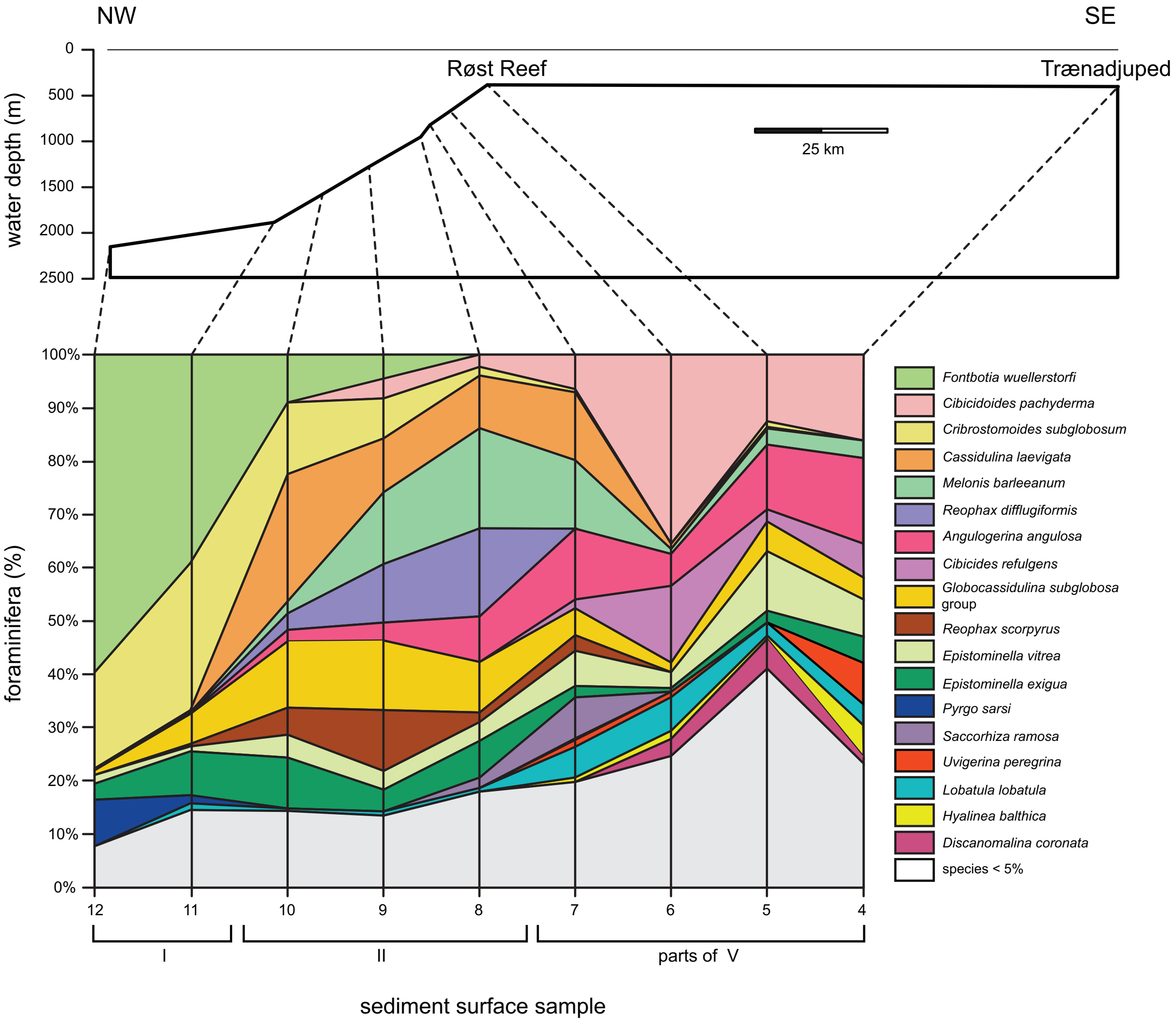

Figure 3.4 Percent distribution of the most abundant benthic foraminiferal species (> 5%) along a bathymetric transect across the Mid-Norwegian shelf at 67°N comprising 5 off-reef stations (11 and 12, group I; 8, 9, and 10, group II) and 4 reef associated stations (4, 5, 6, and 7, parts of group V).

Table 3.4 Species numbers (S) and Fisher's α of the dead (unstained) benthic foraminiferal fauna of surface sediments (0-2 cm sediment depth) associated to Clusters I to VI.

Sample	Facies	Species richness (S)	Fisher's α Index
23	*living coral framework facies*	50	15.04
31	*living coral framework facies*	55	17.14
5	*sediment clogged coral framework*	53	19.88
18	*sediment clogged coral framework*	45	14.03
29	*sediment clogged coral framework*	44	13.91
1	*coral rubble facies*	47	12.37
2	*coral rubble facies*	46	12.83
3	*coral rubble facies*	54	15.17
4	*coral rubble facies*	46	11.93
14	*coral rubble facies*	35	10.39
15	*coral rubble facies*	50	15.58
20	*coral rubble facies*	36	10.64
22	*coral rubble facies*	30	8.61
24	*coral rubble facies*	40	10.49
25	*coral rubble facies*	33	9.34
28	*coral rubble facies*	50	16.28
30	*coral rubble facies*	51	17.62
6	*pebbly sand facies*	52	14.22
7	*pebbly sand facies*	38	12.05
13	*pebbly sand facies*	31	8.01
19	*pebbly sand facies*	32	8.16
21	*pebbly sand facies*	19	4.83
27	*pebbly sand facies*	38	9.99
16	*mud facies (shallow)*	44	9.94
17	*mud facies (shallow)*	34	8.69
26	*mud facies (shallow)*	48	13.21
32	*mud facies (shallow)*	35	9.77
8	*mud facies (deep)*	37	10.86
9	*mud facies (deep)*	34	8.11
10	*mud facies (deep)*	34	9.10
11	*mud facies (deep)*	32	7.13
12	*mud facies (deep)*	23	4.69

(91–140 m; Bray-Curties Similarity 61.9%). Twenty-two species and/or groups account for 81.2% of the average similarity (Tab. 3.5). Cluster V includes samples from the mid Norwegian reefs (278–761 m; Bray-Curties Similarity 55.1%). Fifteen species and/or groups account for 81.5% of the average similarity (Tab. 3.5). Cluster VI includes samples from the northern Norwegian reefs (172–327 m; Bray-Curties Similarity 58.9%). Seventeen species and/or groups account for 80.3% of the average similarity (Tab. 3.5). The dissimilarities between each group are given in Table 3.6.

3.5 Discussion

3.5.1 Planktonic foraminifera

Seasonal plankton blooms have been described for coastal zones and shelf areas (Drebes, 1974; Le Fèvre, 1986). On the Norwegian continental margin and shelf plankton blooms are related to high nutrient transport caused by seasonal upwelling and eddies (Berner and Wefer, 1994; Sætre, 1999; Mitchelson-Jacob and Sundby, 2001). As demonstrated by Schiebel et al. (2001) and Schiebel and Hemleben (2005) for the NAC, pulses of primary productivity result in a predictable seasonally mixed assemblage of planktonic foraminiferal species in the sediment record. Areas influenced by upwelling are characterized by small opportunistic species of *Globigerina bulloides*, *Turborotalita quinqueloba*, and *Globigerinita glutinata* (e.g., Bé and Tolderlund, 1971; Thiede, 1975; Hemleben et al., 1989; Marchant et al., 1998; Rutherford et al., 1999; Schmidt et al., 2004) whereas the presence of *Neogloboquadrina incompta* indicates warmer and low-productive waters (Sautter and Thunnel, 1991; Schiebel et al., 2001).

Cluster I groups samples from the Norwegian continental slope and outer shelf area. The high proportion of *N. incompta* in the assemblages is interpreted to reflect the dominance of relatively warm and nutrient-poor waters of the NAC during summer whereas the high abundance of *T. quinqueloba* and *G. bulloides* indicates the prevalence of cool and nutrient-rich conditions during upwelling in wintertime. Cluster II groups the samples from the inner shelf areas, which are dominated by the NCC. Very small specimens of *G. glutinata*, *T. quinqueloba* and *G. uvula*, ranging in size from 63 µm to 125 µm, are the dominant species in this cluster. These species indicate cool and nutrient-rich conditions and must, therefore, be related to upwelling and eddies in winter.

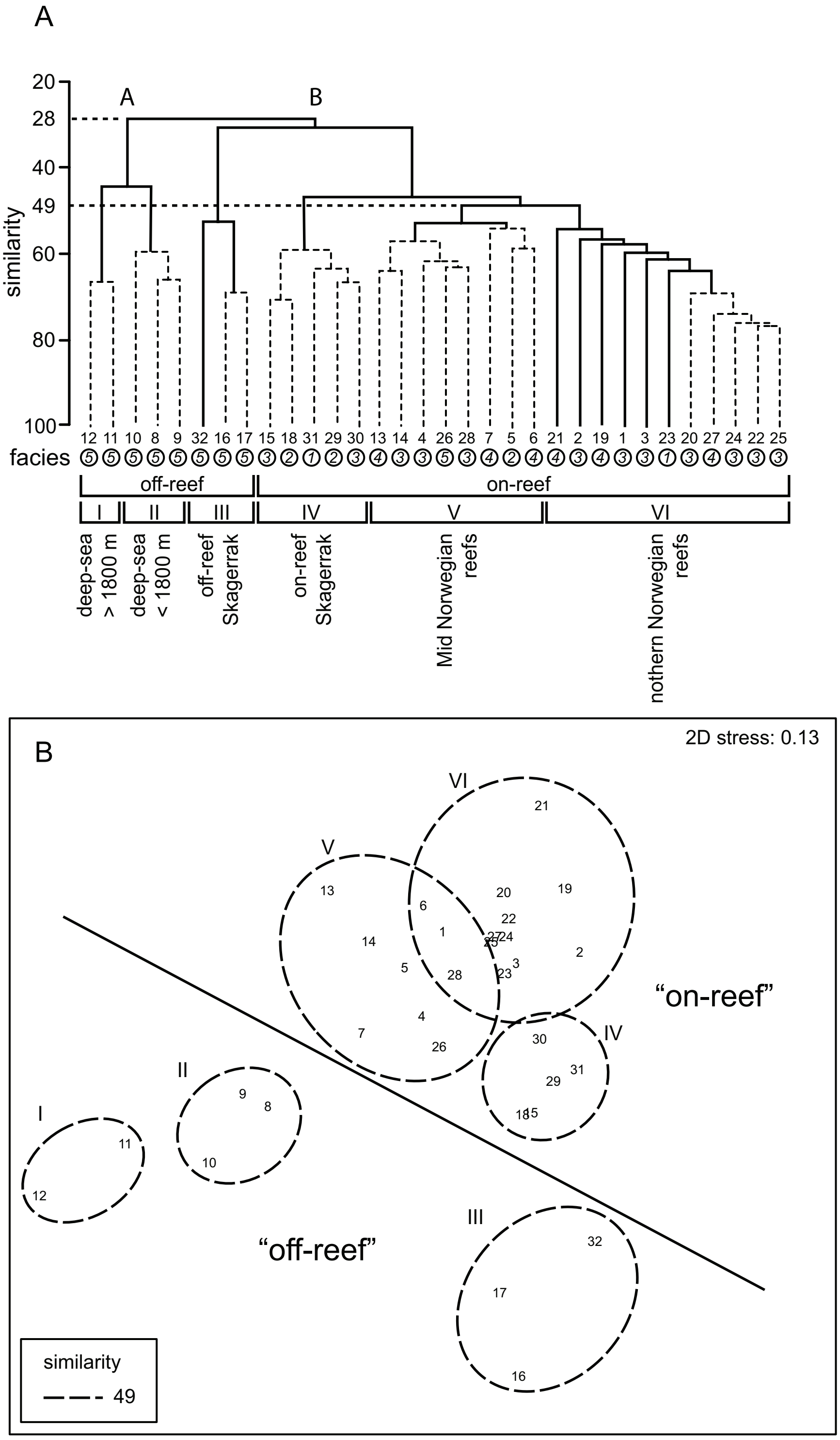

Figure 3.5 A) Hierarchical Cluster Analysis based on the Bray-Curties similarity matrix of benthic foraminifera compositional data. A and B indicate high-level cluster separating at 28% of Bray-Curties Similarity. I, II, III, IV, V, and VI display clusters at a lower level separating at 49% of Bray-Curties Similarity. Dashed lines indicate non-significantly differing samples (SIMPROF $\rho > 0.05$). The different facies are also specified: *1) living coral framework facies*, *2) sediment-clogged coral facies*, *3) coral rubble facies*, *4) pebbly sand facies*, *5) mud facies.* B) Non-metric MultiDimensional Scaling (nMDS) plot obtained from Bray-Curties similarity matrix of benthic foraminifera compositional data.

Planktonic foraminifera do not tolerate hyposaline conditions (e.g., Kucera, 2007). During summer the NCC dominantly originate from the discharge of freshwaters from the Baltic Sea and freshwater runoff from Norway (Mork, 1981), therefore, their influence may explain the low contribution of warm and nutrient-

Table 3.5 List of benthic species and statistical parameters associated with the similarity in Clusters I to VI. Average similarity within the group of station, average abundance, average similarity, contribution (%), and cumulative contribution (%) are given for each species with respect to the total similarity for each group.

Cluster I	**Average similarity: 66.56**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	6.99	18.23	27.39	27.39
Cribrostomoides subglobosum	4.74	12.32	18.5	45.89
Epistominella exigua	2.35	5.23	7.85	53.75
Oridorsalis umbonatus	1.47	4.04	6.07	59.82
Pyrgo sarsi	2.04	3.5	5.26	65.08
Fissurina spp.	1.02	2.86	4.3	69.38
Lobatula lobatula	1.01	2.61	3.93	73.31
Epistominella vitrea	1.05	2.61	3.92	77.23
Globocassidulina subglobosa group	1.49	2.34	3.51	80.74
Cluster II	**Average similarity: 61.64**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Globocassidulina subglobosa group	3.41	7.01	11.38	11.38
Cassidulina laevigata group	3.73	6.81	11.04	22.42
Reophax difflugiformis	3.08	5.01	8.12	30.54
Epistominella exigua	2.61	4.93	8	38.54
Melonis barleeanum	3.17	4.77	7.74	46.29
Epistominella vitrea	1.94	4.08	6.61	52.9
Cribrostomoides subglobosum	2.6	4.04	6.55	59.45
Reophax scorpiurus	2.34	3.65	5.91	65.36
Angulogerina angulosa	2.04	3.38	5.49	70.85
Cibicidoides pachyderma	1.25	1.74	2.82	73.67
Paratrochammina challengeri	1.01	1.64	2.66	76.33
Rhabdammina abyssorum	0.92	1.64	2.66	78.99
Lobatula lobatula	0.82	1.61	2.61	81.6
Cluster III	**Average similarity: 58.08**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Globobulimina affinis	4.53	7.99	13.76	13.76
Eggerelloides scaber	2.52	4.32	7.44	21.2
Hyalinea balthica	2.73	3.8	6.55	27.75
Bigenerina cylindrica	1.99	3.69	6.35	34.1
Textularia tenuissima	2.12	3.28	5.64	39.74
Melonis barleeanum	1.7	2.98	5.12	44.86
Bulimina marginata	1.78	2.65	4.56	49.43
Bolivina spp.	1.98	2.6	4.47	53.9
Cassidulina carinata	2	2.48	4.26	58.16
Melonis pompilioides	1.9	2.35	4.05	62.21
Cassidulina laevigata group	1.69	2.3	3.97	66.18
Stainforthia fusiformis	1.25	2.12	3.65	69.83
Uvigerina peregrina	1.44	2.01	3.46	73.28
Trochammina robertsoni	1.14	1.88	3.23	76.52
Pullenia subcarinata	2.1	1.8	3.1	79.62
Nonionella turgida	0.78	1.36	2.34	81.96
Cluster IV	**Average similarity: 61.92**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Lobatula lobatula	3.65	5.51	8.9	8.9
Cibicidoides pachyderma	3.05	4.57	7.39	16.28
Melonis pompilioides	2.91	4.56	7.36	23.64
Melonis barleeanum	2.29	3.6	5.81	29.45
Bulimina marginata	2.44	3.3	5.32	34.77
Cassidulina laevigata group	2.22	3.01	4.85	39.63
Cibicides refulgens	1.87	2.34	3.79	43.41
Hyalinea balthica	1.81	2.32	3.74	47.15
Epistominella exigua	1.54	2.17	3.5	50.65
Cibicidoides sp.	1.46	2.11	3.42	54.07
Astrononion gallowayi	1.4	1.91	3.08	57.15
Angulogerina angulosa	1.4	1.88	3.03	60.18
Nonionella iridea	1.33	1.86	3.01	63.19
Gavelinopsis spp.	1.37	1.85	2.99	66.18
Spiroplectinella wrightii	1.11	1.7	2.74	68.92
Globocassidulina subglobosa group	1.09	1.43	2.31	71.23
Cassidulina carinata	1.39	1.43	2.3	73.53
Bolivina spp.	1.06	1.08	1.74	75.27
Quinqueloculina seminula	0.66	0.97	1.56	76.83

Table 3.5 (continued)

Adercotryma wrightii	0.97	0.96	1.55	78.38
Eggerelloides scaber	0.93	0.87	1.41	79.79
Fissurina spp.	0.86	0.85	1.37	81.16
Cluster V	**Average similarity: 55.11**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Angulogerina angulosa	3.67	6.24	11.32	11.32
Cibicidoides pachyderma	3.41	5.05	9.17	20.48
Epistominella vitrea	2.66	4.36	7.91	28.39
Globocassidulina subglobosa group	2.34	3.79	6.87	35.26
Cibicides refulgens	2.25	3.36	6.09	41.35
Melonis barleeanum	1.96	2.91	5.27	46.63
Cibicidoides kullenbergi	1.53	2.32	4.22	50.84
Hyalinea balthica	1.56	2.16	3.93	54.77
Cassidulina carinata	1.49	2.13	3.86	58.63
Lobatula lobatula	1.62	2.01	3.65	62.28
Uvigerina peregrina	1.94	1.88	3.41	65.68
Epistominella exigua	1.29	1.76	3.2	68.88
Discanomalina coronata	1.49	1.53	2.77	71.66
Fissurina spp.	0.91	1.4	2.55	74.2
Cassidulina laevigata group	1.37	1.4	2.54	76.75
Hanzawaia boueana	1.17	1.31	2.37	79.12
Cibicidoides sp.	1.17	1.29	2.34	81.46
Cluster VI	**Average similarity: 58.98**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Cibicidoides pachyderma	4.57	8.51	14.43	14.43
Lobatula lobatula	2.81	4.69	7.94	22.38
Globocassidulina subglobosa group	2.6	4.68	7.94	30.31
Discanomalina coronata	2.93	4.54	7.7	38.02
Cibicides refulgens	2.56	3.73	6.33	44.35
Angulogerina angulosa	2.15	3.39	5.74	50.09
Cassidulina laevigata group	1.81	3.02	5.12	55.21
Melonis barleeanum	1.66	2.82	4.78	59.99
Cibicidoides sp.	1.7	2.56	4.34	64.33
Astrononion gallowayi	1.38	1.91	3.25	67.58
Gavelinopsis spp.	1.13	1.81	3.06	70.64
Fissurina spp.	1.16	1.79	3.04	73.68
Epistominella vitrea	1.14	1.58	2.68	76.37
Nonionella iridea	0.72	1.25	2.12	78.49
Epistominella exigua	0.89	1.08	1.83	80.32

poor indicator species. Samples associated to Cluster II are dominated by small opportunistic species, which are interpreted to be mainly deposited during high productivity in winter.

In summary, planktonic foraminiferal assemblages in both clusters reflect a seasonal mixed signal. Cluster I represents the seasonal mixed assemblage on the continental margin and shelf associated with the NAC with a contribution of both cold and warm water species. Cluster II is dominated by the fauna associated with high winter productivity in the NCC. In this cluster warm water species although present contribute very little to the assemblage.

Cool and deep waters are undersaturated in calcium carbonate and result in the dissolution of foraminiferal tests (e.g., Hemleben et al., 1989). Continental shelves in cold regions (Alexandersson, 1978), slopes and basins deeper than the carbonate compensation depth (e.g., Murray, 2006) may have corrosive bottom waters with respect to the $CaCO_3$. Cluster I includes planktonic foraminifera from sample obtained in water depths ranging between 278 m (sample 14) and 2098 m (sample 12) from the Norwegian slope (Tab.3.1; Fig. 3.3). Since no remarkable changes in composition or abundance have been observed in the planktonic assemblage, it is reasonable to assume that dissolution does not affect the fragile planktonic foraminiferal tests. Consequently, the benthic foraminiferal assemblages can also be considered as being unaffected by carbonate dissolution confirming the observations on pristine benthic assemblages by Mackensen et al. (1985) from the Southwest Norwegian slope.

3.5.2 Benthic foraminiferal assemblage

3.5.2.1 High-level cluster A and B: the bathymetric imprint

Benthic foraminiferal communities show conspicuous

Table 3.6 List of benthic species and statistical parameter associated with the dissimilarity between each pair of Clusters I to VI. For each pair of cluster the average dissimilarity is shown. For each species the average abundance, average dissimilarity, contribution (%), and cumulative contribution (%) to the total similarity are also given.

	Average dissimilarity = 51.33				
	Cluster VI	**Cluster V**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Discanomalina coronata	2.93	1.49	1.91	3.71	3.71
Uvigerina peregrina	0.25	1.94	1.89	3.68	7.39
Cibicidoides pachyderma	4.57	3.41	1.77	3.45	10.84
Angulogerina angulosa	2.15	3.67	1.62	3.15	14
Epistominella vitrea	1.14	2.66	1.54	3.01	17
Cibicidoides kullenbergi	0.2	1.53	1.4	2.74	19.74
Lobatula lobatula	2.81	1.62	1.37	2.66	22.4
Cibicides refulgens	2.56	2.25	1.33	2.58	24.98
Hyalinea balthica	0.54	1.56	1.3	2.53	27.52
Cassidulina carinata	0.63	1.49	1.13	2.19	29.71
Cassidulina laevigata group	1.81	1.37	1.08	2.1	31.81
Cibicidoides sp.	1.7	1.17	0.97	1.9	33.71
Cibicides/Cibicidoides juv	1.01	0.28	0.95	1.86	35.56
Hanzawaia boueana	0.83	1.17	0.88	1.71	37.27
Gavelinopsis spp.	1.13	0.39	0.87	1.69	38.97
Astrononion gallowayi	1.38	0.63	0.83	1.61	40.58
Melonis barleeanum	1.66	1.96	0.71	1.39	41.97
Epistominella exigua	0.89	1.29	0.71	1.39	43.36
Discorbinella bertheloti	0.72	0.21	0.71	1.39	44.74
Miliolinella subrotunda	0.74	0.29	0.71	1.38	46.13
Globocassidulina subglobosa group	2.6	2.34	0.69	1.35	47.48
Pullenia osloensis	0.82	0.69	0.67	1.3	48.78
Melonis pompilioides	0.53	0.39	0.65	1.26	50.04
Cibicides ungerianus	0.58	0.56	0.64	1.25	51.29
Hanzawaia concentrica	0.65	0.16	0.64	1.25	52.54
Pullenia subcarinata	0.26	0.7	0.63	1.23	53.77
Planulina ariminensis	0	0.62	0.62	1.22	54.98
Patellina corrugata	0.67	0.16	0.58	1.13	56.12
Bolivina spp.	0.73	0.27	0.55	1.08	57.19
Sigmoilopsis schlumbergeri	0	0.52	0.53	1.03	58.22
Bulimina marginata	0.05	0.54	0.52	1.01	59.24
Quinqueloculina viennensis	0.47	0.29	0.52	1.01	60.24
Fissurina spp.	1.16	0.91	0.51	1	61.25
Pullenia bulloides	0.05	0.51	0.5	0.98	62.23
Sphaeroidina bulloides	0.11	0.46	0.5	0.98	63.21
Sacchorhiza ramosa	0.07	0.46	0.5	0.96	64.17
Nonionella iridea	0.72	0.58	0.49	0.96	65.14
Nonionella turgida	0.11	0.47	0.47	0.92	66.06
Spiroplectinella wrightii	0.4	0.45	0.46	0.89	66.95
Pullenia quinqueloba	0.22	0.34	0.43	0.84	67.79
Trochammina inflata	0.04	0.44	0.43	0.83	68.62
Uvigerina mediterranea	0	0.39	0.42	0.82	69.44
Pullenia quadriloba	0.17	0.39	0.41	0.8	70.24
Hyrrokkin sarcophaga	0.04	0.43	0.41	0.79	71.04
Verneulina propinqua	0.24	0.29	0.39	0.76	71.8
Rosalina globularis	0.21	0.29	0.36	0.7	72.5
Haplofragmoides membranaceum	0.05	0.36	0.36	0.7	73.2
Quinqueloculina lamarckiana	0.18	0.31	0.34	0.67	73.87
Elphidium frigidum	0.08	0.32	0.34	0.66	74.53
Cribrostomoides jeffreysii	0.33	0.06	0.34	0.66	75.19
Nonionella labradorica	0.37	0.14	0.34	0.65	75.85
Reophax scorpiurus	0.12	0.25	0.33	0.64	76.49
Favulina spp.	0.27	0.33	0.32	0.62	77.1
Homalohedra borealis	0.15	0.28	0.32	0.61	77.72
Gyroidinoides laevigatus	0.04	0.31	0.31	0.61	78.33
Eggerella bradyi	0.05	0.27	0.3	0.58	78.9
Paratrochammina challengeri	0.04	0.3	0.29	0.56	79.46
Elphidium clavatum	0.26	0	0.28	0.54	80
Gyroidina spp.	0.08	0.25	0.27	0.52	80.53

Table 3.6 (continued)

			Average dissimilarity = 79.30		
	Cluster VI	**Cluster I**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	0.05	6.99	8.58	10.82	10.82
Cribrostomoides subglobosum	0	4.74	5.78	7.29	18.11
Cibicidoides pachyderma	4.57	0.2	5.46	6.89	25
Discanomalina coronata	2.93	0	3.72	4.68	29.68
Cibicides refulgens	2.56	0.2	3.04	3.83	33.51
Pyrgo sarsi	0	2.04	2.56	3.23	36.74
Lobatula lobatula	2.81	1.01	2.19	2.76	39.51
Angulogerina angulosa	2.15	0.4	2.17	2.73	42.24
Cibicidoides sp.	1.7	0	2.07	2.61	44.84
Oridorsalis umbonatus	0	1.47	1.81	2.28	47.12
Epistominella exigua	0.89	2.35	1.79	2.26	49.38
Melonis barleeanum	1.66	0.28	1.69	2.13	51.51
Globocassidulina subglobosa group	2.6	1.49	1.5	1.89	53.39
Cassidulina laevigata group	1.81	0.63	1.43	1.81	55.2
Astrononion gallowayi	1.38	0.2	1.43	1.8	57
Gavelinopsis spp.	1.13	0	1.37	1.73	58.73
Cibicides/Cibicidoides juv	1.01	0	1.21	1.52	60.25
Rhabdammina abyssorum	0.09	0.94	1.08	1.36	61.62
Pullenia osloensis	0.82	0	0.99	1.25	62.87
Cycloforina angularis	0	0.8	0.98	1.24	64.1
Hanzawaia boueana	0.83	0	0.97	1.22	65.33
Miliolinella subrotunda	0.74	0	0.91	1.15	66.48
Bolivina spp.	0.73	0	0.87	1.1	67.57
Discorbinella bertheloti	0.72	0	0.86	1.09	68.66
Hormonisella guttifera	0.04	0.73	0.84	1.06	69.72
Cassidulina carinata	0.63	0.8	0.84	1.06	70.78
Gyroidinoides laevigatus	0.04	0.69	0.8	1.01	71.8
Patellina corrugata	0.67	0	0.79	1	72.8
Hanzawaia concentrica	0.65	0	0.78	0.98	73.78
Pullenia subcarinata	0.26	0.73	0.73	0.92	74.7
Cibicides ungerianus	0.58	0	0.7	0.89	75.58
Epistominella vitrea	1.14	1.05	0.66	0.83	76.41
Botellina labyrinthica	0	0.56	0.66	0.83	77.24
Melonis pompilioides	0.53	0	0.61	0.77	78.01
Hyalinea balthica	0.54	0	0.61	0.76	78.78
Pullenia quinqueloba	0.22	0.4	0.59	0.74	79.52
Quinqueloculina viennensis	0.47	0	0.58	0.73	80.26

			Average dissimilarity = 76.44		
	Cluster V	**Cluster I**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	0	6.99	8.16	10.67	10.67
Cribrostomoides subglobosum	0.25	4.74	5.19	6.79	17.46
Angulogerina angulosa	3.67	0.4	3.84	5.02	22.48
Cibicidoides pachyderma	3.41	0.2	3.71	4.85	27.33
Pyrgo sarsi	0	2.04	2.42	3.16	30.49
Cibicides refulgens	2.25	0.2	2.39	3.12	33.62
Uvigerina peregrina	1.94	0	2.33	3.05	36.67
Melonis barleeanum	1.96	0.28	1.97	2.58	39.25
Epistominella vitrea	2.66	1.05	1.86	2.43	41.68
Hyalinea balthica	1.56	0	1.84	2.4	44.08
Cibicidoides kullenbergi	1.53	0	1.82	2.38	46.46
Discanomalina coronata	1.49	0	1.66	2.18	48.63
Oridorsalis umbonatus	0.14	1.47	1.55	2.03	50.66
Hanzawaia boueana	1.17	0	1.36	1.78	52.44
Cibicidoides sp.	1.17	0	1.35	1.76	54.2
Epistominella exigua	1.29	2.35	1.29	1.69	55.89
Globocassidulina subglobosa group	2.34	1.49	1.2	1.56	57.45
Lobatula lobatula	1.62	1.01	1.07	1.4	58.85
Cassidulina carinata	1.49	0.8	0.98	1.29	60.14
Cassidulina laevigata group	1.37	0.63	0.97	1.27	61.41
Cycloforina angularis	0	0.8	0.93	1.21	62.62
Rhabdammina abyssorum	0.15	0.94	0.92	1.2	63.82
Hormonisella guttifera	0	0.73	0.84	1.09	64.92
Gyroidinoides laevigatus	0.31	0.69	0.78	1.02	65.93

Table 3.6 (continued)

Pullenia osloensis	0.69	0	0.77	1.01	66.95
Planulina ariminensis	0.62	0	0.72	0.95	67.9
Cibicides ungerianus	0.56	0	0.66	0.87	68.76
Reophax scorpiurus	0.25	0.45	0.64	0.83	69.6
Botellina labyrinthica	0	0.56	0.62	0.81	70.41
Sigmoilopsis schlumbergeri	0.52	0	0.61	0.8	71.21
Nonionella iridea	0.58	0.48	0.59	0.77	71.98
Astrononion gallowayi	0.63	0.2	0.57	0.74	72.72
Nonionella turgida	0.47	0	0.55	0.72	73.44
Pullenia subcarinata	0.7	0.73	0.55	0.72	74.17
Sphaeroidina bulloides	0.46	0	0.55	0.72	74.88
Sacchorhiza ramosa	0.46	0	0.54	0.7	75.59
Bulimina marginata	0.54	0.2	0.53	0.69	76.27
Elphidium frigidum	0.32	0.28	0.51	0.67	76.95
Pullenia bulloides	0.51	0.2	0.51	0.66	77.61
Trochammina inflata	0.44	0	0.5	0.65	78.26
Uvigerina mediterranea	0.39	0	0.5	0.65	78.9
Spiroplectinella wrightii	0.45	0	0.49	0.64	79.54
Hyrrokkin sarcophaga	0.43	0	0.47	0.62	80.16

			Average dissimilarity = 66.01		
	Cluster VI	**Cluster II**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Cibicidoides pachyderma	4.57	1.25	3.62	5.48	5.48
Discanomalina coronata	2.93	0	3.22	4.88	10.36
Reophax difflugiformis	0.2	3.08	3.07	4.65	15.01
Cibicides refulgens	2.56	0	2.8	4.25	19.25
Cribrostomoides subglobosum	0	2.6	2.79	4.23	23.48
Reophax scorpiurus	0.12	2.34	2.4	3.63	27.11
Cassidulina laevigata group	1.81	3.73	2.12	3.21	30.31
Lobatula lobatula	2.81	0.82	2.11	3.2	33.51
Epistominella exigua	0.89	2.61	1.87	2.83	36.34
Melonis barleeanum	1.66	3.17	1.84	2.78	39.12
Fontbotia wuellerstorfi	0.05	1.7	1.82	2.76	41.89
Cibicidoides sp.	1.7	0	1.8	2.73	44.62
Paratrochammina challengeri	0.04	1.01	1.04	1.57	46.19
Astrononion gallowayi	1.38	0.44	1.02	1.54	47.73
Pullenia quinqueloba	0.22	1.01	1.01	1.53	49.26
Cibicides/Cibicidoides juv	1.01	0.15	1.01	1.52	50.79
Cassidulina carinata	0.63	0.88	0.96	1.45	52.23
Gavelinopsis spp.	1.13	0.25	0.95	1.44	53.67
Globocassidulina subglobosa group	2.6	3.41	0.93	1.41	55.08
Rhabdammina abyssorum	0.09	0.92	0.93	1.41	56.49
Angulogerina angulosa	2.15	2.04	0.92	1.39	57.87
Epistominella vitrea	1.14	1.94	0.91	1.37	59.25
Hormonisella guttifera	0.04	0.85	0.88	1.33	60.58
Pullenia quadriloba	0.17	0.87	0.87	1.31	61.89
Pullenia osloensis	0.82	0.19	0.81	1.22	63.11
Miliolinella subrotunda	0.74	0	0.79	1.2	64.32
Hanzawaia boueana	0.83	0.26	0.78	1.18	65.5
Bolivina spp.	0.73	0	0.76	1.15	66.65
Discorbinella bertheloti	0.72	0	0.75	1.14	67.79
Patellina corrugata	0.67	0	0.69	1.05	68.84
Hanzawaia concentrica	0.65	0	0.68	1.03	69.87
Adercotryma wrightii	0.12	0.62	0.63	0.95	70.82
Fissurina spp.	1.16	0.71	0.62	0.94	71.77
Cibicides ungerianus	0.58	0.19	0.6	0.91	72.67
Stainforthia fusiformis	0.1	0.55	0.56	0.84	73.51
Melonis pompilioides	0.53	0	0.54	0.82	74.33
Hyalinea balthica	0.54	0	0.53	0.81	75.14
Pelosina cylindrica	0	0.5	0.52	0.78	75.92
Pullenia subcarinata	0.26	0.48	0.51	0.77	76.69
Quinqueloculina viennensis	0.47	0	0.51	0.77	77.46
Sacchorhiza ramosa	0.07	0.46	0.5	0.76	78.22
Pullenia bulloides	0.05	0.42	0.44	0.67	78.9
Cycloforina angularis	0	0.41	0.43	0.66	79.55
Spiroplectinella wrightii	0.4	0	0.42	0.63	80.19

Table 3.6 (continued)

			Average dissimilarity = 62.41		
	Cluster V	**Cluster II**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Reophax difflugiformis	0	3.08	3.12	4.99	4.99
Cassidulina laevigata group	1.37	3.73	2.49	4	8.99
Cribrostomoides subglobosum	0.25	2.6	2.41	3.87	12.86
Cibicides refulgens	2.25	0	2.29	3.66	16.52
Cibicidoides pachyderma	3.41	1.25	2.18	3.49	20.02
Reophax scorpiurus	0.25	2.34	2.17	3.48	23.5
Uvigerina peregrina	1.94	0.15	1.93	3.09	26.59
Fontbotia wuellerstorfi	0	1.7	1.75	2.81	29.4
Angulogerina angulosa	3.67	2.04	1.73	2.77	32.16
Melonis barleeanum	1.96	3.17	1.61	2.58	34.75
Hyalinea balthica	1.56	0	1.61	2.58	37.32
Cibicidoides kullenbergi	1.53	0	1.59	2.55	39.87
Discanomalina coronata	1.49	0	1.47	2.35	42.22
Epistominella exigua	1.29	2.61	1.37	2.2	44.42
Cibicidoides sp.	1.17	0	1.18	1.9	46.32
Globocassidulina subglobosa group	2.34	3.41	1.11	1.78	48.1
Cassidulina carinata	1.49	0.88	1.09	1.74	49.84
Hanzawaia boueana	1.17	0.26	1.08	1.73	51.57
Lobatula lobatula	1.62	0.82	1.05	1.69	53.26
Hormonisella guttifera	0	0.85	0.87	1.39	54.65
Pullenia quinqueloba	0.34	1.01	0.82	1.31	55.96
Rhabdammina abyssorum	0.15	0.92	0.8	1.28	57.24
Epistominella vitrea	2.66	1.94	0.78	1.26	58.49
Pullenia quadriloba	0.39	0.87	0.76	1.22	59.71
Sacchorhiza ramosa	0.46	0.46	0.76	1.21	60.93
Paratrochammina challengeri	0.3	1.01	0.73	1.17	62.09
Planulina ariminensis	0.62	0	0.63	1.02	63.11
Adercotryma wrightii	0.08	0.62	0.6	0.95	64.06
Pullenia osloensis	0.69	0.19	0.57	0.91	64.97
Stainforthia fusiformis	0	0.55	0.55	0.88	65.85
Pullenia subcarinata	0.7	0.48	0.55	0.88	66.73
Nonionella iridea	0.58	0.82	0.54	0.86	67.6
Sigmoilopsis schlumbergeri	0.52	0	0.54	0.86	68.46
Pelosina cylindrica	0.12	0.5	0.54	0.86	69.31
Cibicides ungerianus	0.56	0.19	0.51	0.82	70.13
Trochammina inflata	0.44	0.32	0.48	0.77	70.9
Sphaeroidina bulloides	0.46	0	0.48	0.77	71.67
Bulimina marginata	0.54	0.17	0.48	0.76	72.44
Gavelinopsis spp.	0.39	0.25	0.45	0.72	73.15
Nonionella turgida	0.47	0.39	0.44	0.71	73.87
Spiroplectinella wrightii	0.45	0	0.43	0.69	74.56
Uvigerina mediterranea	0.39	0	0.43	0.69	75.24
Pullenia bulloides	0.51	0.42	0.43	0.68	75.93
Hyrrokkin sarcophaga	0.43	0	0.42	0.67	76.59
Cycloforina angularis	0	0.41	0.41	0.66	77.26
Astrononion gallowayi	0.63	0.44	0.41	0.66	77.91
Melonis pompilioides	0.39	0	0.4	0.64	78.56
Oridorsalis umbonatus	0.14	0.33	0.38	0.6	79.16
Haplofragmoides membranaceum	0.36	0	0.36	0.57	79.73
Cibicides/Cibicidoides juv	0.28	0.15	0.35	0.56	80.29
Quinqueloculina lamarckiana	0.31	0.19	0.34	0.54	80.83

			Average dissimilarity = 55.74		
	Cluster I	**Cluster II**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	6.99	1.7	6.64	11.91	11.91
Cassidulina laevigata group	0.63	3.73	3.89	6.97	18.88
Melonis barleeanum	0.28	3.17	3.61	6.47	25.36
Reophax difflugiformis	0.2	3.08	3.56	6.39	31.75
Cribrostomoides subglobosum	4.74	2.6	2.62	4.7	36.45
Pyrgo sarsi	2.04	0	2.61	4.68	41.14
Globocassidulina subglobosa group	1.49	3.41	2.45	4.4	45.54
Reophax scorpiurus	0.45	2.34	2.42	4.34	49.88
Angulogerina angulosa	0.4	2.04	2.07	3.71	53.59
Oridorsalis umbonatus	1.47	0.33	1.43	2.56	56.15

Table 3.6 (continued)

Cibicidoides pachyderma	0.2	1.25	1.32	2.37	58.52
Epistominella vitrea	1.05	1.94	1.11	2	60.52
Pullenia quadriloba	0	0.87	1.08	1.93	62.45
Cassidulina carinata	0.8	0.88	1.04	1.86	64.31
Paratrochammina challengeri	0.4	1.01	0.86	1.54	65.85
Gyroidinoides laevigatus	0.69	0	0.82	1.47	67.31
Epistominella exigua	2.35	2.61	0.8	1.43	68.75
Pullenia quinqueloba	0.4	1.01	0.77	1.39	70.14
Adercotryma wrightii	0	0.62	0.77	1.38	71.51
Botellina labyrinthica	0.56	0	0.67	1.2	72.71
Pelosina cylindrica	0	0.5	0.6	1.08	73.79
Stainforthia fusiformis	0.28	0.55	0.59	1.05	74.84
Sacchorhiza ramosa	0	0.46	0.56	1	75.84
Hormonisella guttifera	0.73	0.85	0.54	0.97	76.81
Nonionella turgida	0	0.39	0.49	0.89	77.69
Cycloforina angularis	0.8	0.41	0.49	0.89	78.58
Hormosina globulifera	0.4	0.17	0.48	0.87	79.45
Astrononion gallowayi	0.2	0.44	0.47	0.83	80.28

			Average dissimilarity = 52.29		
	Cluster VI	**Cluster IV**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Discanomalina coronata	2.93	0.22	2.67	5.1	5.1
Bulimina marginata	0.05	2.44	2.28	4.36	9.46
Melonis pompilioides	0.53	2.91	2.28	4.35	13.81
Cibicidoides pachyderma	4.57	3.05	1.67	3.19	17
Hyalinea balthica	0.54	1.81	1.43	2.74	19.74
Globocassidulina subglobosa group	2.6	1.09	1.42	2.72	22.46
Cibicides refulgens	2.56	1.87	1.33	2.54	25
Lobatula lobatula	2.81	3.65	1.14	2.18	27.18
Cassidulina carinata	0.63	1.39	1.02	1.96	29.14
Angulogerina angulosa	2.15	1.4	0.95	1.82	30.96
Epistominella vitrea	1.14	0.26	0.9	1.73	32.69
Cassidulina laevigata group	1.81	2.22	0.88	1.68	34.37
Eggerelloides scaber	0.04	0.93	0.86	1.64	36
Adercotryma wrightii	0.12	0.97	0.85	1.63	37.64
Cibicides/Cibicidoides juv	1.01	0.37	0.83	1.59	39.22
Epistominella exigua	0.89	1.54	0.76	1.45	40.67
Pullenia osloensis	0.82	0.84	0.76	1.44	42.11
Textularia truncata	0	0.76	0.72	1.37	43.48
Textularia tenuissima	0.04	0.77	0.71	1.37	44.85
Spiroplectinella wrightii	0.4	1.11	0.7	1.34	46.19
Melonis barleeanum	1.66	2.29	0.69	1.31	47.5
Hanzawaia boueana	0.83	0.76	0.67	1.29	48.79
Hanzawaia concentrica	0.65	0.71	0.67	1.28	50.07
Cibicidoides sp.	1.7	1.46	0.66	1.27	51.34
Hopkinsina atlantica	0	0.7	0.66	1.27	52.61
Bolivina spp.	0.73	1.06	0.66	1.27	53.88
Astrononion gallowayi	1.38	1.4	0.65	1.25	55.13
Cribrostomoides jeffreysii	0.33	0.69	0.64	1.23	56.36
Elphidium frigidum	0.08	0.69	0.64	1.22	57.58
Fissurina spp.	1.16	0.86	0.63	1.2	58.78
Uvigerina peregrina	0.25	0.66	0.63	1.2	59.98
Stainforthia fusiformis	0.1	0.71	0.62	1.18	61.16
Miliolinella subrotunda	0.74	0.2	0.61	1.17	62.33
Nonionella iridea	0.72	1.33	0.59	1.14	63.47
Discorbinella bertheloti	0.72	0.68	0.59	1.12	64.59
Bigenerina cylindrica	0	0.61	0.58	1.12	65.71
Quinqueloculina seminula	0.09	0.66	0.55	1.05	66.75
Cibicides ungerianus	0.58	0.1	0.53	1.02	67.77
Patellina corrugata	0.67	0.33	0.53	1.01	68.79
Gavelinopsis spp.	1.13	1.37	0.53	1	69.79
Pullenia subcarinata	0.26	0.54	0.51	0.97	70.76
Globobulimina affinis	0.17	0.63	0.51	0.97	71.73
Quinqueloculina viennensis	0.47	0.27	0.44	0.84	72.57
Trochammina robertsoni	0.05	0.46	0.44	0.83	73.4
Elphidium clavatum	0.26	0.3	0.41	0.78	74.19
Trochammina inflata	0.04	0.43	0.4	0.76	74.94

Table 3.6 (continued)

Favulina spp.	0.27	0.4	0.34	0.65	75.6
Robertinoides spp.	0.13	0.37	0.33	0.64	76.23
Nonionella labradorica	0.37	0.25	0.33	0.64	76.87
Paratrochammina challengeri	0.04	0.33	0.3	0.58	77.45
Rosalina globularis	0.21	0.2	0.3	0.58	78.03
Sigmoilopsis schlumbergeri	0	0.32	0.3	0.58	78.61
Lenticulina inornata	0.07	0.31	0.28	0.54	79.14
Reophax difflugiformis	0.2	0.26	0.28	0.53	79.68
Nonionella turgida	0.11	0.26	0.28	0.53	80.21
Homalohedra apiopleura	0.17	0.26	0.28	0.53	80.74
Recurvoides trochamminiformis	0.14	0.21	0.27	0.52	81.26
Quinqueloculina lamarckiana	0.18	0.21	0.27	0.51	81.78
Verneulina propinqua	0.24	0.12	0.26	0.49	82.27
Reophax scorpiurus	0.12	0.21	0.25	0.48	82.75
Parafissurina spp.	0.25	0	0.24	0.46	83.21
Cibicidoides kullenbergi	0.2	0.12	0.24	0.45	83.66
Pyrgo elongata	0.23	0.1	0.23	0.43	84.09
Labrospira crassimargo	0.04	0.22	0.23	0.43	84.53
Textularia pseudogramen	0	0.23	0.22	0.42	84.95
Stainforthia schreibersiana	0.08	0.21	0.21	0.4	85.35
Hyrrokkin sarcophaga	0.04	0.21	0.21	0.4	85.75
Spirillina vivipara	0.22	0	0.21	0.39	86.14
Cycloforina stalkeri	0	0.21	0.2	0.39	86.53
Pullenia quinqueloba	0.22	0	0.2	0.38	86.91
Elphidium incertum	0.12	0.12	0.2	0.38	87.29
Biloculinella globula	0.21	0	0.2	0.38	87.67
Protelphidium anglicum	0	0.21	0.2	0.37	88.04
Bigenerina nodosaria	0	0.2	0.19	0.36	88.4
Homalohedra borealis	0.15	0.1	0.19	0.36	88.76
Bulimina aculeata	0.04	0.16	0.18	0.34	89.09
Gyroidinoides laevigatus	0.04	0.16	0.18	0.34	89.43
Lenticulina gibba	0.04	0.15	0.16	0.31	89.73
Quinqueloculina cuvieriana	0.09	0.12	0.16	0.3	90.04

Average dissimilarity = 55.79

	Cluster V	**Cluster IV**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Melonis pompilioides	0.39	2.91	2.28	4.09	4.09
Epistominella vitrea	2.66	0.26	2.17	3.89	7.98
Angulogerina angulosa	3.67	1.4	2.06	3.7	11.68
Lobatula lobatula	1.62	3.65	1.85	3.31	15
Bulimina marginata	0.54	2.44	1.74	3.11	18.11
Uvigerina peregrina	1.94	0.66	1.4	2.51	20.62
Cibicidoides kullenbergi	1.53	0.12	1.31	2.35	22.97
Cassidulina laevigata group	1.37	2.22	1.21	2.17	25.14
Discanomalina coronata	1.49	0.22	1.17	2.11	27.24
Globocassidulina subglobosa group	2.34	1.09	1.17	2.1	29.34
Cibicidoides pachyderma	3.41	3.05	0.97	1.74	31.08
Gavelinopsis spp.	0.39	1.37	0.96	1.72	32.8
Eggerelloides scaber	0	0.93	0.84	1.5	34.3
Bolivina spp.	0.27	1.06	0.83	1.48	35.78
Cibicides refulgens	2.25	1.87	0.82	1.47	37.26
Adercotryma wrightii	0.08	0.97	0.82	1.47	38.73
Hanzawaia boueana	1.17	0.76	0.78	1.41	40.14
Cassidulina carinata	1.49	1.39	0.78	1.39	41.53
Hyalinea balthica	1.56	1.81	0.76	1.37	42.9
Nonionella iridea	0.58	1.33	0.73	1.31	44.21
Astrononion gallowayi	0.63	1.4	0.72	1.29	45.49
Textularia tenuissima	0	0.77	0.7	1.26	46.75
Textularia truncata	0	0.76	0.69	1.23	47.99
Cibicidoides sp.	1.17	1.46	0.68	1.22	49.2
Melonis barleeanum	1.96	2.29	0.66	1.19	50.4
Pullenia osloensis	0.69	0.84	0.65	1.17	51.57
Stainforthia fusiformis	0	0.71	0.64	1.15	52.72
Hopkinsina atlantica	0	0.7	0.64	1.14	53.86
Discorbinella bertheloti	0.21	0.68	0.63	1.13	54.99
Spiroplectinella wrightii	0.45	1.11	0.63	1.13	56.11
Hanzawaia concentrica	0.16	0.71	0.62	1.12	57.23

Table 3.6 (continued)

Cribrostomoides jeffreysii	0.06	0.69	0.61	1.1	58.33
Elphidium frigidum	0.32	0.69	0.61	1.09	59.42
Quinqueloculina seminula	0	0.66	0.6	1.08	60.49
Epistominella exigua	1.29	1.54	0.56	1.01	61.5
Bigenerina cylindrica	0	0.61	0.56	1	62.5
Pullenia subcarinata	0.7	0.54	0.54	0.97	63.47
Globobulimina affinis	0.06	0.63	0.53	0.95	64.42
Planulina ariminensis	0.62	0.11	0.52	0.94	65.36
Cibicides ungerianus	0.56	0.1	0.48	0.86	66.22
Pullenia bulloides	0.51	0	0.47	0.84	67.06
Sigmoilopsis schlumbergeri	0.52	0.32	0.44	0.79	67.85
Fissurina spp.	0.91	0.86	0.43	0.77	68.62
Sphaeroidina bulloides	0.46	0	0.43	0.76	69.38
Cibicides/Cibicidoides juv	0.28	0.37	0.43	0.76	70.15
Sacchorhiza ramosa	0.46	0	0.42	0.75	70.9
Trochammina robertsoni	0.06	0.46	0.42	0.74	71.64
Nonionella turgida	0.47	0.26	0.41	0.74	72.38
Trochammina inflata	0.44	0.43	0.41	0.73	73.11
Uvigerina mediterranea	0.39	0	0.38	0.68	73.79
Reophax scorpiurus	0.25	0.21	0.36	0.65	74.44
Quinqueloculina viennensis	0.29	0.27	0.36	0.65	75.09
Hyrrokkin sarcophaga	0.43	0.21	0.36	0.65	75.74
Pullenia quadriloba	0.39	0	0.35	0.63	76.37
Rosalina globularis	0.29	0.2	0.34	0.61	76.98
Gyroidinoides laevigatus	0.31	0.16	0.34	0.61	77.59
Favulina spp.	0.33	0.4	0.33	0.59	78.18
Robertinoides spp.	0.17	0.37	0.33	0.59	78.77
Miliolinella subrotunda	0.29	0.2	0.33	0.59	79.37
Patellina corrugata	0.16	0.33	0.33	0.59	79.96
Haplofragmoides membranaceum	0.36	0	0.32	0.57	80.53

Average dissimilarity = 80.66

Species	**Cluster I Av.Abund**	**Cluster IV Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	6.99	0	7.65	9.48	9.48
Cribrostomoides subglobosum	4.74	0	5.13	6.36	15.84
Melonis pompilioides	0	2.91	3.16	3.92	19.76
Cibicidoides pachyderma	0.2	3.05	3.13	3.88	23.64
Lobatula lobatula	1.01	3.65	2.86	3.55	27.18
Bulimina marginata	0.2	2.44	2.45	3.03	30.22
Pyrgo sarsi	2.04	0	2.26	2.81	33.02
Melonis barleeanum	0.28	2.29	2.21	2.73	35.76
Hyalinea balthica	0	1.81	1.99	2.47	38.22
Cibicides refulgens	0.2	1.87	1.83	2.27	40.49
Cassidulina laevigata group	0.63	2.22	1.74	2.15	42.65
Oridorsalis umbonatus	1.47	0	1.6	1.98	44.63
Cibicidoides sp.	0	1.46	1.59	1.97	46.6
Gavelinopsis spp.	0	1.37	1.48	1.84	48.43
Astrononion gallowayi	0.2	1.4	1.3	1.61	50.05
Spiroplectinella wrightii	0	1.11	1.2	1.49	51.53
Bolivina spp.	0	1.06	1.16	1.44	52.98
Angulogerina angulosa	0.4	1.4	1.12	1.39	54.36
Adercotryma wrightii	0	0.97	1.04	1.29	55.65
Rhabdammina abyssorum	0.94	0	1.01	1.26	56.91
Eggerelloides scaber	0	0.93	1	1.24	58.15
Cassidulina carinata	0.8	1.39	0.93	1.15	59.3
Epistominella exigua	2.35	1.54	0.92	1.14	60.44
Nonionella iridea	0.48	1.33	0.91	1.13	61.57
Pullenia osloensis	0	0.84	0.91	1.12	62.69
Cycloforina angularis	0.8	0	0.87	1.08	63.77
Epistominella vitrea	1.05	0.26	0.86	1.07	64.84
Textularia tenuissima	0	0.77	0.84	1.05	65.89
Hanzawaia boueana	0	0.76	0.82	1.02	66.91
Textularia truncata	0	0.76	0.82	1.02	67.94
Globocassidulina subglobosa group	1.49	1.09	0.79	0.98	68.91
Hormonisella guttifera	0.73	0	0.78	0.97	69.88
Hanzawaia concentrica	0	0.71	0.77	0.95	70.84
Hopkinsina atlantica	0	0.7	0.76	0.95	71.78

Table 3.6 (continued)

Cribrostomoides jeffreysii	0	0.69	0.75	0.93	72.71
Discorbinella bertheloti	0	0.68	0.74	0.92	73.63
Gyroidinoides laevigatus	0.69	0.16	0.72	0.9	74.53
Uvigerina peregrina	0	0.66	0.72	0.9	75.43
Quinqueloculina seminula	0	0.66	0.72	0.89	76.32
Elphidium frigidum	0.28	0.69	0.68	0.85	77.16
Globobulimina affinis	0	0.63	0.68	0.84	78
Bigenerina cylindrica	0	0.61	0.67	0.83	78.84
Stainforthia fusiformis	0.28	0.71	0.59	0.73	79.57
Botellina labyrinthica	0.56	0	0.58	0.72	80.29
Trochammina robertsoni	0	0.46	0.51	0.64	80.93

			Average dissimilarity = 68.04		
	Cluster II	**Cluster IV**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Melonis pompilioides	0	2.91	2.8	4.11	4.11
Lobatula lobatula	0.82	3.65	2.71	3.99	8.1
Reophax difflugiformis	3.08	0.26	2.7	3.97	12.07
Cribrostomoides subglobosum	2.6	0	2.51	3.69	15.76
Globocassidulina subglobosa group	3.41	1.09	2.25	3.3	19.06
Bulimina marginata	0.17	2.44	2.19	3.23	22.28
Reophax scorpiurus	2.34	0.21	2.06	3.03	25.31
Cibicides refulgens	0	1.87	1.8	2.65	27.96
Cibicidoides pachyderma	1.25	3.05	1.76	2.58	30.54
Hyalinea balthica	0	1.81	1.76	2.58	33.13
Fontbotia wuellerstorfi	1.7	0	1.66	2.43	35.56
Epistominella vitrea	1.94	0.26	1.62	2.38	37.94
Cassidulina laevigata group	3.73	2.22	1.45	2.13	40.08
Cibicidoides sp.	0	1.46	1.4	2.06	42.14
Melonis barleeanum	3.17	2.29	1.37	2.01	44.15
Gavelinopsis spp.	0.25	1.37	1.09	1.6	45.75
Spiroplectinella wrightii	0	1.11	1.06	1.56	47.31
Epistominella exigua	2.61	1.54	1.03	1.52	48.83
Bolivina spp.	0	1.06	1.03	1.51	50.34
Cassidulina carinata	0.88	1.39	1.03	1.51	51.85
Pullenia quinqueloba	1.01	0	0.98	1.44	53.29
Astrononion gallowayi	0.44	1.4	0.92	1.35	54.64
Eggerelloides scaber	0	0.93	0.89	1.31	55.94
Rhabdammina abyssorum	0.92	0	0.89	1.31	57.25
Pullenia quadriloba	0.87	0	0.83	1.22	58.47
Hormonisella guttifera	0.85	0	0.82	1.21	59.68
Angulogerina angulosa	2.04	1.4	0.79	1.16	60.83
Pullenia osloensis	0.19	0.84	0.77	1.13	61.96
Textularia tenuissima	0	0.77	0.75	1.1	63.06
Textularia truncata	0	0.76	0.73	1.07	64.13
Hanzawaia concentrica	0	0.71	0.68	1	65.13
Hanzawaia boueana	0.26	0.76	0.68	1	66.12
Adercotryma wrightii	0.62	0.97	0.66	0.97	67.1
Cribrostomoides jeffreysii	0	0.69	0.66	0.97	68.07
Elphidium frigidum	0	0.69	0.66	0.97	69.04
Discorbinella bertheloti	0	0.68	0.66	0.97	70.01
Paratrochammina challengeri	1.01	0.33	0.65	0.96	70.96
Quinqueloculina seminula	0	0.66	0.64	0.94	71.9
Bigenerina cylindrica	0	0.61	0.59	0.87	72.77
Hopkinsina atlantica	0.19	0.7	0.57	0.83	73.61
Uvigerina peregrina	0.15	0.66	0.55	0.81	74.42
Nonionella iridea	0.82	1.33	0.53	0.78	75.2
Stainforthia fusiformis	0.55	0.71	0.52	0.76	75.96
Globobulimina affinis	0.17	0.63	0.5	0.74	76.7
Pullenia subcarinata	0.48	0.54	0.47	0.69	77.39
Pelosina cylindrica	0.5	0	0.47	0.69	78.07
Trochammina robertsoni	0	0.46	0.45	0.67	78.74
Trochammina inflata	0.32	0.43	0.45	0.66	79.4
Sacchorhiza ramosa	0.46	0	0.43	0.64	80.04

Table 3.6 (continued)

Cribrostomoides jeffreysii	0.06	0.69	0.61	1.1	58.33
Elphidium frigidum	0.32	0.69	0.61	1.09	59.42
Quinqueloculina seminula	0	0.66	0.6	1.08	60.49
Epistominella exigua	1.29	1.54	0.56	1.01	61.5
Bigenerina cylindrica	0	0.61	0.56	1	62.5
Pullenia subcarinata	0.7	0.54	0.54	0.97	63.47
Globobulimina affinis	0.06	0.63	0.53	0.95	64.42
Planulina ariminensis	0.62	0.11	0.52	0.94	65.36
Cibicides ungerianus	0.56	0.1	0.48	0.86	66.22
Pullenia bulloides	0.51	0	0.47	0.84	67.06
Sigmoilopsis schlumbergeri	0.52	0.32	0.44	0.79	67.85
Fissurina spp.	0.91	0.86	0.43	0.77	68.62
Sphaeroidina bulloides	0.46	0	0.43	0.76	69.38
Cibicides/Cibicidoides juv	0.28	0.37	0.43	0.76	70.15
Sacchorhiza ramosa	0.46	0	0.42	0.75	70.9
Trochammina robertsoni	0.06	0.46	0.42	0.74	71.64
Nonionella turgida	0.47	0.26	0.41	0.74	72.38
Trochammina inflata	0.44	0.43	0.41	0.73	73.11
Uvigerina mediterranea	0.39	0	0.38	0.68	73.79
Reophax scorpiurus	0.25	0.21	0.36	0.65	74.44
Quinqueloculina viennensis	0.29	0.27	0.36	0.65	75.09
Hyrrokkin sarcophaga	0.43	0.21	0.36	0.65	75.74
Pullenia quadriloba	0.39	0	0.35	0.63	76.37
Rosalina globularis	0.29	0.2	0.34	0.61	76.98
Gyroidinoides laevigatus	0.31	0.16	0.34	0.61	77.59
Favulina spp.	0.33	0.4	0.33	0.59	78.18
Robertinoides spp.	0.17	0.37	0.33	0.59	78.77
Miliolinella subrotunda	0.29	0.2	0.33	0.59	79.37
Patellina corrugata	0.16	0.33	0.33	0.59	79.96
Haplofragmoides membranaceum	0.36	0	0.32	0.57	80.53

Average dissimilarity = 80.66

	Cluster I	**Cluster IV**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	6.99	0	7.65	9.48	9.48
Cribrostomoides subglobosum	4.74	0	5.13	6.36	15.84
Melonis pompilioides	0	2.91	3.16	3.92	19.76
Cibicidoides pachyderma	0.2	3.05	3.13	3.88	23.64
Lobatula lobatula	1.01	3.65	2.86	3.55	27.18
Bulimina marginata	0.2	2.44	2.45	3.03	30.22
Pyrgo sarsi	2.04	0	2.26	2.81	33.02
Melonis barleeanum	0.28	2.29	2.21	2.73	35.76
Hyalinea balthica	0	1.81	1.99	2.47	38.22
Cibicides refulgens	0.2	1.87	1.83	2.27	40.49
Cassidulina laevigata group	0.63	2.22	1.74	2.15	42.65
Oridorsalis umbonatus	1.47	0	1.6	1.98	44.63
Cibicidoides sp.	0	1.46	1.59	1.97	46.6
Gavelinopsis spp.	0	1.37	1.48	1.84	48.43
Astrononion gallowayi	0.2	1.4	1.3	1.61	50.05
Spiroplectinella wrightii	0	1.11	1.2	1.49	51.53
Bolivina spp.	0	1.06	1.16	1.44	52.98
Angulogerina angulosa	0.4	1.4	1.12	1.39	54.36
Adercotryma wrightii	0	0.97	1.04	1.29	55.65
Rhabdammina abyssorum	0.94	0	1.01	1.26	56.91
Eggerelloides scaber	0	0.93	1	1.24	58.15
Cassidulina carinata	0.8	1.39	0.93	1.15	59.3
Epistominella exigua	2.35	1.54	0.92	1.14	60.44
Nonionella iridea	0.48	1.33	0.91	1.13	61.57
Pullenia osloensis	0	0.84	0.91	1.12	62.69
Cycloforina angularis	0.8	0	0.87	1.08	63.77
Epistominella vitrea	1.05	0.26	0.86	1.07	64.84
Textularia tenuissima	0	0.77	0.84	1.05	65.89
Hanzawaia boueana	0	0.76	0.82	1.02	66.91
Textularia truncata	0	0.76	0.82	1.02	67.94
Globocassidulina subglobosa group	1.49	1.09	0.79	0.98	68.91
Hormonisella guttifera	0.73	0	0.78	0.97	69.88
Hanzawaia concentrica	0	0.71	0.77	0.95	70.84
Hopkinsina atlantica	0	0.7	0.76	0.95	71.78

Table 3.6 (continued)

Cribrostomoides jeffreysii	0.06	0.69	0.61	1.1	58.33
Elphidium frigidum	0.32	0.69	0.61	1.09	59.42
Quinqueloculina seminula	0	0.66	0.6	1.08	60.49
Epistominella exigua	1.29	1.54	0.56	1.01	61.5
Bigenerina cylindrica	0	0.61	0.56	1	62.5
Pullenia subcarinata	0.7	0.54	0.54	0.97	63.47
Globobulimina affinis	0.06	0.63	0.53	0.95	64.42
Planulina ariminensis	0.62	0.11	0.52	0.94	65.36
Cibicides ungerianus	0.56	0.1	0.48	0.86	66.22
Pullenia bulloides	0.51	0	0.47	0.84	67.06
Sigmoilopsis schlumbergeri	0.52	0.32	0.44	0.79	67.85
Fissurina spp.	0.91	0.86	0.43	0.77	68.62
Sphaeroidina bulloides	0.46	0	0.43	0.76	69.38
Cibicides/Cibicidoides juv	0.28	0.37	0.43	0.76	70.15
Sacchorhiza ramosa	0.46	0	0.42	0.75	70.9
Trochammina robertsoni	0.06	0.46	0.42	0.74	71.64
Nonionella turgida	0.47	0.26	0.41	0.74	72.38
Trochammina inflata	0.44	0.43	0.41	0.73	73.11
Uvigerina mediterranea	0.39	0	0.38	0.68	73.79
Reophax scorpiurus	0.25	0.21	0.36	0.65	74.44
Quinqueloculina viennensis	0.29	0.27	0.36	0.65	75.09
Hyrrokkin sarcophaga	0.43	0.21	0.36	0.65	75.74
Pullenia quadriloba	0.39	0	0.35	0.63	76.37
Rosalina globularis	0.29	0.2	0.34	0.61	76.98
Gyroidinoides laevigatus	0.31	0.16	0.34	0.61	77.59
Favulina spp.	0.33	0.4	0.33	0.59	78.18
Robertinoides spp.	0.17	0.37	0.33	0.59	78.77
Miliolinella subrotunda	0.29	0.2	0.33	0.59	79.37
Patellina corrugata	0.16	0.33	0.33	0.59	79.96
Haplofragmoides membranaceum	0.36	0	0.32	0.57	80.53

			Average dissimilarity = 80.66		
	Cluster I	**Cluster IV**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Fontbotia wuellerstorfi	6.99	0	7.65	9.48	9.48
Cribrostomoides subglobosum	4.74	0	5.13	6.36	15.84
Melonis pompilioides	0	2.91	3.16	3.92	19.76
Cibicidoides pachyderma	0.2	3.05	3.13	3.88	23.64
Lobatula lobatula	1.01	3.65	2.86	3.55	27.18
Bulimina marginata	0.2	2.44	2.45	3.03	30.22
Pyrgo sarsi	2.04	0	2.26	2.81	33.02
Melonis barleeanum	0.28	2.29	2.21	2.73	35.76
Hyalinea balthica	0	1.81	1.99	2.47	38.22
Cibicides refulgens	0.2	1.87	1.83	2.27	40.49
Cassidulina laevigata group	0.63	2.22	1.74	2.15	42.65
Oridorsalis umbonatus	1.47	0	1.6	1.98	44.63
Cibicidoides sp.	0	1.46	1.59	1.97	46.6
Gavelinopsis spp.	0	1.37	1.48	1.84	48.43
Astrononion gallowayi	0.2	1.4	1.3	1.61	50.05
Spiroplectinella wrightii	0	1.11	1.2	1.49	51.53
Bolivina spp.	0	1.06	1.16	1.44	52.98
Angulogerina angulosa	0.4	1.4	1.12	1.39	54.36
Adercotryma wrightii	0	0.97	1.04	1.29	55.65
Rhabdammina abyssorum	0.94	0	1.01	1.26	56.91
Eggerelloides scaber	0	0.93	1	1.24	58.15
Cassidulina carinata	0.8	1.39	0.93	1.15	59.3
Epistominella exigua	2.35	1.54	0.92	1.14	60.44
Nonionella iridea	0.48	1.33	0.91	1.13	61.57
Pullenia osloensis	0	0.84	0.91	1.12	62.69
Cycloforina angularis	0.8	0	0.87	1.08	63.77
Epistominella vitrea	1.05	0.26	0.86	1.07	64.84
Textularia tenuissima	0	0.77	0.84	1.05	65.89
Hanzawaia boueana	0	0.76	0.82	1.02	66.91
Textularia truncata	0	0.76	0.82	1.02	67.94
Globocassidulina subglobosa group	1.49	1.09	0.79	0.98	68.91
Hormonisella guttifera	0.73	0	0.78	0.97	69.88
Hanzawaia concentrica	0	0.71	0.77	0.95	70.84
Hopkinsina atlantica	0	0.7	0.76	0.95	71.78

Table 3.6 (continued)

Average dissimilarity = 73.75

	Cluster II	**Cluster III**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Globobulimina affinis	0.17	4.53	4.63	6.27	6.27
Globocassidulina subglobosa group	3.41	0.28	3.33	4.51	10.79
Reophax difflugiformis	3.08	0	3.24	4.4	15.19
Hyalinea balthica	0	2.73	2.92	3.95	19.14
Eggerelloides scaber	0	2.52	2.67	3.62	22.76
Textularia tenuissima	0	2.12	2.24	3.03	25.79
Cassidulina laevigata group	3.73	1.69	2.16	2.93	28.72
Bolivina spp.	0	1.98	2.12	2.87	31.59
Bigenerina cylindrica	0	1.99	2.1	2.85	34.44
Cribrostomoides subglobosum	2.6	0.66	2.07	2.81	37.24
Reophax scorpiurus	2.34	0.44	2.04	2.76	40.01
Pullenia subcarinata	0.48	2.1	2.04	2.76	42.77
Melonis pompilioides	0	1.9	1.99	2.7	45.47
Epistominella exigua	2.61	0.84	1.87	2.54	48.01
Angulogerina angulosa	2.04	0.28	1.86	2.53	50.54
Fontbotia wuellerstorfi	1.7	0	1.83	2.48	53.01
Epistominella vitrea	1.94	0.28	1.77	2.4	55.41
Melonis barleeanum	3.17	1.7	1.73	2.34	57.76
Bulimina marginata	0.17	1.78	1.71	2.31	60.07
Hopkinsina atlantica	0.19	1.55	1.56	2.12	62.19
Cassidulina carinata	0.88	2	1.55	2.1	64.29
Uvigerina peregrina	0.15	1.44	1.35	1.84	66.13
Trochammina robertsoni	0	1.14	1.2	1.63	67.76
Pullenia quinqueloba	1.01	0	1.08	1.46	69.22
Pullenia quadriloba	0.87	0	0.91	1.24	70.46
Hormonisella guttifera	0.85	0	0.91	1.23	71.69
Paratrochammina challengeri	1.01	0.2	0.85	1.15	72.84
Pullenia osloensis	0.19	0.79	0.84	1.14	73.98
Nonionella labradorica	0	0.78	0.82	1.12	75.1
Cibicidoides pachyderma	1.25	0.72	0.82	1.12	76.21
Stainforthia fusiformis	0.55	1.25	0.79	1.07	77.28
Nonionella iridea	0.82	0.31	0.67	0.9	78.19
Stainforthia schreibersiana	0	0.62	0.65	0.88	79.07
Elphidium frigidum	0	0.58	0.61	0.82	79.89
Adercotryma wrightii	0.62	0.53	0.55	0.75	80.64

Average dissimilarity = 56.37

	Cluster IV	**Cluster III**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Globobulimina affinis	0.63	4.53	3.68	6.53	6.53
Lobatula lobatula	3.65	0.74	2.72	4.83	11.36
Cibicidoides pachyderma	3.05	0.72	2.2	3.91	15.27
Pullenia subcarinata	0.54	2.1	1.79	3.18	18.45
Cibicides refulgens	1.87	0.25	1.52	2.69	21.14
Eggerelloides scaber	0.93	2.52	1.5	2.66	23.8
Textularia tenuissima	0.77	2.12	1.35	2.4	26.2
Bigenerina cylindrica	0.61	1.99	1.29	2.28	28.48
Melonis pompilioides	2.91	1.9	1.24	2.2	30.68
Hopkinsina atlantica	0.7	1.55	1.23	2.19	32.87
Hyalinea balthica	1.81	2.73	1.23	2.18	35.04
Cibicidoides sp.	1.46	0.18	1.2	2.13	37.17
Gavelinopsis spp.	1.37	0.12	1.17	2.08	39.25
Cassidulina carinata	1.39	2	1.13	2.01	41.26
Bolivina spp.	1.06	1.98	1.07	1.9	43.16
Angulogerina angulosa	1.4	0.28	1.07	1.89	45.05
Nonionella iridea	1.33	0.31	0.96	1.7	46.75
Bulimina marginata	2.44	1.78	0.95	1.69	48.44
Spiroplectinella wrightii	1.11	0.12	0.93	1.65	50.09
Cassidulina laevigata group	2.22	1.69	0.91	1.62	51.71
Pullenia osloensis	0.84	0.79	0.88	1.55	53.26
Globocassidulina subglobosa group	1.09	0.28	0.79	1.41	54.67
Uvigerina peregrina	0.66	1.44	0.79	1.4	56.07
Epistominella exigua	1.54	0.84	0.73	1.29	57.36
Textularia truncata	0.76	0	0.71	1.27	58.62
Hanzawaia boueana	0.76	0	0.71	1.26	59.88

Table 3.6 (continued)

Astrononion gallowayi	1.4	0.67	0.7	1.25	61.13
Adercotryma wrightii	0.97	0.53	0.67	1.19	62.32
Hanzawaia concentrica	0.71	0	0.66	1.18	63.49
Trochammina robertsoni	0.46	1.14	0.65	1.16	64.65
Fissurina spp.	0.86	0.3	0.63	1.12	65.78
Quinqueloculina seminula	0.66	0	0.62	1.1	66.88
Cribrostomoides jeffreysii	0.69	0.31	0.62	1.1	67.98
Cribrostomoides subglobosum	0	0.66	0.62	1.1	69.08
Melonis barleeanum	2.29	1.7	0.62	1.1	70.18
Discorbinella bertheloti	0.68	0.18	0.61	1.08	71.25
Stainforthia fusiformis	0.71	1.25	0.58	1.03	72.29
Elphidium frigidum	0.69	0.58	0.54	0.95	73.24
Nonionella labradorica	0.25	0.78	0.53	0.95	74.19
Rhabdammina abyssorum	0	0.56	0.52	0.91	75.1
Stainforthia schreibersiana	0.21	0.62	0.51	0.91	76.01
Nonionella turgida	0.26	0.78	0.51	0.91	76.92
Cibicides/Cibicidoides juv	0.37	0.36	0.46	0.81	77.73
Stainforthia skagerakensis	0	0.47	0.44	0.78	78.51
Cibicides ungerianus	0.1	0.48	0.43	0.77	79.27
Trochammina inflata	0.43	0	0.4	0.71	79.98
Reophax scorpiurus	0.21	0.44	0.39	0.69	80.67

patterns of depth segregation in virtually all marine basins (e.g., Mackensen et al., 1985). The reason for this partitioning is a combination of many ecological parameters such as temperature, salinity, hydrodynamics, oxygen concentration of the bottom waters, and organic matter flux (e.g., Sen Gupta, 1999; Van der Zwaan et al. 1999; Gooday, 2003; Murray, 2006) that vary with depth. Two bathymetry-controlled clusters separate at a high level of the cluster analysis (Fig. 3.5). Cluster A includes all samples from 889 to 2098 m and cluster B integrates all samples above 889 m (Fig. 3.4).

The depth distribution of the dead (unstained) benthic foraminifera in the studied samples generally corresponds to the known depth of occurrence of these species on the Norwegian slope (Mackensen et al. 1985; Fig. 3.4). *Cribrostomoides subglobosum*, *E. exigua*, *F. wuellerstorfi*, the *Globocassidulina subglobosa* group, the *C. laevigata* group, and *Epistominella vitrea* dominate the deep-water fauna (Fig. 3.4). They thrive in the cold waters of the NSDW and NSBW. Contrarily, *Cibicidoides pachyderma*, *L. lobatula*, *M. barleeanum*, *A. angulosa*, the *G. subglobosa* group, *Cibicides refulgens*, and the *C. laevigata* group dominate the shallow-water fauna. They thrive in the high bottom currents (Mackensen et al., 1985) mainly produced by internal tides (Holbrook et al., 2009). The close similarity between living (stained) and dead foraminiferal assemblages described by Mackensen et al. (1985) suggests that our assemblages also strongly represent the actual living fauna.

3.5.2.2 Characterization of “off-reef” sites

A separation between “on-reef” and “off-reef” can only be distinguished in the lower level clusters (Fig. 3.5). Six clusters separate at the 49% of the Bray-Curties Similarity. Cluster I combines all the deep-sea samples from below 1800 m water depth. The foraminiferal assemblage is dominated by *F. wuellerstorfi*, *C. subglobosum*, *Oridorsalis umbonatus*, *P. sarsi*, and *E. exigua* (Tab. 3.5; Fig. 3.4). *Fontbotia wuellerstorfi* and *C. subglobosum* live in well-ventilated waters with low organic carbon flux (Lutze and Thiel, 1989; Linke and Lutze, 1993; Mackensen et al., 1995; Gooday, 2003; Murray, 2006). *Epistominella exigua* indicates seasonal deposits of phytodetritus (Gooday, 1993; Loubere, 1998; Smart et al., 1994; Thomas et al., 1995; Thomas and Gooday, 1996; Suhr et al., 2003) caused by seasonal phytoplankton. *Oridorsalis umbonatus* is a typical species of nutrient-poor, cold, deep Atlantic waters (Belanger and Streeter, 1980; Mackensen et al., 1985; Murray et al., 1986). Therefore, this cluster is interpreted to represent nutrient-poor deep-sea environments influenced by seasonal pulses of nutrient availability.

Cluster II combines samples from the continental slope between 1800 m and 800 m water depth. The fauna is dominated by the *G. subglobosa* group, the *C. laevigata* group, *Reophax* spp., *Epistominella* spp., *M. barleeanum*, and *C. subglobosum* (Tab. 3.5; Fig. 3.4). The *G. subglobosa* group and *Epistominella* spp. are indicator species for seasonally enhanced phytodetritus fluxes. The abundance of the *C. laevigata* group, and *M. barleeanum* indicate a generally high organic carbon flux (Corliss, 1985; Gooday, 1986; Mackensen and Hald, 1988; Caralp, 1989; Murray, 2006). Therefore, this cluster is interpreted to represent environments affected by a higher background nutrient flux than

Cluster I but also showing seasonal pulses of nutrient availability.

Cluster III combines all "off-reef" samples from the Skagerrak. The fauna is dominated by *Globobulimina affinis*, *Eggerelloides scaber*, *H. balthica*, *Bigenerina cylindrica*, *Textularia tenuissima*, *Bulimina marginata, Melonis* spp., and *Bolivina* spp. These species/groups are generally found in poorly oxygenated environments (Bernhard, 1986; Sen Gupta and Machain-Castillo, 1993; Jorissen et al., 1995; Bernhard and Sen Gupta, 1999) in fine-grained sediments rich in refractory organic matter (Fontanier et al., 2002, 2005), e.g., in the Northern Skagerrak region (Corliss and Van Weering, 1993; Bergsten et al., 1996; Alve and Murray, 1997). Therefore, this cluster is interpreted to represent an environment with high organic matter (possibly refractory) flux and low oxygen levels.

3.5.2.3 Characterization of "on-reef" sites

Cluster IV combines all samples from the coral reefs in the Oslofjord. The benthic foraminiferal assemblage is dominated by *L. lobatula*, *C. pachyderma*, *Melonis* spp., *B. marginata*, the *C. laevigata* group, and *C. refulgens*. *Lobatula lobatula* and *C. refulgens* live attached to elevated substratum (Murray, 1971; Van der Zwaan, 1982; Lutze and Thiel, 1989; Kaiho, 1994, 1999; Kouwenhoven, 2000; Schönfeld, 2002; Murray, 2006) and together with *C. pachyderma*, they are interpreted to indicate high bottom currents and well-oxygenated environments. The *C. laevigata* group, *B. marginata* and *Melonis* spp. are interpreted

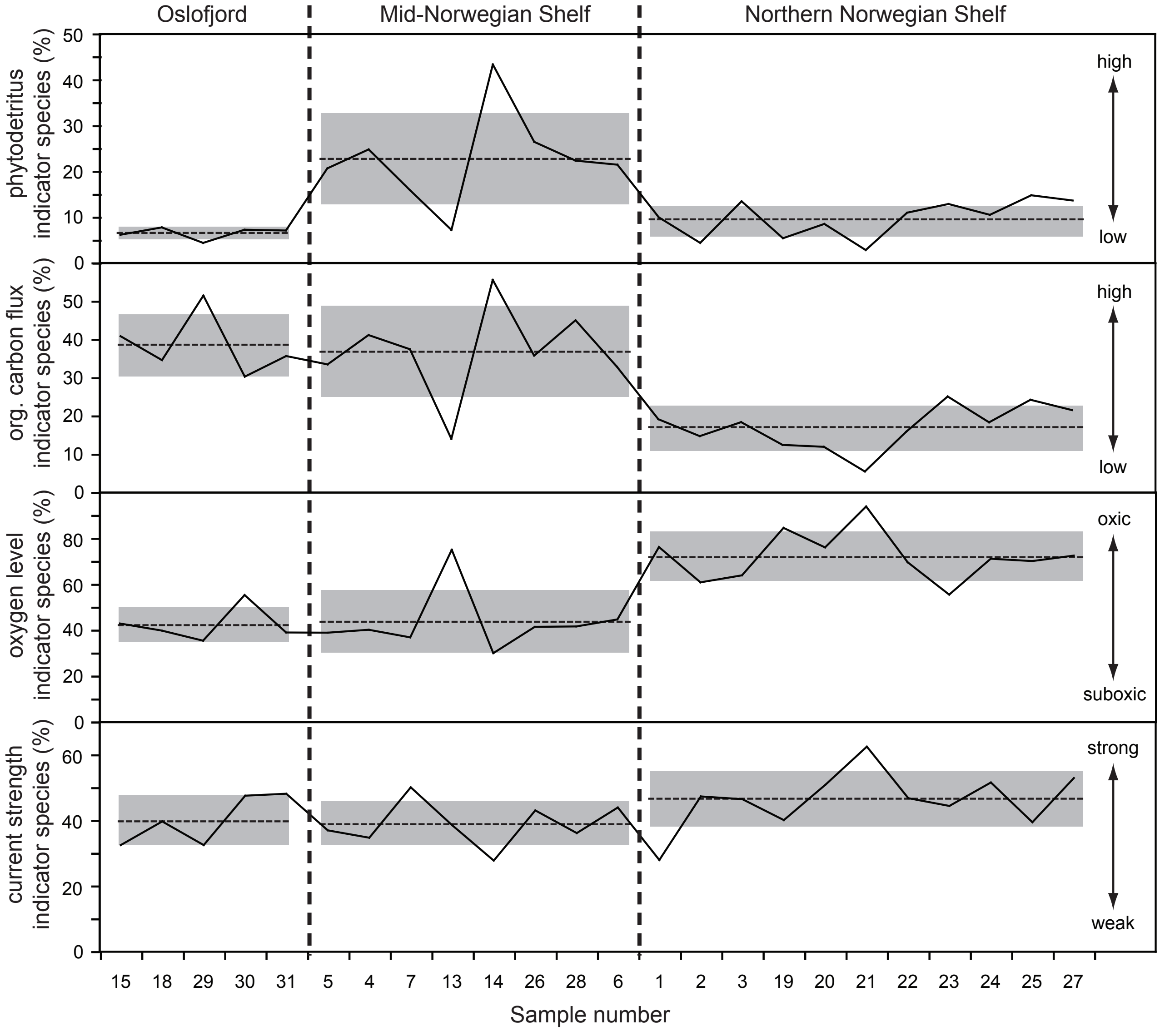

Figure 3.6 Indicator species for phytodetritus flux, organic carbon flux, oxygen level and current strength (according to Murray, 2006 and Margreth et al., 2009) for Clusters IV to VI: Oslofjord, Mid- and Northern Norwegian Shelf. Dotted line indicates the mean values with standard deviation (grey area).

to indicate an elevated organic carbon flux, with a high proportion of refractory components (e.g., Corliss, 1985; Mullins et al. 1985, Gooday, 1986; Mackensen and Hald, 1988; Mackensen et al., 1990). Therefore, this cluster should represent environments with strong bottom currents, high oxygen levels and an elevated organic carbon flux with high proportions of probably refractory components. This is also supported by the absence of phytodetritus indicator species (Fig. 3.6).

Cluster V combines the samples from the Mid Norwegian CWC-reefs. The benthic fauna is dominated by *A. angulosa*, *C. pachyderma*, *E. vitrea*, and the *G. subglobosa* group, *C. refulgens*, *M. barleeanum.* Passive suspension feeders like *C. refulgens* living epifaunal-attached on elevated substrate together with *A. angulosa* are interpreted to indicate high bottom currents (Murray 1971; Van der Zwaan 1982; Mackensen et al. 1985; Lutze and Thiel 1989; Kaiho 1994; Schönfeld, 1997, Kaiho, 1999; Kouwenhoven, 2000; Schönfeld, 2002; Murray, 2006; Margreth et al., 2009). *Epistominella vitrea* is an opportunistic species capable of responding to elevated food availability (Jorissen et al., 1992) whereas the *G. subglobosa* group is known to feed on phytodetritus (Suhr et al., 2003). The infaunal species *M. barleeanum* lives in muddy to silty sediment and is related to high levels of organic matter flux (e.g., Corliss, 1985; Gooday, 1986). Therefore, this cluster is interpreted to represent an environment characterized by strong bottom currents, elevated oxygen levels and a high flux of organic matter including phytodetritus (Fig. 3.6).

Cluster VI combines the northern Norwegian reef samples. The fauna is dominated by *C. pachyderma*, *L. lobatula*, the *G. subglobosa* group, *D. coronata*, *C. refulgens*, and *A. angulosa. Lobatula lobatula, D. coronata*, *C. refulgens* are passive suspension feeders living epifaunal-attached on elevated substratum and together with *A. angulosa* indicate strong bottom currents. The abundance of *G. subglobosa* may indicate an elevated phytodetritus flux but generally lower than on the Mid-Norwegian shelf. Therefore, this cluster is interpreted to represent strong bottom currents, high oxygen levels and a moderate organic matter flux mainly composed of seasonal pulses of phytodetritus input (Fig. 3.6).

In summary, the benthic foraminiferal assemblages indicate changes in specific environmental parameters such as bathymetry, substrate availability, current strength, oxygenation level, and quantity/quality of the organic carbon flux. The deep-sea environments below 1800 m water depth, are oligotrophic with only seasonally controlled organic matter fluxes, whereas the "off-reef" environments on the upper continental slope above 1800 m show evidence of an elevated nutrient flux to the sea floor.

"On-reef", the ecological demands of the recovered planktonic and benthic foraminiferal assemblages point to conditions of strong bottom currents, a high surface productivity and, therefore, an elevated flux of organic matter to the sediment. The ecological requirements of the benthic foraminifera from this cluster are identical with the ecological requirements of CWCs. They occur exclusively in environments characterised by strong currents (Frederiksen et al., 1992; Freiwald et al., 2002; Rüggeberg et al., 2007) and large amounts of organic matter in the form of phytoplankton detritus (Duineveld et al., 2004). The strong currents transport the food to the coral polyps and prevent them from getting buried by fine-grained sediments. The organic matter feeds the zooplankton, which is the main food source for CWCs (Mortensen, 2001; Freiwald et al., 2002).

In the Oslofjord, observations made from the submersible JAGO showed extended reef complexes, which were however, mainly composed of dead corals and coral rubble. Octocorals are generally highly abundant on CWC-reefs (Freiwald et al., 2004) but completely absent in the Skagerrak. Only relatively small patches of living *L. pertusa* were observed indicating that conditions for the growth of cold-water corals were not optimal. We suggest, that the reason for this large amount of dead corals may be the nature of the organic matter. According to Carney (1989) two types of organic matter reach the sea floor, the labile and the refractory organic matter. The refractory component mainly consists of terrestrial organic matter and the labile component mainly consist of phytodetritus. This latter is rapidly remineralised at the sediment-water interface using aerobic pathways and can be used immediately by living organisms. Although, benthic foraminiferal assemblages in this region indicates an elevated flux of organic matter to the sea floor, the very low abundance of phytodetritus-feeding species (Fig. 3.6) suggest that the labile component of the organic matter is very rare.

3.5.2.4 "On- and off-reef" diversity

Warm-water coral reefs commonly show high faunal diversity compared to "off-reef" environments (e.g., Connell, 1978, Carpenter et al., 1998). This is also in agreement with diversity studies comparing the macrofauna of cold-water coral reefs and the surrounding "off-reef" environments. Henry and

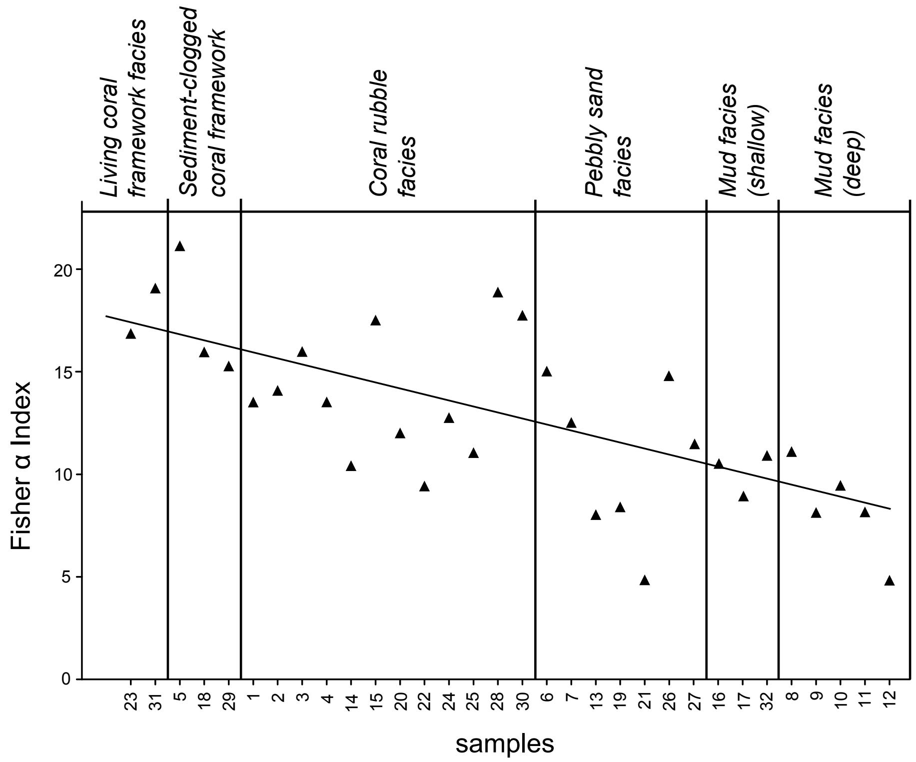

Figure 3.7 Fisher's α Diversity Index of the benthic foraminifera for the different sedimentary facies.

Roberts (2007) concluded that the high vertical habitat heterogeneity on a cold-water coral reef provides a diverse range of niches over small spatial scales that support a characteristic "reef-fauna". Langer and Lipps (2003) showed that heterogeneity of microhabitats within warm-water coral reefs are an important factor for high foraminiferal species diversity. This seems to be valid also for cold-water coral reefs where the highest foraminiferal diversity is observed "on-reef" represented by Clusters IV, V, and VI. A possible reason for the observed "on-reef" high diversity is substrate availability for epifaunal and epifaunal-attached species, which preferentially live on the skeletal framework and hard substrates whereas, infaunal species prefer baffled fine-grained sediment (Fig. 3.7).

3.5.2.5 Norwegian cold-water coral reefs versus reefs associated to carbonate mounds along the Irish margin

CWC-reefs on carbonate mounds on the Irish margin are wide spread and typically different facies are well distinct (Margreth et al., 2009). Benthic foraminifera are highly abundant and the assemblages reflect the different facies of the CWC-reefs. Uvigerinids are characteristic for "off-reef" sediments. The dropstone facies is dominated by *G. subglobosa* and *Cibicidoides* spp., whereas the *Dead Coral Facies* is characterized by *Planulina ariminensis*, *Hanzawaia boueana*, *E. vitrea*, and *A. angulosa*. For the *Living Coral Facies* the epifaunal *D. coronata*, *L. lobatula* but also highly abundant infaunal species like *Gavelinopsis* spp., *G. subglobosa*, *Bolivina* spp. are typical. The *Sandwave Facies* is dominated by epifaunal-attached species like *D. coronata*, *C. refulgens* and the epifaunal species *Sigmoilopsis schlumbergeri*, *C. pachyderma* (Margreth et al., 2009). A distinct relation of the benthic foraminiferal assemblages to a specific sedimentary facies, such as observed in the CWC-reefs associated to carbonate mounds along the Irish margin, is not well expressed in the Norwegian coral reefs.

However, the assemblage on the Norwegian reefs show a strong latitudinal gradient and are not significantly different for the "on-reef" facies 1-4 (Fig. 3.5) indicating that benthic foraminiferal habitats on Norwegian coral reefs are weakly defined and grade one into the other. The gradual changes in assemblages observed on the Norwegian margin can be attributed to the changes in reef facies that are restricted within tens of metres whereas different facies are extensive on the Irish carbonate mounds (Freiwald et al., 2002, Hühnerbach et al., 2008, Margreth et al., 2009).

However, the species and/or groups of species between the two areas show a remarkable resemblance, indicating that the ecological conditions on the CWC-reefs along the Norwegian margin are similar to the reefs associated to the carbonate mounds along the

Irish margin. A high abundance of indicator species for elevated organic matter flux conditions and strong currents can be observed in both areas. On the Irish margin these indicator species are mainly associated with living coral colonies in the central parts of the carbonate mounds (Margreth et al., 2009) along the Norwegian margin they are concentrated ”on reef”.

3.5.2.6 Benthic foraminiferal species characteristic for cold-water coral reefs

The distribution of benthic foraminiferal species depends on a variety of ecological parameters (Murray, 2006). Species for which the threshold for certain ecological parameters is constrained can be used for indicating particular conditions in paleoenvironmental reconstructions.

Rüggeberg et al. (2007) studied the evolution through time of benthic foraminifera from a CWC-reef associated with a carbonate mound in the Porcupine Seabight along the Irish margin. The assemblage was composed of reef-related forms with a high abundance of epibenthic-attached species including *D. coronata* as a dominant species. *Discanomalina coronata* has also been described from sediment samples on Pleistocene and early Holocene CWC-reefs in the Mediterranean (Remia and Taviani, 2005; Margreth et al. in review.). A more recent and focused study on surface samples from different CWC-bearing carbonate mounds found specific coral-associated assemblages along the Irish margin (Margreth et al., 2009) and *Discanomalina coronata* was identified as an indicator species for cold-water coral reefs in this region.

Similarly to the Irish margin, the occurrence of *D. coronata* along the mid and northern Norwegian margin is restricted to the living CWC-habitats. In the Oslofjord (Skagerrak), where large areas of the CWC-reefs are dead, *D. coronata* is also almost absent (Fig. 8). The co-occurrence of *D. coronata* and CWC along the Irish margin and on the Norwegian reefs indicates that their ecological and hydrographic requirements are related. Therefore, *D. coronata* is here proposed as an indicator species for living and healthy CWC also on Norwegian cold-water coral reefs.

3.6 Conclusion

Cluster analysis, nMDS and diversity studies on dead (unstained) planktonic and benthic foraminiferal assemblages along the Norwegian margin have been used to characterize the CWC ecosystems along the Norwegian margin. They revealed that the distribution of planktonic foraminiferal assemblages is related to different current systems. *Neogloboquadrina incompta*, *G. uvula*, *T. quinqueloba* and *G. bulloides* occur on the Norwegian shelf and slope, influenced by the NAC, and suggest possible seasonal phytoplankton blooms. *Globigerinita glutinata*, *T. quinqueloba*, and *G. uvula* indicated upwelling on the inner continental shelf. High similarity of the fragile planktonic foraminiferal assemblage over a depth range of more than 2000 m indicates that carbonate dissolution in the area does not affect tests. The distribution of the benthic fauna is statistically separated into six different assemblages: I) deep-sea below 1800 m water depth; II) deep-sea between 1800 and 800 m water depth; III) “off-

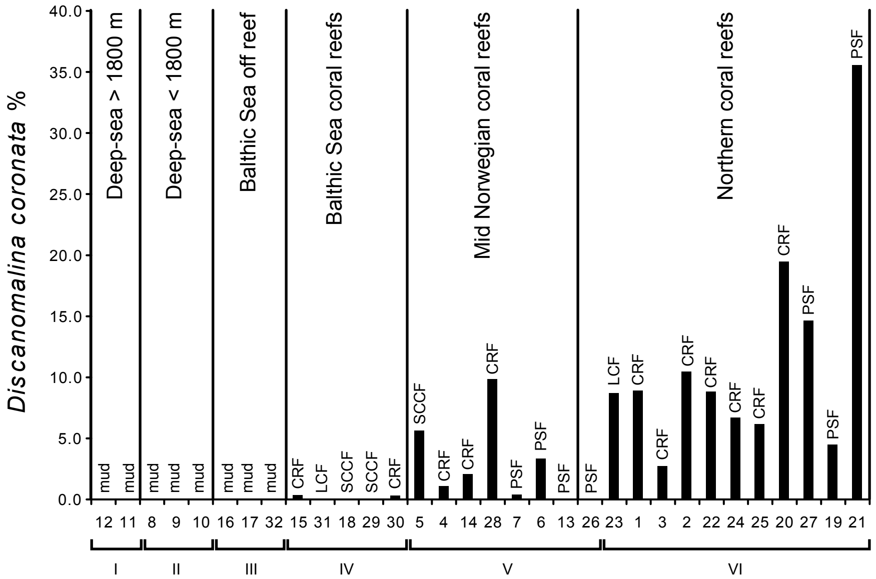

Figure 3.8 Abundance of *Discanomalina coronata* for Clusters I to VI and different sedimentary facies.

reef" Skagerrak; IV) "on-reef" Skagerrak; V) mid-Norwegian coral reefs, and VI) northern Norwegian coral reefs. The benthic fauna provides information on currents, oxygenation and organic matter content. In particular, benthic foraminifera associated to CWC-reefs indicate an environment characterized by high energy, well-oxygenated waters and high amounts of organic matter (derived from seasonal phytoplankton blooms) reaching the sea floor. The benthic foraminiferal fauna associated with coral reefs in the Skagerrak indicates that, although the flux of organic matter is high, the labile component usable for CWC growth is low and explains the extensive occurrence of dead corals in this area. High diversity of benthic foraminifera is observed "on-reef". Diversity is highest in the central parts of the reefs, in the *living coral framework facies* and *sediment clogged coral framework facies*, with a dense coral framework. However, the benthic foraminiferal habitats are only weakly defined and grade one into the other preventing a sharp facies separation as observed along the Irish margin where the assemblages are strictly related to facies. The gradual changes in the assemblages observed on the Norwegian margin can be attributed to the changes in the reef facies, which are restricted within tens of metres, whereas on the Irish carbonate mounds different facies occur over long distances. *Discanomalina coronata* is only abundant on healthy CWC-reefs along the Mid Norwegian shelf and northern Norway. It is almost absent in the Oslofjord and completely absent "off-reef". Co-occurrence of *D. coronata* and healthy CWC has been observed along the Irish margin. Based on these observations *D. coronata* is interpreted to require similar ecological conditions as CWCs and, therefore, proposed as an indicator species for healthy CWC-reefs also on the Norwegian margin.

4 - DEVELOPMENT OF COLD-WATER CORAL ECOSYSTEMS ON MUD VOLCANOES IN THE WEST ALBORAN BASIN: PALEOCEANOGRAPHIC IMPLICATIONS

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submitted to Marine Geology

The Dhaka and Maya mud volcanoes (MV), located in the Mud Diapir Province in the Western Alboran Basin along the Moroccan Coasts, were cored during the TTR-17, Leg 1 cruise. Cores were taken on the top of the volcanoes at a water depth of 370 m on the Dhaka MV (core TTR17-MS411G) and of 410 m on the Maya MV (core TTR17-MS419G). On both mud volcanoes the extruded mud breccia provides the nucleation point for the colonization and development of cold-water corals and associated ecosystems. Two phases of cold-water coral growth are observed: (1) between 2230 +/- 59 years BP and slightly older than 4175 +/- 62 years BP at Dhaka, and (2) between 7613 +/- 38 years BP and slightly older than 15583 +/- 185 years BP at Maya. On the top of the Maya MV only a small patch reef and/or isolated corals proliferated, whereas a more extended patch reef colonized the top of the Dhaka MV. At both sites the cold-water corals development was triggered by high nutrient availability related to upwelling and/or strong currents that mobilized nutrient horizontal fluxes. During the intervals of coral growth planktonic foraminiferal assemblages were dominated by *Neogloboquadrina incompta*. The decline of coral ecosystems on the mud volcanoes is accompanied at surface by a shift from the *N. incompta* dominated assemblage to a *Globorotalia inflata* dominated assemblage, possibly reflecting more modern paleoceanographic conditions and a deep pycno-nutricline. This shift seems to occur at the passage from wet to arid conditions at the end of the African Humid Period (Maya MV) and as a combined effect of an early human impact on a fragile environment, which was already stressed by desiccation at the time of the development of complex human society along the Mediterranean coasts (Dhaka MV). No relation with seepage is observed at both volcanoes.

4.1 INTRODUCTION

Mud volcanoes and mud diapirs are common features in the Alboran Sea in the Western Mediterranean (e.g., Sautkin et al., 2003) and along the Atlantic margin of the associated Gulf of Cadiz (e.g., Fernandez-Puga et al., 2007; Pinheiro et al., 2003; Somoza et al., 2003). Mud volcanism and associated phenomena such as cold seepage, hydrocarbon venting and gas hydrates in the Gulf of Cadiz have been investigated since 1996 (Baraza et al., 1999; Baraza and Ercilla, 1996; Gardner, 2001; Ivanov et al., 2000, 2001; Kenyon et al., 2001; Mazurenko et al., 2002; Pinheiro et al., 2003; Somoza et al., 2000). An exploratory cruise of R/V Belgica in 2002 on an accretionary setting in the Gulf of Cadiz (Gutscher et al., 2002) off Larache (Morocco), led to the discovery of a cluster of nine mud volcanoes: the El Arraiche mud volcanoes field (Van Rensbergen et al., 2005). These structures are generally associated to cold-water corals carbonate mounds, which are up to 60 m high and located in water depths of 500-600 m on the Pen Duik Escarpement (Foubert et al., 2008; Van Rensbergen et al., 2005; Wienberg et al., 2009).

The existence of mud volcanoes in the Alboran Sea was first documented in 1999 during the UNESCO-IOC Training Through Research Program (TTR-9) Leg 2 along the Moroccan margin. A further survey carried out in 2002 by TTR-12 Leg 3 revealed the existence of mud volcanism along both Spanish (Northern Mud-Volcano Field) and Moroccan (Southern Mud-Volcano Field) margins of the West Alboran Basin. Additional mud volcanoes were discovered during the TTR-14 between the northern and southern mud-volcano fields (Comas and Ivanov, 2006; Comas et al., 2000, 2003a, 2003b; Sautkin et al., 2003; Talukder et al., 2003). In 2007, a cruise of the R/V Hesperides focusing on mud volcanoes in the Alboran Sea (Comas and Pinheiro, 2007) unveiled an outcropping mound province off Melilla, which displays striking affinities with the Cadiz cold-water coral carbonate mounds and with those discovered in the North Atlantic (e.g., Henriet et al., 1998). The Melilla field was cored for the first time in June 2008 during the TTR-17 cruise (Comas and the SAGAS08 - TTR17, Leg 1 - Scientific Party, unpublished). Other targets of the same cruise were

Table 4.1 Geographic position and water depths of the two investigated cores.

Gravity Core	Latitude	Longitude	Site	Length [m]	Depth [m]
TTR17-MS411G	35°25,43'N	04°31,89'W	Dhaka Mud Volcano	162	370
TTR17-MS419G	35°27,11'N	04°37,14'W	Maya Mud Volcano	167	410

also the mud volcanoes from the southern part of the Alboran Sea to test if cold-water coral carbonate mounds in the Alboran Sea were also associated to mud volcanoes as observed in the Gulf of Cadiz.

Aim of this research is the study of the sedimentary pelagic sequence deposited on the top of the Dhaka and Maya mud volcanoes in the Alboran Sea (Fig. 4.1) to reconstruct the paleoceanographic setting and to identify a possible causal link between these geological structures.

4.2 Regional setting

The Alboran Sea is a 400 km long and 200 km wide basin with a water depth not exceeding 2 km, located in the westernmost part of the Mediterranean Sea (e.g., Comas et al., 1999). Its complex seafloor morphology shows ridges, seamounts and troughs and it is divided in three sub-basins: the West Alboran, the East Alboran and the South Alboran Basins (Fig. 4.1). The West Alboran and the South Alboran Basins are separated by the Alboran Ridge, a prominent NE-SW linear relief, locally forming the small Alboran Island.

The formation of the Alboran Basin as part of the Gibraltar Arc started in the late Cretaceous as a consequence of crustal extension in a setting of overall convergence of the African and Eurasian plates that have had variable directions of relative motion since the late Cretaceous (e.g., Dewey et al., 1989). Seismic data show that present-day plate tectonics contribute to the actual deformation of the Alboran Basin (e.g., Fernandez-Ibañez et al., 2007, and references therein; Frizon de Lamotte et al., 2006). Early Miocene under-compacted shales and olistostromic sediments mobilized by fluid flows in a back-arc basin setting characterized by coeval extensional tectonics have been suggested as the source layer for the Mud Diapir Province in the Western Alboran Basin, which during the post-Messinian compressive tectonics developed pierced diapirs and subsequent mud volcanoes (Chalouan et al., 1997; Comas et al., 1992, 1999; Jurado and Comas, 1992; Pérez-Belzuz et al., 1997; Sautkin et al., 2003, Talukder et al., 2003).

4.2.1 Dhaka and Maya Mud Volcanoes

The Dhaka and Maya mud volcanoes are located in the Mud Diapir Province in the Western Alboran Basin (35°25.43’ N; 04°31.89’ W and 35°27.11’ N; 04°37.14’ W respectively) along the Moroccan Coasts. The Dhaka mud volcano is a semi-circular structure with a diameter of about 1 km. The Maya mud volcano is elongated in an E-W direction and about 120 m long. Cores were taken on the top of the volcanoes at a water depth of 370 m on the Dhaka mud volcano (TTR17-MS411G) and of 410 m on the Maya mud volcano (TTR17-MS419G) (Fig. 4.1; Tab. 4.1).

According to the on-board description modified after shore-based investigations, the cored material at the Dhaka mud volcano includes from top to bottom an hemi-pelagic drape (from the top of the core to 30 cm), a cold-water coral fragments-rich unit (from 35 cm to 60 cm), a typical mud-breccia layer (from 65 cm to 145 cm), and possibly a lowermost level of pelagic sediments mixed with the mud breccia (from 145 cm to the bottom of the core).

The cored material at the Maya mud volcano includes, from top to bottom, a hemi-pelagic drape (from the top of the core to 94 cm), a cold-water coral fragments-rich unit (from 100 cm to 126 cm), and a typical mud-breccia layer (from 127 cm to the bottom of the core). Both volcanoes are presently not active as testified by the presence of a pelagic drape on their top.

4.3 MATERIAL AND METHODS

The sediments representing the hemi-pelagic drape have been sampled at five cm resolution (Dhaka) and two to ten cm resolution (Maya) for the determination of planktonic and benthic foraminifera assemblages. Sediment samples for micropaleontological analyses were processed following Spezzaferri and Coric (2001). Samples were dried at room temperature, weighted and washed through 250 µm, 125 µm and 63 µm mesh sieves. The obtained three size fractions of residue were dried at room temperature and weighted. When a residue contained more than 400 specimens, the volume was reduced by splitting. About 200 specimens per fraction (600 specimens per sample) were picked,

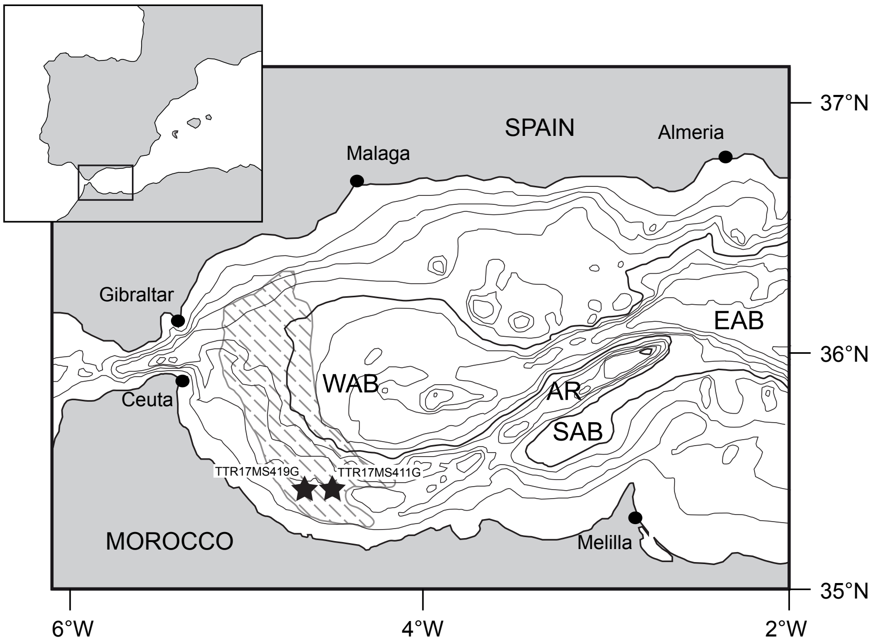


Figure 4.1 Location map of the studied cores. Shaded area: Mud Diapir Province. WAB: West Alboran Basin; EAB: East Alboran Basin; SAB: South Alboran Basin; AR: Alboran Ridge. Modified from Arnone et al. (1990).

collected in slides, sorted at species level and counted. In case of samples containing less than 100 specimens per fraction, all specimens were counted. The identified different benthic and planktonic foraminiferal species are listed in Appendix E and F.

A multivariate statistical treatment on faunal data was performed with the software PRIMER 6 (Clarke, 1993; Clarke and Gorley, 2006; Clarke and Warwick, 2001). Data have been double-square root transformed to limit the contribution of the most abundant and ubiquitous species (Field et al., 1982). Bray-Curtis (dis-) similarities were calculated following Clifford and Stephenson (1975). The same similarity matrix was used to obtain the non-metric MultiDimensional Scaling (nMDS plot) (Kruskal, 1964; Kruskal and Wish, 1978). The significance and potential of the nMDS plot has been discussed in detail in Spezzaferri and Coric (2001) and Margreth et al. (2009). Based on the clusters given in the nMDS plot, the Similarity Percentage Analysis (SIMPER) was obtained to highlight the contribution of each species to the total average (dis-) similarity between different groups and within one group (e.g., Basso and Spezzaferri, 2000; Clarke and Warwick, 2001; Kruskal, 1964; Kruskal and Wish, 1978). Quantitative data of benthic and planktonic foraminifera used for the multivariate statistic are given in Appendix E and F.

The chronology of the two cores retrieved on Dhaka and Maya mud volcanoes (TTR17-MS411G and TTR17-MS419G, respectively) is based on 8 AMS ^{14}C age determination (Tab. 4.2) obtained at the Leibniz Laboratory for Age Determinations and Isotope Research at the University of Kiel. For each sample, at least 5 mg of *Globorotalia inflata* were handpicked to provide 0.2 to 1.2 mg of carbonate. The organic material was removed in an ultrasonic bath with 15% H_2O_2. The hydrolysis of the residual pure calcite was obtained at 90°C with 100% orthophosphoric acid. The carbon dioxide was converted to graphite with hydrogen on an iron catalyst. The iron–graphite mixture was measured on the AMS mass spectrometer. A reservoir correction of 400 years (Siani et al., 2000) was subtracted to the obtained radiocarbon conventional ages, which were calibrated using the program Calib 5.1 (Stuiver and Reimer, 1993).

Stable oxygen and carbon isotope analyses (δ^{18}O and δ^{13}C) on about 5-10 specimens of *Discanomalina coronata* were performed on 3 samples from the coral-rich level from the Dhaka mud volcano (Tab. 4.3). These isotope ratios were measured on a Finnigan MAT 252 mass spectrometer with a Kiel II preparation device at the IFM-GEOMAR, Leibniz-Institute of Marine Sciences (Kiel University). The reproducibility was ± 0.035‰ for δ^{18}O and ± 0.029‰ for δ^{13}C. The isotopes ratios are presented relative to Vienna Pee Dee Belemnite standard (VPDB) based on calibrations of National Bureau of Standards (NBS).

Table 4.2. Result of AMS ^{14}C dating on planktonic foraminifera *G. inflata*. Calibration using the software Calib 5.1 (Stuiver and Reimer, 1993). A reservoir effect of 400 years was subtracted (Siani et al., 2000).

Gravity Core	Depth [cm]	Species	Lab Code	Conventional [yr BP]	Calibrated Age [yr BP]
TTR17-MS411G	0	*Gr. inflata*	KIA 39074	1145 ±30	689 ±27
TTR17-MS411G	35	*Gr. inflata*	KIA 39075	2550 ±40	2230 ±59
TTR17-MS411G	55	*Gr. inflata*	KIA 39076	4120 ±35	4175 ±62
TTR17-MS411G	150	*Gr. inflata*	KIA 39078	4240 ±40	4345 ±60
TTR17-MS419G	0	*Gr. inflata*	KIA 39197	1475 ±25	1013 ±40
TTR17-MS419G	25	*Gr. inflata*	KIA 39198	2425 ±35	2059 ±53
TTR17-MS419G	98	*Gr. inflata*	KIA 39199	7145 ±40	7613 ±38
TTR17-MS419G	115	*Gr. inflata*	KIA 39200	13580 ±70	15583 ±185

4.4 RESULTS

4.4.1 Micropaleontology

A hemi-pelagic drape and a cold-water coral fragments-rich unit, even if at different depth in the cores, characterize both Dhaka and Maya mud volcanoes. The hemi-pelagic drape, from the top of the core to 30 cm in Dhaka MV and from the top of the core to 94 cm in Maya MV, yields very similar foraminiferal assemblages. Planktonic foraminifera include very abundant *Globorotalia inflata, Globigerinoides* spp., *Turborotalita quinqueloba, Globigerinita glutinata* and benthic foraminifera such as *Globocassidulina subglobosa, Uvigerina mediterranea, Cassidulina carinata, Bolivina difformis* (Appendix E). In the cold-water coral fragments-rich unit (from 35 cm to 60 cm in Dhaka MV and from 100 cm to 126 cm in Maya MV) planktonic fauna is represented by dominant *Neogloboquadrina incompta, Turborotalita quinqueloba* and associated less abundant *Globigerinita glutinata* and *Globigerina bulloides*. In this unit, epifaunal-attached benthic foraminifera are more abundant than in the above hemi-pelagic sediments and are characterized by *Discanomalina coronata*, a species that is interpreted as bioindicator of living cold water coral ecosystems along the Irish coasts in the North Atlantic (Margreth et al., 2009), *Cibicidoides* sp., *Cibicidoides pachyderma, Angulogerina angulosa*, and *Lobatula lobatula* (Appendix E). The residues used for foraminiferal investigations contain also fragments of cold-water corals such as *Madrepora oculata*, *Lophelia pertusa* and solitary species such as *Desmophyllum* sp. and/or *Dendrophyllia* sp. (Fig. 4.2).

4.4.2 Quantitative analyses and statistical treatment of data

Quantitative analyses of planktonic and benthic foraminifera were performed on samples from the hemi-pelagic drape of both mud volcanoes in order to evaluate species abundance and diversities and to plot abundance curves of selected species (Fig. 4.3).

Planktonic foraminifera (Dhaka MV) – A clear positive peak of abundance (almost 50%) is observed for *N. incompta* at about 50 cm (Fig. 4.3A) within the interval containing coral fragments. Abundance of *G. inflata* increases from 45 cm up to over 30% in the upper part of the core with a negative peak (10%) at 35 cm. In the hemi-pelagic sediments above the coral-rich interval the abundances of *G. incompta* and *Globigerinoides* spp. remain below 10%.

Benthic foraminifera (Dhaka MV) – In the interval containing also coral fragments *D. coronata* is more abundant (around 15%; Fig. 4.3B). From the base of this interval to the top of the core, the abundance of *G. subglobosa* increases from a minimum of around 10 to 25%, respectively. Uvigerinids (*U. mediterranea* and *U. peregrina*) also increase in abundance but never exceed 10%.

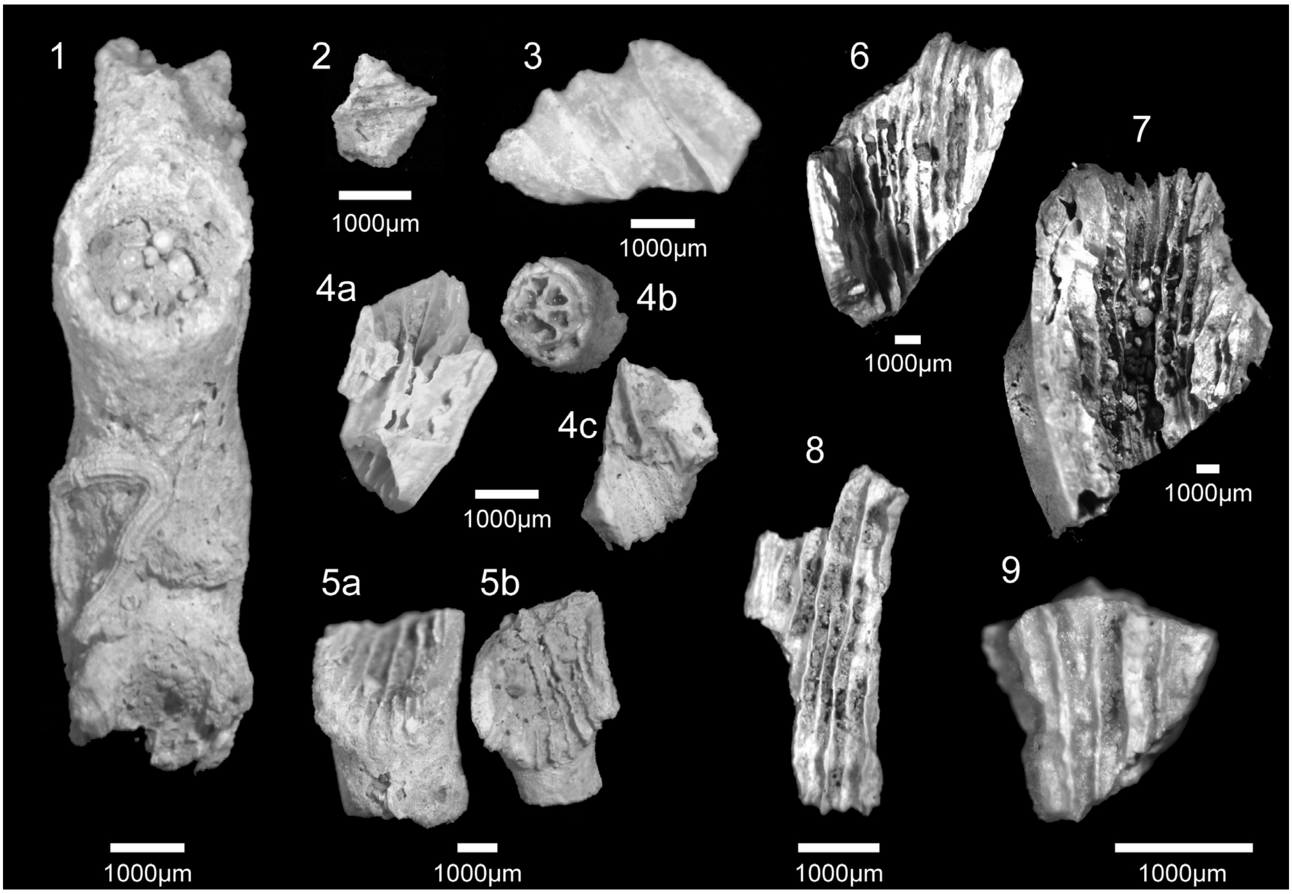
Planktonic foraminifera (Maya MV) - The lower abundances of *G. inflata* and *Globigerinoides* spp. are observed in the level containing also coral fragments (Fig. 4.3C), whereas *N. incompta* is very abundant (maximum value 40%). At about 85 cm, the curves of the three species reverse their trend: *G. inflata* becomes abundant (almost 30%) while *N. incompta* and *Globigerinoides* spp. never exceed 10%, showing a strict resemblance to the trend of the same species at Dhaka mud volcano.

Benthic foraminifera (Maya MV) – *D. coronata* is low abundant (1%) only in the coral-rich level in this core (Fig. 4.3D). *G. subglobosa* increases in abundance from the base of the coral-rich horizon (7%) to the top of the core (22%). Uvigerinids are not abundant, with values fluctuating from 3 to 8%. However, *U. peregrina* highest abundance of around 15% is observed in the coral-rich level. Very often patterns of community structures are not clear and/or readily apparent (Clarke and Warwick, 1994). Therefore, to highlight them, we have statistically treated our complete benthic and planktonic foraminifera data to better identify

Table 4.3 Benthic δ^{13}C and δ^{18}O measured on *Discanomalina coronata* from three samples of core TTR17-MS411G (Dhaka MV).

Gravity Core	Depth [cm]	Species	δ^{13}C [‰ VPDB]	δ^{18}O [‰ VPDB]
TTR17-MS411G	35	*D. coronata*	0.013	2.933
TTR17-MS411G	55	*D. coronata*	-0.218	3.542
TTR17-MS411G	70	*D. coronata*	-0.661	3.118

Figure 4.2 Scleractinian cold-water coral fragments, most certainly *Madrepora oculata* (1), *Lophelia pertusa* and solitary species like *Desmophyllum* sp. or *Dendrophyllia* sp. from the two investigated cores: (1) D25; TTR17-MS411G; 25 cm, (2) D45; TTR17-MS411G; 45 cm, (3) D40; TTR17-MS411G; 40 cm, (4a-c) D30; TTR17-MS411G; 30 cm, (5a-b) D25; TTR17-MS411G; 25 cm, (6) M115; TTR17-MS419G; 115 cm, (7) M107; TTR17-MS419G; 107 cm, (8) M100; TTR17-MS419G; 100 cm, (9) M102; TTR17-MS419G; 102 cm



and characterize changes in the assemblage structures and possibly relate them to changing environmental conditions. The multivariate statistical analyses, including agglomerative clustering based on the Bray-Curtis Similarity, is shown in Fig. 4.4. Two clusters separate for planktonic foraminifera and three clusters separate for benthic as shown in the nMDS plots in Fig. 4.3. Species and groups accounting for the average similarity and dissimilarity in all clusters are listed in order of decreasing contribution in Tab. 4.4, 4.5, 4.6 and 4.7.

4.4.3 AMS ^{14}C dating and sedimentation rate

The results of the AMS ^{14}C dating are reported in Tab. 4.2. The sediments from Core TTR17-MS411G (Dhaka MV) yield ages ranging from 689 ± 27 years at the top to 4346 ± 60 years at the bottom. The coral-rich interval is comprised within about 2230 ± 59 years BP and slightly older than 4175 ± 62 years BP. The sediments from Core TTR17-MS419 G (Maya MV) yield ages ranging from 1013 ± 40 years at the top to 15583 ± 185 years at the bottom. The coral-rich interval is comprised within 7613 ± 38 years BP and the breccia layers starting 10 cm below the sample dated as old as 15583 ± 185 years BP. The AMS ^{14}C

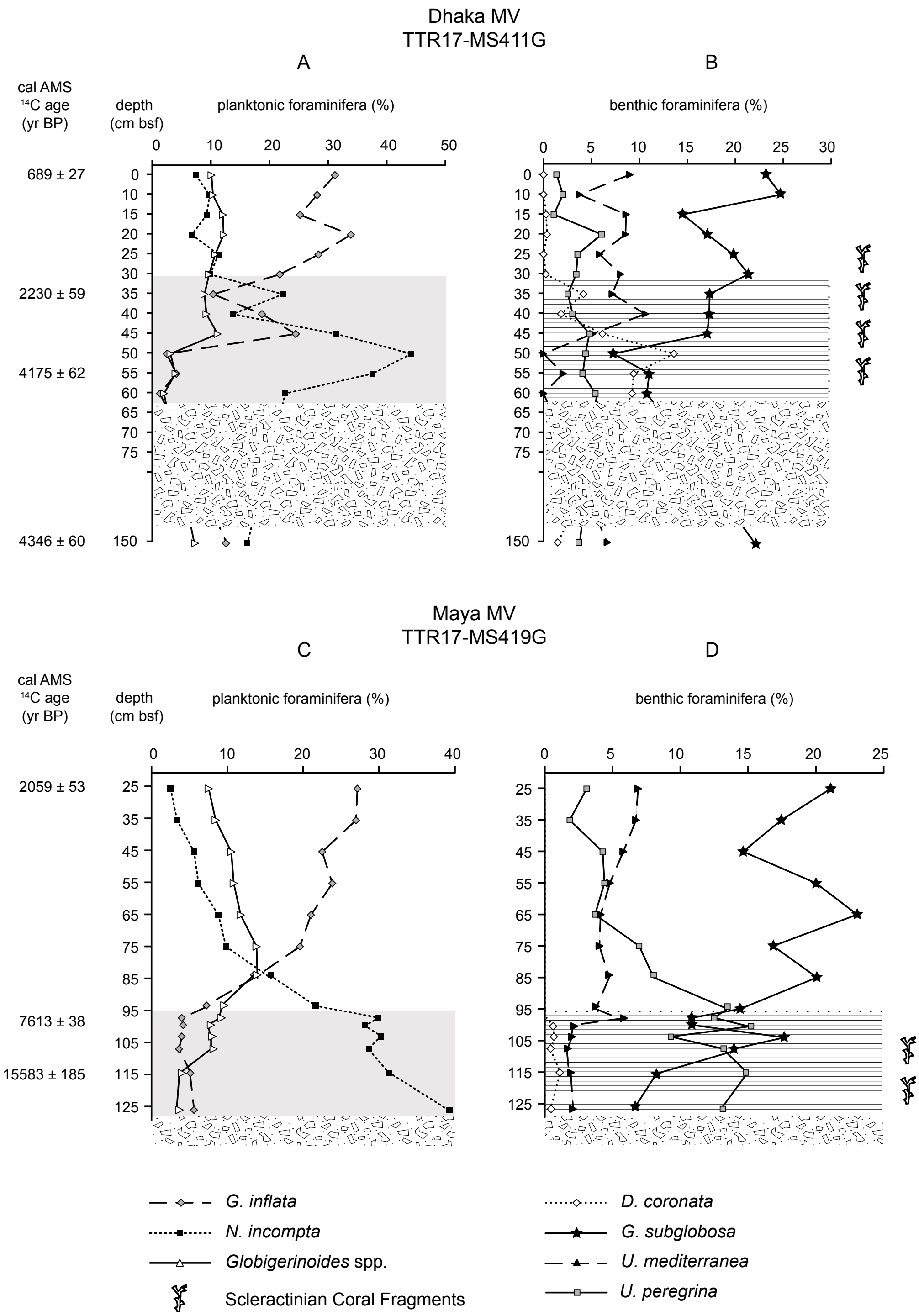


Figure 4.3 Relative abundance of the most significant planktonic (A/C) and benthic (B/D) foraminiferal species for the two investigated cores. Shaded areas: *N. incompta* period in the planktonic foraminiferal assemblage; striped areas: *D. coronata* period in the benthic foraminiferal assemblage; patterned areas: mud breccia level.

dating allowed plotting the sedimentation rate curves for the hemi-pelagic drape at the two sites (Fig. 4.5). The higher values of sedimentation rate are observed between 0 and 35 cm at Dhaka MV (22.7 cm kyr^{-1}) and from 0 to 25 cm at Maya MV (23.9 cm kyr^{-1}). The lower values correspond to the cold-water coral-rich layers and are 10.3 cm kyr^{-1} and 2.1 cm kyr^{-1}, respectively.

4.5 DISCUSSION

It has been demonstrated that the basic requirements of cold-water corals are hard substratum for their settlement and colonization, nutrient supply and low sedimentation rates (e.g., Alvarez-Péréz et al., 2005; De Mol et al., 2002; Frederiksen et al., 1992;

Table 4.4 List of planktonic foraminiferal species and statistical parameters associated with the similarity in cluster I to II. Average similarity within the group of station, average abundance, average similarity, contribution (%), and cumulative contribution (%) are given for each species with respect to the total similarity for each cluster.

Cluster I	**Average similarity: 84.72**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Gr. inflata	4.72	12.61	14.89	14.89
Tr. quinqueloba	4.61	12.58	14.85	29.74
Ga. glutinata	4.05	10.58	12.49	42.23
N. incompta	3.17	7.77	9.17	51.4
Gs. ruber	2.78	7.57	8.93	60.33
G. bulloides	2.74	6.97	8.23	68.56
Gs. elongatus	1.23	3.04	3.59	72.15
Ga. uvula	1.27	2.99	3.53	75.68
Tr. humilis	1.09	2.68	3.16	78.84
Cluster II	**Average similarity: 84.15**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Tr. quinqueloba	5.62	17.65	20.97	20.97
N. incompta	5.43	16.61	19.73	40.71
Ga. glutinata	3.92	11.95	14.2	54.9
G. bulloides	2.19	6.51	7.73	62.64
Gs. ruber	2.22	6.2	7.36	70
Gr. inflata	2.12	6.01	7.15	77.14

Freiwald, 2002; Roberts et al., 2006; Rogers, 1999). Also important are long-term stable cool conditions of temperature and current-strength (Freiwald et al., 2004). Recently Dullo et al. (2008) have demonstrated that cold-water corals in the Atlantic can adapt to a wide range of environmental conditions but they only thrive in a density gradient between 27.35 to 27.65 kg m^{-3}. Freiwald et al. (2009) identified the limiting density in the Mediterranean between 29.08 and 29.13 kg m^{-3}.

More than 20 mud volcanoes are presently known to be colonized by fossil scleractinian corals in the Gulf of Cadiz (Pinheiro et al., 2003; Somoza et al., 2003). Some of them are located along the Spanish margin in water depths between 530 and 1100 m and others are located along the Moroccan margin in a much wider water depth range of 420 – 1300 m (Wienberg et al., 2009). Cold-water corals were previously documented in the Gibraltar Strait (Alvarez-Péréz et al., 2005). However, no data concerning the sedimentary sequences containing fossil cold-water coral remains on top of the Alboran mud volcanoes were available until the TTR-17-Leg 1 research cruise.

The first step in our study was to demonstrate that the cold-water coral intervals observed in the Dhaka and Maya mud volcanoes at the top of the extruded mud breccia were in situ and not coral debris reworked and/or displaced from older layers during mud volcanic activity. Since the sedimentological analysis of the cores did not provide any conclusive evidence,

Table 4.5 List of planktonic species and statistical parameter associated with the dissimilarity between each pair of clusters I to II. The average dissimilarity is shown. For each species the average abundance, average dissimilarity, contribution (%), and cumulative contribution (%) to the total similarity are also given.

	Average dissimilarity = 23.66				
	Cluster I	**Cluster II**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Gr. inflata	4.72	2.12	4.02	16.97	16.97
N. incompta	3.17	5.43	3.55	15	31.98
Tr. quinqueloba	4.61	5.62	1.6	6.77	38.75
Ga. glutinata	4.05	3.92	1.11	4.7	43.45
G. bulloides	2.74	2.19	1.06	4.47	47.92
Gs. ruber	2.78	2.22	1	4.25	52.17
Ta. rubescens	1.24	0.91	0.93	3.93	56.1
Gs. immaturus	0.85	0.3	0.88	3.72	59.82
Gs. sacculifer	0.71	0.19	0.85	3.59	63.4
N. pachyderma	0.73	0.6	0.79	3.32	66.72
Gs. elongatus	1.23	0.9	0.7	2.94	69.66
Gr. scitula	0.61	0.49	0.66	2.8	72.46
N. dutertrei	0.29	0.5	0.66	2.77	75.23
Tr. humilis	1.09	0.8	0.64	2.71	77.94

Table 4.6 List of benthic foraminiferal species and statistical parameters associated with the similarity in cluster 1 to 3. Average similarity within the group of station, average abundance, average similarity, contribution (%), and cumulative contribution (%) are given for each species with respect to the total similarity for each cluster.

Cluster 1	**Average similarity: 63.31**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Globocassidulina subglobosa group	19.6	17.73	28	28
Uvigerina mediterranea	5.78	4.31	6.81	34.81
Bolivina difformis	4.77	3.79	5.98	40.79
Bulimina marginata	4.8	3.71	5.86	46.65
Uvigerina peregrina	3.88	2.73	4.32	50.97
Cassidulina carinata	3.38	2.39	3.78	54.75
Gavelinopsis praegeri	3.39	2.27	3.58	58.33
Cibicidoides sp.	2.92	1.95	3.08	61.41
Melonis barleeanum	2.71	1.94	3.07	64.48
Hyalinea balthica	2.64	1.73	2.74	67.22
Amphicoryna scalaris	2.41	1.52	2.4	69.63
Bigenerina nodosaria	1.86	1.3	2.05	71.67
Hoeglundina elegans	1.64	1.08	1.7	73.37
Cibicidoides pseudoungerianus	1.63	0.9	1.42	74.79
Lobatula lobatula	1.38	0.87	1.38	76.17
Sigmoilopsis schlumbergeri	1.27	0.76	1.2	77.37
Sphaeroidina bulloides	1.38	0.73	1.16	78.53
Cassidulina laevigata	1.35	0.65	1.03	79.56
Quinqueloculina viennensis	1.25	0.65	1.03	80.59

Cluster 2	**Average similarity: 71.06**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Uvigerina peregrina	13.09	12.01	16.9	16.9
Globocassidulina subglobosa group	11.86	9.51	13.38	30.28
Bulimina marginata	7.97	6.87	9.66	39.94
Hyalinea balthica	7.14	5.71	8.03	47.98
Melonis barleeanum	3.99	3.21	4.52	52.5
Amphicoryna scalaris	3.03	2.31	3.25	55.75
Bulimina striata	3.03	2.28	3.21	58.97
Cassidulina carinata	2.96	2.25	3.16	62.13
Uvigerina mediterranea	2.78	2.01	2.82	64.95
Sigmoilopsis schlumbergeri	2.16	1.82	2.56	67.51
Cibicidoides pseudoungerianus	2.02	1.72	2.42	69.94
Sphaeroidina bulloides	1.94	1.41	1.98	71.92
Bolivina difformis	1.87	1.35	1.9	73.82
Bulimina aculeata	1.58	1.09	1.53	75.35
Hoeglundina elegans	1.4	1.04	1.46	76.81
Spiroplectinella wrighti	1.31	1	1.41	78.22
Bolivina spathulata	1.39	0.97	1.36	79.58

Cluster 3	**Average similarity: 63.23**			
Species	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
Discanomalina coronata	10.74	9.28	14.68	14.68
Globocassidulina subglobosa group	9.69	8.44	13.36	28.04
Bolivina difformis	5.75	4.57	7.23	35.27
Uvigerina peregrina	4.61	4.18	6.61	41.88
Cibicidoides sp.	6.85	3.44	5.44	47.32
Cibicidoides pachyderma	3.68	2.93	4.63	51.96
Hyalinea balthica	2.91	2.59	4.1	56.05
Melonis barleeanum	2.76	2.39	3.77	59.83
Gavelinopsis praegeri	2.57	2.27	3.59	63.42
Angulogerina angulosa	2.71	2	3.16	66.58
Bolivina subaenariensis	2.37	1.86	2.94	69.52
Bulimina marginata	2.25	1.63	2.57	72.09
Cassidulina carinata	2.43	1.57	2.48	74.57
Cassidulina laevigata	2.92	1.57	2.48	77.05
Lobatula lobatula	2.21	1.24	1.96	79.02
Cibicidoides pseudoungerianus	1.65	1.16	1.83	80.85

planktonic and benthic foraminiferal analyses were performed and the results compared with the study of Margreth et al. (2009) on modern foraminiferal assemblages from cold-water coral mounds in the Porcupine Basin and Rockall Bank off-shore Ireland. These authors showed that benthic foraminiferal assemblages provide an independent tool to identify and describe the different facies related to cold-

Table 4.7 List of benthic species and statistical parameter associated with the dissimilarity between each pair of clusters 1 to 3. For each pair of clusters the average dissimilarity is shown. For each species the average abundance, average dissimilarity, contribution (%), and cumulative contribution (%) to the total similarity are also given.

Average dissimilarity = 45.19

Species	**Cluster 1** **Av.Abund**	**Cluster 2** **Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Uvigerina peregrina	3.88	13.09	4.61	10.19	10.19
Globocassidulina subglobosa group	19.6	11.86	3.95	8.75	18.94
Hyalinea balthica	2.64	7.14	2.31	5.12	24.05
Uvigerina mediterranea	5.78	2.78	1.73	3.84	27.89
Bulimina marginata	4.8	7.97	1.71	3.78	31.68
Bolivina difformis	4.77	1.87	1.48	3.27	34.95
Gavelinopsis praegeri	3.39	1.08	1.22	2.69	37.64
Bulimina striata	0.76	3.03	1.13	2.51	40.15
Cibicidoides sp.	2.92	1.12	0.96	2.12	42.27
Melonis barleeanum	2.71	3.99	0.91	2.02	44.29
Cassidulina carinata	3.38	2.96	0.83	1.83	46.11
Amphicoryna scalaris	2.41	3.03	0.79	1.76	47.87
Cassidulina laevigata	1.35	1.42	0.64	1.42	49.29
Sphaeroidina bulloides	1.38	1.94	0.63	1.4	50.69
Discanomalina coronata	1.18	0.38	0.62	1.38	52.07
Cibicidoides pseudoungerianus	1.63	2.02	0.59	1.3	53.38
Bulimina aculeata	0.57	1.58	0.56	1.23	54.61
Sigmoilopsis schlumbergeri	1.27	2.16	0.55	1.22	55.83
Bigenerina nodosaria	1.86	1.19	0.55	1.21	57.03
Gyroidina altiformis	0.81	1.08	0.52	1.14	58.18
Quinqueloculina viennensis	1.25	0.44	0.51	1.12	59.3
Lobatula lobatula	1.38	1.35	0.5	1.11	60.4
Cibicidoides pachyderma	1.06	0.16	0.49	1.09	61.49
Hoeglundina elegans	1.64	1.4	0.47	1.03	62.53
Gyroidina neosoldanii	1.24	0.63	0.46	1.02	63.55
Bolivina spathulata	1.18	1.39	0.46	1.02	64.57
Spiroplectinella wrighti	1.09	1.31	0.44	0.97	65.54
Melonis pompilioides	0.45	1.21	0.42	0.94	66.48
Bolivina dilatata	0.84	1.23	0.42	0.93	67.41
Bolivina suspinescens	0.41	1.05	0.4	0.89	68.3
Cibicides refulgens	0.71	0.44	0.4	0.89	69.19
Bolivina striatula	0.34	1.05	0.4	0.88	70.07
Cibicidoides kullenbergi	1.06	0.57	0.38	0.84	70.91
Planulina ariminensis	0.56	0.96	0.37	0.82	71.73
Nuttalides umboniferus	0.72	0	0.36	0.79	72.52
Globobulimina affinis	0.81	0.57	0.35	0.77	73.29
Rectuvigerina elongatastriata	0.72	0.05	0.35	0.77	74.06
Angulogerina angulosa	0.66	0.57	0.34	0.75	74.81
Textularia agglutinans	0.69	0.03	0.33	0.74	75.55
Lenticulina inornata	0.74	0.22	0.33	0.73	76.28
Bolivina subaenariensis	0.12	0.67	0.31	0.68	76.96
Discorbinella bertheloti	0.42	0.74	0.3	0.67	77.63
Hanzawaia boueana	0.91	0.45	0.3	0.67	78.31
Cycloforina laevigata	0.31	0.6	0.3	0.67	78.98
Rosalina globularis	0.67	0.51	0.29	0.64	79.62

Average dissimilarity = 50.06

Species	**Cluster 1** **Av.Abund**	**Cluster 3** **Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Globocassidulina subglobosa group	19.6	9.69	4.96	9.9	9.9
Discanomalina coronata	1.18	10.74	4.78	9.55	19.45
Uvigerina mediterranea	5.78	0.68	2.57	5.14	24.59
Cibicidoides sp.	2.92	6.85	2.27	4.54	29.12
Cibicidoides pachyderma	1.06	3.68	1.33	2.65	31.77
Bulimina marginata	4.8	2.25	1.31	2.63	34.4
Bolivina subaenariensis	0.12	2.37	1.12	2.24	36.64
Cassidulina laevigata	1.35	2.92	1.07	2.14	38.78
Bolivina difformis	4.77	5.75	1.03	2.06	40.84
Angulogerina angulosa	0.66	2.71	1.03	2.06	42.9
Uvigerina peregrina	3.88	4.61	0.92	1.83	44.73
Cassidulina carinata	3.38	2.43	0.89	1.79	46.52
Bigenerina nodosaria	1.86	0.14	0.87	1.74	48.26
Gavelinopsis praegeri	3.39	2.57	0.84	1.68	49.93

Table 4.7 (continued)

Amphicoryna scalaris	2.41	1.04	0.81	1.61	51.55
Cibicides refulgens	0.71	1.49	0.74	1.49	53.03
Marginulina subalata	0.06	1.46	0.74	1.48	54.51
Hyalinea balthica	2.64	2.91	0.69	1.38	55.89
Lobatula lobatula	1.38	2.21	0.68	1.37	57.25
Bolivina spathulata	1.18	0.95	0.68	1.37	58.62
Pyrgo anomala	0.08	1.3	0.64	1.27	59.89
Bulimina aculeata	0.57	1.66	0.63	1.25	61.14
Quinqueloculina viennensis	1.25	0.73	0.62	1.24	62.39
Cibicidoides pseudoungerianus	1.63	1.65	0.59	1.17	63.56
Hoeglundina elegans	1.64	1.55	0.59	1.17	64.73
Sigmoilopsis schlumbergeri	1.27	0.16	0.58	1.16	65.89
Sphaeroidina bulloides	1.38	0.65	0.56	1.12	67.01
Melonis barleeanum	2.71	2.76	0.55	1.11	68.11
Miliolinella subrotunda	0.46	1.36	0.55	1.1	69.21
Spiroplectinella wrighti	1.09	0.26	0.49	0.98	70.19
Gyroidina neosoldanii	1.24	0.68	0.49	0.97	71.16
Cibicidoides kullenbergi	1.06	1.35	0.47	0.93	72.1
Hanzawaia boueana	0.91	1.57	0.44	0.88	72.98
Bolivina dilatata	0.84	1.3	0.41	0.82	73.8
Gyroidina altiformis	0.81	0	0.4	0.81	74.61
Globobulimina affinis	0.81	0.14	0.37	0.74	75.34
Gyroidina soldanii	0.5	0.84	0.37	0.73	76.08
Rectuvigerina elongatastriata	0.72	0	0.36	0.72	76.8
Textularia agglutinans	0.69	0	0.34	0.68	77.48
Nuttalides umboniferus	0.72	0.08	0.34	0.67	78.15
Fissurina marginata	0.09	0.73	0.33	0.66	78.82
Lenticulina inornata	0.74	0.26	0.33	0.66	79.48

Average dissimilarity = 54.15

	Cluster 2	**Cluster 3**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Contrib%**	**Cum.%**
Discanomalina coronata	0.38	10.74	5.18	9.56	9.56
Uvigerina peregrina	13.09	4.61	4.24	7.83	17.39
Cibicidoides sp.	1.12	6.85	2.86	5.28	22.68
Bulimina marginata	7.97	2.25	2.86	5.28	27.96
Hyalinea balthica	7.14	2.91	2.12	3.91	31.87
Bolivina difformis	1.87	5.75	1.94	3.58	35.45
Globocassidulina subglobosa group	11.86	9.69	1.78	3.29	38.74
Cibicidoides pachyderma	0.16	3.68	1.76	3.25	41.99
Bulimina striata	3.03	0.73	1.15	2.12	44.11
Angulogerina angulosa	0.57	2.71	1.1	2.03	46.14
Uvigerina mediterranea	2.78	0.68	1.07	1.98	48.12
Amphicoryna scalaris	3.03	1.04	1	1.85	49.97
Sigmoilopsis schlumbergeri	2.16	0.16	1	1.85	51.82
Cassidulina laevigata	1.42	2.92	1	1.84	53.66
Bolivina subaenariensis	0.67	2.37	0.85	1.57	55.23
Melonis barleeanum	3.99	2.76	0.78	1.44	56.67
Cassidulina carinata	2.96	2.43	0.75	1.38	58.05
Gavelinopsis praegeri	1.08	2.57	0.75	1.38	59.43
Marginulina subalata	0	1.46	0.73	1.34	60.77
Sphaeroidina bulloides	1.94	0.65	0.71	1.31	62.08
Bolivina spathulata	1.39	0.95	0.71	1.31	63.39
Lobatula lobatula	1.35	2.21	0.69	1.27	64.66
Cibicides refulgens	0.44	1.49	0.67	1.24	65.9
Pyrgo anomala	0.06	1.3	0.64	1.18	67.08
Bulimina aculeata	1.58	1.66	0.58	1.07	68.14
Miliolinella subrotunda	0.23	1.36	0.57	1.05	69.2
Hanzawaia boueana	0.45	1.57	0.57	1.05	70.25
Spiroplectinella wrightii	1.31	0.26	0.56	1.04	71.29
Gyroidina altiformis	1.08	0	0.54	1	72.28
Bigenerina nodosaria	1.19	0.14	0.53	0.98	73.27
Hoeglundina elegans	1.4	1.55	0.53	0.97	74.24
Bolivina suspinescens	1.05	0	0.52	0.97	75.21
Melonis pompilioides	1.21	0.24	0.49	0.91	76.11
Cibicidoides kullenbergi	0.57	1.35	0.46	0.84	76.95
Planulina ariminensis	0.96	0.08	0.44	0.81	77.76
Quinqueloculina viennensis	0.44	0.73	0.44	0.81	78.57
Spiroloculina excavata	0	0.87	0.43	0.8	79.37

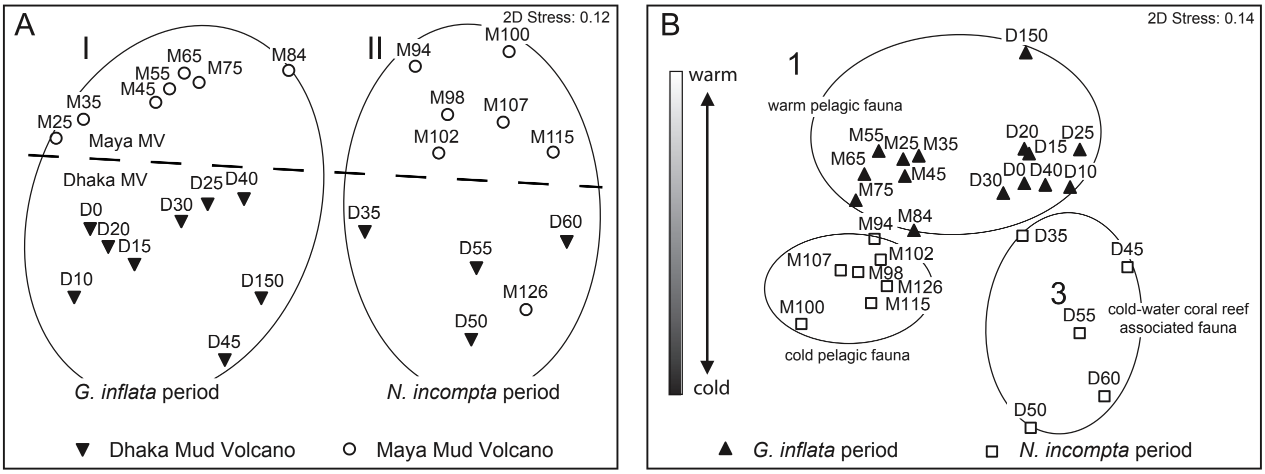


Figure 4.4 Non-metric Multi Dimensional Scaling (nMDS) plot obtained from the Bray-Curties similarity matrix of planktonic (A) and benthic (B) foraminifera compositional data. (A) Planktonic foraminifera clusters in the nMDS in a *G. inflata* dominated group (I) and in an *N. incompta* dominated group (II; Tables 4 and 5). (B) Benthic foraminiferal assemblages plot in three clusters: (1) pelagic benthic foraminifera; (2) pelagic benthic foraminifera under more eutrophic conditions and lower oxygen; (3) cold-water coral associated foraminifera (Tab. 4.6 and 4.7).

water coral mounds. In particular, they identified the species *D. coronata*, associated with other epi- and infaunal species, as a bioindicator for cold-water coral ecosystems and uvigerinids as bioindicators for off-mound sediments. The distribution pattern of the benthic assemblages in the samples from the two mud volcanoes is consistent with their distribution pattern observed in the cold-water coral mounds off-shore Ireland. In particular, *D. coronata* and the associated benthic assemblage seem to be consistently present in association with coral fragments (Fig. 4.6; Appendix E). The above and below sediments contain the off-mound typical association described for the Porcupine Basin and Rockall Bank, which is not present in the coral-rich levels, thus suggesting that the coral-rich layers are in situ. The fragmentation of the corals can be explained as a later effect of a weak and/or partial reactivated mud volcanic activity (e.g., weak seepage) that may produce dissolution of aragonites as observed by e.g., Foubert et al. (2008) and Kopf et al. (2004).

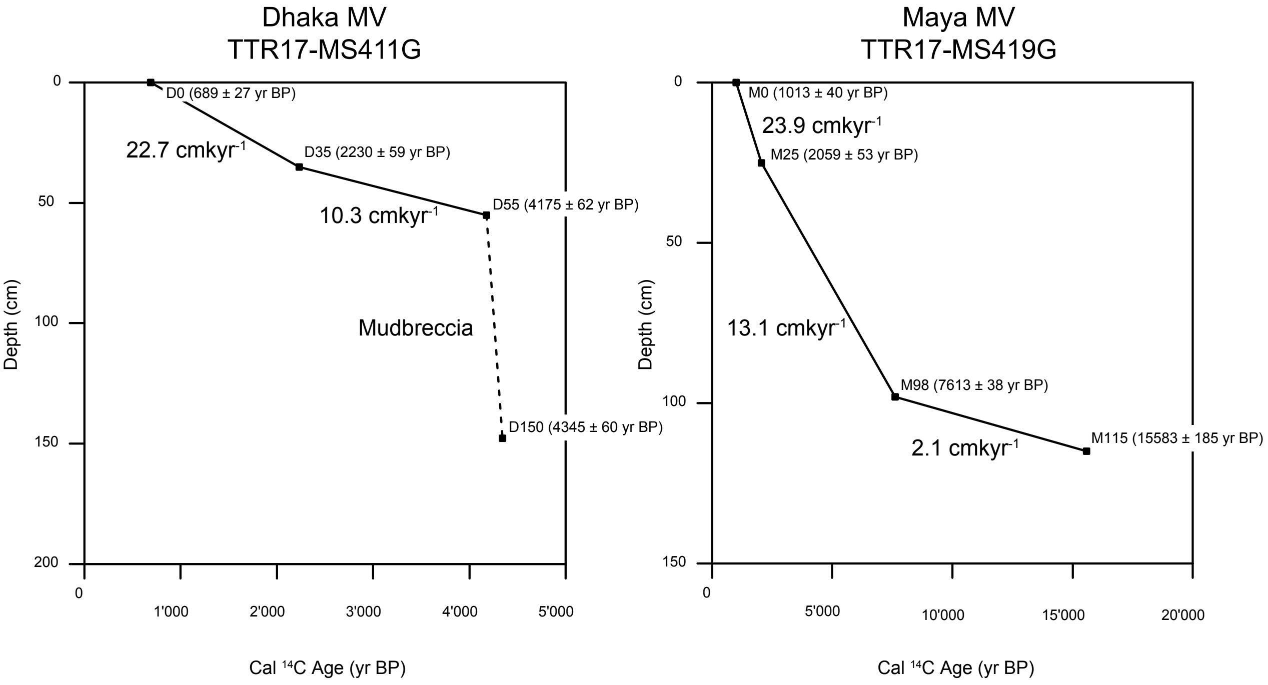


Figure 4.5 Calibrated ^{14}C ages (reservoir corrected) versus depth and sedimentation rates in cores TTR17-MS411G (Dhaka MV) and TTR17-MS419G (Maya MV).

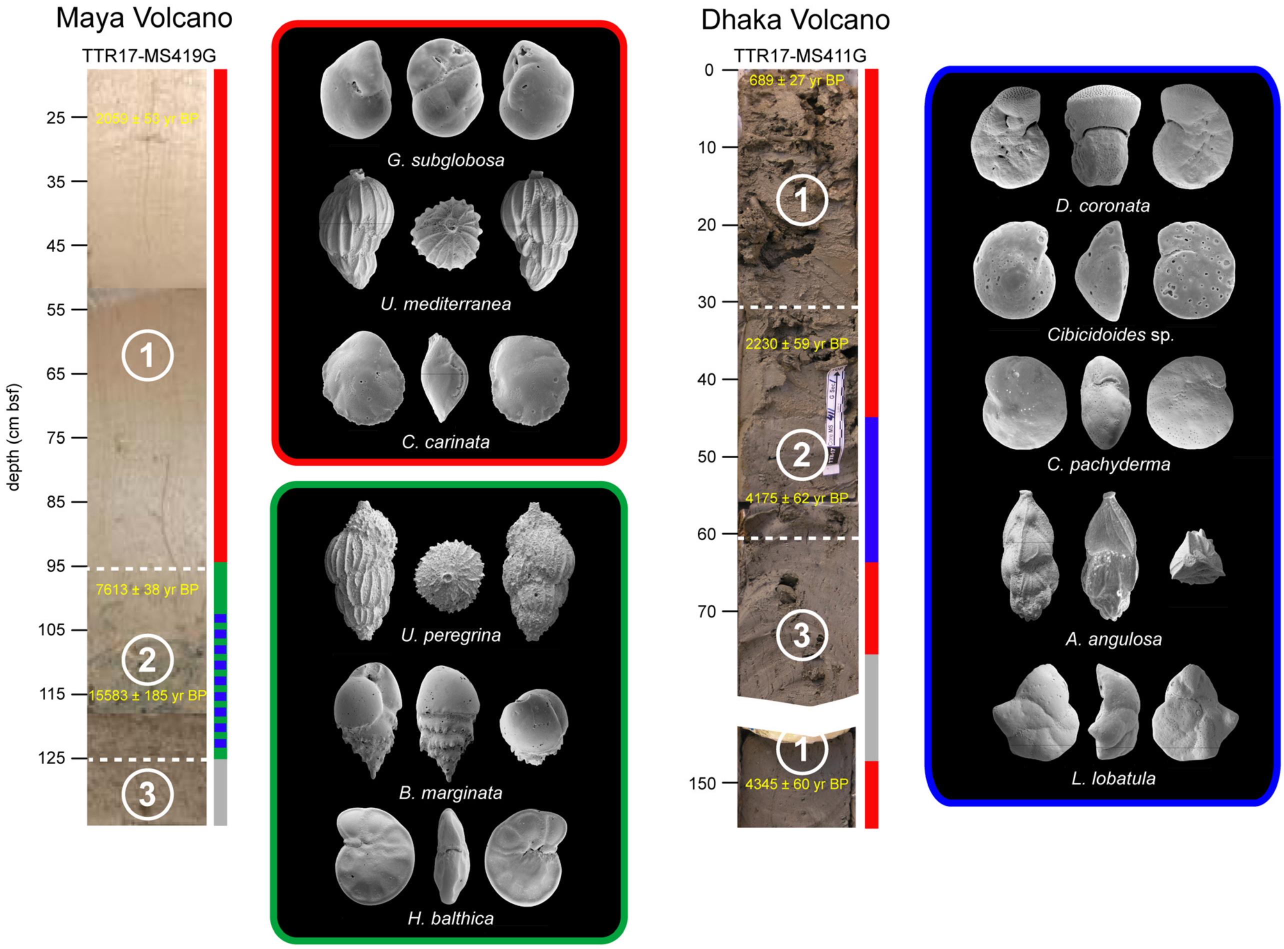


Figure 4.6 Benthic foraminiferal assemblages derived from the three nMDS clusters in cores TTR17-MS411G (Dhaka MV) and TTR17-MS419G (Maya MV). Red: pelagic benthic foraminiferal community; green: pelagic sediments with a higher nutrient supply and higher abundance of low oxygen tolerable foraminifera; blue: attached-epifaunal species typically associated to cold-water coral reefs. 1) *G. inflata* period , 2) *N. incompta* period, 3) mud breccia.

4.5.1 Similarities and differences between Dhaka and Maya mud volcanoes

Suitable substratum, low sedimentation rate, relatively long duration of stable conditions and similar density values seem to be a common feature for both volcanoes. León et al. (2007) suggested that colonization of mud volcanoes by non-chemosynthetic organisms such as corals might be related to periods of slow seepage activity inducing the formation of carbonate crusts. Sediment cores from various mud volcanoes in the Gulf of Cadiz show sequences of mud breccia with intercalation of intervals rich in cold-water coral debris (Akhmetzhanov et al., 2007; Foubert et al., 2008). However, in the cores from the Dhaka and Maya mud volcanoes, no carbonate crusts are observed. Therefore, the clasts contained in the mud breccia extruded by both mud volcanoes very reasonably acted as nucleation points and as a suitable hard substratum for cold-water coral colonization (Fig. 4.3), which was also facilitated by the elevated position of these structures (Masson et al., 2003). The AMS ^{14}C dating indicate that, according to the distribution of coral fragments and of the typical cold-water coral-associated benthic foraminiferal fauna in the cores, the duration of cold-water coral colonization was at least 2000 years at Dhaka and 7000 years at Maya, thus long enough to provide stable paleoceanographic conditions for cold-water coral development. Low sedimentation rate is one of the favourable factors for cold-water coral ecosystem development (Huvenne et al., 2002), because corals must sufficiently keep up with hemi-pelagic sedimentation (Dorschel et al., 2005; Rüggeberg et al., 2005; 2007). In both volcanoes the coral-rich layers correspond to the lower values of sedimentation rates for their respective site e.g., 10.3 cm kyr^{-1} for Dhaka and 2.1 cm kyr^{-1} for Maya mud volcano, respectively, thus confirming this essential thriving requirement and supporting our hypothesis of in-situ coral development. Dullo et al. (2008) have demonstrated that in the North Atlantic cold-water corals only thrive in density gradients between 27.35 to 27.65 kg m^{-3}, whereas Freiwald et al. (2009) show that in the Mediterranean Sea they grow between 29.08 and 29.13 kg m^{-3}. These Mediterranean water density values correspond to the boundary between light and dense Mediterranean Water at 29.08 kg m^{-3} (Millot, 2009). Today the boundary between the two water masses is approximately at 430 m (Millot, 2009), thus too deep for coral growth on the two investigated mud volcanoes that are at 370 m water depth (Dhaka) and 410 m water depth (Maya). During the deglaciation times, Rogerson et al. (2008) show a shoaling of the interface between these intermediate and deep water, that we suggest shallowed up to the coral site on the mud volcanoes.

4.5.2 Paleoceanographic setting

A preliminary indication of similarity between the paleoceanographic conditions during the deposition of the hemi-pelagic drapes on top of the mud breccia of both mud volcanoes is given by the nMDS plots obtained with multivariate statistical analysis of the complete data set. In particular we observe that a *G. inflata* dominated period and a *N. incompta* dominated period are clearly discriminated and distinct in both volcanoes (Fig. 4.4A; Tab. 4.4 and 4.5). Additionally, also benthic foraminifera show clear separation in the two mud volcanoes according to a warm pelagic fauna (cluster 1) dominated by *G. subglobosa*, *U. mediterranea*, *B. marginata* and *B. difformis*, a cold pelagic fauna (cluster 2) dominated by *U. peregrina*, *G. subglobosa*, *B. marginata* and *H. balthica*, and a cold-water corals associated fauna (cluster 3) dominated by *B. difformis*, *U. peregrina*, *Cibicidoides* spp. and *D. coronata* (Figs. 4.4B and 4.6; Tab. 4.6 and 4.7). However, since the cold-water corals development on the two mud volcanoes occurred at different times, we discuss them separately to investigate if these ecosystems responded to similar paleoceanographic settings and/or to identify a causal link to possible more extended and/or global paleoceanographic events.

4.5.3 Maya Mud Volcano

An indication of the paleoceanographic conditions of surface waters can be obtained by the distribution patterns of planktonic foraminiferal assemblages. The sediments corresponding to the coral-rich layer spanning a time interval from 7613 +/- 38 years BP to slightly older than 15583 +/- 185 years BP, were deposited on the top of the mud breccia and are dominated by *N. incompta* with very low contribution of warm water species (e.g., *Globigerinoides* spp.) (Figs. 4.3C and 4.4A; Tab. 4.4 and 4.5). This interval corresponds to a deglaciation time including the Bølling-Allerød period, the Younger Dryas, and the Early Holocene. It also contains a few specimens of *D. coronata*, *U. peregrina*, *B. marginata*, *H. balthica* and *A. angulosa* (Fig. 4.4B; Tables 4.6 and 4.7). According to Margreth et al. (2009), these lines of evidence support the interpretation of an environment characterized by enhanced nutrient supply to the surface of the Alboran Sea (e.g., Rogerson et al., 2008) and by cooler and nutrient richer waters at the sea floor, as also corroborated by high Total Organic Carbon values in the Alboran deep basin (e.g., Jimenez-Espejo et al., 2008; Rogerson et al., 2008). Presently the Alboran Sea is considered as one of the highest productivity areas associated with upwelling activity (Jimenez-Espejo et al., 2008; Morel, 1991) in the otherwise oligotrophic Mediterranean Sea (Cruzado, 1985). The occurrence of a few specimens of *D. coronata* indeed, underlines the presence of cold-water corals, but its low contribution points to a reef further away, to a small patch reef, or to the presence of solitary corals e.g., *Desmophyllum* spp. This period is also interpreted, based on other proxies, to be characterized by fresh, enhanced vertical mixing, and wet conditions on continent (Frisia et al., 2006; Zanchetta et al., 2007). According to Jimenez-Espejo et al. (2008) and Pérez-Folgado et al. (2003) these conditions ended between 7.7 and 7.2 ka BP, when a major oceanographic change occurred, giving rise to the modern setting of eddies and frontal circulation patterns of the Western Mediterranean Sea. The abundance curve of *N. incompta* reverses its trend with respect to the *Globigerinoides* spp. and *G. inflata* at 85 cm, 13 cm above the sample dated at 7613 ± 38 years BP (Fig. 4.3C). A similar reversal was also observed at about 8 ka by Rohling et al. (1995) and at 7/8 ka by Rohling and De Rijk (1999), attributed to a shallowing of the pycnocline/nutricline at this time due to the on-set of modern conditions (Fairbanks and Wiebe, 1980; Fairbanks et al., 1982; Reynolds and Thunell, 1986; Rohling et al., 1995; Sautter and Thunell, 1989; Weaver and Pujol, 1988). Our data confirm the age of the circulation shift as reported by these previous authors and allow to link it to the end of the African Humid Period which started as early as 7 – 8 ka in many North African areas (Liu et al., 2007). The slight discrepancy in the age between the present research and the cited literature may be due to two factors: 1) an additional reversal younger than that observed in Rohling et al. (1995) cannot be ruled out; 2) Rohling et al. (1995) derive their age model on core KS310 from three non calibrated data points obtained by Pujol and Vergnaud-Grazzini (1989) on Core KS8232 adjacent to core KS310. The hemi-pelagic drape above the interval, where the reverse of

N. incompta occurs, contains dominant *G. inflata* and reflects paleoceanographic conditions more similar to the modern ones with a relatively deep pycnocline (~200 m) and a surface layer containing actively meandering jets of Modified Atlantic Waters (Rohling et al., 1995).

4.5.4 Dhaka Mud Volcano

The coral-rich interval at Dhaka mud volcano developed between 4175 ± 62 and 2230 ± 59 years BP contains planktonic and benthic foraminiferal assemblages strictly similar to those observed at Maya mud volcano. Planktonic assemblages are dominated by *N. incompta*, suggesting a shallow pycnocline/nutricline and high nutrient availability (Figs. 4.3A and 4.4A). The benthic foraminiferal assemblages contain abundantly the cold-water coral associated *D. coronata* (Margreth et al., 2009), together with other epifaunal species and *A. angulosa*. The presence of this species points toward an environment characterized by high energy and strong currents (Mackensen et al., 1985), that are important for the lateral transport of sufficient fresh food particle to the suspension feeding cold-water corals (Frederiksen et al., 1992; White et al., 2005, 2007) and are conducive of their development and growth (e.g., Roberts et al., 2006). Therefore, we suggest that the top of the mud breccia at Dhaka MV was colonized by a more patch reef-like ecosystem than at Maya MV.

The shift between the *N. incompta* and the *G. inflata* dominated assemblages is less marked than at Maya MV and is observed at about 30 cm (~ 2230 ± 59 years BP). The interpretation of this shift in the circulation from high productivity and shallow pycno/nutricline to a more modern system dominated by less nutrient supply and a deeper pycno/nutricline is more difficult to explain with respect to the oldest similar event documented at Maya MV. Pollen records identify a progressive climatic aridity along the Mediterranean coasts between 6000 and 4000 years BP, roughly corresponding to the end of the African Humid Period at 5500 years BP, with dry conditions observed on the continental records (Barriendos and Martin-Vide, 1998; De Menocal et al., 2000; Liu et al., 2007; Swezey, 2001). At about 4000 years BP the progressive development of complex human society occurred along the Mediterranean coasts (Roberts, 1989) resulting in a drastic anthropogenic-related change in the natural vegetation in the Eastern Mediterranean clearly detectable in pollen diagrams (Van Zeist et al., 1975) and culminating at about 3400 to 2400 years BP (Baruch, 1994; Roberts, 1989). Riehl (2009) observed consistent changes in vegetation at about 2000 years BP in correlation to increased aridity along the Eastern Mediterranean coasts. Although this early human impact is mainly recorded in the Eastern Mediterranean, we suggest that it may have had also affected the western basin as a combined effect of human impact on a fragile environment which was already stressed by desiccation.

4.5.5 Relation to mud volcano-related seepage activity

When cold-water coral ecosystems were discovered in the North Atlantic, Hovland and Thomsen (1997) proposed a relation between the development of these peculiar ecosystems and seepage of light hydrocarbons as trigger of local primary production. In this context, the mud volcanism in the Alboran Sea has the potential to support cold-water coral ecosystems as many mud volcanoes in the region are still active, e.g., the Carmen mud volcano, where gas bubbling was documented during the TTR-17 Leg 1 (Comas et al., in press). However, Becker et al. (2009) showed that the presence of cold-water corals is not primarily due to nutrients linked to seepage activity but rather to the formation of seep-related carbonate crusts on elevated topography characterized by intense bottom currents and mixing resulting in increased food supply (Roberts et al., 2006). The Dhaka and Maya mud volcanoes are presently not active, and is therefore difficult to prove a possible relationship between seepage, nutrient supply and cold-water corals. However, oxygen and carbon isotopic values from shells of *Discanomalina coronata* from the Dhaka mud volcano (Tab. 4.3) do not show the strong isotopic anomaly found for foraminifera associated to methane seeps as e.g., in Hill et al. (2003), Rathburn et al. (2000) and Sen Gupta et al. (1997). Therefore, seepage activity during cold-water coral development on the Dhaka mud volcano can be ruled out.

4.6 CONCLUSION

Cold-water coral-rich layers were found at the top of the Dhaka and Maya mud volcanoes in the Alboran Sea. On both mud volcanoes the extruded mud breccia provides the nucleation point for the colonization and development of the corals. The co-occurrence of cold-water corals and the benthic foraminifera *D. coronata* together with the associated in- and epi-fauna as observed in the Porcupine Basin and on the Rockall Bank (Margreth et al., 2009; Fig. 4.6) suggests that these ecosystems are in situ. Two phases of cold-water corals growth are observed: at Dhaka MV they occur between 2230 ± 59 years BP and slightly older than

4175 ± 62 years BP; at Maya they occur between 7616 ± 38 years BP and slightly older than 15583 ± 185 years BP. The development of these ecosystems at different times on two mud volcanoes that are geographically close is probably related to the nature of the substratum, which plays a very important role for cold-water corals colonization. Our data indicate the mud breccia as the potential substratum, and that the two volcanoes were active before 4175 ± 62 years BP and 15583 ± 185 years BP, respectively, thus providing suitable substratum in different time slices. Our data suggest that on the top of the Maya mud volcano only a small patch reef and/or isolated corals proliferated, whereas a more extended patch reef colonized the top of the Dhaka mud volcano. At both mud volcanoes the cold-water corals development is related to times characterized by high nutrient availability, triggered by upwelling and/or strong currents that mobilized the nutrient horizontal fluxes. These intervals are characterized by high abundances of the planktonic foraminifera *N. incompta*. The shift from the *N. incompta* dominated period to the *G. inflata* dominated period, which reflects more modern paleoceanographic conditions and a deep pycno-nutricline, seems to occur at the passage from wet to arid conditions, at the end of the African Humid Period (Maya MV) and at the initiation of the complex human society along the Mediterranean coasts with consequent impact on the natural vegetation culminating at about 3400 to 2400 years BP (Dhaka MV). At both volcanoes no relation with seepage is observed.

5 - CONCLUSIONS

5. CONCLUSIONS

The presented work provides the first detailed documentation of foraminiferal fauna associated to cold-water coral ecosystems. Foraminiferal assemblages have been quantitatively investigated at three key sites for cold-water coral growth along the European continental margin:

- Giant cold-water carbonate mounds supporting cold-water coral ecosystems in the Porcupine/ Rockall area (Chapter 2).
- Widespread cold-water coral reefs on the Norwegian margin and in its upper slope area (Chapter 3).
- Buried reefs in the Western Mediterranean (Chapter 4).

Investigations on these sites allow to describe in details all species of benthic foraminifera associated to these ecosystems, to identify indicator species to demonstrate the link between foraminiferal assemblages and sedimentary facies, and to highight the potential of this group of organisms to detect cold-water coral ecosystems in the past. In parallel, the study of planktonic foraminifera has provided the scenario for the environmental conditions of the surface water masses.

Based on the results presented and discussed in previous chapters, the following conclusions can be highlighted:

- Benthic foraminiferal assemblages associated to cold-water coral ecosystems show remarkable similarities from northern Norway to the Western Mediterranean. Such similarity may be related to environmental requirements of foraminifera similar to those of cold-water corals. In particular, the cold-water coral associated assemblages are dominated by epifaunal-attached species such as *Discanomalina coronata*, *Cibicides refulgens*, and *Lobatula lobatula* but also infaunal foraminifera such as *Globocassidulina* spp., *Epistominella* spp., and *Cassidulina* spp.
- The benthic fauna can efficiently provide relevant information on currents, oxygenation and organic matter content in the sediments within and adjacent the cold-water coral reefs and/or mounds. In particular, these organisms indicate the preference of these ecosystems for strong bottom currents, well-oxygenated waters and high organic matter supply derived from seasonal phytoplankton and reaching the sea floor.
- Several species of benthic foramnifera that give important environmental indications are small-sized (63-125 µm). Our results underline the importance of analysing the small fractions to highlight the contribution of small-sized species to the interpretation of complex environmental settings.
- The planktonic fauna provides information on nutrient availability and primary productivity in surface waters. In particular, active/living reefs are accompanied by planktonic foraminiferal assemblages typical of surface waters particularly rich in nutrients. The decline of the cold-water coral ecosystems in the Alboran Sea co-occurred together with a shift in the planktonic foraminiferal assemblage from euthrophic (nutrient-rich) to more oligotrophic (nutrient-poor) conditions at the surface.
- *Discanomalina coronata* is only abundant in healthy cold-water coral ecosystems and completely absent outside the reefs and mounds. For this reason *D. coronata* is interpreted to respond to similar conditions as cold-water corals and, therefore, it is here proposed as an indicator species for healthy cold-water coral ecosystems along the European margin.
- Benthic foraminiferal assemblages provide an independent tool to identify different sedimentary facies on cold-water coral mounds on the Irish

margin, where these facies are strongly defined. Each facies is clearly identified with respect to the adjacent ones over a distance of several hundreds of meters (over 2000 m).
- In the cold-water coral reefs of the Norwegian margin, benthic foraminiferal habitats are only weakly defined and grade one into the other. The gradual changes in foraminiferal assemblages can be attributed to changes in the reef facies, which are restricted within tens of meter, whereas on the carbonate mounds the different facies occur over long distances.
- Foraminiferal diversity on the Norwegian and in along the Irish margins reefs is higher in the living parts of the cold-water coral reefs and gradually decreases towards the distal parts.
- The peculiar cold-water coral associated foraminiferal assemblage can be used to identify these ecosystems in the geologic record, e.g., even when the aragonitic corals are strongly dissolved like in the Alboran Sea.

5.1. Follow-up

The study of foraminifera associated to cold-water coral ecosystem is still very far to be completed as our understanding of the dynamics of foraminiferal assemblages living in these ecosystems is still in a preliminary phase. Although presently we have a better understanding of ecological and environmental control on foraminifera and corals, we still do not completely know how these ecosystems worked in different time periods.

Several questions are still open such as:

- Can we use the same bioindicators also for living cold-water coral ecosystems in regions far from the Atlantic margin e.g., New Zealand?
- Are benthic foraminiferal assemblages associated to these ecosystems similar worldwide?
- What foraminifera do tell us about paleoceanographic changes in terms of sea level, climate, productivity and ocean chemistry in the geological past of these ecosystems?
- Can we find the same bioindicators also for past ecosystems?
- If not, which species respond to similar ecological condition as cold-water corals?
- When did foraminifera acquire these similar requirements?
- Further studies on the geochemistry of the shells, in different locations and on the geological record will clarify these issues and give us an answer.

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SYSTEMATIC DESCRIPTION

to be submitted to Earth-Science Reviews

Order Foraminiferida Eichwald, 1830
Suborder Textulariina Delage and Hérouard, 1896
Superfamily Astrorhizacea Brady, 1881
Family Astrorhizidae Brady, 1881
Subfamily Astrorhizinae Brady, 1881

Genus *Astrorhiza* Sandahl, 1858
Type species: *Astrorhiza limnicola* Sandahl, 1858, p. 301

Astrorhiza cf. *catenata* Norman, 1877
Pl. 1, fig. 1

Astrorhiza catenata Norman *in* Norman, 1877, p. 213
Astrorhiza catenata Norman *in* Brady, 1879, p. 42, pl. 4, figs. 12-13
Aschemonella catenata Norman *in* Jones, 1994, p. 35, pl. 27, fig. 3, pl. 27A, fig. 3

Family Bathysiphonidae Avnimelech, 1951

Genus *Bathysiphon* M. Sars, 1872
Type species: *Bathysiphon filiformis* M. Sars, 1872, p. 251

Bathysiphon filiformis M. Sars, 1872
Pl. 1, fig. 2

Bathysiphon filiformis M. Sars *in* G. O. Sars, 1872, p. 251, pl. 6, fig. 4
Bathysiphon filiformis M. Sars *in* Brady, 1884, p. 248, pl. 26, figs. 15, 17-20
Bathysiphon filiformis M. Sars *in* Cushman, 1921, p. 41, pl. 2, fig. 1
Bathysiphon filiformis M. Sars *in* Gooday, 1988, p. 98, textfig. 1
Bathysiphon filiformis M. Sars *in* Jones, 1994, p. 34, pl. 26, figs 15, 17-20

Family Rhabdamminidae Brady, 1884
Subfamily Rhabdammininae Brady, 1884

Genus *Rhabdammina* M. Sars, 1869
Type species: *Rhabdammina abyssorum* M. Sars, 1869, *in* Carpenter, p. 61

Rhabdammina abyssorum M. Sars, 1869
Pl. 1, fig. 3

Rhabdammina abyssorum M. Sars *in* Carpenter, p. 61
Rhabdammina abyssorum M. Sars *in* Brady, 1884, p. 266, pl. 21, figs. 1-8, 10-13
Rhabdammina abyssorum M. Sars *in* Höglund, 1947, p. 25, pl. 1, fig. 2
Rhabdammina abyssorum M. Sars *in* Jones, 1994, p. 32, pl. 21, figs. 1-8, 10-13

Family Hippocrepinellidae Loeblich and Tappan, 1984

Genus *Hippocrepinella* Heron-Allen and Earland, 1932
Type species: *Hippocrepinella hirudinea* Heron-Allen and Earland, 1932, p. 71

Hippocrepinella hirudinea Heron-Allen and Earland, 1932
Pl. 1, fig. 4

Hippocrepinella hirudinea Heron-Allen and Earland *in* Heron-Allen and Earland, p. 258, pl. 1, figs. 7-15

Family Psammosphaeridae Haeckel, 1894
Subfamily Psammosphaerinae Haeckel, 1894

Genus *Psammosphaera* Schulze, 1875
Type species: *Psammosphaera fusca* Schulze, 1875, p. 113

Psammosphaera fusca Schulze, 1875
Pl. 5, fig. 5

Psammosphaera fusca Schulze *in* Schulze, 1875, p. 113, pl. 2, fig. 8
Psammosphaera fusca Schulze *in* Brady, 1884, p. 249, pl. 18, figs. 1-8
Psammosphaera fusca Schulze *in* Höglund, 1947, p. 46, pl. 4, figs. 9-14
Psammosphaera fusca Schulze *in* Hofker, 1972, p. 32, pl. 7, figs. 1-3
Psammosphaera fusca Schulze *in* Schröder, 1986, p. 36, pl. 10, figs. 1
Psammosphaera fusca Schulze *in* Jones, 1994, p. 31, pl. 18, figs. 1-8

Psammosphaera fusca Schulze var. *testacea* Flint, 1899
Pl. 1, fig. 6

Psammosphaera fusca var. testacea Flint *in* Flint, 1899, p. 268, pl. 8, fig. 2

Family Saccamminidae Brady, 1884
Subfamily Saccamminiae Brady, 1884

Genus *Lagenammina* Rhumbler, 1911
Type species: *Lagenammina laguncula* Rhumbler, 1911, p. 92, 111

Lagenammina fusiformis (Williamson, 1858)
Pl. 1, fig. 7

Proteonina fusiformis Williamson *in* Williamson, 1858, p. 1, pl. 1, fig. 1
Reophax fusiformis Williamson *in* Brady, 1884, p. 290, pl. 30, figs. 7-10, ?11
Reophax fusiformis Williamson *in* Schröder, 1986, p. 44, pl. 15, fig. 9
Lagenammina fusiformis Williamson *in* Cimerman and Langer, 1991, p. 15, pl. 1, fig. 4-5
Reophax fusiformis Williamson *in* Jones, 1994, p. 37, pl. 30, figs. 7-10, ?11

Lagenammina arenulata (Williamson, 1858)
Pl. 1, fig. 8

Reophax difflugiformis Brady var. *arenulata* Skinner *in* Skinner, 1961, p. 1239, pl. 30, fig. 5
Lagenammina arenulata Skinner *in* Jones, 1994, p. 37, pl. 30, fig. 5

Genus *Saccammina* Carpenter, 1869
Type species: *Saccammina sphaerica* Brady, 1871, p. 183

Saccammina sphaerica M. Sars, 1872
Pl. 1, fig. 9

Saccammina sphaerica M. Sars *in* G. O. Sars, 1872, p. 250
Saccammina sphaerica M. Sars *in* Brady, 1884, p. 253, pl. 18, figs. 11-15, 17
Saccammina sphaerica M. Sars *in* Cushman, 1918, p. 44, pl. 16, figs 4-5
Saccammina sphaerica M. Sars *in* Höglund, 1947, p. 50, pl. 4, figs 15-17
Saccammina sphaerica M. Sars *in* Loeblich and Tappan, 1964, p. C196, fig. 112.1
Saccammina sphaerica M. Sars *in* Hofker, 1972, p. 44, pl. 12, figs 1-3
Saccammina sphaerica M. Sars *in* Zheng, 1988, p. 33, pl. 4, fig. 12
Saccammina sphaerica M. Sars *in* Jones, 1994, p. 31, pl. 18, figs 11-15, ? 17

Superfamily Hippocrepinacea Rhumbler, 1895
Family Hippocrepinidae Rhumbler, 1895
Subfamily Hyperammininae Eimer and Fickert, 1899

Genus *Hyperammina* Brady, 1878
Type species: *Hyperammina elongata* Brady, 1878, p. 433

Hyperammina elongata Brady, 1878
Pl. 1, fig. 10

Hyperammina elongata Brady *in* Brady, 1878, p. 433, pl. 20, fig. 2
Hyperammina elongata Brady *in* Brady, 1884, p. 257, pl. 23, fig. 8
Hyperammina elongata Brady *in* Hofker, 1972, p. 45, pl. 12, figs 4-7
Hyperammina elongata Brady *in* Schröder, 1986, p. 34, pl. 6, fig. 2
Hyperammina elongata Brady *in* Zheng, 1988, p. 28, pl. 4, figs 4-5
Hyperammina elongata Brady *in* Jones, 1994, p. 33, pl. 23, fig. 8

Genus Saccorhiza Eimer and Fickert, 1899
Type species: *Hyperammina ramose* Brady, 1879, p. 33

Saccorhiza ramosa (Brady, 1879)

Pl. 1, fig. 11

Hyperammina ramosa Brady *in* Brady, 1879, p. 33, pl. 3, figs. 14-15
Saccorhiza ramosa Brady *in* Schröder, 1986, p .35, pl. 7, fig. 1
Saccorhiza ramosa Brady *in* Loeblich and Tappan, 1987, p. 43, pl. 32, figs. 10-15
Saccorhiza ramose Brady *in* Cimerman and Langer, 1991, p. 16, pl. 2, figs. 4-5
Saccorhiza ramosa Brady *in* Jones, 1994, p. 33, pl. 23, figs 15-19

Family Ammodiscidae Rheuss, 1862
Subfamily Ammodiscinae Reuss, 1862

Genus *Ammodiscus* Reuss, 1862
Type species: *Ammodiscus infimus* L. G. Bornemann, 1874, p. 725

Ammodiscus incertus (d'Orbigny, 1839)
Pl. 2, fig. 4

Operculina incerta d'Orbigny *in* d'Orbigny, 1839, p. 49, pl. 6, figs. 16-17
Ammodiscus incertus d'Orbigny *in* Brady, 1884, p. 330, pl. 38, figs. 1-3
Ammodiscus incertus d'Orbigny *in* Cushman, 1910, p. 73, figs. 95-96
Ammodiscus incertus d'Orbigny *in* Schröder, 1986, p. 39, pl. 10, fig. 10
Ammodiscus anguillae Höglund *in* Jones, p. 43, pl. 38, figs. 1, 3

Subfamily Tolypammininae Cushman, 1928

Genus *Ammolagena* Eimer and Fickert, 1899
Type species: *Trochammina irregularis* d'Orbigny var. *clavata* Jones and Parker, 1860, p. 304

Ammolagena clavata (Jones and Parker, 1860)
Pl. 2, fig. 7

Trochammina irregularis d'Orbigny var. *clavata* Jones and Parker *in* Jones and Parker, 1860, p. 304
Webbina clavata Jones and Parker *in* Brady, 1884, p. 349, pl. 41, figs, 12-16
Ammolagena clavata Jones and Parker *in* Cushman, 1921, p. 61, pl. 6, figs 1-4; pl. 10, figs 3-4
Ammolagena clavata Jones and Parker *in* Saidova, 1961, p. 24, pl. 7, fig. 32
Ammolagena clavata Jones and Parker *in* Schröder, 1986, p. 40, pl. 11, figs. 5-6
Ammolagena clavata Jones and Parker *in* Jones, 1994, p. 46, p. 41, figs. 12-16
Ammolagena clavata Jones and Parker *in* Abu-Zied et al., 2008, p. 51, pl. 1, fig. 1

Subfamily Ammovertellininae Saidova, 1981

Genus *Glomospira* Rzehak, 1885
Type species: *Trochammina squamata* Jones and Parker var. *gordialis* Jones and Parker, 1860, p. 304

Glomospira charoides (Jones and Parker, 1878)
Pl. 2, fig. 5

Trochammina squamata Jones and Parker var. *charoides* Jones and Parker *in* Jones and Paker, 1860, p. 304
Ammodiscus charoides Jones and Parker *in* Brady, 1884, p. 334, pl. 36, figs. 10-16
Glomospira charoides Jones and Parker *in* Cushman, 1918, p. 100, pl. 36, figs. 10-15
Glomospira charoides Jones and Parker *in* Höglund, 1947, p. 129, pl. 3, fig. 11
Glomospira charoides Jones and Parker *in* Resig, 1981, pl. 9, fig. 8
Repmanina Jones and Parker *in* Loeblich and Tappan, 1987, p. 52, pl. 39, figs. 24-26
Repmanina Jones and Parker *in* Cimerman and Langer, 1991, p. 17, pl. 3, figs. 6-9
Usbekistania charoides Jones and Parker *in* Jones, 1994, p. 43, pl. 38, figs. 10-16
Glomospira charoides Jones and Parker *in* Abu-Zied et al., 2008, p. 51, pl. 1, figs. 2-3

Superfamily Hormosinacea Haeckel, 1894
Family Hormosinidae Haeckel, 1894
Subfamily Reophacinae Cushman, 1910

Genus *Hormosinella* Shchedrina, 1969
Type species: *Reophax distans* Brady, 1881, p. 50

Hormosinella guttifera (Brady, 1881)
Pl. 2, fig. 2

Reophax guttifera Brady *in* Brady, 1881, p. 49, pl. 31, figs. 10-15
Hormosinella guttifera Brady *in* Jones, 1994, p. 38, pl. 32, figs. 18-22
Hormosinella guttifera Brady *in* Lobegeier and Gupta, 2008, p. 110, pl. 4, fig. 6

Genus *Reophax* de Montfort, 1808

Type species: *Reophax scorpiurus* de Montfort, 1808, p. 331

Reophax agglutinatus Cushman, 1913

Pl. 2, fig. 1

Reophax agglutinatus Cushman *in* Cushman, 1913, p. 637, pl. 79, fig. 6
Reophax agglutinatus Cushman *in* Jones, 1994, p. 37, pl. 30, fig. 13

Reophax scorpiurus de Montfort, 1808

Pl. 2, fig. 3

Reophax scorpiurus de Montfort *in* de Montfort, 1808, p. 330, fig. 130
Reophax scorpiurus de Montfort *in* Brady, 1884, p. 291, pl. 30, fig. 15-17
Reophax scorpiurus de Montfort *in* Cushman, 1921, p. 65, pl. 6, fig. 6
Reophax scorpiurus de Montfort *in* Cimerman and Langer, 1991, p. 17, pl. 4, figs. 1-4
Reophax sp. nov. (2) *in* Jones, 1994, p. 37, pl. 30, figs. 15-17
Reophax scorpiurus de Montfort *in* Majewski and Zajaczkowski, p. 112, pl. 1, fig. 10

Superfamily Lituolacea de Bainville, 1827

Family Haplophragmoididae Maync, 1952

Genus *Cribrostomoides* Cushman, 1910

Type species: *Cribrostomoides brady* Cushman, 1910, p. 108

Cribrostomoides subglobosum (M. Sars, 1868)

Pl. 2, fig. 6

Lituola subglobosa M. Sars *in* Carpenter, 1869, p . 250
Lituola subglobosa M. Sars *in* G. O. Sars, 1872, p. 253
Haplophragmoides subglobosa M. Sars *in* Cushman, 1910b, p. 105, figs. 162-164
Cribrostomoides bradyi M. Sars *in* Cushman, 1910b, p. 108, fig. 167
Cribrostomoides bradyi M. Sars *in* Loeblich and Tappan, 1987, p. 65, pl . 49, figs 1-3
Cribrostomoides subglobosum M. Sars *in* Schröder, 1986, p. 48, pl. 18, figs 15-16
Cribrostomoides subglobosus Cushman *in* Jones, 1994, p. 40, pl. 34, figs 8-10

Genus *Haplophragmoides* Cushman, 1910

Type species: *Nonionina canariensis* d'Orbigny, 1839, p. 128

Haplophragmoides robertsoni Brady, 1887

Pl. 3, figs. 1-2

Haplophragmoides robertsoni Brady *in* Brady, 1887, p. 893
Haplophragmoides brady Robertson *in* Robertson, 1891, p. 388
Haplophragmoides brady Robertson *in* Höglund, 1947, p. 134, pl. 10, fig. 1; fig. 111
Haplophragmoides brady Robertson *in* Murray, 1971, p. 25, pl. 5, figs. 1-2
Haplophragmoides brady Robertson *in* Schröder, 1986, p. 46, pl. 18, fig. 8

Haplophragmoides membranaceum Höglund, 1947

Pl. 3, fig. 3

Haplophragmoides membranaceum Höglund *in* Höglund, 1947, p. 136, pl. 10, fig. 5
Haplophragmoides membranaceum Höglund *in* Gabel, 1971, p. 30, pl. 3, figs. 25-25
Haplophragmoides membranaceum Höglund *in* de Stigter et al., 1998, p. 45, pl. 1, fig. 8

Genus *Labrospira* Höglund, 1947

Type species: *Haplophragmium crassimargo* Norman, 1892, p. 17

Labrospira jeffreysii (Williamson, 1858)

Pl. 2, figs. 8-9

Nonionina jeffreysii Williamson *in* Williamson, 1858, p. 34, pl. 3, figs. 72-73
Haplophragmium canariensis d'Orbigny *in* Brady, 1884, p. 310, pl. 35, figs 1-3, 5
Cribrostomoids jeffreysii Williamson in Öki, 1989, p. 71, pl. 1, fig. 14
Veleroninoides jeffreysii Williamson *in* Jones, 1994, p. 41, pl. 35, figs. 1-3, 5
Cribrostomoids jeffreysii Williamson *in* Murray, 2003, p. 11, pl. 2, fig. 5
Labrospira jeffreysii Williamson *in* Majewski and Anderson, 2009, p. 138, fig. 6

Family Lituolidae de Bainville, 1827

Subfamily Ammomarginulininae Podobina, 1978

Genus *Ammobaculites* Cushman, 1910

Type species: *Spirolina agglutinans* d'Orbigny, 1846, p. 137

Ammobaculites agglutinans (d'Orbigny, 1846)
Pl. 3, fig. 4

Spirolina agglutinans d'Orbigny *in* d'Orbigny, 1846, p. 137, pl. 7, figs. 10-12
Haplophragmium agglutinans d'Orbigny *in* Brady, 1884, p. 301, pl. 32, figs 19-20, 24-26.
Ammobaculites agglutinans d'Orbigny *in* Schröder, 1986, p. 50, pl. 21, figs 1-4
Ammobaculites agglutinans d'Orbigny *in* Jones, 1994, p. 39, pl. 32, figs 19-20, 24-26

Superfamily Haplophragmiacea Eimer and Fickert, 1899
Family Ammosphaeroidinidae Cushman, 1927
Subfamily Ammosphaeroidininae Cushman, 1927

Genus *Adercotryma* Loeblich and Tappan, 1952
Type species: *Lituola glomerata* Brady, 1878, p. 433

Adercotryma wrighti Brönnimann and Whittaker, 1987
Pl. 3, fig. 5

Adercotryma wrighti Brönnimann and Whittaker *in* Brönnimann and Whittaker, 1987, p. 27, figs. 3B, 7

Superfamily Spiroplectamminacea Cushman, 1927
Family Spiroplectamminidae Cushman, 1927
Subfamily Spiroplectammininae Cushman, 1927

Genus *Spiroplectinella* Kisel'man, 1972
Type species: *Spiroplecta wrightii* Silvestri, 1903, p. 63

Spiroplectinella wrightii (Silvestri, 1903)
Pl. 3, fig. 6

Spiroplecta wrightii Silvestri *in* Silvestri, 1903, p. 59, figs. 1-6
Textularia sagittula Defrance *in* Brady, 1884, p. 361, pl. 42, figs 17-18
Spirorutilus wrightii Silvestri *in* Banner and Pereira, 1981, p. 104, pl. 6, figs 7-8, 10; pl. 7, figs 1-2, 5
Spiroplectinella wrightii Silvestri *in* Kisel'man, 1972, p. 135, fig. 1
Spiroplectinella wrightii Silvestri *in* Loeblich and Tappan, 1987, p. 112, pl. 120, figs 1-10
Spiroplectinella wrightii Silvestri *in* Jones, 1994, p . 47, pl. 42, figs 17-18

Subfamily Vulvulininae Saidova, 1981

Genus *Vulvulina* d'Orbigny, 1826
Type species: *Vulvulina capreolus* d'Orbigny, 1826 = *Nautilus* (*Ortoceras*) *pennatula* Batsch, 1791

Vulvulina pennatula Batsch, 1791
Pl. 4, fig. 1

Vulvulina pennatula Batsch *in* Batsch, 1791, p. 3, 5, pl. 4, fig. 13
Vulvulina pennatula Batsch *in* Jones, 1994, p. 49, pl. 45, figs. 1-8
Vulvulina pennatula Batsch *in* Holbourn and Henderson, 2002, p. 10, pl. 2, figs. 17-18

Superfamily Trochamminacea Schwager, 1877
Family Trochamminidae Schwager, 1877
Subfamily Trochammininae Schwager, 1877

Genus *Portatrochammina* R. J. Echols, 1971
Type species: *Portatrochammina eltaninae* R. J. Echols, 1971

Portatrochammina antarctica (Parr, 1950)
Pl. 4, fig. 4

Trochammina antarctica Parr *in* Parr, 1950, p. 280, pl. 5, figs. 2-4
Portatrochammina antarctica Parr *in* Lobegeier and Gupta, 2008, p. 110, pl. 4, figs. 14-15
Portatrochammina antarctica Parr *in* Majewski and Anderson, 2009, p. 138, textfig. 3, fig. 7

Genus *Tritaxis* Schubert, 1921
Type species: *Tritaxis fusca* Williamson, 1858, p. 55

Tritaxis fusca (Williamson, 1858)
Pl. 4, fig. 3

Rotalina fusca Williamson *in* Williamson, 1858, p. 55, pl. 5, figs. 114-115
Tritaxis fusca Williamson *in* Hedley, Hurdle and Burdett, 1964, p. 420, fig. 1.
Tritaxis fusca Williamson *in* Loeblich and Tappan, 1987, p. 122, pl. 128, fig. 1-4
Tritaxis fusca Williamson *in* Jones, 1994, p. 54, pl. 49, fig. 13

Genus *Trochammina* Parker and Jones, 1859

Type species: *Nautilus inflatus* Montagu, 1808, p. 81

Trochammina labiosa Höglund, 1947
Pl. 4, fig. 2

Trochammina labiosa Höglund *in* Höglund, 1947, p. 207, pl. 15, fig. 6
Trochammina labiosa Höglund *in* Gabel, 1971, p. 40, pl. 8, figs. 3-5

Subfamily Polystomammininae Brönnimann and Beurlen, 1977

Genus *Lepidodeuterammina* Brönnimann and Whittaker, 1983

Type species: *Rotalina ochracea* Williamson, 1858, p. 55

Lepidodeuterammina ochracea (Williamson, 1858)
Pl. 4, fig. 5

Rotalina ochracea Williamson *in* Williamson, 1858, p. 55, pl. 4, figs. 112, pl. 5, figs. 113
Lepidodeuterammina ochracea Williamson *in* Vazquez Riveiros and Patterson, 2008, p. 10, pl. 4, fig. 3

Superfamily Verneuilinacea Cushman, 1911
Family Verneuilinidae Suleymanov, 1973
Subfamily Verneuilininae Cushman, 1911

Genus *Gaudryina* d'Orbigny, 1839

Type species: *Gaudryina rugosa* d'Orbigny, 1840, p. 44

Gaudryina rudis Wright, 1900
Pl. 4, fig. 6

Gaudryina rudis Wright *in* Wright, 1900, p. 53, pl. 2, fig. 1
Gaudryina rudis Wright *in* Gabel, p. 34, pl. 5, figs. 1-2
Gaudryina rudis Wright *in* Wagener, 1988, p. 126, pl. 21, fig. 15
Connemarella rudis Wright *in* Cimerman and Langer, p. 23, pl. 8, figs. 1-4
Gaudryina rudis Wright *in* Murray, 2003, p. 13, pl. 2, figs. 12-13

Gaudryina pseudotrochus (Cushman, 1922)
Pl. 5, fig. 1

Textularia pseudotrochus Cushman *in* Cushman, 1922, p. 21, pl. 5, fig. 1-3
Textularia pseudotrochus Cushman *in* Lacroix, p. 12, pl. 5
Textularia pseudotrochus Cushman *in* Hofker, 1960, p. 238, pl. A, figs. 21-23
Textularia barkeri Hofker *in* Hofker, 1978, p. 27, pl. 1, fig. 3
Sahulia patelliformis Hofker *in* Loeblich and Tappan, 1985, p. 203, pl. 14, figs 1-10
Sahulia barkeri Hofker *in* Jones, 1994, p. 48, pl. 43, figs 15-16, 18-19

Superfamily Textulariacea Ehrenberg, 1838
Family Eggerellidae Cushman, 1937
Subfamily Eggerellinae Cushman, 1937

Genus *Eggerella* Cushman, 1935

Type species: *Verneuilina bradyi* Cushman 1911, p. 54

Eggerella humboldti Todd and Brönnimann, 1957
Pl. 5, fig. 2

Eggerella humboldti Todd and Brönnimann *in* Todd and Brönnimann, 1957, p. 26, pl. 2, fig. 26

Genus *Eggerelloides* Haynes, 1973

Type species: *Bulimina scabra* Williamson, 1858, p. 65

Eggerelloides scaber (Williamson, 1858)
Pl. 5, fig. 4

Bulimina scabra Williamson *in* Williamson, 1858, p. 65, pl. 5, figs. 136-137
Eggerelloides scabrus Williamson *in* Loeblich and Tappan, 1987, p. 170, pl. 189, figs. 5-7
Eggerelloides scabrus Williamson *in* Cimerman and Langer, 1991, p. 21, pl. 8, fig. 7
Eggerelloides scaber Williamson *in* Jones, 1994, p. 52, pl. 47, figs. 15-17
Eggerelloides scaber Williamson *in* Murray, 2003, p. 13, pl. 2, fig. 11

Genus *Karreriella* Cushman, 1933

Type species: *Gaudryina siphonella* Reuss, 1851, p. 78

Karreriella bradyi (Cushman, 1911)
Pl. 5, fig. 3

Gaudryina bradyi Cushman *in* Cushman, 1911, p. 67,

pl. 107
Gaudryina bradyi Cushman *in* Cushman, 1921, p. 149, pl. 29, fig. 3
Karreriella bradyi Cushman *in* Schröder, 1986, p. 55, pl. 22, fig. 8-9
Karreriella bradyi Cushman *in* Jones, 1994, p. 50, pl. 46, figs. 1-4
Karreriella bradyi Cushman *in* Loeblich and Tappan, 1994, p. 25, pl. 30, figs 8-16
Karreriella bradyi Cushman *in* Holbourn and Henderson, 2002, p. 11, pl. 2, fig. 4-5

Family Textulariidae Ehrenberg, 1838
Subfamily Textulariinae, Ehrenberg, 1838

Genus *Bigenerina* d'Orbigny, 1826
Type species: *Bigenerina nodosaria* d'Orbigny, 1826, p. 27

Bigenerina cylindrica Cushman, 1922
Pl. 5, fig. 6

Bigenerina cylindrica Cushman *in* Cushman, 1922, p. 26, pl. 3, figs. 7-8
Bigenerina cylindrica Cushman *in* Jones, p. 49, pl. 44, figs. 19-24

Bigenerina nodosaria d'Orbigny, 1826
Pl. 5, fig. 5

Bigenerina nodosaria d'Orbigny *in* d'Orbigny, 1826, p. 261, pl. 11, figs. 9-12
Bigenerina ? *nodosaria* d'Orbigny *in* Cimerman and Langer, p. 21, pl. 9, figs. 1-6
Bigenerina nodosaria d'Orbigny *in* Jones, p. 49, pl. 44, figs. 14-18
Bigenerina nodosaria d'Orbigny *in* Murray, 2003, p. 11, pl. 2, fig. 4
Bigenerina nodosaria d'Orbigny *in* Duchemin et al., 2005, p. 205, pl. 1, fig. 5

Genus *Textularia* Defrance, 1824
Type species: *Textularia sagittula* Defrance *in* de Bainville, 1824, p. 177

Textularia lateralis Laliker, 1935
Pl. 5, fig. 8

Textularia lateralis Laliker *in* Laliker, 1935, p. 1, pl. 1, figs 3-5
Textularia lateralis Laliker *in* Zheng, 1988, p.111, pl. 26, fig. 4
Textularia lateralis Laliker *in* Loeblich and Tappan, 1994, p. 28, pl. 33, figs. 13-16

Textularia truncata (Höglund, 1947)
Pl. 6, fig. 1

Textularia truncata Höglund *in* Höglund, 1947, p. 175, pl. 12, figs. 8-9
Textularia truncata Höglund *in* Gabel, 1971, p. 32, pl. 4, figs. 20-21
Textularia truncata Höglund *in* Cimerman and Langer, 1991, p. 22, pl. 12, figs. 1-3
Textularia truncata Höglund *in* Murray, 2003, p. 15, pl. 3, figs. 17-18

Textularia tenuissima Earland, 1933
Pl. 2, fig. 2

Textularia elegans Lacroix *in* Lacroix, 1931, p. 14
Textularia elegans Lacroix *in* Lacroix, 1932, p. 8, pl. 4-6
Textularia tenuissima Earland *in* Earland, 1933, p. 3, pl. 21-30
Textularia tenuissima Earland *in* Murray, 2003, p. 15, pl. 3, figs. 15-16
Textularia tenuissima Earland *in* Blais, 1995, p. 92, pl. 2-2, fig. 1

Subfamily Siphotextulariinae, Loeblich and Tappan, 1985

Genus *Siphotextularia* Finlay, 1939
Type species: *Siphotextularia wairoana* Finlay, 1939

Siphotextularia obesa Parr, 1950
Pl. 5, fig. 7

Siphotextularia obesa Parr *in* Parr, 1950, p. 276, pl. 5, figs. 1

Family Valvulinidae Berthelin, 1880
Subfamily Valvulininae Berthelin, 1880

Genus *Clavulina* d'Orbigny, 1826
Type species: *Clavulina parisiensis* d'Orbigny, 1826, p. 268

Clavulina parisiensis d'Orbigny, 1826
Pl. 6, fig. 3

Clavulina parisiensis d'Orbigny *in* d'Orbigny, 1826, p. 268

Suborder Spirillinina Hohenegger and Piller, 1975
Family Spirillinidae Reuss and Fritsch, 1861

Genus *Mychostomina* Berthelin, 1881
Type species: *Spirillina vivipara* Ehrenberg var. *revertens* Rhumbler, 1906, p. 32

Mychostomina revertens (Rhumbler, 1906)
Pl. 6, fig. 4

Spirillina vivipara Ehrenberg var. *revertens* Rhumbler *in* Rhumbler, 1906, p. 32, pl. 2, figs. 8-10
Mychostomina revertens Rhumbler *in* Jones, 1994, p. 92, pl. 85, fig. 5

Genus *Spirillina* Ehrenberg, 1843
Type species: *Spirillina vivipara* Ehrenberg, 1843

Spirillina vivipara Ehrenberg, 1843
Pl. 6, fig. 5

Spirillina vivipara Ehrenberg *in* Heron-Allen and Earland, 1930, p. 178
Spirillina vivipara Ehrenberg *in* Y. Le Calvez, 1958, p. 181
Spirillina vivipara Ehrenberg *in* Barker, 1960, pl. 85, figs. 1-5
Spirillina vivipara Ehrenberg *in* Colom, 1974, p. 139, figs. 23 c, d
Spirillina vivipara Ehrenberg *in* Loeblich and Tappan, 1987, p. 304, pl. 318, figs. 4-7
Spirillina vivipara Ehrenberg *in* Murray, 2003, p. 15, pl. 4, fig. 1

Family Patellinidae Rhumbler, 1906
Subfamily Patellininae Rhumbler, 1906

Genus *Patellina* Williamson, 1858
Type species: *Patellina corrugata* Williamson, 1858, p. 46

Patellina corrugata Williamson, 1858
Pl. 6, fig. 6

Patellina corrugata Williamson *in* Williamson, 1858, p. 46, pl. 3, figs. 86-89
Patellina corrugata Williamson *in* Loeblich and Tappan, 1987, p. 306, pl. 320, figs. 7-14
Patellina corrugata Williamson *in* Jones, 1994, p. 93, pl. 86, figs. 1-7
Patellina corrugata Williamson *in* Cimerman and Langer, 1991, p. 24, pl. 15, figs. 7-14
Patellina corrugata Williamson *in* Murray, 2003, p. 24, pl. 9, figs. 6-7

Suborder Miliolina Delage and Hérouard, 1896
Superfamily Cornuspiracea Schultze, 1854
Family Cornuspiridae Schultze, 1854
Subfamily Cornuspirinae Schultze, 1854

Genus *Cornuspira* Schultze, 1854
Type species: *Orbis foliaceus* Philippi, 1844

Cornuspira foliacea (Philippi, 1844)
Pl. 6, fig. 8

Orbis foliaceus Philippi *in* Philippi, 1844, p. 147, pl. 24, fig. 26
Cornuspira foliacea Philippi *in* Loeblich and Tappan, 1987, p. 310, pl. 322, figs. 7-8
Cornuspira foliacea Philippi *in* Cimerman and Langer, 1991, p. 24, pl. 15, figs. 1-3

Cornuspira involvens (Reuss, 1850)
Pl. 6, fig. 7

Operculina involvens Reuss *in* Reuss, 1850, p. 370, pl. 46, fig. 20
Cornuspira involvens Reuss *in* Cimerman and Langer, 1991, p. 25, pl. 15, figs. 4-7
Cornuspira involvens Reuss *in* Jones, 1994, p. 26, pl. 11, figs. 1-3
Cornuspira involvens Reuss *in* Murray, 2003, p. 15, pl. 4, fig. 5

Family Hemigordiopsidae A. Nikitina, 1969
Subfamily Hemigordiopsinae A. Nikitina, 1969

Genus *Gordiospira* Heron-Allen and Earland, 1932
Type species: *Gordiospira fragilis* Heron-Allen and Earland, 1932

Gordiospira elongata Collins, 1958
Pl. 6, fig. 10

Gordiospira elongata Collins *in* Collins, 1958, p. 347, pl. 1, figs 6-7
Gordiospira elongata Collins *in* Loeblich and Tappan, 1994, p. 37, pl. 56, figs. 17-18; pl. 57, figs. 1-4

Gordiospira sp.
Pl. 6, fig. 9

Remarks. Test discoidal, planispiral, proloculus followed by an undivided second chamber, which is irregularly enroled, surface with transverse groth wrinkle.

Superfamily Miliolacea Ehrenberg, 1839
Family Spiroloculinidae Wiesner, 1920

Genus *Spiroloculina* d'Orbigny, 1826
Type species: *Spiroloculina depressa* d'Orbigny, 1826

Spiroloculina dilatata d'Orbigny, 1846
Pl. 7, fig. 2

Spiroloculina dilatata d'Orbigny *in* d'Orbigny, 1846, p. 271, pl. 16, figs. 16-18
Spiroloculina dilatata d'Orbigny *in* Wiesner, 1923, p. 35, pl. 4, fig. 26
Spiroloculina dilatata d'Orbigny *in* Cimerman and Langer, 1991, p. 30, pl.22, figs. 5-8

Spiroloculina excavata d'Orbigny, 1846
Pl. 7, fig. 3

Spiroloculina excavata d'Orbigny *in* d'Orbigny, 1846, p. 271, pl. 16, figs. 19-21
Spiroloculina excavata d'Orbigny *in* Cimerman and Langer, 1991, p. 30, pl. 23, figs. 1-3
Spiroloculina excavata d'Orbigny *in* Sgarrella and Moncharmont-Zei, 1993, p. 169, pl. 5, fig. 6
Spiroloculina excavata d'Orbigny *in* Murray, 1991, p. 17, pl. 4, figs. 13-14

Spiroloculina tenuiseptata Brady, 1884
Pl. 7, fig. 1

Spiroloculina tenuiseptata Brady *in* Brady, 1884, p. 153, pl. 10, fig. 5
Spiroloculina tenuiseptata Brady *in* Le Calvez, 1958, p. 162, pl. 1, fig. 7
Spiroloculina tenuiseptata Brady *in* Cimerman and Langer, 1991, p. 31, pl. 24, figs. 6-9

Family Hauerinidae Schwager, 1876
Subfamily Siphonapertinae Saidova, 1975

Genus *Ammomassilina* Cushman, 1933
Type species: *Massilina alveoliniformis* Millett, 1898, p. 609

Ammomassilina arenaria (Brady, 1884)
Pl. 7, fig. 4

Spiroloculina arenaria Brady *in* Brady, 1884, p. 153, pl. 8, fig. 12

Subfamily Hauerininae Schwager, 1876

Genus *Cycloforina* Luczkowska, 1972
Type species: *Quinqueloculina contorta* d'Orbigny, 1846, p. 298

Cycloforina laevigata (d'Orbigny, 1839)
Pl. 7, fig. 5

Quinqueloculina laevigata d'Orbigny *in* d'Orbigny, 1839, p. 301, pl. 3, figs. 31-33

Cycloforina stalkeri (Loeblich and Tappan, 1953)
Pl. 7, fig. 6

Quinqueloculina stalkeri Loeblich and Tappan *in* Loeblich and Tappan, 1953, p. 40, pl. 5, figs. 5-9
Quinqueloculina stalkeri Loeblich and Tappan *in* Sgarrella and Moncharmont-Zei, 1993, p. 174, pl. 5, figs. 13-14.

Genus *Quinqueloculina* d'Orbigny, 1826
Type species: *Serpula seminulum* Linné, 1758, p. 786

Quinqueloculina arctica Cushman, 1933
Pl. 8, fig. 1

Quinqueloculina arctica Cushman *in* Cushman, 1933, p. 2, pl. 1, fig. 3

Quinqueloculina seminula (Linné, 1758)
Pl. 7, fig. 8

Serpula seminula Linné *in* Linné, 1758, p. 786, pl. 2, figs. 1
Quinquloculina seminula Linné *in* Schlumberger, 1893, p. 208, pl. 4, figs. 80-81
Quinquloculina seminula Linné *in* Murray, 1971, p. 65, pl. 24, figs. 1-6
Quinquloculina seminula Linné *in* Cimerman and Langer, 1991, p. 38, pl. 34, figs. 9-12

Quinqueloculina viennensis Le Calvez and Le Calvez, 1958
Pl. 7, fig. 7

Miliolina cuvieriana d'Orbigny *in* d'Orbigny, 1839, p. 190, pl. 11, figs. 19-21

Quinquloculina viennensis Le Calvez and Le Calvez *in* Le Calvez and Le Calvez, 1958, p. 187, pl. 5, figs. 42, 44, 45
Quinquloculina viennensis Le Calvez and Le Calvez *in* Vénec-Peyré, 1984 pl. 4, fig. 1
Quinquloculina viennensis Le Calvez and Le Calvez *in* Sgarrella and Moncharmont - Zei, p. 176, pl. 7, fig. 8

Subfamily Miliolinellinae Vella, 1957

Genus *Biloculinella* Wiesner, 1931

Type species: *Biloculina labiata* Schlumberger, 1891, p. 556

Biloculinella depressa (Wiesner, 1923)

Pl. 8, fig. 3

Biloculina labiata Schlumberger var. *depressa* Wiesner *in* Wiesner, 1923, pp. 89, 90, pl. 18, fig. 263
Biloculina depressa Wiesner *in* Cimerman and Langer, 1991, p. 39, pl. 36, fig. 11
Biloculina depressa Wiesner *in* Murray, 2003, p. 15, pl. 4, figs. 2-3

Biloculinella fragilis Le Calvez and Le Calvez, 1958

Pl. 8, fig. 4

Biloculinella fragilis Le Calvez and Le Calvez *in* Le Calvez and Le Calvez, 1958, pp. 202-203, pl. 16, figs. 182-183

Biloculinella globula (Bornemann, 1855)

Pl. 8, fig. 2

Biloculina globula Bornemann *in* Bornemann, 1855, p. 349, pl. 19, fig. 3
Biloculinella globula Bornemann *in* Cimerman and Langer, 1991, p. 40, pl. 36, figs. 1-2

Genus *Miliolinella* Wiesner, 1931

Type species: *Vermiculum subrotundum* Montagu, 1803, p. 1298

Miliolinella subrotunda (Montagu, 1803)

Pl. 8, fig. 5

Vermiculum subrotundum Montagu *in* Montagu, 1803, p. 521
Miliolinella subrotunda Montagu *in* Loeblich and Tappan, 1987, p. 340, pl. 350, figs. 1-12
Miliolinella subrotunda Montagu *in* Cimerman and Langer, 1991, p. 42, pl. 38, figs. 4-9
Miliolinella subrotunda Montagu *in* Jones, 1994, p. 20, pl. 4, fig. 3
Miliolinella subrotunda Montagu *in* Murray, 2003, p. 15, pl. 4, fig. 6
Miliolinella subrotunda Montagu *in* Duchemin et al., 2007, p. 16, pl. 1, fig. 9

Miliolinella elongata Kruit, 1955

Pl. 9, fig. 1

Miliolinella circularis Borneman var. *elongata* Kruit *in* Kruit, 1955, p. 468, pl.1, fig. 15
Miliolinella elongata Kruit *in* Cimerman and Langer, 1991, p. 41, pl. 37, figs. 8
Miliolinella circularis var. *elongata* Kruit *in* Kruit, Sgarrella and Moncharmont-Zei, 1993, p. 187, pl. 8, fig. 2

Genus *Pyrgo* Defrance, 1824

Type species: *Pyrgo laevis* Defrance, 1824, p. 273

Pyrgo anomala (Schlumberger, 1891)

Pl. 9, fig. 4

Biloculina anomala Schlumberger *in* Schlumberger, 1891, p. 569, pl. 11, figs. 84-86, pl. 12, fig. 101
Pyrgo anomala Schlumberger *in* Cimerman and Langer, 1991, p. 44, pl. 41, figs. 3-5

Pyrgo comata (Brady, 1881)

Pl. 9, fig. 3

Biloculina comata Brady *in* Brady, 1881, p. 45, pl. 3, fig. 9
Biloculina comata Brady *in* Brady, 1884, p. 144, pl. 3, figs. 9 a, b
Biloculina comata Brady *in* Schlumberger, 1891, p. 565, pl. 10, figs. 72, 73,
Biloculina comata Brady *in* Cushman, 1917, p. 81, pl. 34, fig. 1
Biloculina comata Brady *in* Cimerman and Langer, 1991, p. 44, pl. 41, fig.9
Biloculina comata Brady *in* Jones, 1994, p. 19, pl. 3, fig. 9

Pyrgo elongata (d'Orbigny, 1826)

Pl. 10, fig. 5

Biloculina elongata d'Orbigny *in* d'Orbigny, 1826, p. 298
Pyrgo elongata d'Orbigny *in* Cimerman and Langer, 1991, p. 44, pl. 41, figs. 6-8
Pyrgo elongata d'Orbigny *in* Gabel, 1971, p. 38, pl. 7, figs. 27-28

Pyrgo elongata d'Orbigny *in* Sgarrella and Moncharmont-Zei, 1993, p. 182, pl. 9, fig. 1.

Pyrgo inornata (d'Orbigny, 1846)
Pl. 9, fig. 2

Biloculina inornata d'Orbigny *in* d'Orbigny, 1846, p. 266, pl. 16, figs. 7-9

Pyrgo lucernula (Schwager, 1866)
Pl. 10, fig. 4

Biloculina lucernula Schwager *in* Schwager, 1866, p. 202, pl. 4, fig. 17
Pyrgo lucernula Schwager *in* Cimerman and Langer, p. 45, pl. 41, figs. 10-11
Pyrgo lucernula Schwager *in* Jones, p. 18, pl. 2, figs. 5-6

Pyrgo murrhina (Schwager, 1866)
Pl. 10, fig. 3

Biloculina murrhina Schwager *in* Schwager, 1866, p. 203, pl. 4, fig. 15
Pyrgo murrhina Schwager *in* Mullineaux and Lohmann, 1981, p. 38, pl. 1, fig. 13
Pyrgo murrhina Schwager *in* Murgese and De Deckker, 2005, p. 34, text-fig. 4, figs. 9-10
Pyrgo murrhina Schwager *in* Abu-Zied et al., 2008, p. 51, pl. 1, figs. 16-17

Pyrgo sarsi Schlumberger, 1891
Pl. 10, figs. 1-2

Biloculina ringens Lamarck *in* Brady, 1884, p. 139
Pyrgo sarsi Schlumberger *in* Schlumberger, 1891, p. 553, pl. 9, figs. 55-59
Pyrgo fornasinii Chapman and Parr *in* Chapman and Parr, 1935, p. 5
Pyrgo sarsi Schlumberger *in* Jones, 1994, p. 18, pl. 2, fig. 7

Pyrgo subsphaerica (d'Orbigny, 1840)
Pl. 9, figs. 5

Biloculina subsphaerica d'Orbigny *in* d'Orbigny, 1839, p. 162, pl. 8, figs. 25-27

Pyrgo williamsoni (Silvestri, 1923)
Pl. 9, figs. 6

Biloculina ringens Lamarck "*typica*" Williamson *in* Williamson, 1858, p. 79, pl. 6, 169-170
Biloculina williamsoni Silvestri *in* Silvestri, 1923, p. 73
Pyrgo williamsoni Silvestri *in* Haynes, 1973, p. 61, text-fig. 14, nos. 1-3
Pyrgo williamsoni Silvestri *in* Murray, 2003, p. 17, pl. 4, figs. 7-8

Genus *Triloculina* d'Orbigny, 1826
Type species: *Miliolites trigonula* Lamarck, 1804, p. 351

Triloculina marioni Schlumberger, 1893
Pl. 11, fig. 1

Triloculina marioni Schlumberger *in* Schlumberger, 1893, p. 62, pl. 1, figs. 38-41.
Triloculina marioni Schlumberger *in* Le Calvez and Le Calvez, 1958, p. 191, pl.6, figs. 54-56.
Triloculina marioni Schlumberger *in* Cimerman and Langer, 1991, p. 46, pl. 43, figs. 1-5.

Triloculina tricarinata d'Orbigny, 1826
Pl. 11, fig. 3

Triloculina tricarinata d'Orbigny *in* d'Orbigny, 1826, p. 299
Triloculina tricarinata d'Orbigny *in* Bock, 1971, p. 28, pl. 12, figs. 1-2
Triloculina tricarinata d'Orbigny *in* Cimerman and Langer, 1991, p. 46, pl. 44, figs. 3-4
Triloculina tricarinata d'Orbigny *in* Sgarrella and Moncharmont - Zei, 1993, p. 187, pl. 9, figs. 14-15
Triloculina tricarinata d'Orbigny *in* Hottinger et al, 1993, p. 65, pl. 68, figs. 7-12

Triloculina trigonula (Lamarck, 1804)
Pl. 11, fig. 2

Miliolites trigonula Lamarck *in* Lamarck, 1804, p. 351, pl. 17, fig. 4
Triloculina trigonula Lamarck *in* Cushman, 1917, p. 65, pl. 25, fig. 3
Triloculina trigonula Lamarck *in* Whittaker and Hodgkinson, 1979, p. 34, pl. 3, fig. 8
Triloculina trigonula Lamarck *in* Zheng, 1988, p. 242, pl. 19, fig. 3; pl. 23, fig. 9; pl. 33, fig. 5; text-fig. 59
Triloculina trigonula Lamarck *in* Jones, 1994, p. 20, pl. 3, figs. 15-16
Triloculina trigonula Lamarck *in* Hayward et al., 1999, p. 106, pl. 5, figs 31-32

Subfamily Sigmoilinitinae Luczkowska, 1974

Genus *Sigmoinella* Saidova, 1975
Type species: *Sigmoinella borealis* Saidova, 1975, p. 157

Sigmoinella borealis Saidova, 1975
Pl. 11, fig. 4

Sigmoinella borealis Saidova *in* Saidova, 1975, p. 158m pl. 45, fig. 2
Sigmoinella borealis Saidova *in* Loeblich and Tappan, 1987, p. 349, pl. 356, figs. 19-20

Subfamily Sigmoilopsinae Vella, 1957

Genus *Sigmoilopsis* Finlay, 1947
Type species: *Sigmoilina schlumbergeri* Silvestri, 1904, p. 267

Sigmoilopsis schlumbergeri (Silvestri, 1904)
Pl. 11, fig. 5

Sigmoilina schlumbergeri Silvestri *in* Silvestri, 1904, pp. 267, 269
Sigmoilopsis schlumbergeri Silvestri *in* Cimerman and Langer, 1991, p. 48, pl. 46, figs. 10-14
Sigmoilopsis schlumbergeri Silvestri *in* Loeblich and Tappan, 1987, p. 350, pl. 356, figs. 8-13
Sigmoilina schlumbergeri Silvestri *in* Kihle and Løfaldli, 1975

Sigmoilopsis woodi Atkinson, 1968
Pl. 11, fig. 6

Sigmoilopsis woodi Atkinson *in* Atkinson, 1968, p. 161, pl. 18, fig. 4

Suborder Lagenina Delage and Hérouard, 1896
Superfamily Nodosariacea Ehrenberg, 1838
Family Nodosariidae Ehrenberg, 1838
Subfamily Nodosariinae Ehrenberg, 1838

Genus *Dentalina* Risso, 1826
Type species: *Nodosaria cuvieri* d'Orbigny, 1826, p. 255

Dentalina cuvieri (d'Orbigny, 1826)
Pl. 12, fig. 1

Nodosaria cuvieri d'Orbigny *in* d'Orbigny, 1826, p. 255, pl. 9, fig. 57

Dentalina lamarcki Neugeboren, 1856
Pl. 12, fig. 2

Dentalina lamarcki Neugeboren *in* Neugeboren, 1856, p. 91, pl. 4, fig. 16

Genus *Grigelis* Mikhalevich, 1981
Type species: *Nodosaria pyrula* d'Orbigny, 1826, p. 253

Grigelis orectus (Loeblich and Tappan, 1994)
Pl. 12, fig. 3

Nodosaria pyrula d'Orbigny *in* Schwager, p. 217, pl. 5, fig. 38
Nodosaria pyrula d'Orbigny *in* Brady, 1884, p. 497, pl. 62, figs 10-12
Nodosaria pyrula d'Orbigny *in* Cushman, 1921, p. 187, pl. 33, figs 3-5
Dentalina guttifera d'Orbigny *in* Barker, 1960, p. 130, pl. 62, figs 10-12
Grigelis guttifera d'Orbigny *in* Loeblich and Tappan, 1987, p. 396, pl. 441, figs 2-3
Grigelis sp. nov. Jones, 1994, p. 73, pl. 62, figs 10-12
Grigelis orectus Loeblich and Tappan *in* Loeblich and Tappan, 1994, p. 64, pl. 115, fig. 22

Genus *Laevidentalina* Loeblich and Tappan, 1986
Type species: *Laevidentalina aphelis* Loeblich and Tappan, 1986, p. 242

Laevidentalina sidebottomi (Cushman, 1933)
Pl. 12, fig. 4

Dentalina sidebottomi Cushman *in* Cushman, 1933, p. 12, pl. 3, fig. 4

Family Vaginulinidae Reuss, 1860
Subfamily Lenticulininae Chapman, Parr, and Collins, 1934

Genus *Lenticulina* Lamarck, 1804
Type species: *Lenticulites rotulatus* Lamarck, 1823, p. 153

Lenticulina calcar (Linné, 1758)
Pl. 12, fig. 5

Nautilus calcar Linné *in* Linné, 1758, p. 709, pl. 19, figs. b-c
Lenticulina calcar Linné in Cimerman and Langer, 1991, p. 51, pl. 53, figs. 1-4

Lenticulina gibba (d'Orbigny, 1826)
Pl. 12, fig. 7

Cristellaria gibba d'Orbigny *in* d'Orbigny, 1826, p. 292, no. 17
Lenticulina gibba d'Orbigny *in* Kihle and Løfaldli, 1975
Lenticulina gibba d'Orbigny *in* Cimerman and Langer, 1991, p. 51, pl. 53, figs. 7-11
Lenticulina gibba d'Orbigny *in* Jones, 1994, p. 81, pl. 69, figs. 8-9

Lenticulina inornata (d'Orbigny, 1846)
Pl. 12, fig. 9

Robulina inornata d'Orbigny *in* d'Orbigny, 1846, p. 102, pl. 4, figs. 25-26

Lenticulina orbicularis (d'Orbigny, 1846)
Pl. 12, fig. 8

Robulina orbicularis d'Orbigny *in* d'Orbigny, 1826, p. 288, pl. 15, figs. 8-9
Lenticulina orbicularis d'Orbigny *in* Cimerman and Langer, 1991, p. 51, pl. 53, fig. 12
Lenticulina orbicularis d'Orbigny *in* Jones, 1994, p. 81, pl. 69, fig. 17
Lenticulina orbicularis d'Orbigny *in* Kihle and Løfaldli, 1975

Lenticulina vortex (Fichtel and Moll, 1798)
Pl. 12, fig. 6

Nautilus vortex Fichtel and Moll *in* Fichtel and Moll, 1798, p. 33, pl. 2, figs. d-i
Lenticulina vortex Fichtel and Moll *in* Jones, 1994, p. 81, pl. 69, figs. 14-16

Genus *Neolenticulina* McCulloch, 1977
Type species: *Neolenticulina chathamensis* McCulloch, 1977, p. 8

Neolenticulina peregrina (Schwager, 1866)
Pl. 12, fig. 10

Cristellaria peregrina Schwager *in* Schwager, 1866, p. 245, pl. 7, figs. 89
Cristellaria variabilis Reuss *in* Brady, 1884 (not Reuss, 1850), p. 541, pl. 68, figs 11-16.
Lenticulina peregrina Schwager *in* Cushman and McCulloch, 1950, p. 302, pl. 39, fig. 5.
Dimorphina peregrina Schwager *in* Hofker, 1978, p . 37, pl. 3, figs 3-4, 7-8.
Neolenticulina variabilis Reuss *in* Jones, 1994, p . 80, pl. 68, figs 11-16.
Neolenticulina peregrina Schwager *in* Loeblich and Tappan, 1987, p. 406, pl. 447, figs 9-12, 16.

Genus *Saracenaria* Defrance, 1824
Type species: *Saracenaria italica* Defrance, 1824, *in* de Blainville p. 176

Saracenaria caribbeana Hofker, 1976
Pl. 13, fig. 1

Cristellaria italica Defrance *in* Brady, 1884, p. 22, pl. 68, fig. 17
Saracenaria caribbeana Hofker *in* Hofker, 1976, p. 191, pl. 65
Saracenaria caribbeana Hofker *in* Jones, 1994, p. 80, pl. 68, fig. 17

Subfamily Marginulininae Wedekind, 1937

Genus *Amphicoryna* Schlumberger, 1881
Type species: *Nautilus scalaris* Batsch, 1791, p. 1, 4

Amphicoryna scalaris (Batsch, 1791)
Pl. 13, figs. 2-3

Nautilus (*Ortoceras*) *scalaris*, Batsch *in* Batsch, 1791, p. 91, pl. 2, figs. 4 a-b
Nodosaria scalaris Batsch *in* Cushman, 1921, p. 199, pl. 35, fig. 6
Amphicoryna scalaris Batsch *in* Barker, 1960, pl. 63, figs. 28-31
Amphicoryna scalaris Batsch *in* Cimerman and Langer, 1991, p. 52, pl. 54, figs. 1-9
Amphicoryna scalaris Batsch *in* Jones, 1994, p. 75, pl. 63, figs 28-31

Genus *Astacolus* de Montfort, 1908
Type species: *Nautilus crepidula* Fichtel and Moll, 1798, p. 64

Astacolus beerae Brenner and McMillan, 1976
Pl. 13, fig. 4

Astacolus beerae Brenner and McMillan *in* McLachlan, Brenner, and McMillan, 1976, p. 351, pl. 11, figs. 13-18

Subfamily Vaginulininae Reuss, 1860

Genus *Planularia* Defrance, 1826
Type species: *Peneroplis auris* Defrance *in* de Blainville, 1824, p. 178

Planularia perculata McCulloch, 1977
Pl. 13, fig. 5

Planularia perculata McCulloch, 1977, p. 10, pl. 96, fig. 14

Planularia costata (d'Orbigny, 1902)
Pl. 13, fig. 7

Robulina costata d'Orbigny *in* d'Orbigny, 1902, p. 43, pl. 44, fig. 3

Family Lagenidae Reuss, 1862

Genus *Lagena* Walker and Jacob, 1798
Type species: *Serpula* (*Lagena*) *sulcata* Walker and Jacob, *in* Kanmacher, 1798, p. 634

Lagena substriata Williamson, 1848
Pl. 13, fig. 6

Lagena substriata Williamson *in* Williamson, 1848, p. 15, pl. 2, fig. 12
Lagena substriata Williamson *in* Murray, 2003, p. 17, pl. 5, fig. 7
Lagena substriata Williamson *in* Jones, 1994, p. 64, pl. 57, fig. 19

Lagena meridionalis Wiesner, 1931
Pl. 13, fig. 8

Lagena gracilis Williamson var. *meridionalis* Wiesner *in* Wiesner, 1931, p. 117, pl. 18, fig. 211
Lagena meridionalis Williamson *in* Jones, 1994, p. 66, pl. 58, fig. 19
Lagena meridionalis Williamson *in* Vazquez Riveiros and Patterson, 2008, p. 16, pl. 6, fig. 4

Lagena semilineata var. *spinigera* Earland, 1934
Pl. 13, fig. 9

Lagena semilineata Wright var. *spinigera* Earland *in* Earland, 1934, p. 173, pl. 7, fig. 21
Lagena semilineata Wright var. *spinigera* Earland *in* Jones, 1994, p. 65, pl. 58, figs. 4?, 17

Lagena squamosoalata Brady, 1881
Pl. 13, fig. 11

Lagena squamosoalata Brady *in* Brady, 1881, p. 61, pl. 60, fig. 23
Lagena squamosoalata Brady *in* Jones, 1994, p. 70, pl. 60, fig. 23

Lagena trigonolaevigata Balkwill and Millett, 1884
Pl. 13, fig. 12

Lagena trigonolaevigata Balkwill and Millett *in* Balwill and Millett, 1884, p. 86, pl. 3, fig. 4

Genus *Pygmaeoseistron* Patterson and Richardson, 1987
Type species: *Lagena hispidula* Cushman. 1913, p. 14

Pygmaeoseistron laevis ovalis (Williamson, 1848)
Pl. 13, fig. 10

Serpula laevis ovalis Walker and Boys *in* Walker and Boys, 1784, p. 3, pl. 1, fig. 9
Vermiculum laeve Montagu *in* Montagu, 1803, p. 524, pl. 1, fig. 9

Genus *Hyalinonetrion* Patterson and Richardson, 1987
Type species: *Hyalinonetrion sahulense* Patterson and Richardson, 1987

Hyalinonetrion gracillimum (Costa, 1856)
Pl. 14, fig. 1

Amphorina gracilis Costa *in* Costa, 1856, p. 121, pl. 11, fig. 11a
Lagena gracillima Costa *in* Feyling-Hanssen, 1971, p. 206, pl. 4, fig. 1
Lagena gracillima Costa *in* Gabel, 1971, p. 45, pl. 10, figs. 1, 2
Hyalinonetrion gracillimum Costa *in* Cimerman and Langer, , p. 52, pl. 55, figs. 1-2

Family Polymorphinidae d'Orbigny, 1839
Subfamily Polymorphininae d'Orbigny, 1839

Genus *Globulina* d'Orbigny, 1839
Type species: *Polymorphina gibba* d'Orbigny, 1826, p. 266

Globulina aequalis d'Orbigny, 1846
Pl. 14, fig. 2

Globulina aequalis d'Orbigny *in* d'Orbigny, 1846, p. 227, pl. 13, figs. 11, 12

Genus *Pseudopolymorphina* Cushman and Ozawa, 1928

Type species: *Pseudopolymorphina hanzawai* Cushman and Ozawa, 1928, p. 15

Pseudopolymorphina sp.
Pl. 14, fig. 3

Genus *Pyrulina* d'Orbigny, 1839
Type species: *Polymorphina gutta* d'Orbigny, 1926, p. 267, 310

Pyrulina cylindroids (Roemer, 1930)
Pl. 14, fig. 4

Polymorphina cylindroides Roemer *in* Roemer, p. 385, pl. 3, fig 26
Pyrulina cylindroides Roemer *in* Feyling-Hannsen, p. 219, pl. 5, figs. 10, 11

Family Ellipsolagenidae A. Silvestri, 1923
Subfamily Oolininae Loeblich and Tappan, 1961

Genus *Favulina* Patterson and Richardson, 1987
Type species: *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1848, p. 20

Favulina squamosa (Montagu, 1803)
Pl. 14, fig. 5

Vermiculum squamosum Montagu *in* Montagu, 1803, p. 526, pl. 14, fig. 2
Oolina squamosa Montagu *in* Jones, 1994, p. 66, pl. 58, fig. 32
Oolina squamosa Montagu *in* Kihle and Løfaldli, 1975

Favulina melo (d'Orbigny, 1839)
Pl. 14, fig. 6

Oolina squamosa Montagu *in* Jones, 1994, p. 66, pl. 58, fig. 28-30
Oolina melo d'Orbigny *in* Kihle and Løfaldli, 1975
Favulina melo d'Orbigny *in* Vazquez Riveiros and Patterson, 2008, p. 17, pl. 7, fig. 2

Favulina hexagona (Williamson, 1858)
Pl. 14, fig. 7

Entosolenia squamosa Montagu var. *hexagona* Williamson *in* Williamson, 1848, p. 20, pl. 2, fig. 23
Oolina hexagona Williamson *in* Jones, 1994, p. 66, pl. 58, fig. 33
Favulina hexagona Williamson *in* Cimerman and Langer, 1991, p. 55, pl. 58, figs. 8-9

Genus *Homalohedra* Patterson and Richardson, 1987
Type species: *Lagena guntheri* Earland, 1987, p. 151

Homalohedra williamsoni (Alcock, 1865)
Pl. 14, fig. 8

Entosolenia williamsoni Alcock *in* Alcock, 1865, p. 195
Oolina williamsoni Alcock *in* Feyling-Hannsen, p. 227, pl. 18, gigs. 1,2
Oolina williamsoni Alcock *in* Murray, 2003, p. 17, pl. 5, fig. 10

Homalohedra apiopleura (Loeblich and Tappan, 1953)
Pl. 14, fig. 9

Lagena apiopleura Loeblich and Tappan *in* Loeblich and Tappan, 1953, p. 59, pl. 10, figs. 14, 15
Oolina apiopleura Loeblich and Tappan *in* Jones, 1994, p. 65, pl. 57, fig. 32
Homalohedra apiopleura Loeblich and Tappan *in* Vazquez Riveiros and Patterson, 2008, p. 17, pl. 7, fig. 3

Homalohedra borealis (Loeblich and Tappan, 1954)
Pl. 15, fig. 1

Entosolenia costata Williamson *in* Williamson, 1858, p. 9, pl. 1, fig. 18
Oolina costata Williamson *in* Loeblich and Tappan, 1953, p. 68, pl. 13, figs. 4-6
Oolina borealis Loeblich and Tappan *in* Loeblich and Tappan, 1954, p. 384
Homalohedra borealis Loeblich and Tappan *in* Vazquez Riveiros and Patterson, 2008, p. 17, pl. 7, fig. 4

Homalohedra eucostata (McCulloch, 1977)
Pl. 15, fig. 2

Oolina eucostata McCulloch *in* McCulloch, 1977, pp. 78, 79, pl. 55, fig. 7

Genus *Oolina* d'Orbigny, 1839
Type species: *Oolina laevigata* d'Orbigny, 1839, p. 19

Oolina lineata subsp. *communis* McCulloch, 1977
Pl. 15, fig. 3

Oolina lineata Williamson subsp. *communis* McCulloch *in* McCulloch, 1977, p. 81, pl. 55, fig. 18

Oolina ampulladistoma (Jones, 1874)
Pl. 15, fig. 4

Lagena vulgaris Williamson var. *ampulla-distoma* Jones *in* Jones, 1874, p. 63, pl. 19, fig. 5

Oolina globosa (Montagu, 1803)
Pl. 15, fig. 5

Vermiculum globosum Montagu *in* Montagu, 1803, p. 3, pl. 1, fig. 8
Oolina globosa Montagu *in* Jones, 1994, p. 61, pl. 56, figs. 1-3

Oolina laevigata d'Orbigny, 1839
Pl. 15, fig. 6

Oolina laevigata d'Orbigny *in* d'Orbigny, 1839, p. 19, pl. 5, fig. 3

Genus *Fissurina* Reuss, 1850
Type species: *Fissurina laevigata* Reuss, 1850, p. 366

Fissurina agassizi Todd and Bronnimann, 1957
Pl. 15, fig. 7

Fissurina agassizi Todd and Bronnimann *in* Todd and Bronnimann, 1957, p. 36, pl. 9, fig. 14

Fissurina annectens (Burrows and Holland, 1895)
Pl. 16, fig. 4

Lagena annectens Burrows and Holland *in* Jones, 1895, p. 203, pl. 7, fig. 11
Fissurina annectens Kihle and Løfaldli, 1975

Fissurina circularis Todd, 1954
Pl. 15, fig. 8

Fissurina circularis Todd *in* Todd, 1954, p. 351, pl. 87, fig. 27

Fissurina lucida (Williamson, 1848)
Pl. 16, fig. 1

Entosolenia marginata Monatgu var. *lucida* Williamson *in* Williamson, 1848, p. 17, pl. 2, fig. 17
Fissurina lucida Williamson *in* Kihle and Løfaldli, 1975
Fissurina lucida Williamson *in* Vazquez Riveiros and Patterson, 2008, p. 19, pl. 8, Fig. 2

Fissurina eburnea Buchner, 1940
Pl. 16, fig. 2

Fissurina eburnea Buchner *in* Buchner, 1940, p. 458, pl. 9, figs. 146, 147
Fissurina eburnea Buchner *in* Vazquez Riveiros and Patterson, p. 19, pl. 8, figs. 1, 8

Fissurina kerguelensis Parr, 1950
Pl. 16, fig. 3

Lagena staphylleraria Schwager *in* Schwager, 1884, p. 474, pl. 59, figs. 8-11
Fissurina kerguelensis Parr *in* Parr, 1950, p. 305, pl. 8, fig. 7

Fissurina crassiporosa McCulloch, 1977
Pl. 16, fig. 5

Fissurina crassiporosa McCulloch *in* McCulloch, 1977, p. 98, pl. 56, figs. 15, 16, 22

Fissurina longpointensis McCulloch, 1977
Pl. 16, fig. 6

Fissurina longpointensis McCulloch *in* McCulloch, 1977, p. 114, pl. 59, fig. 9

Fissurina pseudoorbignyana (Buchner, 1940)
Pl. 17, fig. 3

Lagena pseudoorbignyana Buchner *in* Buchner, 1940, p. 460, pl. 10, figs. 157-160

Fissurina dublini McCulloch, 1977
Pl. 17, fig. 4

Fissurina dublini McCulloch *in* McCulloch, 1977, p. 102, pl. 62, fig. 8

Fissurina derogata McCulloch, 1977
Pl. 17, fig. 5

Fissurina derogata McCulloch *in* McCulloch, 1977, p. 101, pl. 65, fig.6

Fissurina lacunata (Burrows and Holland, 1895)
Pl. 17, fig. 6

Lagena castrensis Brady *in* Brady, 1884, p. 485, pl. 1, figs. 1-3
Lagena lacunata Burrows and Holland *in* T.R. Jones, 1895, p. 205, pl. 7, fig. 12

Fissurina nucelloides (Buchner, 1940)

Pl. 17, fig. 7

Lagena nucelloides Buchner *in* Buchner, 1940, p. 518, pl. 22, figs. 476-477

Fissurina pseudolucida Zheng, 1979
Pl. 17, fig. 8

Fissurina pseudolucida Zheng *in* Zheng, 1979, p. 215, pl. 13, figs. 8-9

Genus *Palliolatella* Patterson and Richardson, 1987
Type species: *Palliolatella avita* Patterson and Richardson, 1987, p. 219

Palliolatella semimarginata (Reuss, 1870)
Pl. 18, fig. 1

Lagena marginata Montagu var. *semimarginata* Reuss *in* Reuss, 1870, p. 468, pl. 4, figs. 4-6, 10-12
Fissurina semimarginata Reuss *in* Jones, 1994, p. 68, pl. 59, figs. 17, 19

Subfamily Parafissurininae R. W. Jones, 1984

Genus *Parafissurina* Parr, 1947
Type species: *Lagena ventricosa* A. Silvestri, 1904, p. 10

Parafissurina basispinata McCulloch, 1977
Pl. 17, fig. 1

Parafissurina basispinata McCulloch *in* McCulloch, 1977, p. 139, pl. 72, figs. 1-3

Parafissurina marginata (Walker and Boys, 1803)
Pl. 17, fig. 2

Serpula (*Lagena*) *marginata* Walker and Boys, 1784, p. 2, pl. 1, fig. 7
Vermiculum marginatum Montagu *in* Montagu, 1803, p. 524, pl. 1, fig. 7
Fissurina marginata Murray *in* Murray, 2003, p. 17, pl. 5, figs. 3-4

Parafissurina felsinea (Fornasini, 1894)
Pl. 18, fig. 4

Lagena felsinea Fornasini *in* Fornasini, 1894, p. 1
Parafissurina felsinea Fornasini *in* Jones, 1994, p. 61, pl. 56, fig. 4

Parafissurina lateralis (Cushman, 1913)
Pl. 18, fig. 2

Lagena lateralis Cushman *in* Cushman, 1913, p. 9, pl. 1, fig. 1
Parafissurina lateralis Cushman *in* Jones, 1994, p. 62, pl. 56, fig. 17, 18

Parafissurina robusta (Zheng, 1979)
Pl. 18, fig. 6

Fissurina robusta Zheng *in* Zheng, 1979, pp. 215-216, pl. 13, fig. 11

Suborder Robertinina Loeblich and Tappan, 1984
Superfamily Ceratobuliminacea Cushman, 1927
Family Epistominidae Wedekind, 1937
Subfamily Epistomininae Wedekind, 1937

Genus *Hoeglundina* Brotzen, 1948
Type species: *Rotalia elegans* d'Orbigny, 1826, p. 272

Hoeglundina elegans (d'Orbigny, 1826)
Pl. 18, fig. 3

Rotalia (*Turbinulina*) *elegans* d'Orbigny *in* d'Orbigny, 1826, p. 276
Hoeglundina elegans d'Orbigny *in* Hermelin and Scott, 1985, p. 210, pl. 6, fig. 6-7
Hoeglundina elegans d'Orbigny *in* Cimerman and Langer, 1991, p. 56, pl. 59, figs. 10-12
Høglundina elegans d'Orbigny *in* Kihle and Løfaldli, 1975

Superfamily Conorboidacea Thalmann, 1952
Family Robertinidae Reuss, 1850
Subfamily Robertininae Reuss, 1850

Genus *Robertinoides* Höglund, 1947
Type species: *Bulimina normani* Goës, 1894, p. 47

Robertinoides bradyi (Cushman and Parker, 1936)
Pl. 18, fig. 7

Bulimina subteres Brady *in* Brady, 1881, p. 55
Bulimina subteres Brady *in* Brady, 1884, p. 403, pl. 50, fig. 18
Robertina bradyi Cushman and Parker *in* Cushman and Parker, 1936, p. 99, pl. 16, fig. 9
Robertinoides bradyi Cushman and Parker *in* Jones, 1994, p. 55, pl. 50, fig. 18

Robertinoides pumilum Höglund, 1947
Pl. 18, fig. 8

Robertinoides pumilum Höglund *in* Höglund, 1947, p. 227, pl. 18, fig.5

Suborder Globigerinina Delange and Hérouard, 1896
Superfamily Heterohelicacea Cushman, 1927
Family Chiloguembelinidae Reiss, 1963

Genus *Strepochilus* Brönnimann and Resig, 1971
Type species: *Bolivina tokelauae* Boersma, 1969, p. 329

Strepochilus tokelauae (Boersma, 1969)
Pl. 23, fig. 6

Bolivina tokelauae Boersma *in* Kierstead et al., 1969, p. 329, pl. 1, fig. 1
Strepochilus tokelauae Boersma *in* Saito, Thompson, and Dee Breger, 1981, p. 161, pl. 55, fig. 3

Superfamily Globorotaliacea Cushman, 1927
Family Globorotsliidae Cushman, 1927

Genus *Berggrenia* F. L., Parker, 1976
Type species: *Globanomalina praepumilio* F. L., Parker, 1967, p. 148

Berggrenia clarkei (Rögl and Bolli, 1973)
Pl. 22, fig. 5

Globigerina clarkei Rögl and Bolli *in* Rögl and Bolli, 1973, p. 563, pl. 14, figs. 13-15
Berggrenia clarkei Rögl and Bolli *in* Saito, Thompson, and Dee Breger, 1981, p. 87, pl. 26, fig. 3

Genus *Neogloboquadrina* Bandy, Frerichs, and Vincent, 1967
Type species: *Globigerina dutertrei* d'Orbigny, 1839, p. 84

Neogloboquadrina dutertrei (d'Orbigny, 1839)
Pl. 22, fig. 4

Globigerina dutertrei d'Orbigny *in* d'Orbigny, 1839, p. 84, pl. 4, figs. 19-21
Neogloboquadrina dutertrei d'Orbigny *in* Kennet and Srinivasan, 1983, p. 198, pl. 48, figs. 7-9
Neogloboquadrina dutertrei d'Orbigny *in* Saito, Thompson, and Dee Breger, 1981, p. 111, pl. 36, fig. 36

Neogloboquadrina incompta (Cifelli, 1961)
Pl. 22, fig. 2

Globigerina incompta Cifelli *in* Cifelli, 1961, p. 83, pl. 4, figs. 1-7
Neogloboquadrina incompta Cifelli *in* Saito, Thompson, and Dee Breger, 1981, p. 108, pl. 34, fig. 2

Neogloboquadrina pachyderma (Ehrenberg, 1861)
Pl. 22, fig. 3

Aristospira pachyderma Ehrenberg *in* Ehrenberg, 1861, pp. 276, 277, 303
Aristospira pachyderma Ehrenberg *in* Ehrenberg, 1872, pl. 1, fig. 4
Neogloboquadrina pachyderma Ehrenberg *in* Kennet and Srinivasan, 1983, p. 192, pl. 47, figs. 2, 6-8
Neogloboquadrina pachyderma Ehrenberg *in* Saito, Thompson, and Dee Breger, 1981, p. 106, pl. 34, fig. 1

Genus *Globorotalia* Cushman, 1927
Type species: *Pulvinulina menardii* d'Orbigny var. *tumida* Brady, 1877, p. 535

Globorotalia inflata (d'Orbigny, 1839)
Pl. 21, fig. 1

Globigerina inflata d'Orbigny *in* d'Orbigny, 1839, p. 134, pl. 12, figs. 7-9
Globorotalia inflata d'Orbigny *in* Kennet and Srinivasan, 1983, p. 118, pl. 27, figs. 7-9
Globorotalia inflata d'Orbigny *in* Saito, Thompson, and Dee Breger, 1981, p. 124, pl. 41, fig. 1

Globorotalia scitula (Brady, 1882)
Pl. 21, fig. 2

Pulvinulina scitula Brady *in* Brady, 1882, p. 716
Globorotalia scitula Brady *in* Kennet and Srinivasan, 1983, p. 134, pl. 31, figs. 1, 3-5
Globorotalia scitula Brady *in* Saito, Thompson, and Dee Breger, 1981, p. 137, pl. 46, fig. 2

Globorotalia hirsuta (d'Orbigny, 1839)
Pl. 21, fig. 3

Rotalia hirsuta d'Orbigny *in* d'Orbigny, 1839
Globorotalia hirsuta d'Orbigny *in* Parker, 1962, pl. 5, figs. 12, 14

Genus *Truncorotalia* Cushman and Bermudez, 1949

Type species: *Rotalina truncatulinoides* d'Orbigny, 1839, p. 132

Truncorotalia crassaformis (Galloway and Wissler, 1927)
Pl. 21, fig. 4

Globigerina crassaformis Galloway and Wissler *in* Galloway and Wissler, p. 41, pl. 7, fig. 12
Globorotalia crassaformis Galloway and Wissler *in* Kennet and Srinivasan, 1983, p. 146, pl. 34, figs. 6-8
Globorotalia crassaformis Galloway and Wissler *in* Saito, Thompson, and Dee Breger, 1981, p. 129, pl. 43, fig. 2

Truncorotalia truncatulinoides (d'Orbigny, 1839)
Pl. 21, fig. 5

Rotalina truncatulinoides d'Orbigny *in* d'Orbigny, 1839, p. 132, pl. 1, figs. 25-27
Globorotalia truncatulinoides d'Orbigny *in* Kennet and Srinivasan, 1983, p. 148, pl. 34, figs. 2, pl. 35, figs. 4-6
Globorotalia truncatulinoides Saito, Thompson, and Dee Breger, 1981, p. 158, pl. 54, fig. 1

Family Pulleniatinidae Cushman, 1927

Genus *Pulleniatina* Cushman, 1927
Type species: *Pullenia obliquiloculata* Parker and Jones, 1865, p. 368

Pulleniatina obliquiloculata (Parker and Jones, 1865)
Pl. 22, fig. 1

Pullenia sphaeroides d'Orbigny var. *obliquiloculata* Parker and Jones *in* Parker and Jones, pp. 365, 368, pl. 19, fig. 4
Pulleniatina obliquiloculata Parker and Jones *in* Kennet and Srinivasan, 1983, p. 202, pl. 49, fig. 2, pl. 50, figs. 6-9
Pulleniatina obliquiloculata Parker and Jones *in* Saito, Thompson, and Dee Breger, 1981, p. 98, pl. 31, fig. 3

Superfamily Globorotaliacea Cushman, 1927
Family Candeinidae Cushman, 1927
Subfamily Tenuitallinae Banner, 1982

Genus *Tenuitella* Fleisher, 1974
Type species: *Globorotalia gemma* Jenkins, 1966, p. 1115

Tenuitella anfracta (Parker, 1967)
Pl. 23, fig. 5

Globorotalia anfracta Parker *in* Parker, 1967, p. 175, pl. 28, figs. 3-8
Globorotalia anfracta Parker *in* Kennet and Srinivasan, 1983, p. 164, pl. 39, figs. 2, 4, pl. 40, figs. 7-9

Tenuitella iota (Parker, 1962)
Pl. 23, fig. 4

Globigerinita iota Parker *in* Parker, 1962, p. 250, pl. 10, figs. 26-30
Globigerinita iota Parker *in* Saito, Thompson, and Dee Breger, 1981, p. 79, pl. 23, fig. 2

Subfamily Globigerinitinae Bermudez, 1961

Genus *Globigerinita* Brönnimann, 1951
Type species: *Globigerinita naparimaensis* Brönnimann, 1951, p. 18

Globigerinita glutinata (Egger, 1893)
Pl. 19, fig. 4

Globigerina glutinata Egger *in* Egger, 1839, p. 371, pl. 13, figs. 19-21
Globigerinita glutinata Egger *in* Kennet and Srinivasan, 1983, p. 224, pl. 56, figs. 1, 3-5
Globigerinita glutinata Egger *in* Saito, Thompson, and Dee Breger, 1981, p. 79, pl. 23, fig. 1

Globigerinita uvula (Ehrenberg, 1861)
Pl. 19, fig. 6

Pylodexia uvula Ehrenberg *in* Ehrenberg, 1861, p. 276, 277, 308
Globigerinita uvula Ehrenberg *in* Kennet and Srinivasan, 1983, p. 224, pl. 56, figs. 6-8
Globigerinita uvula Ehrenberg *in* Saito, Thompson, and Dee Breger, 1981, p. 81, pl. 24, fig. 3

Superfamily Globigerinacea Carpenter, Parker, and Jones, 1862
Subfamily Globigerininae Carpenter, Parker, and Jones, 1862

Genus *Globigerina* d'Orbigny, 1826
Type species: *Globigerina bulloides* d'Orbigny, 1826, p. 36

Globigerina bulloides d'Orbigny, 1826
Pl. 19, fig. 1

Globigerina bulloides d'Orbigny *in* d'Orbigny, 1826, p. 277
Globigerina bulloides d'Orbigny *in* Jones, 1994, p. 88, pl. 77, p. 88, pl. 79, figs. 3-7
Globigerina bulloides d'Orbigny *in* Kennet and Srinivasan, 1983, p. 36, pl. 6, figs. 4-6
Globigerina bulloides d'Orbigny *in* Saito, Thompson, and Dee Breger, 1981, p. 40, pl. 7, fig. 1

Genus *Globigerinella* Cushman, 1927
Type species: *Globigerina aequilateralis* Brady, 1879, p. 285

Globigerinella calida (Parker, 1961)
Pl. 19, fig. 2

Globigerina calida Parker *in* Parker, p. 221, pl. 1, figs. 9-13, 15
Globigerina calida Parker *in* Cimerman and Langer, 1991, p. 57, pl. 60, figs. 2-3
Globigerinella calida Parker *in* Kennet and Srinivasan, 1983, p. 240, pl. 60, figs. 7-9
Globigerinella calida Parker *in* Saito, Thompson, and Dee Breger, 1981, p. 32, pl. 4, fig. 2

Globigerinella siphonifera (d'Orbigny, 1839)
Pl. 19, fig. 3

Globigerina siphonifera d'Orbigny *in* d'Orbigny, 1839, p. 83, pl. 4, figs. 15-18

Genus *Globigerinoides* Cushman, 1927
Type species: *Globigerina rubra* d'Orbigny, 1839, p. 82

Globigerinoides conglobatus Brady, 1879
Pl. 20, fig. 1

Globigerinoides conglobatus Brady *in* Brady, 1879, p. 289
Globigerinoides conglobatus Brady *in* Brady, 1884, p. 603, pl. 80, figs. 1-5, pl. 82, fig. 5
Globigerinoides conglobatus Brady *in* Kennet and Srinivasan, 1983, p. 58, pl. 12, figs. 4-6
Globigerinoides conglobatus Brady *in* Saito, Thompson, and Dee Breger, 1981, p. 56, pl. 14, fig. 1

Globigerinoides elongatus (d'Orbigny, 1826)
Pl. 20, fig. 4

Globigerina elongata d'Orbigny *in* d'Orbigny, 1826, p. 277
Globigerinoides elongata d'Orbigny *in* Cushman, 1941, p. 40, pl. 10, figs. 20-23, pl. 11, fig. 3
Globigerinoides elongatus d'Orbigny *in* Saito, Thompson, and Dee Breger, 1981, p. 62, pl. 16, fig. 2

Globigerinoides ruber (d'Orbigny, 1839)
Pl. 20, fig. 2

Globigerina rubra d'Orbigny *in* d'Orbigny, 1839, p. 82, pl. 4, figs. 12-14
Globigerinoides ruber d'Orbigny *in* Kennet and Srinivasan, 1983, p. 78, pl. 10, fig. 6, pl. 17, figs. 1-3
Globigerinoides ruber d'Orbigny *in* Saito, Thompson, and Dee Breger, 1981, p. 59, pl. 15, fig. 1

Globigerinoides sacculifer (Brady, 1877)
Pl. 20, fig. 3

Globigerina sacculifera Brady *in* Brady, 1877, p. 535
Globigerina sacculifera Brady *in* Brady, 1884, p. 604, pl. 80, figs. 11-17, pl. 81, fig. 2, pl. 82, fig. 4
Globigerinoides sacculifer Brady *in* Kennet and Srinivasan, 1983, p. 66, pl. 14, fig. 4-6
Globigerinoides sacculifer Brady *in* Saito, Thompson, and Dee Breger, 1981, p. 65, pl. 17, fig. 1-2

Globigerinoides trilobus (Reuss, 1850)
Pl. 20, fig. 6

Globigerina triloba Reuss *in* Reuss, 1850, p. 374, pl. 447, fig. 11
Globigerinoides triloba Reuss *in* Kennet and Srinivasan, 1983, p. 62, pl. 10, fig. 4, pl. 13, fig. 1-3

Genus *Globoturborotalita* Hofker, 1976
Type species: *Globigerina rubescens* Hofker, 1956, p. 234

Globoturborotalita rubescens (Hofker, 1956)
Pl. 19, fig. 5

Globigerina rubescens Hofker *in* Hofker, 1956, p. 234, pl. 32, fig. 26, pl. 35, fig. 18-21
Globigerina rubescens Hofker *in* Kennet and Srinivasan, 1983, p. 50, pl. 9, figs. 7-9
Globigerina rubescens Hofker *in* Saito, Thompson, and Dee Breger, 1981, p. 50, pl. 11, fig. 1

Genus *Turborotalita* Blow and Banner, 1962
Type species: *Truncatulina humilis* Brady, 1884, p. 665

Turborotalita quinqueloba (Natland, 1938)
Pl. 23, fig. 1

Globigerina quinqueloba Natland *in* Natland, 1938, p. 149, pl. 6, fig. 7
Globigerina quinqueloba Natland *in* Kennet and Srinivasan, 1983, p. 32, pl. 5, figs. 4-6
Globigerina quinqueloba Natland *in* Saito, Thompson, and Dee Breger, 1981, p. 48, pl. 10, fig. 1-2

Turborotalita humilis (Brady, 1884)
Pl. 23, fig. 2

Truncatulina humilis Brady *in* Brady, 1884, p. 665, pl. 94, fig. 7
Turborotalita humilis Brady *in* Kennet and Srinivasan, 1983, p. 167, pl. 41, figs. 1, 3-5
Turborotalita humilis Brady *in* Saito, Thompson, and Dee Breger, 1981, p. 84, pl. 25, fig. 1-2, 4

Turborotalita cristata (Heron-Allen and Earland, 1929)
Pl. 23, fig. 3

Globigerina cristata Heron-Allen and Earland *in* Heron-Allen and Earland, 1929, p. 331, pl. 4, figs. 33-39
Turborotalita cristata Heron-Allen and Earland *in* Kennet and Srinivasan, 1983, p. 168, pl. 41, figs. 2, 6-8

Subfamily Orbulinininae Schultze, 1854

Genus *Orbulina* d'Orbigny, 1839
Type species: *Orbulina universa* d'Orbigny, 1839, p. 2

Orbulina universa d'Orbigny, 1839
Pl. 20, fig. 5

Orbulina universa d'Orbigny *in* d'Orbigny, 1839, p. 2, pl. 1, fig. 1
Orbulina universa d'Orbigny *in* Jones, 1994, p. 90, pl. 81, figs. 8-27
Orbulina universa d'Orbigny *in* Kennet and Srinivasan, 1983, p. 86, pl. 20, figs. 4-6
Orbulina universa d'Orbigny *in* Saito, Thompson, and Dee Breger, 1981, p. 70, pl. 19, fig. 1-6

Suborder Rotaliina Delange and Hérouard, 1896
Superfamily Bolivinacea Glaessner, 1937

Family Bolivinidae Glaessner, 1937

Genus *Bolivina* d'Orbigny, 1839
Type species: *Bolivina plicata* d'Orbigny, 1839, p. 31

Bolivina alata (Seguenza, 1862)
Pl. 24, fig. 1

Valvulina alata Seguenza *in* Seguenza, 1862, p. 115, pl. 2, fig. 5
Bolivina alata Seguenza *in* Hofker, p. 248, figs. 85-88
Brizalina alata Seguenza *in* Cimerman and Langer, 1991, pl. 61, figs. 12-14

Bolivina dilatata (Reuss, 1850)
Pl. 24, fig. 2

Brizalina dilatata Reuss *in* Reuss, 1850, p. 381, pl. 48, figs 15 a-c.
Brizalina dilatata Reuss *in* Cimerman and Langer, 1991, p. 59, pl. 62, fig. 2.

Bolivina pseudoplicata Heron-Allen and Earland, 1930
Pl. 24, fig. 4

Bolivina pseudo-plicata Heron-Allen and Earland *in* Heron-Allen and Earland, 1930, p. 81, pl. 3, figs. 36-40
Bolivina pseudoplicata Heron-Allen and Earland *in* Kihle and Løfaldli, 1975
Bolivina pseudoplicata Heron-Allen and Earland *in* Cimerman and Langer, 1991, pl. 61, fig. 1-3.

Bolivina difformis (Williamson, 1858)
Pl. 24, fig. 6

Textularia variabilis var. *difformis* Williamson *in* Williamson, 1858, p. 77, pl. 6, figs. 166, 167
Bolivina difformis Williamson *in* Cushman, 1937, p. 164, pl. 15, figs. 13, 17
Bolivina pygmaea Williamson *in* Brady, 1960, pl. 53, figs. 5, 6
Bolivina difformis Williamson *in* Cimerman and Langer, 1991, pl. 61, fig. 9-11
Brizalina difformis Williamson *in* Murray, 2003, p. 20, pl. 6, fig. 2

Bolivina spinescens (Cushman, 1911)
Pl. 24, fig. 7

Bolivina textilarioides Brady *in* Brady, 1884, p. 419, pl. 52, figs. 24, 25
Bolivina spinescens Cushman *in* Cushman, 1911, p.

47, fig. 76

Bolivina subspinescens Cushman, 1922
Pl. 24, fig. 8

Bolivina subspinescens Cushman *in* Cushman, 1922, p. 48, pl. 7, fig. 5
Brizalina subspinescens Cushman *in* Gabel, 1971, p. 54, pl. 15, fig. 4-5

Genus *Bolivinellina* Saidova, 1975
Type species: *Bolivinellina pescicula* Saidova, 1975, p. 301

Bolivinellina pseudopunctata (Höglund, 1947)
Pl. 24, fig. 3

Bolivina pseudopunctata Höglund *in* Höglund, 1947, p. 273, pl. 24, figs. 23-24
Brizalina pseudopunctata Höglund *in* Murray, 1971, p. 109, pl. 44, figs. 3-6.
Bolivinellina pseudopunctata Höglund *in* Murray, 2003, p. 20, pl. 6, fig. 1

Bolivinellina striatula (Cushman, 1922)
Pl. 24, fig. 5

Bolivina striatula Cushman *in* Cushman, 1922, p. 27, pl. 3, fig. 10
Bolivina striatula Cushman *in* Cushman, 1937, p. 154, pl. 18, figs. 30, 31
Brizalina striatula Cushman *in* Cimerman and Langer, 1991, pl. 62, fig. 6-9

Genus *Brizalina* O.G. Costa, 1856
Type species: *Brizalina aenariensis* O.G. Costa, 1856, p. 296

Brizalina subaenariensis (Cushman, 1922)
Pl. 25, fig. 1

Bolivina aenariensis O.G. Costa *in* Brady, 1884, p. 423, pl. 53, figs. 10-11
Bolivina subaenariensis Cushman *in* Cushman, 1922, p. 46, pl. 7, fig. 6

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, p. 282

Cassidulina reniforme Nörvang, 1945
Pl. 25, fig. 3

Cassidulina crassa d'Orbigny var. *reniforme* Nörvang *in* Nörvang, 1945, p. 41, fig. 6
Cassidulina reniforme Nörvang *in* Wollenburg and Mackensen, 2009, p. 18, fig. 3, fig. 12

Cassidulina laevigata d'Orbigny, 1826
Pl. 25, fig. 4

Cassidulina laevigata d'Orbigny *in* d'Orbigny, 1826, p. 282, pl. 15, figs. 4-5
Cassidulina laevigata d'Orbigny *in* Kihle and Løfaldli, 1975
Cassidulina laevigata d'Orbigny *in* Cimerman and Langer, 1991, p. 61, pl. 63, fig. 1-3
Cassidulina laevigata d'Orbigny *in* Murray, 2003, p. 21, pl. 6, fig. 10

Cassidulina carinata Silvestri, 1896
Pl. 25, fig. 5

Cassidulina laevigata d'Orbigny var. *carinata* Silvestri *in* Silvestri, 1896, p. 104, pl. 2, fig. 10
Cassidulina laevigata carinata Silvestri *in* Jorissen, 1987, p. 34, pl. 1, fig. 8
Cassidulina laevigata carinata Silvestri *in* Seidenkrantz, 1995, p. 148, pl. 1, figs. 7-9, p. 156, pl. 5, figs. 7-8

Cassidulina teretis Tappan, 1951
Pl. 25, fig. 6

Cassidulina teretis Tappan *in* Tappan, 1951, p. 7, pl. 1, fig. 30
Cassidulina teretis Tappan *in* Seidenkrantz, 1995, p. 148, pl. 1, fig. 12-13, p. 151, pl. 2, figs. 15-18

Cassidulina neoteretis Seidenkrantz, 1995
Pl. 26, fig. 1

Cassidulina neoteretis Seidenkrantz *in* Seidenkrantz, 1995, p. 148, pl. 1, figs. 1-6, p. 151, pl. 2, figs. 1-14
Cassidulina neoteretis Seidenkrantz *in* Wollenburg and Mackensen, p. 18, fig. 3, fig. 10

Cassidulina crassa d'Orbigny, 1839
Pl. 26, fig. 3

Cassidulina crassa d'Orbigny *in* d'Orbigny, 1839, p. 56, pl. 7, figs. 18-20
Cassidulina crassa d'Orbigny *in* Kihle and Løfaldli,

1975
Cassidulina crassa d'Orbigny *in* Jones, 1994, p. 60, pl. 54, fig. 4
Cassidulina crassa d'Orbigny *in* Wollenburg and Mackensen, 2009, p. 18, fig. 3, fig. 9

Genus *Takayanagia* Nomura, 1983
Type species: *Cassidulina delicata* Cushman, 1927, p. 168

Takayanagia delicata (Cushman, 1927)
Pl. 26, fig. 2

Cassidulina delicata Cushman *in* Cushman, 1927, p. 168, pl. 6, fig. 5
Takayanagia delicata Cushman *in* Loeblich and Tappan, 1987, p. 507, pl. 560, figs. 5-10

Genus *Globocassidulina* Voloshinova, 1960
Type species: *Cassidulina globosa* Hantken, 1876, p. 64

Globocassidulina subglobosa (Brady, 1881)
Pl. 26, fig. 4

Cassidulina subglobosa Brady *in* Brady, 1881, p. 60, pl. 54, fig. 17
Globocassidulina subglobosa Brady *in* Jones, 1994, p. 60, pl. 54, fig. 17
Globocassidulina subglobosa Brady *in* Murray, 2003, p. 24, pl. 8, fig. 7
Globocassidulina subglobosa Brady *in* Cimeman and Langer, 1991, p. 61, pl. 63, fig. 4-6

Genus *Cassidulinoides* Cushman, 1927
Type species: *Cassidulina parkeriana* Brady, 1881, p. 59

Cassidulinoides bradyi (Norman, 1881)
Pl. 26, fig. 6

Cassidulina bradyi Norman *in* Norman, 1881, p. 59, pl. 54, figs. 6-10

Genus *Islandiella* Nørvang, 1959
Type species: *Cassidulina islandica* Nørvang, 1945, p. 41

Islandiella norcrossi (Cushman, 1933)
Pl. 26, fig. 5

Cassidulina norcrossi Cushman *in* Cushman, 1933, p. 7, pl. 2, fig. 7
Islandiella norcrossi Cushman *in* Wollenburg and Mackensen, 2009, p. 18, text-fig. 3, fig. 13

Subfamily Ehrenbergininae Cushman, 1927

Genus *Ehrenbergina* Reuss, 1850
Type species: *Ehrenbergina serrata* Reuss, 1850, p. 377

Ehrenbergina trigona Goës, 1896
Pl. 27, fig. 1

Ehrenbergina serrata Brady var. *trigona* Goës *in* Goës, 1896, p. 434, pl. 55, figs. 2-7
Ehrenbergina trigona Goës *in* Jones, 1994, p. 61, pl. 55, figs. 2-3, 5
Ehrenbergina trigona Goës *in* Hermelin and Scott, 1985, p. 206, pl. 4, figs. 15-16

Superfamily Turrilinacea Cushman, 1927
Family Stainforthiidae Reiss, 1963

Genus *Stainforthia* Hofker, 1956
Type species: *Virgulina concava* Höglund, 1947, p. 257

Stainforthia fusiformis (Williamson, 1858)
Pl. 27, fig. 2

Bulimina pupoides var. *fusiformis* Williamson *in* Williamson, 1858, p. 63,
Stainforthia fusiformis Williamson *in* Kihle and Løfaldli, 1975
Stainforthia fusiformis Williamson *in* Murray, 2002, p. 26, pl. 10, figs. 1-4

Stainforthia loeblichi (Feyling-Hanssen, 1954)
Pl. 27, fig. 3

Virgulina loeblichi Feyling-Hanssen *in* Feyling-Hanssen, 1954, p. 191, pl. 1, figs. 14-18

Stainforthia skagerakensis (Höglund, 1947)
Pl. 27, fig. 5

Virgulina skagerakensis Höglund *in* Höglund, 1947, p. 255, pl. 23, figs. 1-2
Stainforthia skagerakensis Höglund *in* Kihle and Løfaldli, 1975

Superfamily Buliminacea Jones, 1875
Family Siphogenerinoididae Saidova, 1981

Subfamily Siphogenerinoidinae Saidova, 1981

Genus *Parabrizalina* Zweig-Strykowski and Reiss, 1976

Type species: *Bolivina porrecta* Brady, 1881, p. 57

Parabrizalina porrectum (Brady, 1881)

Pl. 25, fig. 2

Bulimina (*Bolivina*) *porrecta* Brady *in* Brady, 1881, p. 57
Bulimina (*Bolivina*) *porrecta* Brady *in* Brady, 1881, pl. 52, fig. 22

Subfamily Tubulogenerininae Saidova, 1981

Genus *Rectuvigerina* Mathews, 1945

Type species: *Siphogenerina multicostata* Cushman and Jarvis, 1929, p. 14

Rectuvigerina elongatastriata (Colom, 1952)

Pl. 27, fig. 6

Uvigerina cf. *tenuistriata* Reuss *in* Colom, 1941, p. 17, pl. 3, figs. 57-58
Angulogerina elongatastriata Colom *in* Colom, 1952, p. 29, pl. 4, figs. 6-9
Rectuvigerina elongatastriata Colom *in* Cimerman and Langer, 1991, p. 61, pl. 63, figs. 7-9

Genus *Siphogenerina* Schlumberger, 1882

Type species: *Siphogenerina costata* Schlumberger, 1883, p. 26

Siphogenerina columellaris (Brady, 1881)

Pl. 27, fig. 7

Uvigerina columellaris Brady *in* Brady, 1881, p. 64, pl. 75, figs. 15-17
Siphogenerina columellaris Brady *in* Jones, 1994, p. 87, pl. 75, figs. 15-17

Family Buliminidae Jones, 1875

Genus *Bulimina* d'Orbigny, 1826

Type species: *Bulimina marginata* d'Orbigny, 1826, p. 269

Bulimina aculeata d'Orbigny, 1826

Pl. 27, fig. 8

Bulimina aculeata d'Orbigny *in* d'Orbigny, 1926, p. 269, n. 7
Bulimina aculeata d'Orbigny *in* Colom, 1974, p. 115, fig. 16g
Bulimina aculeata d'Orbigny *in* Cimerman and Langer, 1991, p. 61, pl. 63, figs. 10-11
Bulimina aculeata d'Orbigny *in* Sgarrella and Moncharmon-Zei, 1993, p. 211, pl. 15, fig. 1

Bulimina marginata d'Orbigny, 1826

Pl. 27, fig. 9

Bulimina marginata d'Orbigny *in* d'Orbigny, 1826, p. 269, pl. 12. figs. 10-12
Bulimina marginata var. *marginata*, d'Orbigny *in* Hottinger, Halicz, and Reiss, 1993, p. 99, pl. 125, figs. 1-6
Bulimina marginata d'Orbigny *in* Cimerman and Langer, 1991, p.62, pl. 64, figs 9-11
Bulimina marginata d'Orbigny *in* Murray, 2003, p. 20, pl. 6, figs. 4-5

Bulimina striata d'Orbigny, 1826

Pl. 27, fig. 10

Bulimina striata d'Orbigny *in* d'Orbigny, 1826, p. 269
Bulimina inflata Seguenza *in* Brady, 1884, p. 406, pl. 51, figs 11, 13
Bulimina striata var. *notoensis* Asano *in* Wang et al., 1988, p. 150, pl. 21, fig. 4
Bulimina striata d'Orbigny *in* Akimoto, 1990, p. 194, pl. 16, fig. 8
Bulimina striata d'Orbigny *in* Van Marle, 1991, p. 88, pl. 5, figs 6-8
Bulimina striata d'Orbigny *in* Loeblich and Tappan, 1994, p. 125, pl. 242, figs 8-14

Genus *Globobulimina* Cushman, 1927

Type species: *Globobulimina pacifica* Cushman, 1927, p. 67

Globobulimina affinis (d'Orbigny, 1839)

Pl. 28, fig. 2

Bulimina affinis d'Orbigny *in* d'Orbigny, 1839, p. 105, pl. 2, figs. 25-26
Bulimina affinis d'Orbigny *in* Brady, 1884, p. 400, pl. 50, fig. 14
Bulimina affinis d'Orbigny *in* Cushman, 1911, p. 79, text-fig. 130
Bulimina affinis d'Orbigny *in* Phleger and Parker,

1951, p. 15, pl. 7, figs 21-22
Bulimina affinis d'Orbigny *in* Loeblich and Tappan, 1994, p. 124, pl. 240, figs 12-13

Globobulimina doliolum (Terquem and Terquem, 1886)
Pl. 28, fig. 5

Bulimina doliolum Terquem and Terquem *in* Terquem and Terquem, 1886, p. 333, pl. 11, figs. 17-18

Globobulimina turgida (Bailey, 1851)
Pl. 28, fig. 1

Bulimina turgida Bailey *in* Bailey, 1851, p. 12, figs. 28-31, 67
Globobulimina turgida Bailey *in* Gabel, 1971, p. 52, pl. 14, fig. 21

Genus *Praeglobobulimina* Hofker, 1951
Type species: *Bulimina pyrula* d'Orbigny var. *spinescens* Brady, 1884, p. 400

Praeglobobulimina ovata (d'Orbigny, 1846)
Pl. 28, fig. 4

Bulimina ovata d'Orbigny *in* d'Orbigny, 1846, p. 185, pl. 11, figs. 13-14
Bulimina ovata d'Orbigny *in* Brady, 1884, p. 400, pl. 50, fig. 13
Praeglobobulimina ovata d'Orbigny *in* Jones, 1994, p. 54, pl. 50, fig. 13

Family Buliminellidae Hofker, 1951

Genus *Buliminella* Cushman, 1911
Type species: *Bulimina elegantissima* d'Orbigny, 1839, p. 51

Buliminella spinigera Cushman, 1922
Pl. 28, fig. 6

Buliminella spinigera Cushman *in* Cushman, 1922, p. 113, pl. 23, figs. 1-3

Subfamily Uvigerininae Haeckel, 1894

Genus *Uvigerina* d'Orbigny, 1826
Type species: *Uvigerina pygmaea* d'Orbigny, 1826, p. 268

Uvigerina mediterranea Hofker, 1932
Pl. 29, fig. 1

Uvigerina mediterranea Hofker *in* Hofker, 1932, p. 118, figs. 32
Uvigerina mediterranea Hofker *in* Colom, 1974, p. 122, figs. 19h-n
Uvigerina mediterranea Hofker *in* Cimerman and Langer, 1991, p. 63, pl. 65, figs. 7-9
Uvigerina mediterranea Hofker *in* Abu-Zied et al., 2008, p. 52, pl. 2, figs. 17-18

Uvigerina peregrina Cushman, 1923
Pl. 29, fig. 2

Uvigerina peregrina Cushman *in* Cushman, 1923, p. 166, pl. 42, figs. 7-10
Uvigerina peregrina Cushman *in* Abu-Zied et al., 2008, p. 52, pl. 2, figs. 19-20
Uvigerina peregrina Cushman *in* Phleger and Parker, 1951, p. 18, pl. 8 , figs 22, 24-26
Uvigerina peregrina Cushman *in* Lutze, 1986, p. 32, pl. 1, figs 1-6
Uvigerina peregrina Cushman *in* Ujiié, 1990, p. 31, pl. 13, figs 1-3

Uvigerina auberiana d'Orbigny, 1839
Pl. 29, fig. 3

Uvigerina auberiana d'Orbigny *in* d'Orbigny, 1839, p. 106, pl. 2 , figs 23-24
Uvigerina asperula Czjzek var. *auberiana* d'Orbigny *in* Brady, 1884, p. 579, pl. 75, fig. 9
Uvigerina asperula Czjzek *in* Brady, 1884, p. 578, pl. 75, figs 6-8
Uvigerina asperula Czjzek *in* Ujiié, 1990, p. 31, pl. 13, figs 7-8
Uvigerina auberiana d'Orbigny *in* Uchio, 1960, p. 65, pl. 7, fig. 11
Uvigerina auberiana d'Orbigny *in* Jones, 1994, p. 86, pl. 75, figs 6-9

Uvigerina peregrina parva Lutze, 1986
Pl. 29, fig. 4

Uvigerina peregrina Cushman var. *parva* Lutze *in* Lutze, 1986, p. 36, pl. 3, fig. 1-5
Uvigerina bradyana Fornasini *in* Austin and Evans, 2000, p. 690, fig. 3.1
Uvigerina peregrina Cushman var. *parva* Lutze *in* Schönfeld, 2006, p. 359, pl. 1, figs. 12-13

Uvigerina pigmaea d'Orbigny, 1826
Pl. 29, fig. 5

Uvigerina pigmea d'Orbigny *in* d'Orbigny, 1826, p. 269, pl. 12, figs. 8, 9
Uvigerina pigmea d'Orbigny *in* Thomas, 1980, pl. 3, fig. 3
Uvigerina pigmea d'Orbigny *in* Timm, 1992, p. 68, pl. 6, figs. 1a-b
Uvigerina pygmea d'Orbigny *in* Lutze, 1986, p. 36, pl. 3, figs. 6-8
Uvigerina pigmea d'Orbigny *in* Schönfeld, 2006, p. 357, pl. 1, figs. 6-11

Subfamily Angulogerininae Galloway, 1933

Genus *Angulogerina* Cushman, 1927
Type species: *Uvigerina angulosa* Williamson, 1858, p. 67

Angulogerina angulosa (Williamson, 1858)
Pl. 29, fig. 6

Uvigerina angulosa Williamson *in* Williamson, 1858, p. 67, pl. 5, fig. 140
Angulogerina angulosa Williamson *in* Y. Le Calvez, 1958, p. 180
Trifarina angulosa Williamson *in* Barker, pl. 74, figs. 15-16
Trifarina angulosa Williamson *in* Daniels, p. 83, pl. 6, fig. 4
Trifarina angulosa Williamson *in* Abu-Zied et al., 2008, p. 52, pl. 2, fig. 21
Angulogerina angulosa Williamson *in* Loeblich and Tappan, 1987, p. 525, pl. 574, figs. 5-9

Genus *Trifarina* Cushman, 1923
Type species: *Trifarina bradyi* Cushman, 1923, p. 99

Trifarina bradyi (Cushman, 1923)
Pl. 29, fig. 7

Rhabdogonium tricarinatum d'Orbigny *in* Brady,1884 , p. 525, pl. 67, figs 1-3
Trifarina bradyi Cushman *in* Cushman, 1923, p. 99, pl. 22, figs 3-9
Trifarina bradyi Cushman *in* Loeblich and Tappan, 1987, p. 526, pl. 574, figs. 10-13
Trifarina bradyi Cushman *in* Van Marle, 1991, p. 110, pl. 7, figs 8-9
Trifarina bradyi Cushman *in* Jones, 1994, p. 78, pl. 67, figs 1-3
Trifarina bradyi Cushman *in* Loeblich and Tappan, 1994, p. 128, pl. 251, figs 6-16

Trifarina fornasini (Selli, 1948)
Pl. 29, fig. 8

Angulogerina fornasini Selli *in* Selli, 1948, p. 40, pl. 43, figs. 1-4

Superfamily Fursenkoinacea Loeblich and Tappan, 1961
Family Fursenkoinidae Loeblich and Tappan, 1961

Genus *Fursenkoina* Loeblich and Tappan, 1961
Type species: *Virgulina squammosa* d'Orbigny, 1826, p. 267

Fursenkoina complanata (Egger, 1893)
Pl. 27, fig. 4

Virgulina schreibersiana Cziczek var. *complanata* Egger *in* Egger, 1893, p. 292, pl. 8, figs. 91-92
Fursenkoina complanata Egger *in* Jones, 1994, p. 56, pl. 52, figs. 1-3
Fursenkoina complanata Egger *in* Austin and Evans, 2000, p. 684, pl. 1, fig. n

Superfamily Stilostomellacea Finlay, 1947
Family Stilostomellidae Finlay, 1947

Genus *Nodogenerina* Cushman, 1927
Type species: *Nodogenerina bradyi* Cushman, 1927, p. 79

Nodogenerina virgula (Brady, 1884)
Pl. 29, fig. 9

Sagrina virgula Brady *in* Brady, 1884, pl. 76, fig. 8
Nodogenerina virgula Brady *in* Jones, 1994, p. 88, pl. 76, fig. 8, suppl. pl. 2, figs. 2-3, 14

Superfamily Discorbacea Ehrenberg, 1838
Family Bagginidae Cushman, 1927
Subfamily Bagginінae Cushman, 1927

Genus *Cancris* de Montfort, 1808
Type species: *Nautilus auricula* Fichtel and Moll, 1798, p. 108

Cancris auriculus (Fichtel and Moll, 1798)
Pl. 29, fig. 10

Nautilus auricula Fichtel and Moll *in* Fichtel and Moll, 1798, p. 102, pl. 18, figs. g-i
Cancris auriculatus Fichtel and Moll *in* Loeblich and

Tappan, 1988, p. 545, pl. 591, figs. 1-4
Cancris auriculus Fichtel and Moll *in* Jones, 1994, p. 105, pl. 106, fig. 4
Cancris auricula Fichtel and Moll *in* Murray, 2003, p. 19, pl. 6, figs. 6-7

Genus *Valvulineria* Cushman, 1926
Type species: *Valvulineria californica* Cushman, 1926, p. 59

Valvulineria bradyana (Fornasini, 1900)
Pl. 30, fig. 1

Discorbina bradyana Fornasini *in* Fornasini, 1900, p. 393, textfig. 43
Valvulineria bradyana Fornasini *in* Jorissen, p. 26, pl. 4, figs. 1-2

Family Eponididae Hofker, 1951
Subfamily Eponidinae Hofker, 1951

Genus *Ioanella* Saidova, 1975
Type species: *Truncatulina tumidula* Brady, 1884, p. 666

Ioanella tumidula (Brady, 1884)
Pl. 30, fig. 2

Truncatulina tumidula Brady *in* Brady, 1884, p. 666, pl. 95, fig. 8
Ioanella tumidula Brady *in* Duchemin et al., 2007, p. 18, pl. 3, figs. 16-18
Ioanella tumidula Brady *in* Wollenburg and Mackensen, 2009, p. 18, textfig. 3, fig. 4

Subfamily Stomatorbininae Saidova, 1981

Genus *Stomatorbina* Doreen, 1948
Type species: *Lamarckina torrei* Cushman and Bermudez, 1937, p. 21

Stomatorbina concentrica (Parker and Jones, 1864)
Pl. 30, fig. 3

Pulvinulina concentrica Parker and Jones *in* Parker and Jones, 1864, p. 470, pl. 48, fig. 14
Stomatorbina concentrica Parker and Jones *in* Cimerman and Langer, 1991, p. 65, pl. 68, figs. 7-9
Mississippina concentrica Parker and Jones *in* Jones, 1994, p. 104, pl. 105, fig. 1

Family Rosalinidae Reiss, 1963

Genus *Hyrrokkin* Cedhagen, 1994
Type species: *Hyrrokkin sarcophaga* Cedhagen, 1994, p. 66

Hyrrokkin sarcophaga Cedhagen, 1994
Pl. 30, figs. 4-5

Pulvinulina repanda var. *punctulata* d'Orbigny *in* Parker and Jones, 1865, p. 394, pl. 14, figs.12-13
Rosalina carnivora Todd *in* Todd, 1965, pp. 834-835, pl. 1, figs. 1-3, pl. 2, figs. 1-4, pl. 3, figs. 1
Hyrrokkin sarcophaga Cedhagen *in* Cedhagen, 1994, p. 66, textfigs. 1-17
Hyrrokkin sarcophaga Cedhagen *in* Freiwald and Schönfeld, 1995, p. 202, textfig. 2

Genus *Gavelinopsis* Hofker, 1951
Type species: *Discorbina praegeri* Heron-Allen and Earland, 1913, p. 122

Gavelinopsis nitida (Williamson, 1858)
Pl. 31, fig. 1

Rotalina nitida Williamson *in* Williamson, 1858, p. 54, pl. 4, figs. 106-108

Gavelinopsis praegeri (Heron-Allen and Earland, 1913)
Pl. 31, fig. 2

Discorbina praegeri Heron-Allen and Earland *in* Heron-Allen and Earland, 1913, p. 122, pl. 10, figs 8-10.
Gavelinopsis praegeri Heron-Allen and Earland *in* Hofker, 1951, p. 486, text-figs 332-334
Gavelinopsis praegeri Heron-Allen and Earland *in* Zheng, 1980, p. 167, pl. 5, fig. 1
Gavelinopsis praegeri Heron-Allen and Earland *in* Loeblich and Tappan, 1987, p. 560, pl. 608, figs 6-12
Gavelinopsis praegeri Heron-Allen and Earland *in* Loeblich and Tappan, 1994, p. 138, pl. 281, figs 1-10
Gavelinopsis praegeri Heron-Allen and Earland *in* Murray, 2003, p. 24, pl. 8, figs. 5-6

Gavelinopsis caledonia Murray and Whittaker, 2001
Pl. 31, fig. 3

Gavelinopsis caledonia Murray and Whittaker *in* Murray and Whittaker, 2001, p. 179, pl. 1, figs. 1-10, pl. 2, figs. 1-7
Gavelinopsis caledonia Murray and Whittaker *in* Murray, 2003, p. 24, pl. 8, figs. 2-4

Genus *Rosalina* d'Orbigny, 1826
Type species: *Rosalina globularis* d'Orbigny, 1826, p. 62

Rosalina globularis d'Orbigny, 1826
Pl. 31, fig. 4

Rosalina globularis d'Orbigny *in* d'Orbigny, 1826, p. 271, pl. 13,
figs 1-4.
Discorbina globularis d'Orbigny *in* Brady, 1884, p . 643, pl. 86, fig. 13
Rosalina globularis d'Orbigny *in* Todd, 1965, p. 11, pl. 3, fig. 4
Rosalina globularis d'Orbigny *in* Loeblich and Tappan, 1987, p. 561, pl . 610, figs 1-5; pl. 611, figs 1-3
Rosalina globularis d'Orbigny *in* Jones, 1994, p . 93, pl. 86, fig. 13

Rosalina brady (Cushman, 1915)
Pl. 31, fig. 5

Discorbina globularis var. *bradyi* Cushman *in* Cushman, 1915, p. 12, pl. 8, fig. 1
Discopulvinulina bradyi Cushman *in* Hofker, 1951, p. 452, figs. 310
Rosalina bradyi Cushman *in* Hornibrook and Vella, 1954, p. 26

Rosalina semipunctata (Bailey, 1851)
Pl. 32, fig. 1

Rotalina semipunctata Bailey *in* Bailey, 1851, p. 11, figs. 17-19, 67

Family Sphaeroidinidae Cushman, 1927

Genus *Sphaeroidina* d'Orbigny, 1826
Type species: *Sphaeroidina bulloides* d'Orbigny, 1826, p. 267

Sphaeroidina bulloides d'Orbigny, 1826
Pl. 32, fig. 2

Sphaeroidina bulloides d'Orbigny *in* d'Orbigny, 1826, p. 267, pl. 2, fig. 58
Sphaeroidina bulloides d'Orbigny *in* Kihle and Løfaldli, 1975
Sphaeroidina bulloides d'Orbigny *in* Loeblich and Tappan, 1987, p. 564, pl. 617, figs. 1-6

Superfamily Glabratellacea Loeblich and Tappan, 1964
Family Glabratellidae Loeblich and Tappan, 1964

Genus *Glabratella* Dorreen, 1948
Type species: *Glabratella crassa* Dorreen, 1948, p. 294

Glabratella patelliformis (Brady, 1884)
Pl. 32, fig. 3

Discorbina patelliformis Brady *in* Brady, 1884, p. 647, pl. 88, fig. 3, pl. 89, fig. 1
Glabratella patelliformis Brady *in* Jones, 1994, p. 94, pl. 88, fig. 3, p. 95, pl. 89, fig. 1

Genus *Heronallenita* Seiglie and Bermudez, 1965
Type species: *Heronallenita striatospinata* Seiglie and Bermudez, 1965, p. 61

Heronallenita lingulata (Burrows and Holland, 1895)
Pl. 32, fig. 5

Discorbina lingulata Burrows and Holland *in* Burrows and Holland, 1895, p. 297, pl. 7, fig. 33
Heronallenita lingulata Burrows and Holland *in* Hermelin, 1989, p. 68, pl. 12, figs. 14, 18
Heronallenita lingulata Burrows and Holland *in* Jones, 1994, pp. 96, pl. 91, fig. 3

Superfamily Siphoninacea Cushman, 1927
Family Siphoninidae Cushman, 1927

Genus *Siphonina* Reuss, 1850
Type species: *Rotalina reticulata* Czjzek, 1848, p. 294

Siphonina reticulata (Czjzek, 1848)
Pl. 32, fig. 4

Rotalia reticulata Czjzek *in* Czjzek, 1848, p. 145, pl. 13, figs. 7-9
Siphonina reticulata Czjzek *in* Cimerman and Langer, 1991, p. 69, pl. 73, figs. 11-13
Siphonina reticulata Czjzek *in* Loeblich and Tappan, 1987, p. 571, pl. 624, figs. 4-6 and 13-15

Superfamily Discorbinellacea Sigal, 1952
Family Parrelloididae Hofker, 1956

Genus *Cibicidoides* Thalmann, 1939

Type species: *Truncatulina mundula* Brady, Parker, and Jones, 1939, p. 228

Cibicidoides mundulus (Parker, 1953)

Pl. 33, fig. 1

Truncatulina mundula Brady, Parker, and Jones *in* Brady, Parker, and Jones, 1888, p. 228, pl. 45, figs. 25
Cibicides kullenbergi Parker *in* Phleger et al., 1953, p. 49, pl. 11, figs. 7-8
Cibicides kullenbergi Parker *in* Boltovskoy, 1978, pl. 3, figs. 9-12
Cibicidoides mundulus Brady, Parker and Jones *in* Hermelin, 1989, p. 86, pl. 17, figs. 9-11

Cibicidoides pachyderma (Rzehak, 1886)

Pl. 33, fig. 2

Truncatulina pachyderma Rzehak *in* Rzehak, 1886, p. 87, pl. 1, fig. 5
Truncatulina pseudoungeriana Cushman *in* Cushman, 1922b, p. 97, pl. 20, fig. 9
Cibicides pseudoungeriana Cushman *in* Cushman, 1931, p. 123, pl. 22, figs 3-7
Cibicidoides pachyderma Rzehak *in* van Morkhoven et al., 1986, p. 68, pl. 22, fig. 1
Cibicidoides pachyderma Rzehak *in* Jones, 1994, p. 98, pl. 94, fig. 9
Cibicidoides pseudoungerianus Cushman *in* Hess, 1998, p. 78, pl. 16, figs 1-2

Family Pseudoparrellidae Voloshinova, 1952
Subfamily Pseudoparrellinae Voloshinova, 1952

Genus *Epistominella* Husezima an Maruhasi, 1944

Type species: *Epistominella pulchella* Husezima an Maruhasi, 1944, p. 397

Epistominella vitrea Parker, 1953

Pl. 33, fig. 3

Epistominella vitrea Parker *in* Parker et al., 1953, p. 9, pl. 4, fig. 34-36, 40-41
Epistominella vitrea Parker *in* Hayward et al., 1999, pl. 13, figs. 14-16
Epistominella vitrea Parker *in* Duchemin et al., 2007, p. 17, pl. 2, figs. 5-6
Epistominella vitrea Parker *in* Margreth et al., 2009, p. 2230, pl. 1, fig. 7

Epistominella exigua (Brady, 1884)

Pl. 33, fig. 4

Pulvinulina exigua Brady *in* Brady, 1884, p. 696, pl. 103, figs. 13-14
Epistominella exigua Brady *in* Hermelin and Scott, 1985, p. 208, pl. 4, fig. 1
Epistominella exigua Brady *in* Wollenburg and Mackensen, 2009, p. 18, textfig. 3, fig. 5
Epistominella exigua Brady *in* Margreth et al., 2009, p. 2230, pl. 1, fig. 6

Family Discorbinellidae Sigal, 1952
Subfamily Discorbinellinae Sigal, 1952

Genus *Discorbinella* Cushman and Martin, 1935

Type species: *Discorbinella montereyensis* Cushman and Martin, 1935, p. 89

Discorbinella bertheloti (d'Orbigny, 1839)

Pl. 33, fig. 5

Rosalina bertheloti d'Orbigny *in* d'Orbigny, 1839b, p. 135, pl. 1 , figs 28-30
Discorbina bertheloti d'Orbigny *in* Brady, 1884, p . 650, pl. 89, figs 10-12
Discorbis bertheloti d'Orbigny *in* Cushman, 1931, p . 16, pl. 3, fig. 2
Discopulvinulina bertheloti d'Orbigny *in* Hofker, 1951, p. 449
Discorbinella bertheloti d'Orbigny *in* Loeblich and Tappan, 1987, p. 577, pl. 630, figs 4-6
Discorbinella bertheloti d'Orbigny *in* Jones, 1994, p. 95, pl. 89, figs 10-12

Superfamily Planorbulinacea Schwager, 1877
Family Planulinidae Bermudez, 1952

Genus *Planulina* d'Orbigny, 1826

Type species: *Planulina ariminensis* d'Orbigny, 1826, p. 66

Planulina ariminensis d'Orbigny, 1826

Pl. 34, fig. 1

Planulina ariminensis d'Orbigny *in* d'Orbigny, 1826, p. 280 pl. 14, fig. 1-3
Planulina ariminensis d'Orbigny *in* Hermelin and Scott, 1985, p. 214, pl. 4, fig. 9-11
Planulina ariminensis d'Orbigny *in* Jones, 1994, p. 98, pl. 93, fig. 10-11
Planulina ariminensis d'Orbigny *in* Abu-Zied et al., 2008, p. 52, pl. 2, figs. 31-32

Genus *Hyalinea* d'Orbigny, 1826

Type species: *Nautilus balthicus* Schröter, 1783, p. 20

Hyalinea balthica (d'Orbigny, 1826)
Pl. 34, fig. 2

Nautilus balthicus d'Orbigny *in* Schröter, 1783, p. 20, pl. 1, fig. 2
Hyalinea balthica d'Orbigny *in* Jones, 1994, p. 110, pl. 112, figs. 1-2
Hyalinea balthica d'Orbigny *in* Cimerman and Langer, 1991, p. 70, pl. 74, figs. 4, 7

Family Cibicididae Cushman, 1927
Subfamily Cibicidinae Cushman, 1927

Genus *Cibicides* de Montfort, 1808
Type species: *Cibicides refulgens* de Montfort, 1808, p. 122

Cibicides ungerianus (d'Orbigny, 1826)
Pl. 34, fig. 3

Rotalina ungeriana d'Orbigny *in* d'Orbigny, 1846, p. 157, pl. 8, figs. 16-18
Cibicides ungerianus d'Orbigny *in* Schweizer et al., 2009, p. 301, textfig. 1, fig. k-l

Cibicides refulgens de Montfort, 1808
Pl. 34, fig. 4

Cibicides refulgens de Montfort *in* de Montfort, 1808, p. 122
Cibicides refulgens de Montfort *in* Kihle and Løfaldli, 1975
Cibicides refulgens de Montfort *in* Cimerman and Langer, 1991, p. 70, pl. 75, figs. 5-9
Cibicides refulgens de Montfort *in* Murray, 2003, p. 21, pl. 7, figs. 1-2

Cibicides aravaensis Perelis and Reiss, 1976
Pl. 34, fig. 5

?*Cibicides* sp. Venec-Peyre *in* Venec-Peyre, 1973, p. 28, pl. C, fig. 2
Cibicides aravaensis Perelis and Reiss *in* Perelis and Reiss, 1976, p. 93, pl. 8, figs. 1-7

Genus *Lobatula* Fleming, 1828
Type species: *Nautilus lobatulus* Walker and Jacob *in* Kanmacher, 1798, p. 642

Lobatula lobatula (Walker and Jacob, 1798)
Pl. 35, fig. 1

Nautilus lobatulus Walker and Jacob *in* Kanmacher, 1798, p. 642, pl. 14, fig. 36
Lobatula lobatula Walker and Jacob *in* Cimerman and Langer, 1991, p. 71, pl. 75, figs. 1-4
Cibicides lobatulus Walker and Jacob *in* Jones, 1994, p. 97, pl. 93, figs. 1, 4-5
Cibicides lobatulus Walker and Jacob *in* Murray, 2003, p. 21, pl. 6, figs. 13-15

Genus *Fontbotia* Gonzales-Donoso and Linares, 1970
Type species: *Anomalina wuellerstorfi* Schwager, 1866, p. 258

Fontbotia wuellerstorfi (Schwager, 1866)
Pl. 35, fig. 2

Anomalina wüllerstorfi Schwager *in* Schwager, 1866, p. 258, pl. 7, figs. 105, 107
Planulina wuellerstorfi Schwager *in* Cushman, 1931, p. 110, pl. 19, fig. 5-6
Fontbotia wuellerstorfi Schwager *in* Gonzales-Donoso and Linares, 1970, p. 238, pl. 1, fig. 4
Fontbotia wuellerstorfi Schwager *in* Loeblich and Tappan, 1987, p. 538, pl. 634, figs. 1-3
Cibicidoides wuellerstorfi Schwager *in* Jones, 1994, p. 98, pl. 93, figs. 8-9
Cibicides wuellerstorfi Schwager *in* Abu-Zied et al., 2008, p. 53, pl. 3, figs. 6-7

Superfamily Asterigerinacea d'Orbigny, 1839
Family Epistomariidae Hofker, 1954
Subfamily Epistomariinae Hofker, 1954

Genus *Pseudoeponides* Uchio, 1950
Type species: *Pseudoeponides japonicus* Uchio, *in* Kawai et al., 1950

Pseudoeponides falsobeccarii Rouvillois, 1974
Pl. 35, fig. 3

Pseudoeponides falsobeccarii Rouvillois *in* Rouvillois, p. 4, pl. 1, figs. 1-12
Ammonia falsobeccarii Rouvillois *in* Gross, p. 69
Ammonia falsobeccarii Rouvillois *in* Murray, p. 19, pl. 5, figs. 14-16
Pseudoeponides falsobeccarii Rouvillois *in* Mojtahid et al., 2009, p. 188, pl. 1, fig. 2

Subfamily Nuttallidinae Saidova, 1981

Genus *Nuttallides* Finlay, 1939

Type species: *Eponides truempyi* Nuttall, 1930

Nuttallides umbonifera (Rouvillois, 1974)
Pl. 35, fig. 4

Pulvinulinella umbonifera Cushman *in* Cushman, 1933, p. 90, pl. 9, fig. 9
Nuttallides umbonifera Cushman *in* Hermelin, 1989, p. 69, pl. 12, figs. 15-17

Nuttallides decorata (Phleger and Parker, 1951)
Pl. 35, fig. 5

Pseudoparrella? decorata Phleger and Parker *in* Phleger and Parker, 1951, p. 28, pl. 15, figs. 4-5
Nuttallides decorata Phleger and Parker *in* Lobegeier and Gupta, 2008, p. 106, pl. 2, figs. 10, 13

Family Astigerinatidae Reiss, 1963

Genus *Astigerinata* Bermudez, 1949
Type species: *Astigerinata dominicana* Bermudez, 1949

Astigerinata mamilla (Williamson, 1858)
Pl. 36, fig. 1

Rotalina mamilla Williamson *in* Williamson, 1858, p. 54, pl. 4, figs. 109-111
Astigerinata mamilla Williamson *in* Cimerman and Langer, p. 73, pl. 82, figs. 1-4
Astigerinata mamilla Williamson *in* Abu-Zied et al., p. 53, pl. 3, figs. 8-9

Superfamily Nonionacea Schultze, 1854
Family Nonionidae Schultze, 1854
Subfamily Nonioninae Schultze, 1854

Genus *Nonion* de Montfort, 1808
Type species: *Nautilus faba* Fichtel and Mol, 1798, p. 103

Nonion fabum (Fichtel and Moll, 1798)
Pl. 36, fig. 2

Nautilus faba Fichtel and Moll *in* Fichtel and Moll, 1798, p. 103, pl. 19, figs. a-c
Nonionina boueana d'Orbigny *in* Brady, 1884, p. 729, pl. 109, figs. 12-13
Nonion fabum Fichtel and Moll *in* Loeblich and Tappan, 1987, p. 617, pl. 690, figs. 1-7 and 14-16
Nonion fabum Fichtel and Moll *in* Jones, p. 108, pl. 109, figs. 12-13

Nonion pauperatus (Balkwill and Wright, 1885)
Pl. 36, fig. 3

Nonionina pauperata Balkwill and Wright *in* Balkwill and Wright, 1885, p. 353, pl. 13, figs. 25-26
Nonion pauperatus Balkwill and Wright *in* Murray, 2003, p. 24, pl. 9, fig. 1

Nonion pauciloculum Cushman, 1944
Pl. 36, fig. 5

Nonion pauciloculum Cushman *in* Cushman, 1944, p. 24, pl. 3, fig. 25

Genus *Nonionella* Cushman, 1926
Type species: *Nonionella miocenica* Cushman, 1926, p. 64

Nonionella turgida (Williamson, 1858)
Pl. 37, fig. 1

Rotalina turgida Williamson *in* Williamson, 1858, p. 50, pl. 4, figs. 95-97
Nonionella turgida Williamson *in* Murray, 2003, p. 24, pl. 9, figs. 4-5
Nonionella turgida Williamson *in* Jones, 1994, p. 108, pl. 109, figs. 17-19
Nonionella turgida Williamson *in* Cimerman and Langer, 1991, p. 74, pl. 84, figs. 6-8

Nonionella iridea Heron-Allen and Earland, 1932
Pl. 37, fig. 2

Nonionella iridea Heron-Allen and Earland *in* Heron-Allen and Earland, 1932, p. 438, pl. 16, figs. 14-16
Nonionella iridea Heron-Allen and Earland *in* Murray, 2003, p. 24, pl. 9, figs. 2-3

Genus *Nonionellina* Cushman, 1926
Type species: *Nonionina labradorica* Dawson, 1860, p. 192

Nonionellina labradorica (Dawson, 1860)
Pl. 36, fig. 4

Nonionina labradorica Dawson *in* Dawson, 1860, p. 192, pl. 4
Nonion labradoricum Dawson *in* Feyling-Hannsen, p. 262, pl. 10, figs. 1-2
Nonionellina labradorica Dawson *in* Vazquez Riveiros and Patterson, 2008, p. 29, pl. 12, fig. 7

Subfamily Astrononioninae Saidova, 1981

Genus *Astrononion* Cushman and Edwards, 1937
Type species: *Nonionina stelligera* d'Orbigny, 1839, p. 128

Astrononion gallowayi Loeblich and Tappan, 1953
Pl. 37, fig. 3

Astrononion gallowayi Loeblich and Tappan *in* Loeblich and Tappan, 1953, p. 90, pl. 17, figs. 4-7
Astrononion gallowayi Loeblich and Tappan *in* Feyling-Hanssen et al., 1971, p. 266, pl. 10, figs. 10-12
Astrononion gallowayi Loeblich and Tappan *in* Hermelin and Scott, 1985, p. 203, pl. 5, fig. 1

Astrononion antarcticus Parr, 1950
Pl. 37, fig. 4

Nonion stelligerus d'Orbigny *in* Dryglaski, 1931, pl. 19, fig. 234
Nonion stelliger d'Orbigny *in* Earland, 1934, p. 189
Astrononion antarcticus Parr *in* Parr, 1950, p. 371, pl. 15, figs. 13-14

Subfamily Pulleniinae Schwager, 1877

Genus *Melonis* de Montfort, 1808
Type species: *Nautilus pompilioides* Fichtel and Moll, 1798, p. 31

Melonis pompilioides (Fichtel and Moll, 1798)
Pl. 37, fig. 5

Nautilus pompilioides Fichtel and Moll *in* Fichtel and Moll, 1798, p. 31, pl. 2, figs. a-c
Melonis etruscus de Montfort *in* de Montfort, 1808, p. 67
Melonis pompilioides Fichtel and Moll *in* Hermelin and Scott, 1985, p. 212, pl. 6, fig. 5
Melonis pompilioides Fichtel and Moll *in* Cimerman and Langer, 1991, p. 74, pl. 85, figs. 1-4

Melonis barleeanum (Williamson, 1858)
Pl. 38, fig. 1

Nonionina barleeana Williamson *in* Williamson, 1858, p. 32, pl. 3, figs. 68-69
Nonion barleeanum Williamson *in* Kihle and Løfaldli, 1975
Nonion barleeanum Williamson *in* Hermelin and Scott, 1985, p. 212, pl. 5, fig. 2
Melonis barleeanum Williamson *in* Murray, 2003, p. 24, pl. 8, figs. 11-14

Genus *Pullenia* Parker and Jones, 1862
Type species: *Nonionina bulloides* d'Orbigny, 1846, p. 107

Pullenia subcarinata (d'Orbigny, 1839)
Pl. 38, fig. 2

Nonionina subcarinata d'Orbigny *in* d'Orbigny, 1839, p. 28, pl. 5, figs. 23-24
Nonionina quinqueloba d'Orbigny *in* Reuss, 1851, p. 71, pl. 5, fig. 31
Pullenia simplex Rhumbler *in* Wiesner, 1931, p. 132, pl. 22, fig. 263
Pullenia quinqueloba d'Orbigny *in* Jones, 1994, p. 92, pl. 84, figs. 14-15

Pullenia bulloides (d'Orbigny, 1826)
Pl. 38, figs. 3-4

Nonionina bulloides d'Orbigny *in* d'Orbigny, 1826, p. 293
Nonionina bulloides d'Orbigny *in* d'Orbigny, 1846, p. 107, pl. 5, figs. 9-10
Pullenia sphaeroides d'Orbigny *in* Brady, 1884, p. 615, pl. 84, figs. 12-13
Pullenia bulloides d'Orbigny *in* Ujiié, 1990, p. 42, pl. 23, figs. 1-2
Pullenia bulloides d'Orbigny *in* Jones, 1994, p. 92, pl. 84, figs. 12-13

Superfamily Chilostomellacea Brady, 1881
Family Chilostomellidae Brady, 1881
Subfamily Chilostomellinae Brady, 1881

Genus *Chilostomella* Reuss, 1849
Type species: *Chilostomella ovoidea* Reuss, 1850, p. 380

Chilostomella oolina Schwager, 1878
Pl. 38, fig. 5

Chilostomella oolina Schwager *in* Schwager, 1878, p. 527, pl. 1, fig. 16
Chilostomella ovoidea Reuss *in* Brady, 1884, p. 436, pl. 55, figs. 12-14, 17-18
Chilostomella oolina Schwager *in* Cushman and Todd, 1949, p. 91, pl. 15, figs 23-24
Chilostomella oolina Schwager *in* Jones, 1994, p. 61, pl. 55, figs. 12-14, 17-18

Chilostomella oolina Schwager *in* Loeblich and Tappan, 1994, p. 160, pl. 349, figs. 12-13

Family Heterolepidae Gonzales-Donoso, 1969

Genus *Anomalinoides* Brotzen, 1942

Type species: *Anomalina pinguis* Jennings, 1936, p. 195

Anomalinoides globulosa (Chapman and Parr, 1937)

Pl. 39, fig. 1

Anomalina globulosa Chapman and Parr *in* Chapmann and Parr, 1937, p. 117, pl. 9, fig. 27
Anomalina globulosa Chapman and Parr *in* Feyling-Hanssen, 1954, p. 258, pl. 9, figs. 1-3
Cibicidoides globulosus Chapman and Parr *in* Jones, 1994, p. 98, pl. 94, fig 4-5

Family Gavelinellidae Hofker, 1956

Subfamily Gavelinellinae Hofker, 1956

Genus *Discanomalina* Asano, 1951

Type species: *Discanomalina japonica* Asano, 1951, p. 13

Discanomalina coronata (Parker and Jones, 1857)

Pl. 39, fig. 2

Anomalina coronata Parker and Jones *in* Parker and Jones, 1857, p. 294, pl. 10, figs. 15-16
Discanomalina coronata Jones *in* Jones, 1994, p. 100, pl. 97, figs. 1-2
Discanomalina coronata Parker and Jones *in* Schönfeld, 2003, p. 1858, pl. 1, fig. 14

Discanomalina japonica Asano, 1951

Pl. 39, fig. 3

Discanomalina japonica Asano *in* Asano, p. 13, figs. 3-5

Genus *Gyroidina*, 1826

Type species: *Gyroidina orbicularis* d'Orbigny, 1826, p. 190

Gyroidina laevigata d'Orbigny, 1826

Pl. 39, fig. 4

Gyroidina laevigata d'Orbigny *in* d'Orbigny, 1826, p. 278

Gyroidina lamarckiana (d'Orbigny, 1839)

Pl. 39, fig. 5

Rotalia lamarckiana d'Orbigny *in* d'Orbigny, 1839b, p. 131, pl. 2 , figs. 13-15
Gyroidina lamarckiana d'Orbigny *in* Phleger et al., 1953, p. 41, pl. 8, figs. 33-34
Gyroidina lamarckiana d'Orbigny *in* Todd, 1965, p. 19, pl. 6, fig. 3
Gyroidina lamarckiana d'Orbigny *in* Loeblich and Tappan, 1994, p. 163, pl . 361, figs. 7-12

Gyroidina soldanii d'Orbigny, 1839

Pl. 40, fig. 1

Gyroidina soldanii d'Orbigny *in* d'Orbigny, 1826, p. 278, no. 5
Rotalia soldanii d'Orbigny *in* d'Orbigny, 1846, p. 155, pI. 8, figs. 10-12
Gyroidina soldanii d'Orbigny *in* Papp and Schmid, 1985, p. 60, pI. 50, figs. 4-9
Hansenisca soldanii d'Orbigny *in* Loeblich and Tappan, 1987, p. 639, pl. 719, figs. 5-9

Gyroidina neosoldanii Brotzen, 1936

Pl. 40, fig. 2

Rotalina soldanii d'Orbigny *in* Brady, 1884, p. 107, figs. 6-7
Gyroidina neosoldanii Brotzen *in* Brotzen, 1936, p. 158
Gyroidinoides soldanii Brotzen *in* Jones, 1994, p. 106, pl. 107, figs. 6-7
Gyroidina neosoldanii Brotzen *in* Hermelin, 1989, p. 81, pl. 15, figs. 16-18

Gyroidina altiformis (Steward and Steward, 1930)

Pl. 40, fig. 3

Gyroidina soldanii d'Orbigny var. *altiformis* Steward and Steward *in* Cushman et al., 1930, p. 67, pl. 9, fig. 2
Gyroidina soldanii d'Orbigny var. *altiformis* Steward and Steward *in* Cushman, 1931, p. 41, pl. 8, fig. 10; pl. 9, fig. 1
Gyroidina soldanii d'Orbigny var. *altiformis* Steward and Steward *in* Renz, 1948, p. 140, pl. 8, fig. 13
Hansenisca altiformis Steward and Steward *in* Finger, 1990, p. 124-125, figs 1-8; text-fig. 2

Genus *Hanzawaia* Asano, 1944

Type species: *Hanzawaia nipponica* Asano, 1944, p. 98

Hanzawaia boueana (d'Orbigny, 1846)
Pl. 40, figs. 4-5

Truncatulina boueana d'Orbigny *in* d'Orbigny, 1846, p. 169, pl. 9, figs. 24-26
Cibicides boueanus d'Orbigny *in* Graham and Militante, 1959, p. 116, pl. 19, fig. 11
Hanzawaia boueana d'Orbigny *in* Zheng, 1980, p. 171, pl. 5, fig. 10
Hanzawaia boueana d'Orbigny *in* Loeblich and Tappan, 1994, p. 164, pl. 364, figs 1-8

Family Trichohyalidae Saidova, 1981

Genus *Buccella* Andersen, 1952

Type species: *Eponides hannai* Phleger and F.L. Parker, 1951, p. 21

Buccella frigida (Cushman, 1922)
Pl. 41, fig. 1

Pulvinulina frigida Cushman *in* Cushman, 1922, p. 144
Buccella frigida Cushman *in* Feyling – Hanssen et al., 1971, p. 253, pl. 8, figs. 12-14, pl. 19, fig. 1
Buccella frigida Cushman *in* Kihle and Løfaldli, 1975
Buccella frigida Cushman *in* Vazquez Riveiros and Patterson, 2008, p. 30, pl. 13, fig. 3

Superfamily Orbitoidacea Schwager, 1876

Family Elphidiinae Galloway, 1933

Genus *Elphidium* de Montfort, 1808

Type species: *Nautilus macellus* var. β Fichtel and Moll, 1798, p. 66

Elphidium albiumbilicatum (Weiss, 1954)
Pl. 41, fig. 2

Nonion pauciloculum Cushman subsp. *albiumbilicatum* Weiss *in* Weiss, 1954, p. 157, pl. 32, figs. 1-2
Elphidium albiumbilicatum Weiss *in* Feyling – Hanssen et al., p. 268, pl. 10, figs. 15-19, pl. 19, figs. 4-8
Elphidium albiumbilicatum Weiss *in* Murray et al., 2003, p. 687, textfig. 6

Elphidium groenlandicum Cushman, 1933
Pl. 41, fig. 3

Elphidium groenlandicum Cushman *in* Cushman, 1933, p. 4, pl. 1, fig. 10
Elphidium groenlandicum Cushman *in* Feyling – Hanssen et al., 1971, p. 275, pl. 12, figs. 1-8, pl. 21, figs. 1-3
Elphidium groenlandicum Cushman *in* Kihle and Løfaldli, 1975

Elphidium hanzawai Asano, 1939
Pl. 41, fig. 4

Elphidium hanzawai Asano *in* Asano, 1939, p. 426, figs. 3-4

Elphidium incertum (Williamson, 1858)
Pl. 42, fig. 1

Polystomella umbilicata Walker var. *incerta* Williamson *in* Williamson, 1858, p. 44, pl. 3, fig. 82a
Polystomella striatopunctata Brady *in* Brady, 1884, p. 739, pl. 109, fig. 23
Elphidium incertum Williamson *in* Feyling – Hanssen et al., 1971, p. 277, pl. 12, figs. 11-12, pl. 21, figs. 8-9
Elphidium incertum Williamson *in* Kihle and Løfaldli, 1975
Cribrononion incertum Williamson *in* Jones, 1994, p. 108, pl. 109, fig. 23

Elphidium magellanicum Heron-Allen and Earland, 1932
Pl. 42, fig. 2

Elphidium (*Polystomella*) *magellanicum* Heron-Allen and Earland *in* Heron-Allen and Earland, p. 440, pl. 16, figs. 26-28
Elphidium magellanicum Heron-Allen and Earland *in* Kihle and Løfladli, 1975
Elphidium magellanicum Heron-Allen and Earland *in* Murray, 2003, p. 21, pl. 7, figs. 9-10
Cribroelphidium magellanicum Heron-Allen and Earland *in* Vazquez Riveiros and Patterson, p. 34, pl. 15, fig. 4

Elphidium subarcticum Cushman, 1944
Pl. 42, fig. 3
Elphidium subarcticum Cushman *in* Cushman, 1944, p. 27, pl. 3, figs. 34-35
Elphidium subarcticum Cushman *in* Kihle and Løfladli, 1975
Elphidium subarcticum Cushman *in* Scott et al., 2008, p. 244, pl. 4, fig. 5

PLATES

to be submitted to Earth-Science Reviews

PLATE 1

1a-b	*Astrorhiza* cf. *catenata* Norman, 1877, Hypotype from PS70/038-2
2a-b	*Bathysiphon filiformis* M. Sars, 1872, Hypotype from PS70/038-2
3a-b	*Rhabdammina abyssorum* M. Sars, 1869, a) Hypotype from AL232 1026; b) Hypotype from PS70/039-2
4a-b	*Hippocrepinella hirudinea* Heron-Allen and Earland, 1932, Hypotype from PS70/033-2
5a-b	*Psammosphaera fusca* Schulze, 1875, Hypotype from PS70/039-2
6a-b	*Psammosphaera fusca* Schulze var. *testacea* Flint, 1899, Hypotype from PS70/037-2
7a-b	*Lagenammina fusiformis* (Williamson, 1858), Hypotype from PS70/037-2
8a-b	*Lagenammina arenulata* (Williamson, 1858), Hypotype from PS70/039-2
9a-b	*Saccammina sphaerica* M. Sars, 1872, Hypotype from AL232 1025
10a-b	*Hyperammina elongata* Brady, 1878, Hypotype from POS391 558-1
11a-b	*Saccorhiza ramosa* (Brady, 1879), Hypotype from PS70/028-2

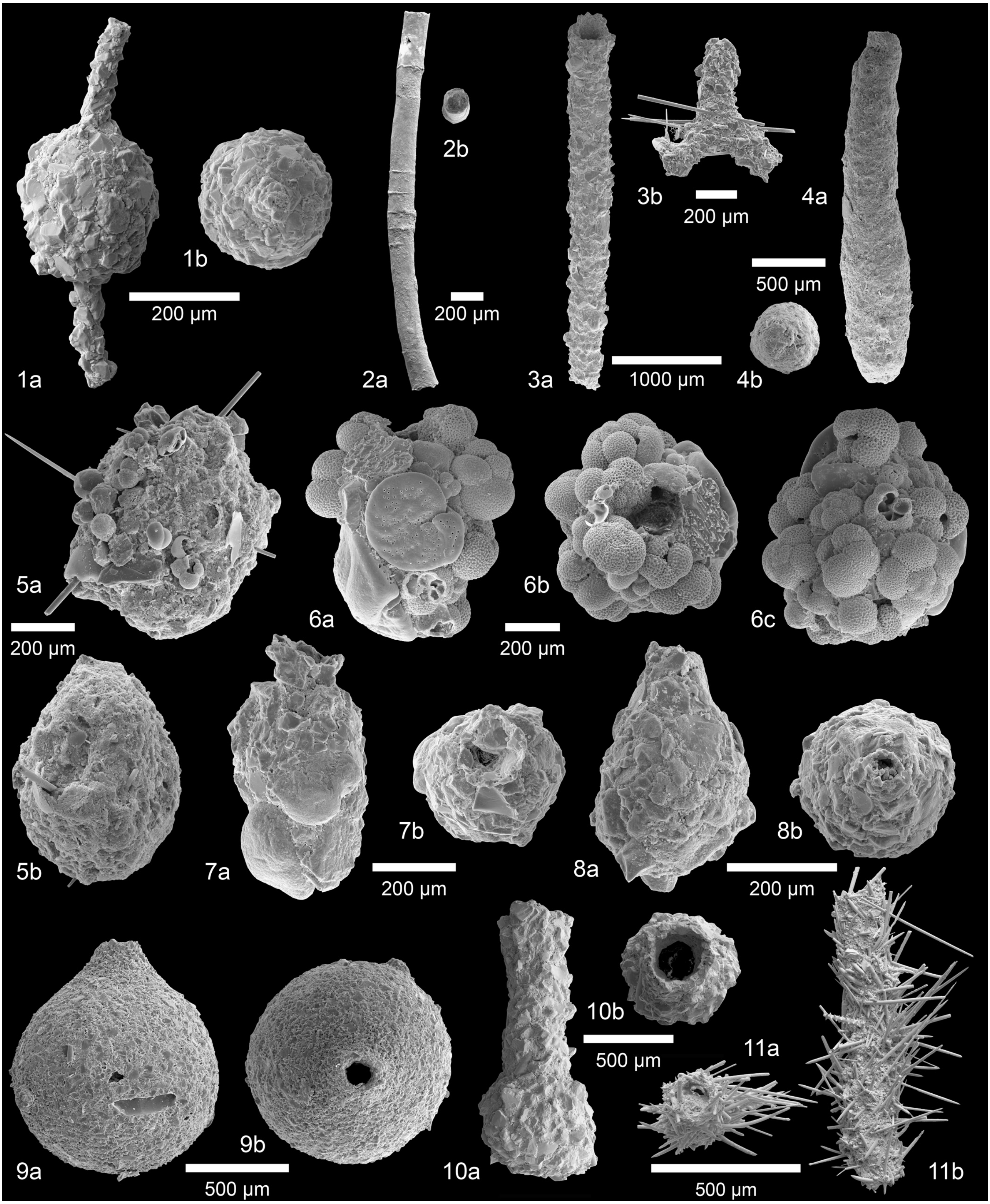
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PLATE 2

1a-b	*Reophax agglutinatus* Cushman, 1913, Hypotype from PS70/037-2
2a-b	*Hormosinella guttifera* (Brady, 1881), Hypotype from PS70/039-2
3a-b	*Reophax scorpiurus* de Montfort, 1808, Hypotype from P292 577-1
4a-b	*Ammodiscus incertus* (d'Orbigny, 1839), Hypotype from PS70/011-1
5a-c	*Glomospira charoides* (Jones and Parker, 1878), Hypotype from PS70/011-1
6a-b	*Cribrostomoides subglobosum* (M. Sars, 1868), Hypotype from PS70/011-1
7	*Ammolagena clavata* (Jones and Parker, 1860), Hypotype from PS70/002-2
8a-c	*Labrospira jeffreysii* (Williamson, 1858), Hypotype from PS70/002-2
9a-c	*Labrospira jeffreysii* (Williamson, 1858), Hypotype from AL232 1025

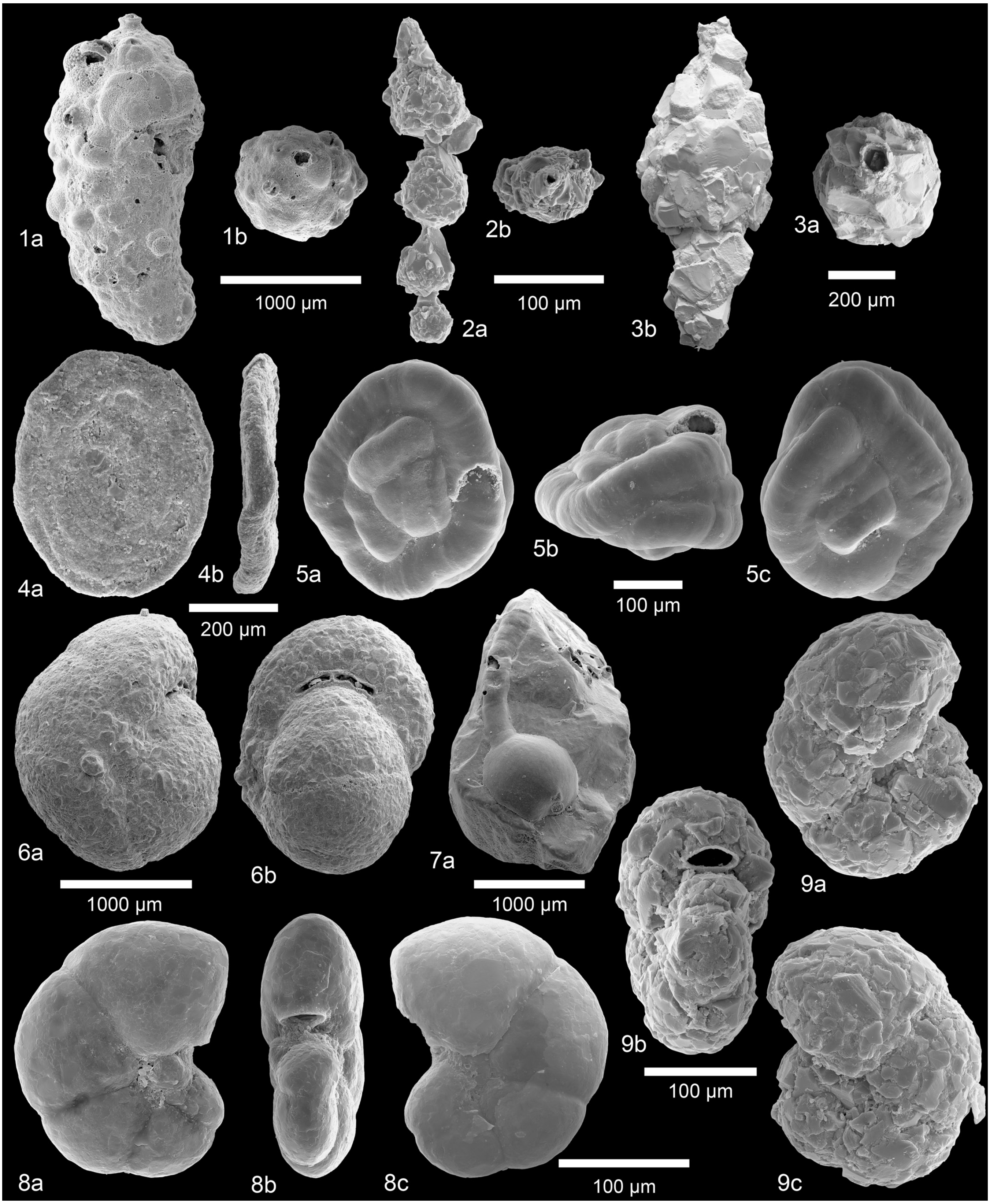
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Plate 3

1a-c	*Haplophragmoides robertsoni* Brady, 1887, Hypotype from POS391 550-1
2a-c	*Haplophragmoides robertsoni* Brady, 1887, Hypotype from PS70/011-1
3a-c	*Haplophragmoides membranaceum* Höglund, 1947, Hypotype from PS70/029-3
4a-b	*Ammobaculites agglutinans* (d'Orbigny, 1846), Hypotype from PS70/032-2
5a-c	*Adercotryma wrighti* Brönnimann and Whittaker, 1987, Hypotype from AL232 1022
6a-c	*Spiroplectinella wrightii* (Silvestri, 1903), Hypotype from POS391 550-1

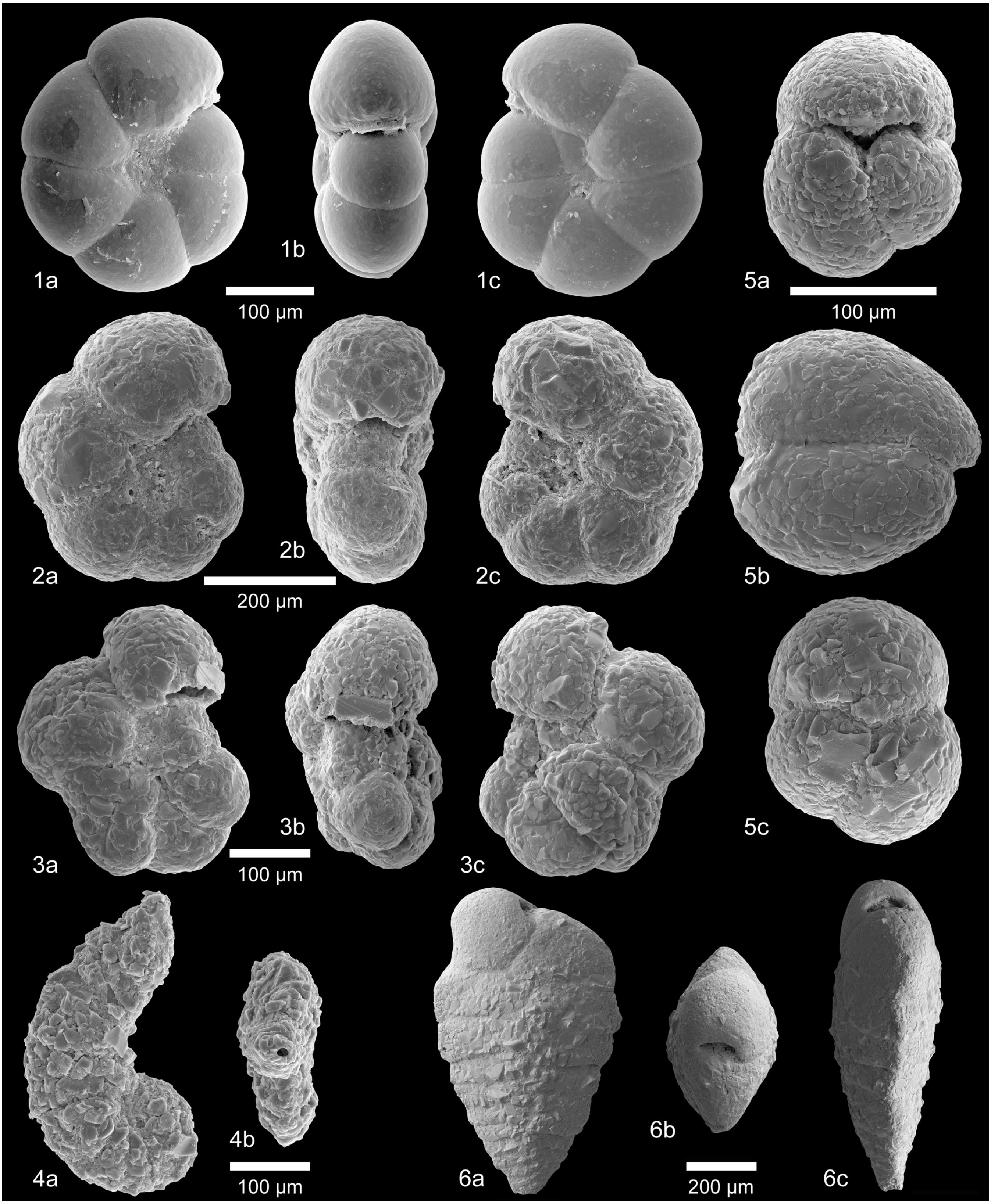
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Plate 4

1a-c *Vulvulina pennatula* Batsch, 1791, Hypotype from TTR17 MS411G 15
2a-b *Trochammina labiosa* Höglund, 1947, Hypotype from POS391 571-1
3a-c *Tritaxis fusca* (Williamson, 1858), P292 580-1
4a-c *Portatrochammina antarctica* (Parr, 1950), Hypotype from PS70/002-2
5a-c *Lepidodeuterammina ochracea* (Williamson, 1858), POS325 455
6a-c *Gaudryina rudis* Wright, 1900, Hypotype from AL232 1025

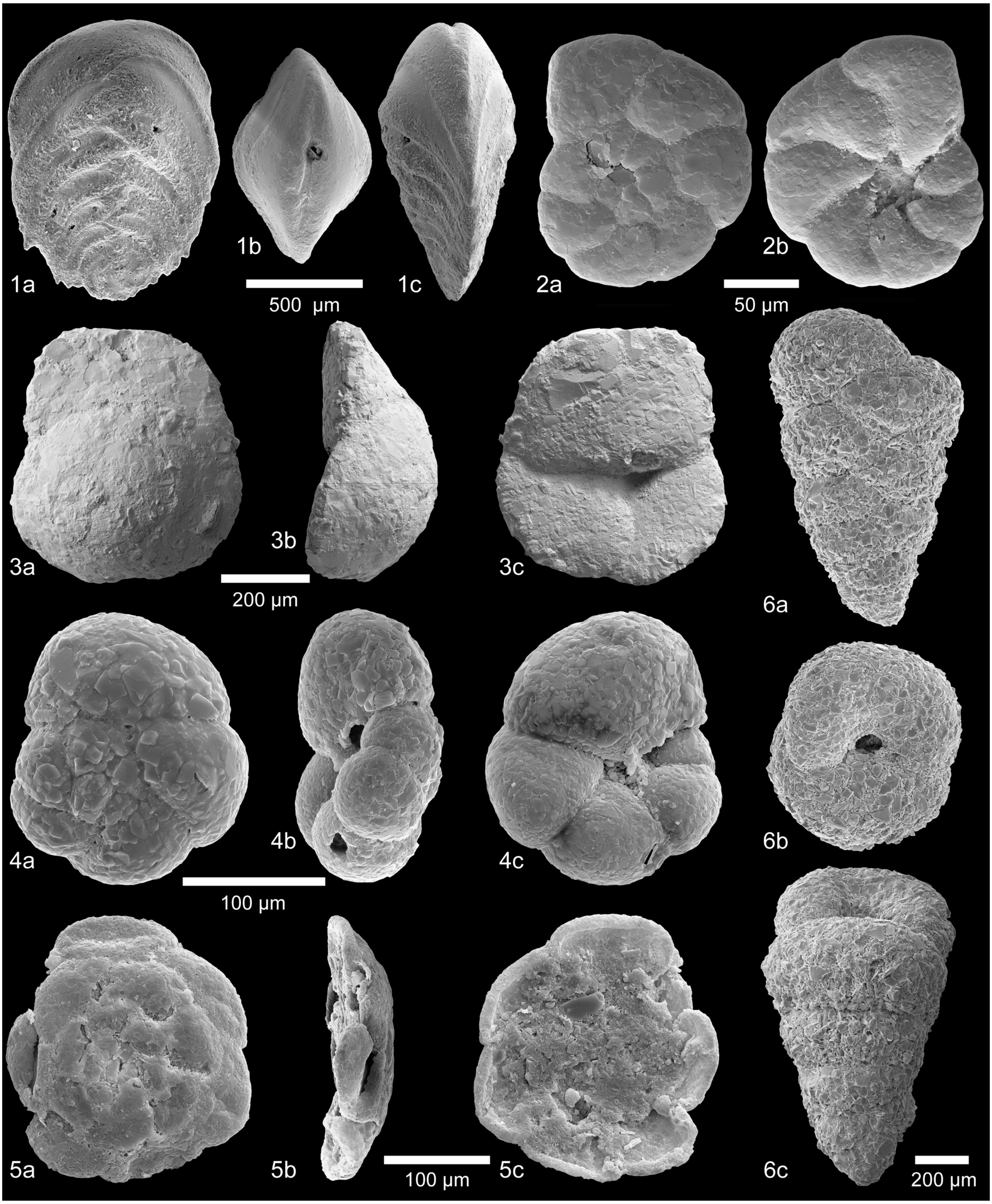
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PLATE 5

1a-c	*Gaudryina pseudotrochus* (Cushman, 1922), Hypotype from GeoB 9204-1
2a-b	*Eggerella humboldti* Todd and Brönnimann, 1957, Hypotype from M07-21
3a-c	*Karreriella bradyi* (Cushman, 1911), Hypotype from M07-23
4a-b	*Eggerelloides scaber* (Williamson, 1858), Hypotype from AL232 1025
5a-c	*Bigenerina nodosaria* d'Orbigny, 1826, Hypotype from P292 577-1
6a-b	*Bigenerina cylindrica* Cushman, 1922, Hypotype from AL232 1025
7a-c	*Siphotextularia obesa* Parr, 1950, Hypotype from P292 578-1
8a-b	*Textularia lateralis* Laliker, 1935, TTR-17 MS411G 20

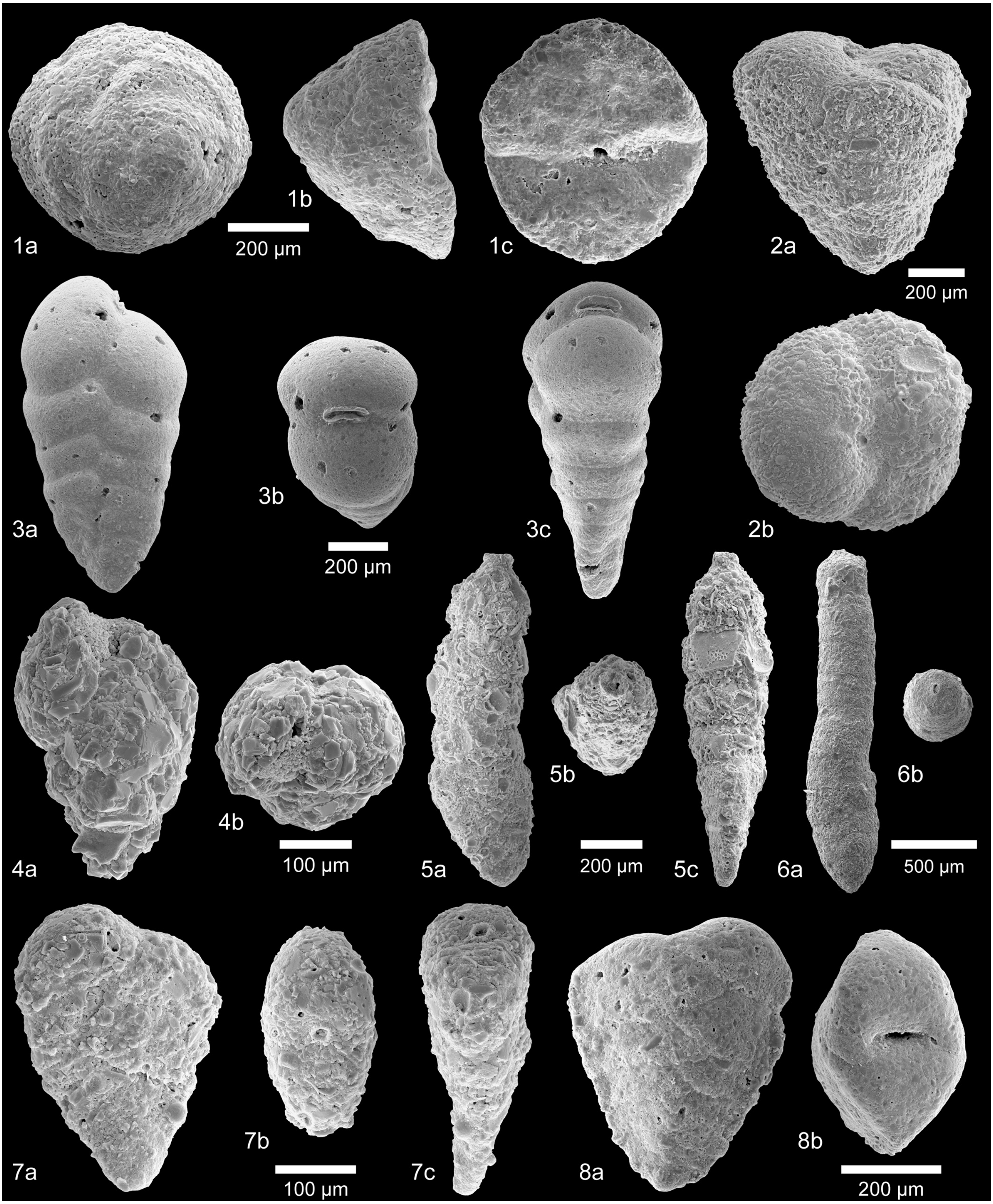
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Plate 6

1a-c *Textularia truncata* Höglund, 1947, Hypotype from TTR17 MS411G 25
2a-c *Textularia tenuissima* Earland, 1933, Hypotype from AL232 1025
3a-b *Clavulina parisiensis* d'Orbigny, 1826, Hypotype from TTR17 MS411G 0
4a-c *Mychostomina revertens* (Rhumbler, 1906), Hypotype from PS70/002-2
5a-c *Spirillina vivipara* Ehrenberg, 1843, Hypotype from POS391 550-1
6a-b *Patellina corrugata* Williamson, 1858, Hypotype from POS391 550-1
7a-c *Cornuspira involvens* (Reuss, 1850), Hypotype from PS70/011-1
8a-b *Cornuspira foliacea* (Philippi, 1844), Hypotype from TTR17 MS411G 15
9a-b *Gordiospira* sp., Hypotype from PS70/028-2
10a-b *Gordiospira elongata* Collins, 1958, Hypotype from TTR17 MS411G45

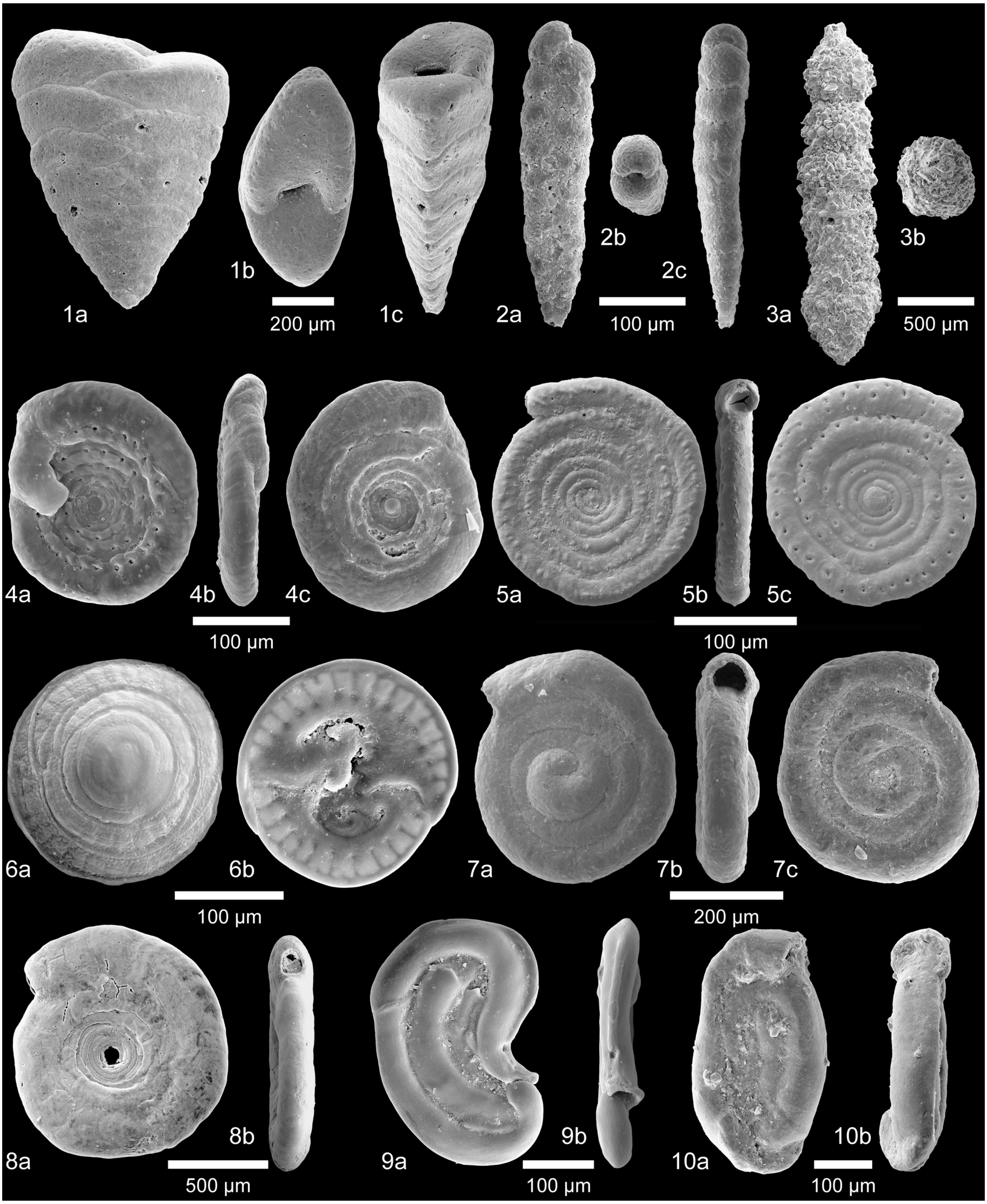
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Plate 7

1a-b	*Spiroloculina tenuiseptata* Brady, 1884, Hypotype from TTR17 MS411G 30
2a-b	*Spiroloculina dilatata* d'Orbigny, 1846, Hypotype from TTR17 MS419G 94
3a-b	*Spiroloculina excavata* d'Orbigny, 1846, Hypotype from TTR17 MS411G 10
4a-b	*Ammomassilina arenaria* (Brady, 1884), Hypotype from TTR17 MS411G 30
5a-c	*Cycloforina laevigata* (d'Orbigny, 1839), Hypotype from TTR17 MS411G 0
6a-c	*Cycloforina stalkeri* (Loeblich and Tappan, 1953), Hypotype from TTR17 MS411G 10
7a-c	*Quinqueloculina viennensis* Le Calvez and Le Calvez, 1958, Hypotype from POS391 556-2
8a-c	*Quinqueloculina seminula* (Linné, 1758), Hypotype from TTR17 MS411G 15

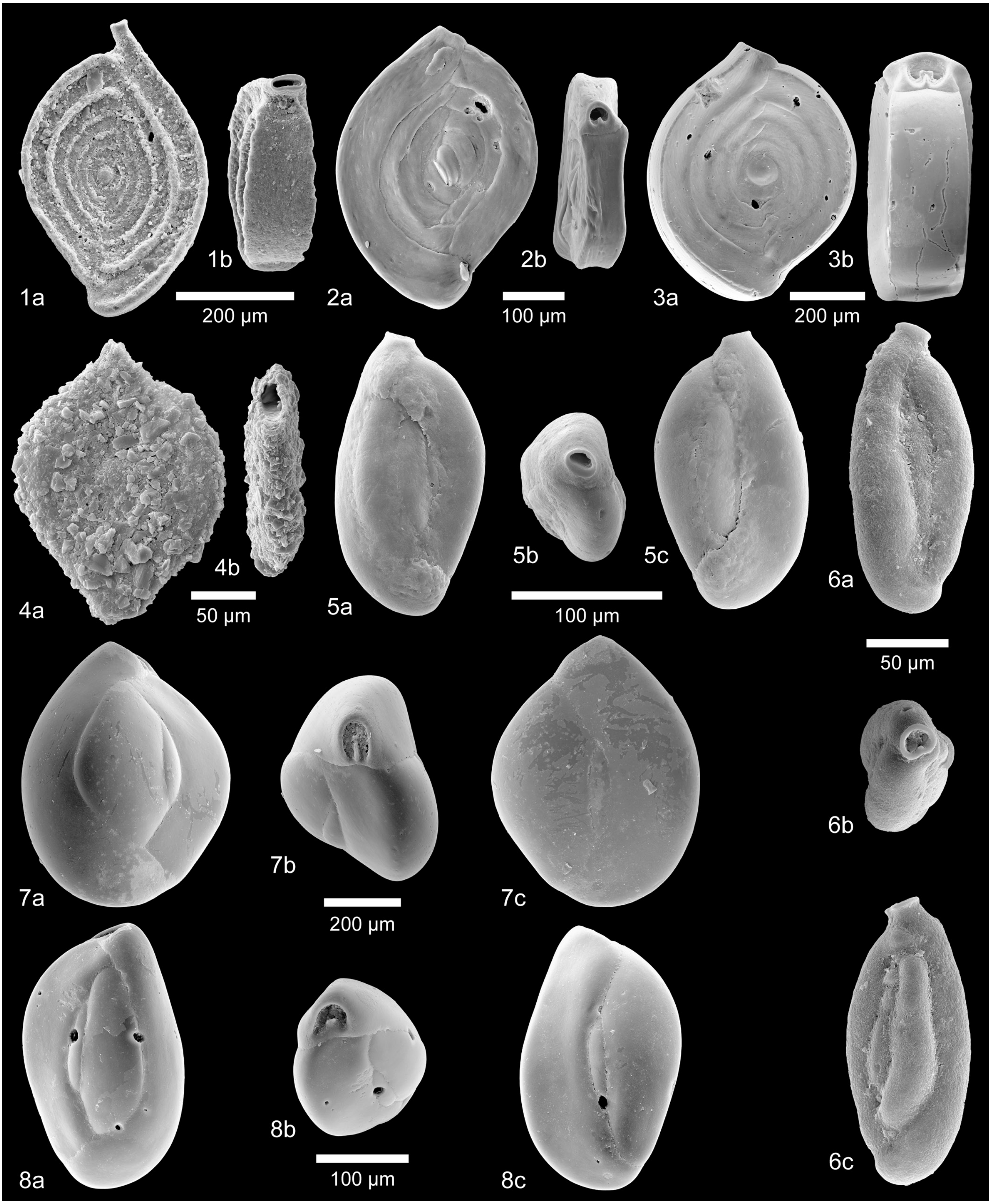
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PLATE 8

1a-c *Quinqueloculina arctica* Cushman, 1933, Hypotype from GeoB9257
2a-c *Biloculinella globula* (Bornemann, 1855), Hypotype from POS391 534-1
3a-c *Biloculinella depressa* (Wiesner, 1923), Hypotype from POS325 455
4a-c *Biloculinella fragilis* Le Calvez and Le Calvez, 1958, Hypotype from TTR17 MS411G 45
5a-c *Miliolinella subrotunda* (Montagu, 1803), Hypotype from POS325 455

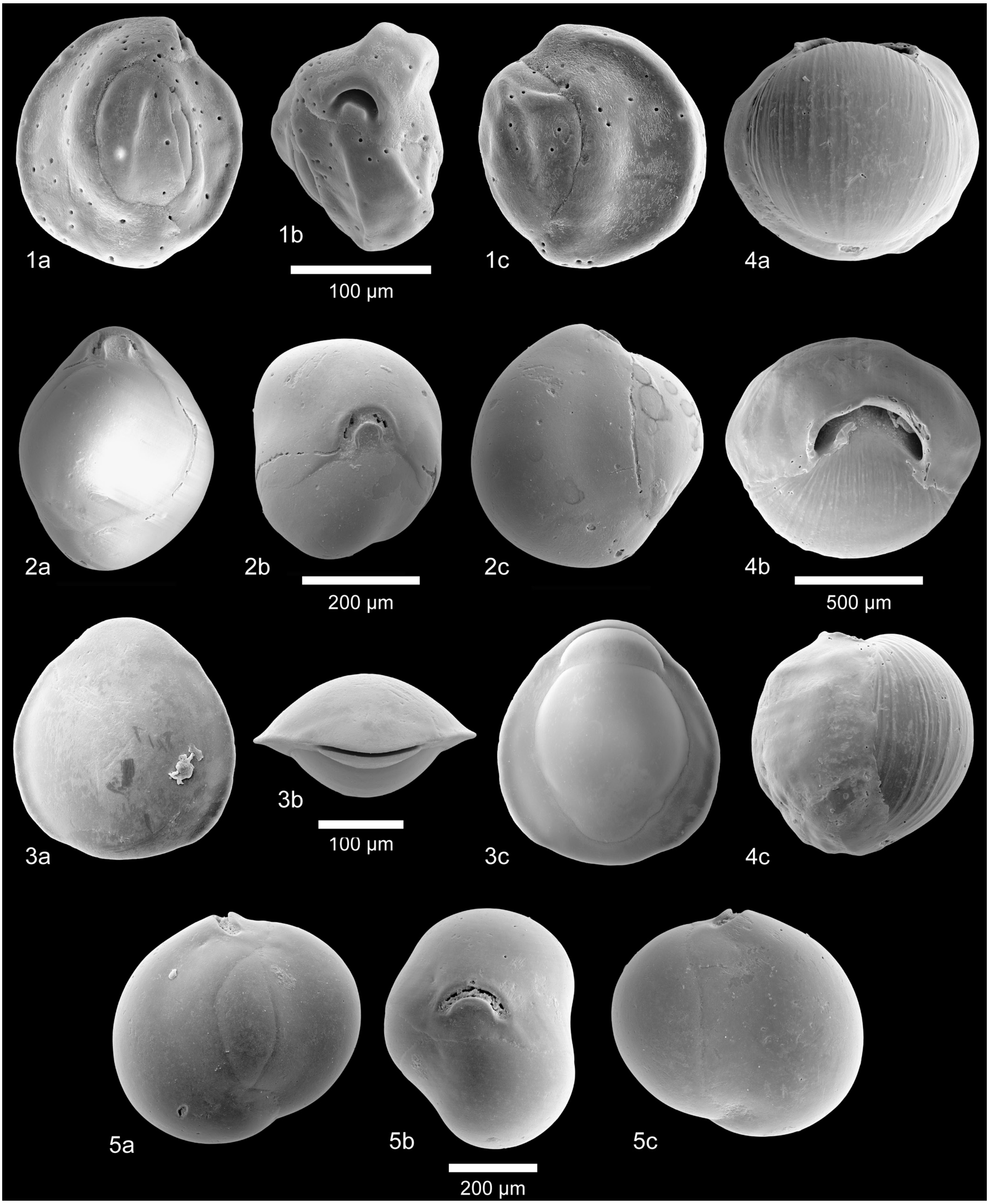
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PLATE 9

1a-c	*Miliolinella elongata* Kruit, 1955, Hypotype from TTR17 MS411G 50
2a-c	*Pyrgo inornata* (d'Orbigny, 1846), Hypotype from TTR17 MS411G 55
3a-c	*Pyrgo comata* (Brady, 1881), Hypotype from Hermi-1_1
4a-c	*Pyrgo anomala* (Schlumberger, 1891), Hypotype from M07-15
5a-c	*Pyrgo subsphaerica* (d'Orbigny, 1840), Hypotype from POS391 559-1
6a-c	*Pyrgo williamsoni* (Silvestri, 1923), Hypotype from AL232 1022

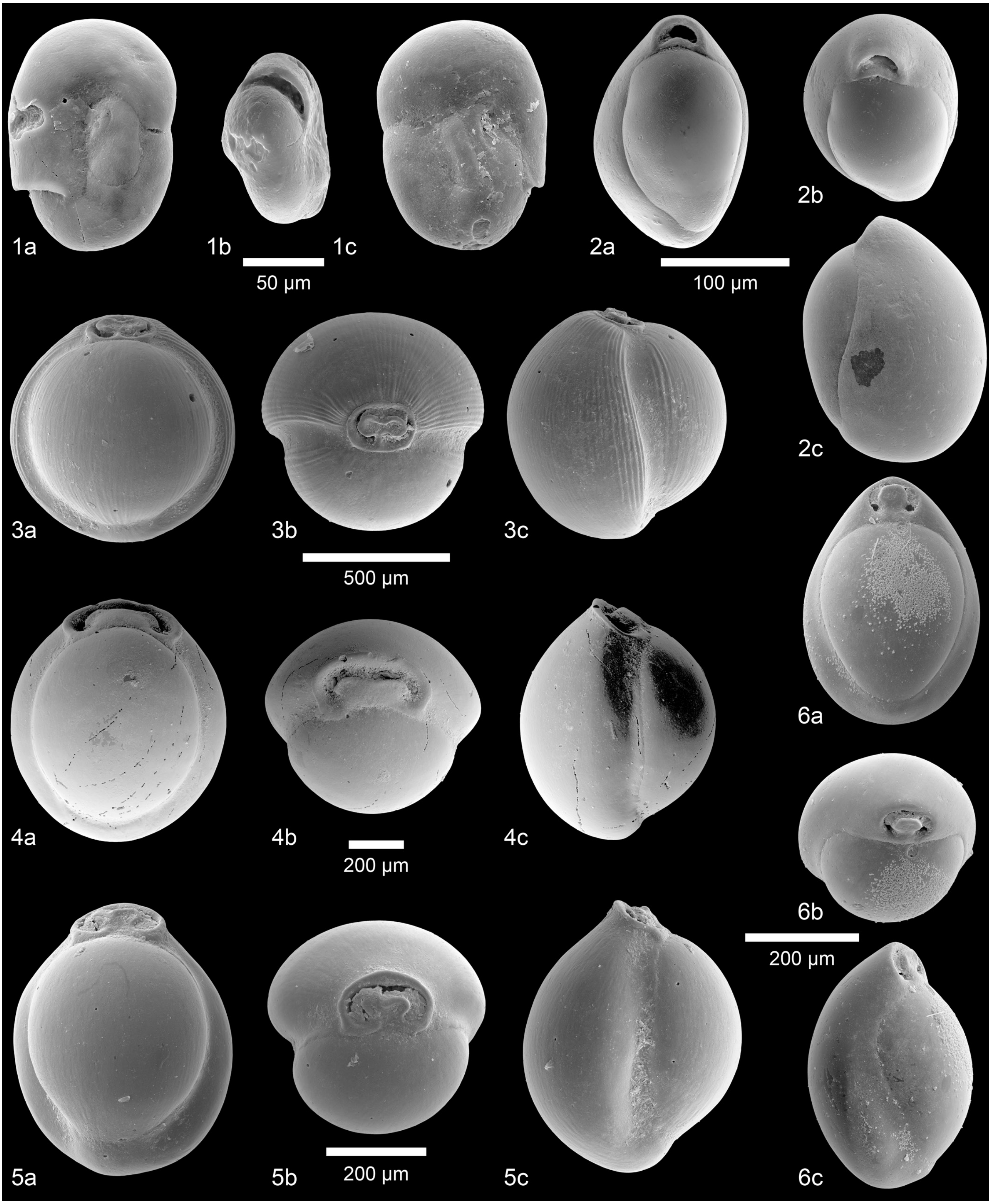
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PLATE 10

1a-c *Pyrgo sarsi* Schlumberger, 1891, Hypotype from PS70/032-2

2a-c *Pyrgo sarsi* Schlumberger, 1891, Hypotype from PS70/032-2

3a-c *Pyrgo murrhina* (Schwager, 1866), Hypotype from PS70/032-2

4a-c *Pyrgo lucernula* (Schwager, 1866), Hypotype from POS391 562-1

5a-c *Pyrgo elongata* (d'Orbigny, 1826), Hypotype from TTR17 MS411G 15

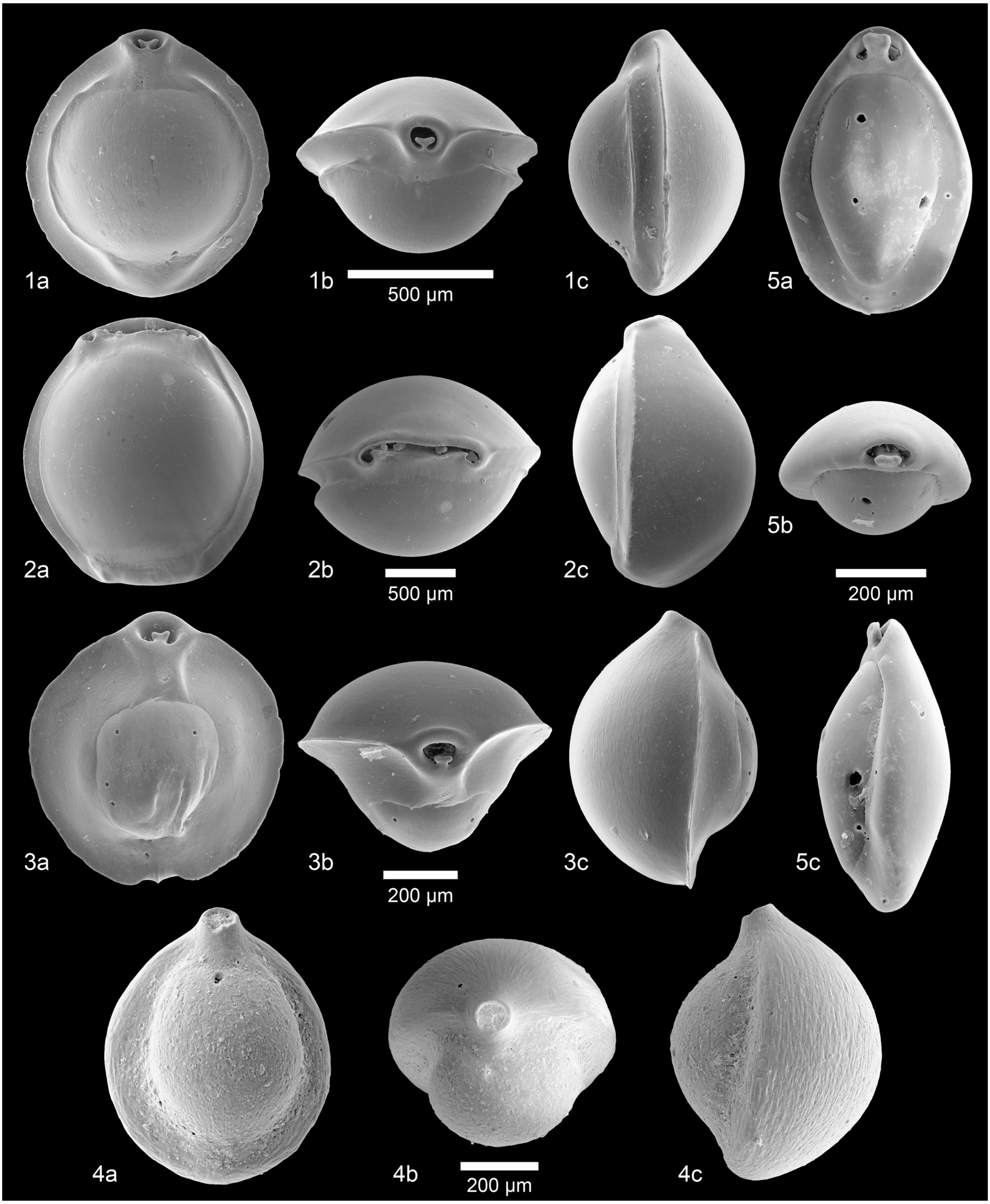
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PLATE 11

1a-c *Triloculina marioni* Schlumberger, 1893, Hypotype from TTR17 MS411G 15

2a-c *Triloculina trigonula* (Lamarck, 1804), Hypotype from PS70/032-2

3a-c *Triloculina tricarinata* d’Orbigny, 1826, Hypotype from TTR17 MS411G 15

4a-c *Sigmoinella borealis* Saidova, 1975, Hypotype from TTR17 MS411G 25

5a-c *Sigmoilopsis schlumbergeri* (Silvestri, 1904), Hypotype from TTR17 MS411G 0

6a-b *Sigmoilopsis woodi* Atkinson, 1968, Hypotype from POS391 570-2

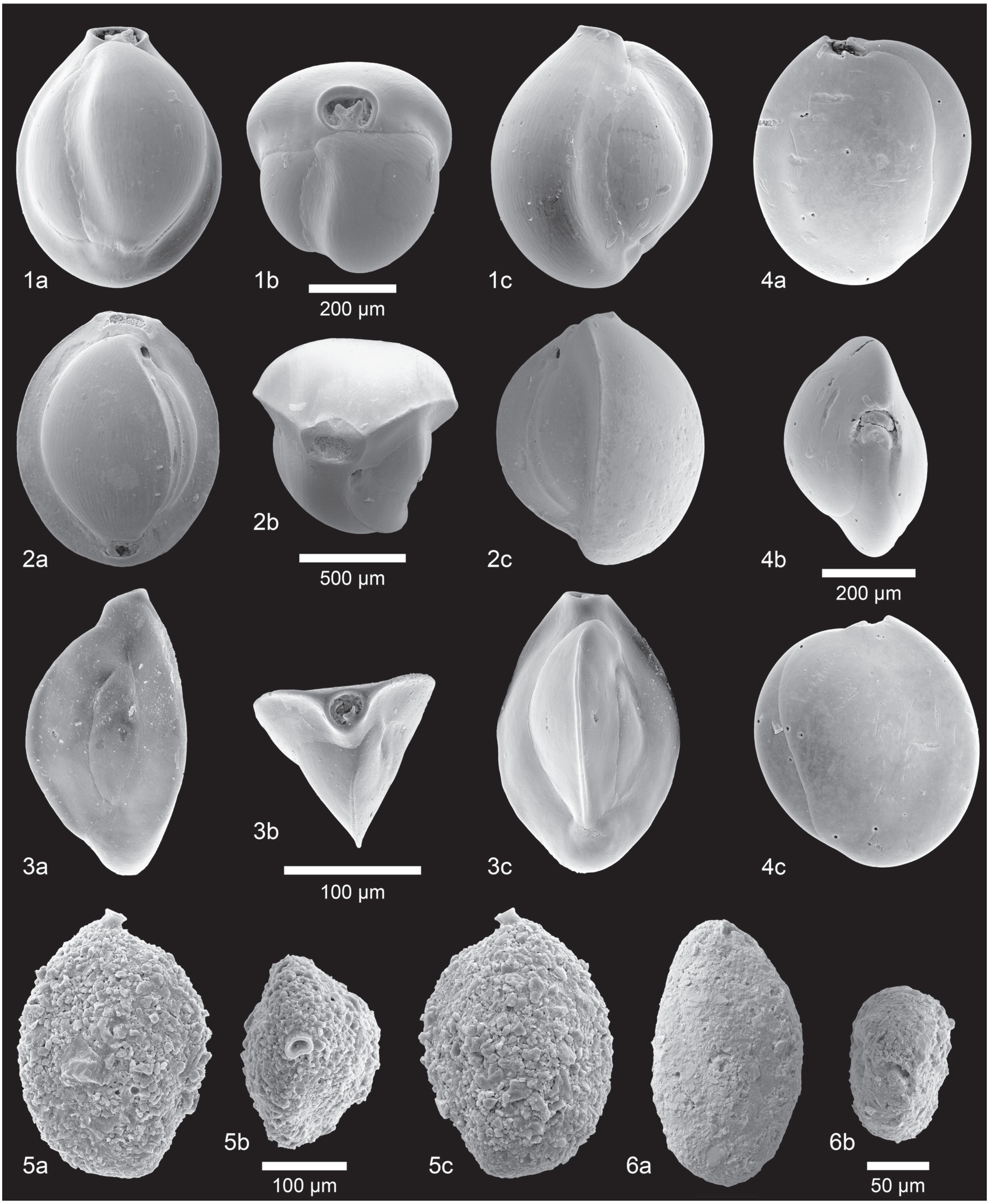
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PLATE 12

1a-b	*Dentalina cuvieri* (d'Orbigny, 1826), Hypotype from P292 574-1
2a-b	*Dentalina lamarcki* Neugeboren, 1856, Hypotype from TTR17 MS411G 30
3a-b	*Grigelis orectus* (Loeblich and Tappan, 1994), Hypotype from TTR17 MS419G 65
4a-b	*Laevidentalina sidebottomi* (Cushman, 1933), Hypotype from TTR17 MS411G 0
5a-b	*Lenticulina calcar* (Linné, 1758), Hypotype from TTR17 MS411G 50
6a-b	*Lenticulina vortex* (Fichtel and Moll, 1798), Hypotype from TTR17 MS411G 10
7a-b	*Lenticulina gibba* (d'Orbigny, 1826), Hypotype from TTR17 MS411G 10
8a-b	*Lenticulina orbicularis* (d'Orbigny, 1846), Hypotype from GeoB 6721-1
9a-b	*Lenticulina inornata* (d'Orbigny, 1846), Hypotype from M07-23
10a-c	*Neolenticulina peregrina* (Schwager, 1866), Hypotype from GeoB 12721-1

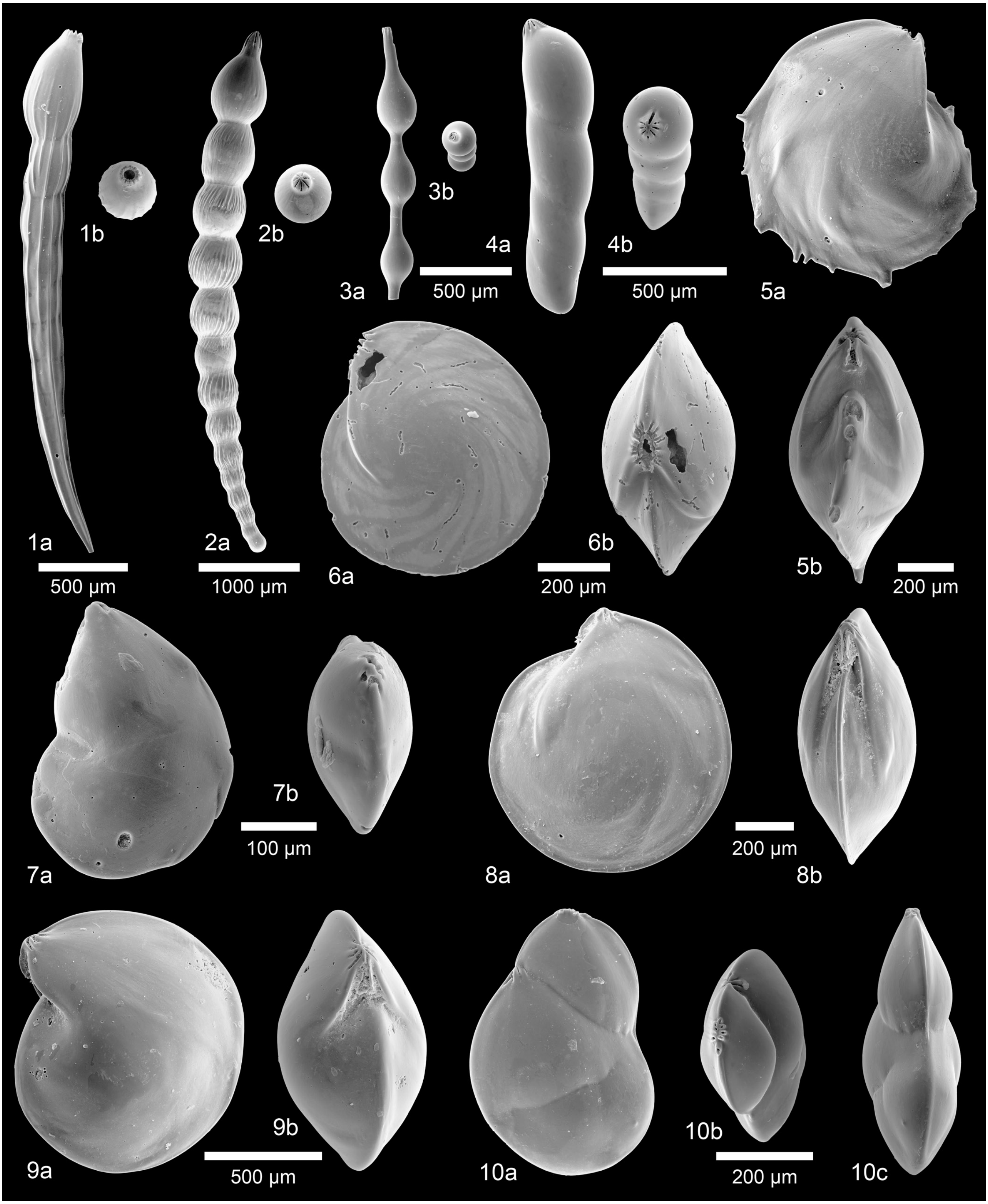
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Plate 13

1a-b *Saracenaria caribbeana* Hofker, 1976, Hypotype from GeoB 12729-1
2a-b *Amphicoryna scalaris* (Batsch, 1791), Hypotype from TTR17 MS411G 0
3a-c *Amphicoryna scalaris* (Batsch, 1791), Hypotype from TTR17 MS411G 10
4a-c *Astacolus beerae* Brenner and McMillan, 1976, Hypotype from PS70/028-2
5a-b *Planularia perculata* McCulloch, 1977, Hypotype from TTR17 MS419G 35
6a-c *Lagena substriata* Williamson, 1848, Hypotype from PS70/033-2
7a-b *Planularia costata* (d'Orbigny, 1902), Hypotype from GeoB12722-1
8a-b *Lagena meridionalis* Wiesner, 1931, Hypotype from TTR17 MS411G 55
9a-b *Lagena semilineata* var. *spinigera* Earland, 1934, Hypotype from POS391 556-1
10a-c *Pygmaeoseistron laevis ovalis* (Williamson, 1848), Hypotype from M07-21
11a-b *Lagena squamosoalata* Brady, 1881, Hypotype from GeoB 9271
12a-b *Lagena trigonolaevigata* Balkwill and Millett, 1884, Hypotype from PS70/029-3

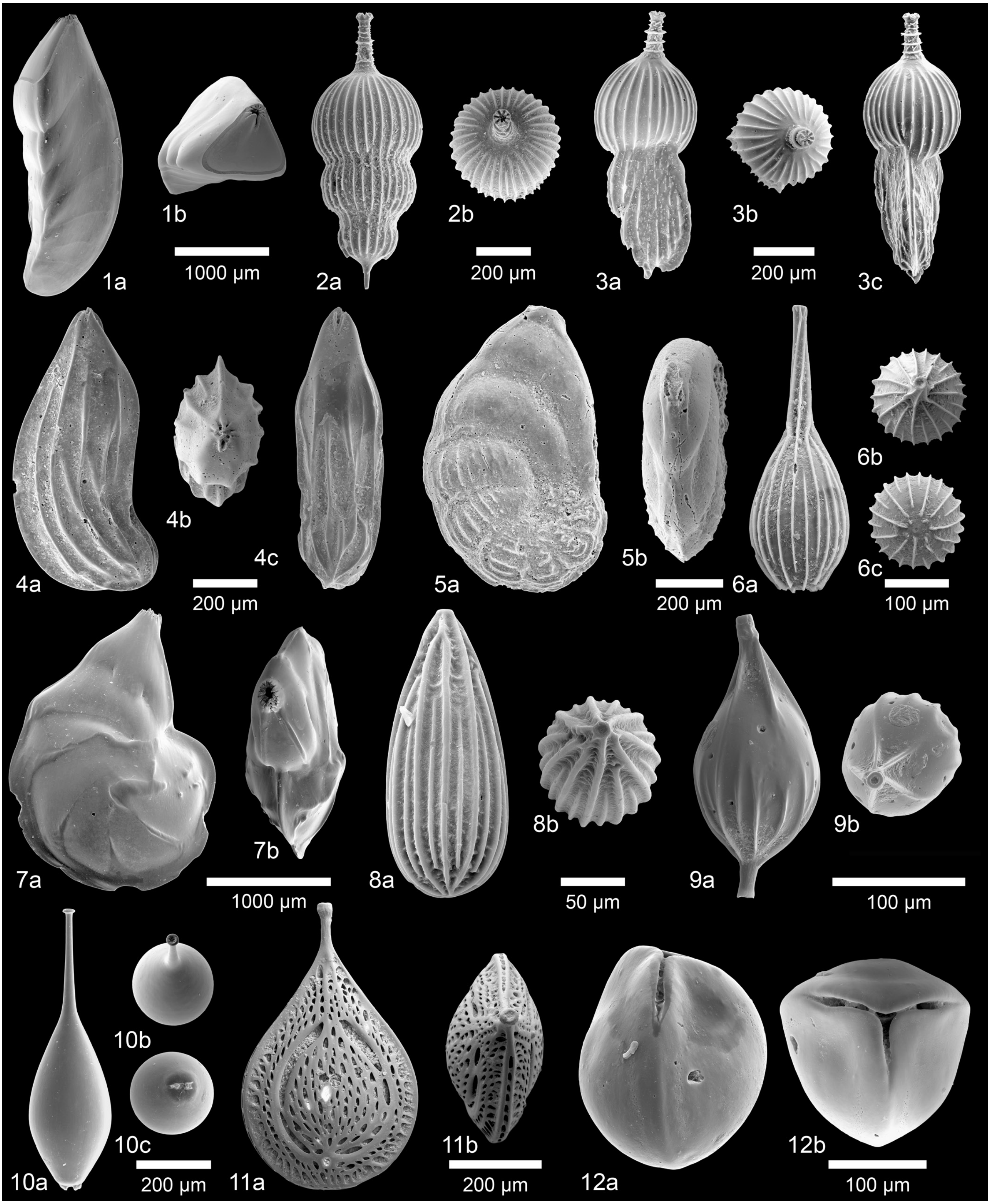
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PLATE 14

1a-b *Hyalinonetrion gracillimum* (Costa, 1856), Hypotype from PS70/011-1
2a-b *Globulina aequalis* d'Orbigny, 1846, Hypotype from AL232 1022
3a-b *Pseudopolymorphina* sp., Hypotype from GeoB 9219
4a-c *Pyrulina cylindroids* (Roemer, 1930), Hypotype from POS391 550-1
5a-c *Favulina squamosa* (Montagu, 1803), Hypotype from TTR17 MS419G 65
6a-b *Favulina melo* (d'Orbigny, 1839), Hypotype from TTR17 MS419G 35
7a-b *Favulina hexagona* (Williamson, 1858), Hypotype from TTR17 MS411G 0
8a-b *Homalohedra williamsoni* (Alcock, 1865), Hypotype from POS391 550-1
9a-c *Homalohedra apiopleura* (Loeblich and Tappan, 1953), Hypotype from TTR17 MS411G 45

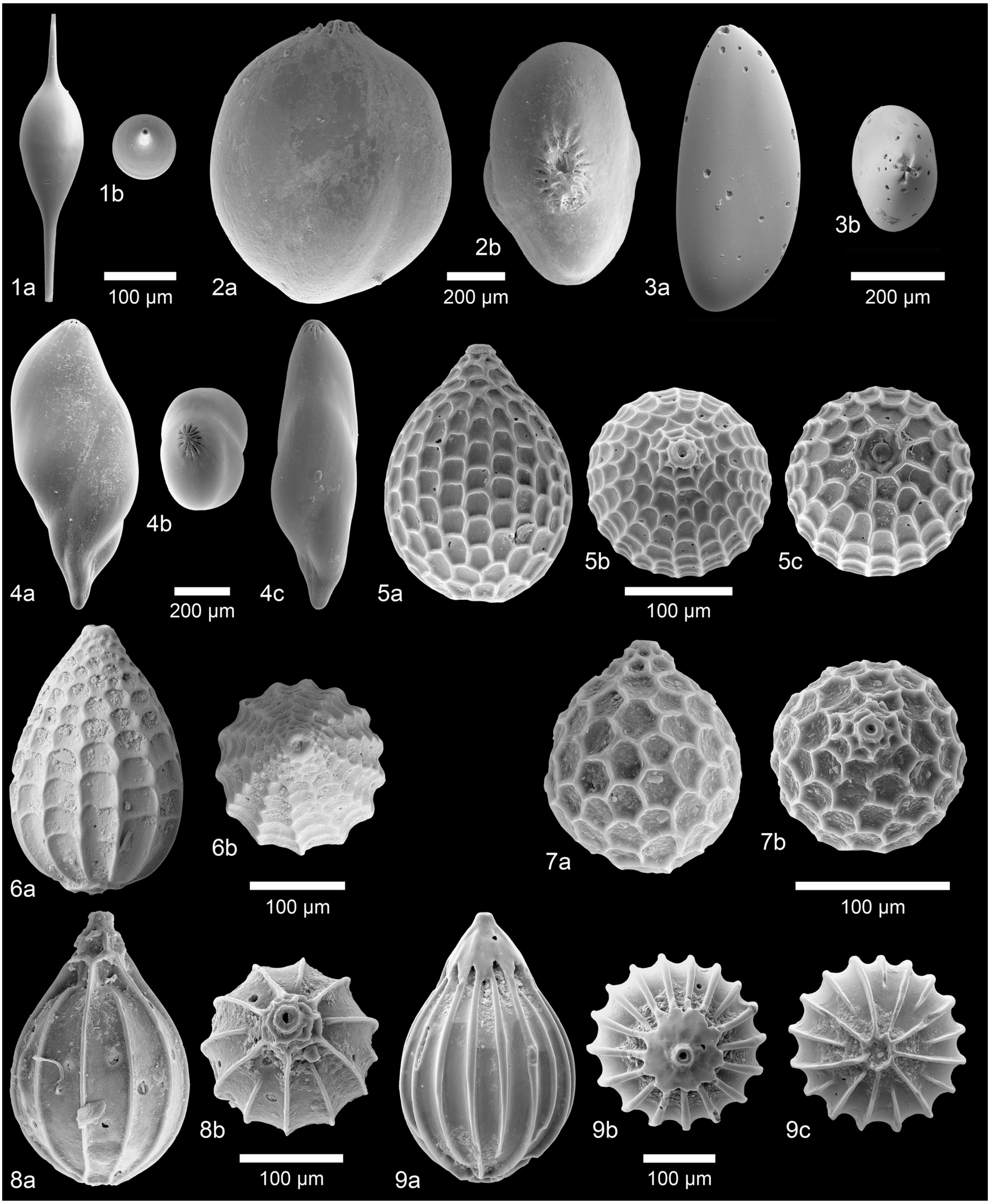
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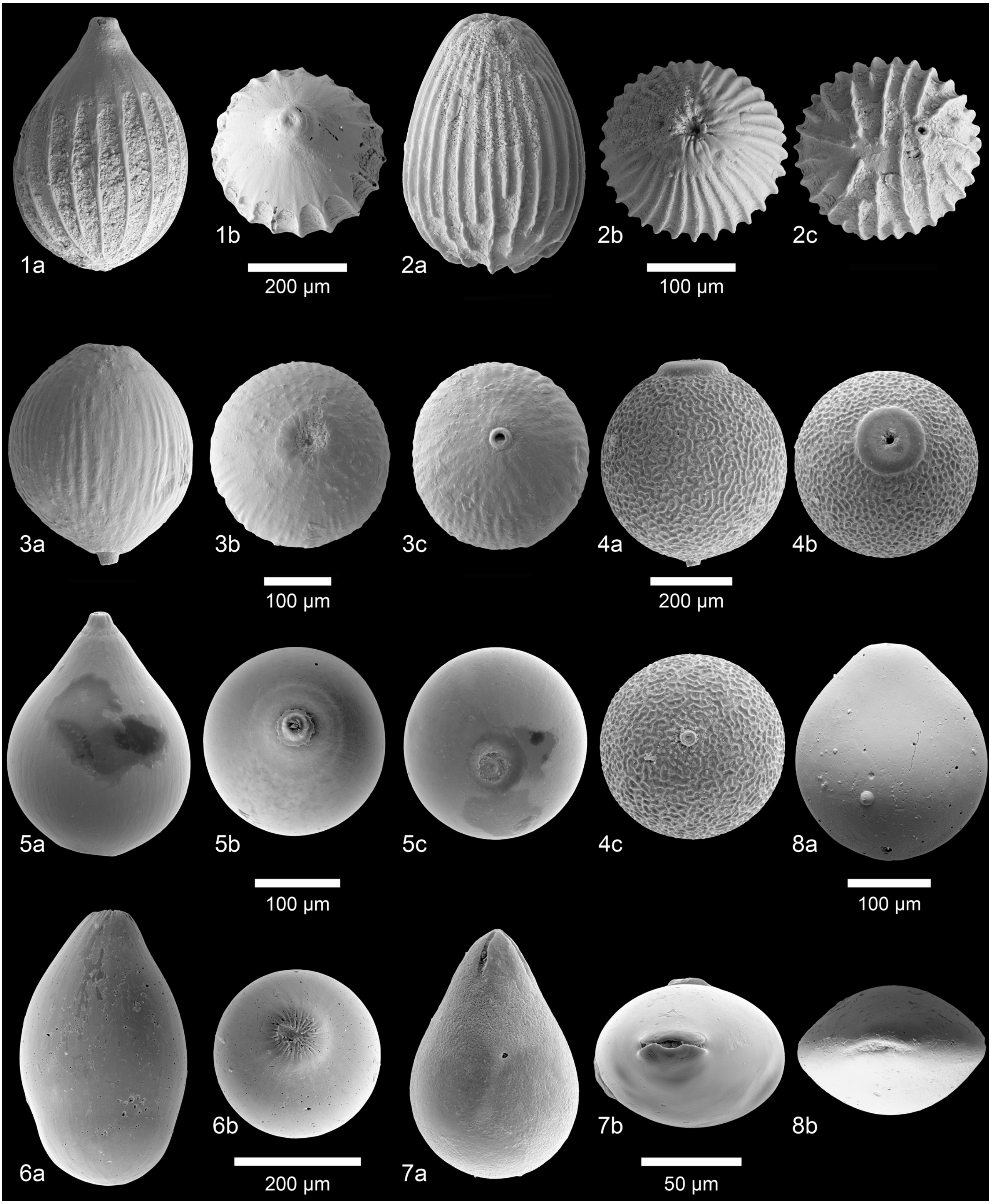
Plate 15

1a-b *Homalohedra borealis* (Loeblich and Tappan, 1954), Hypotype from POS391 550-1
2a-c *Homalohedra eucostata* (McCulloch, 1977), Hypotype from POS391 562-1
3a-c *Oolina lineata* subsp. *communis* McCulloch, 1977, Hypotype from POS391 534-1
4a-c *Oolina ampulladistoma* (Jones, 1874), Hypotype from POS391 558-1
5a-c *Oolina globosa* (Montagu, 1803), Hypotype from POS391 571-1
6a-b *Oolina laevigata* d’Orbigny, 1839, Hypotype from AL232 1022
7a-b *Fissurina agassizi* Todd and Bronnimann, 1957, Hypotype from TTR17 MS419G 45
8a-b *Fissurina circularis* Todd, 1954, Hypotype from GeoB 9271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6b
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7a
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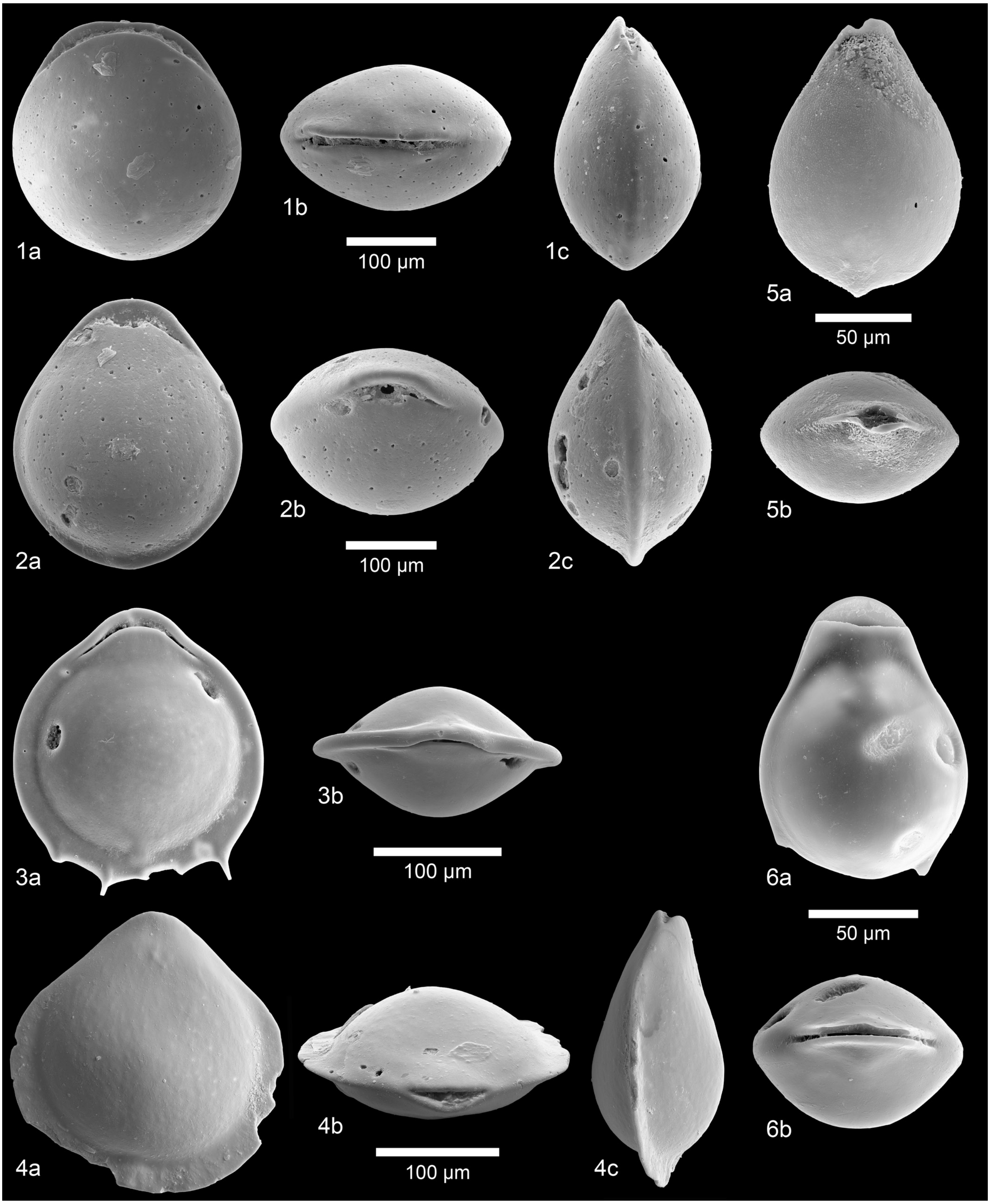
50 µm
8b

PLATE 16

1a-c *Fissurina lucida* (Williamson, 1848), Hypotype from PS70/033-2
2a-c *Fissurina eburnea* Buchner, 1940, Hypotype from POS391 550-1
3a-b *Fissurina kerguelensis* Parr, 1950, Hypotype from TTR17 MS419G 35
4a-c *Fissurina annectens* (Burrows and Holland, 1895), Hypotype from POS391 555-1
5a-b *Fissurina crassiporosa* McCulloch, 1977, Hypotype from TTR17 MS411G 10
6a-b *Fissurina longpointensis* McCulloch, 1977, Hypotype from TTR17 MS411 40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6b

PLATE 17

1a-b *Parafissurina basispinata* McCulloch, 1977, Hypotype from TTR17 MS419G 84
2a-b *Parafissurina marginata* (Walker and Boys, 1803), Hypotype from TTR17 MS411G 60
3a-b *Fissurina pseudoorbignyana* (Buchner, 1940), Hypotype from TTR17 MS411G 10
4a-b *Fissurina dublini* McCulloch, 1977, Hypotype from P292 578-1
5a-b *Fissurina derogata* McCulloch, 1977, Hypotype from TTR17 MS411G 35
6a-b *Fissurina lacunata* (Burrows and Holland, 1895), Hypotype from PS70/028-2
7a-b *Fissurina nucelloides* (Buchner, 1940), Hypotype from GeoB9209-2
8a-c *Fissurina pseudolucida* Zheng, 1979, Hypotype from POS391 544-2

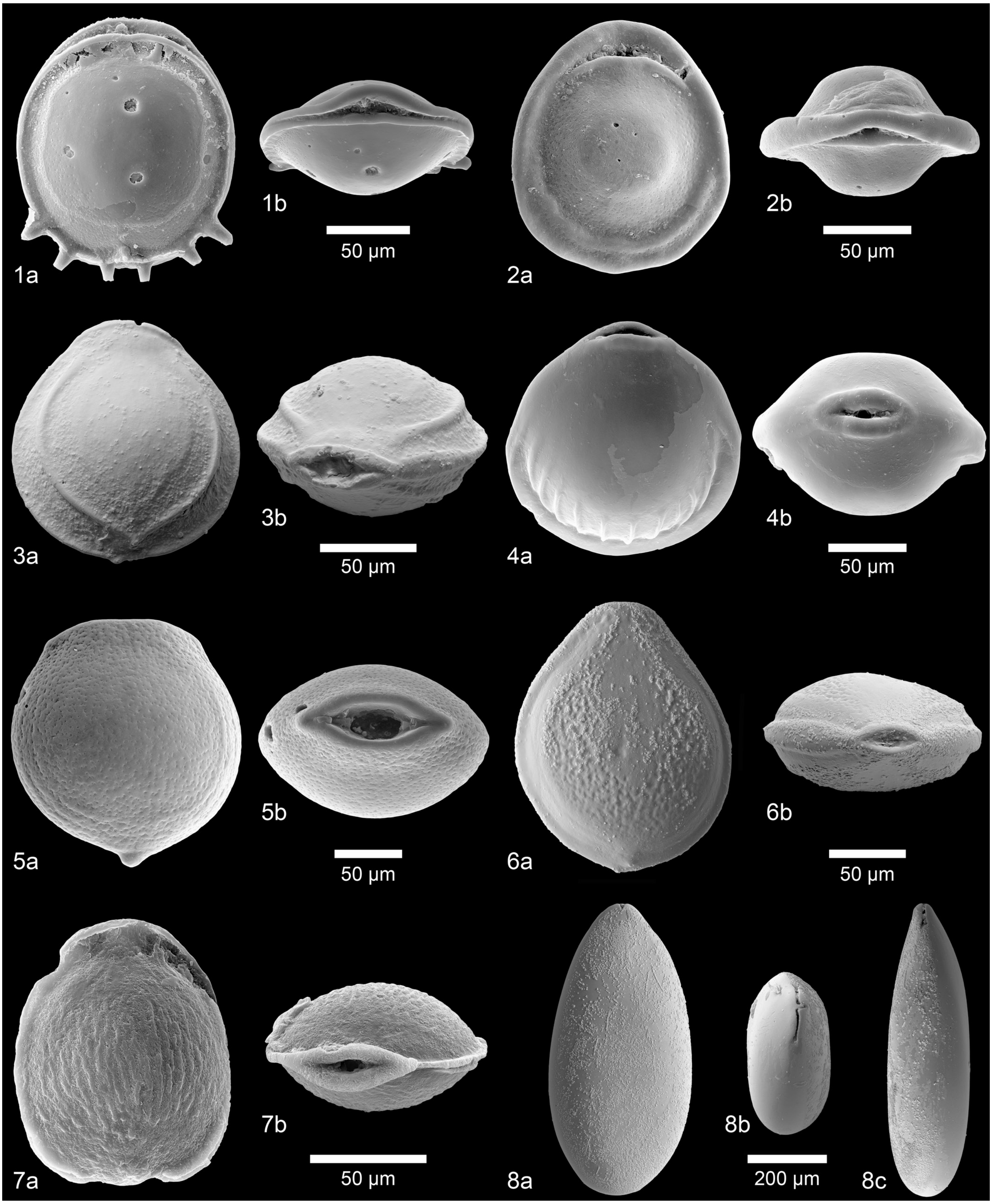
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PLATE 18

1a-b	*Palliolatella semimarginata* (Reuss, 1870), Hypotype from P292 578-1
2a-c	*Parafissurina lateralis* (Cushman, 1913), Hypotype from PS70/033-2
3a-c	*Hoeglundina elegans* (d'Orbigny, 1826), Hypotype from P292 581-1
4a-b	*Parafissurina felsinea* (Fornasini, 1894), Hypotype from PS70/038-2
5a-c	*Robertinoides bradyi* (Cushman and Parker, 1936), Hypotype from M07-15
6a-c	*Parafissurina robusta* (Zheng, 1979), Hypotype from POS326 455
7a-c	*Robertinoides bradyi* d'Orbigny, 1826, Hypotype from PS70/029-3
8a-b	*Robertinoides pumilum* Höglund, 1947, Hypotype from TTR17 MS411G 40

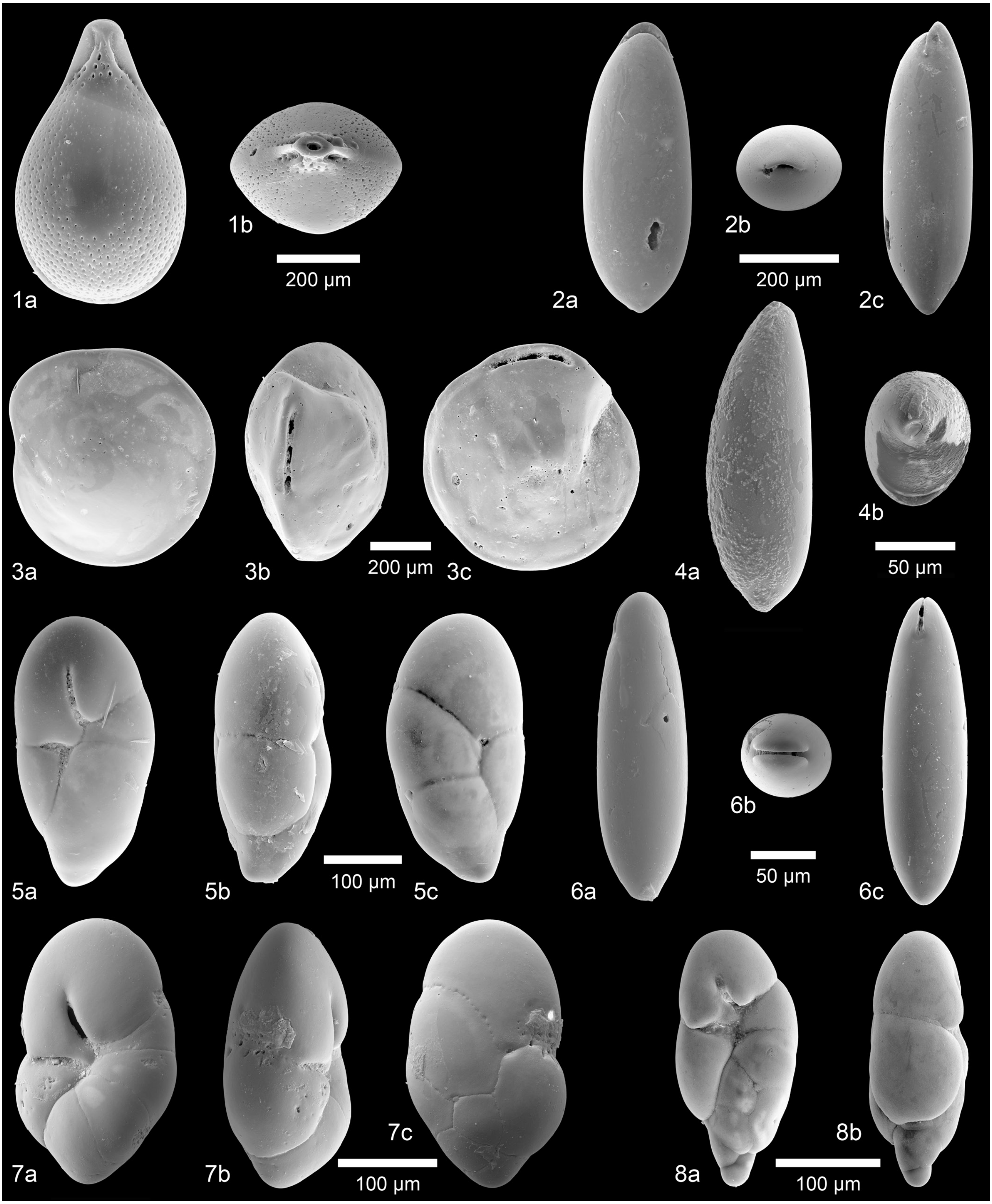
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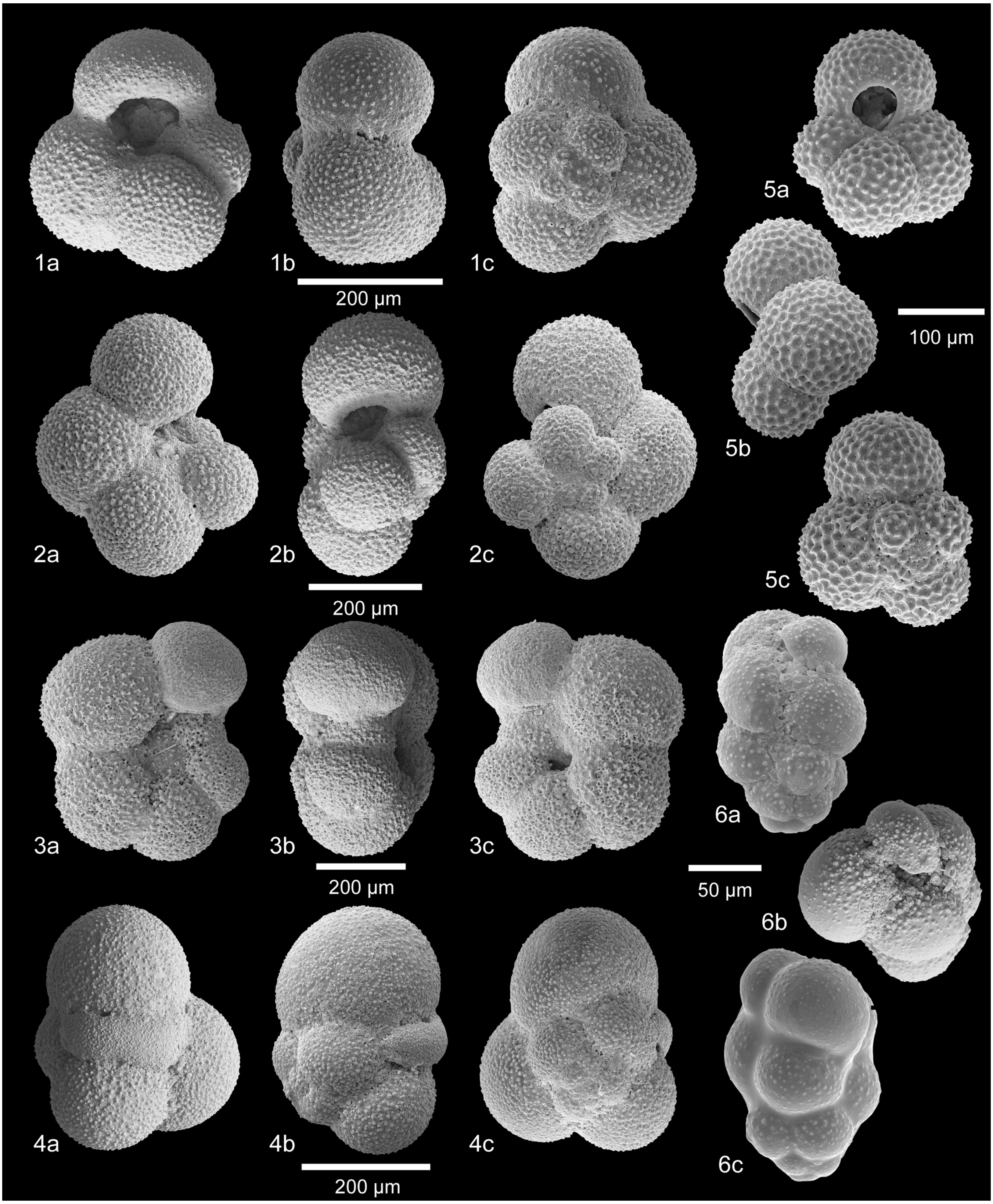
Plate 19

1a-c	*Globigerina bulloides* d'Orbigny, 1826, Hypotype from PS70/028-2
2a-c	*Globigerinella calida* (Parker, 1961), Hypotype from TTR17 MS411G 0
3a-c	*Globigerinella siphonifera* (d'Orbigny, 1839), Hypotype from TTR17 MS411G 15
4a-c	*Globigerinita glutinata* (Egger, 1893), Hypotype from PS70/028-2
5a-c	*Globoturborotalita rubescens* (Hofker, 1956), Hypotype from TTR17 MS411G 40
6a-c	*Globigerinita uvula* (Ehrenberg, 1861), Hypotype from PS70/032-2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4c
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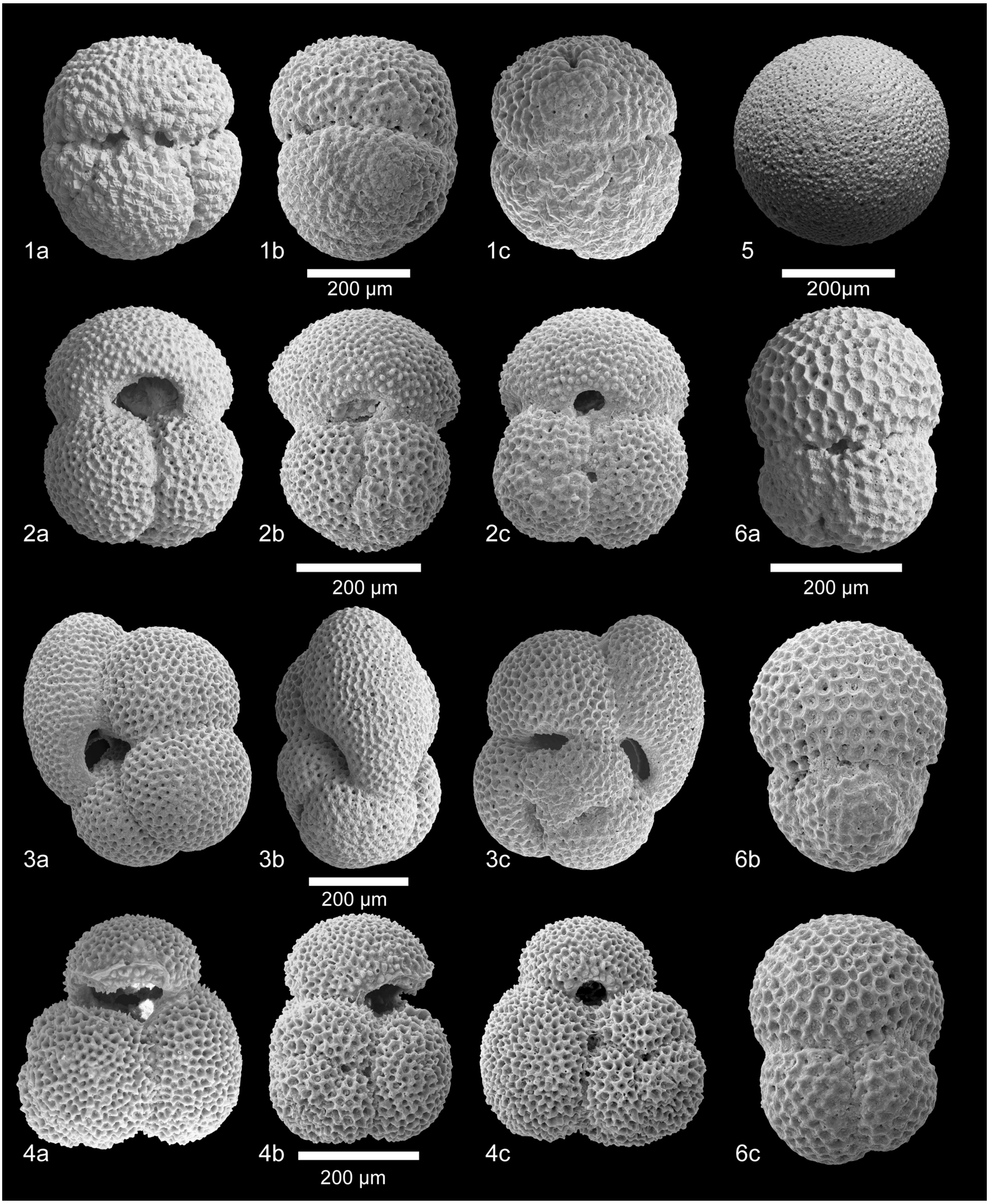
6c

PLATE 20

1a-c *Globigerinoides conglobatus* Brady, 1879, Hypotype from TTR17 MS411G 10
2a-c *Globigerinoides ruber* (d'Orbigny, 1839), Hypotype from TTR17 MS411G 0
3a-c *Globigerinoides sacculifer* (Brady, 1877), Hypotype from TTR17 MS411G 0
4a-c *Globigerinoides elongatus* (d'Orbigny, 1826), Hypotype from TTR17 MS411G 0
5 *Orbulina universa* d'Orbigny, 1839, Hypotype from TTR17 MS411G 0
6a-c *Globigerinoides trilobus* (Reuss, 1850), Hypotype from TTR17 MS411G 0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6c
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PLATE 21

1a-c *Globorotalia inflata* (d'Orbigny, 1839), Hypotype from TTR17 MS411G 0

2a-c *Globorotalia scitula* (Brady, 1882), Hypotype from TTR17 MS411G 0

3a-c *Globorotalia hirsuta* (d'Orbigny, 1839), Hypotype from TTR17 MS411G 0

4a-c *Truncorotalia crassaformis* (Galloway and Wissler, 1927), Hypotype from TTR17 MS411G 25

5a-c *Truncorotalia truncatulinoides* (d'Orbigny, 1839), Hypotype from TTR17 MS411G 0

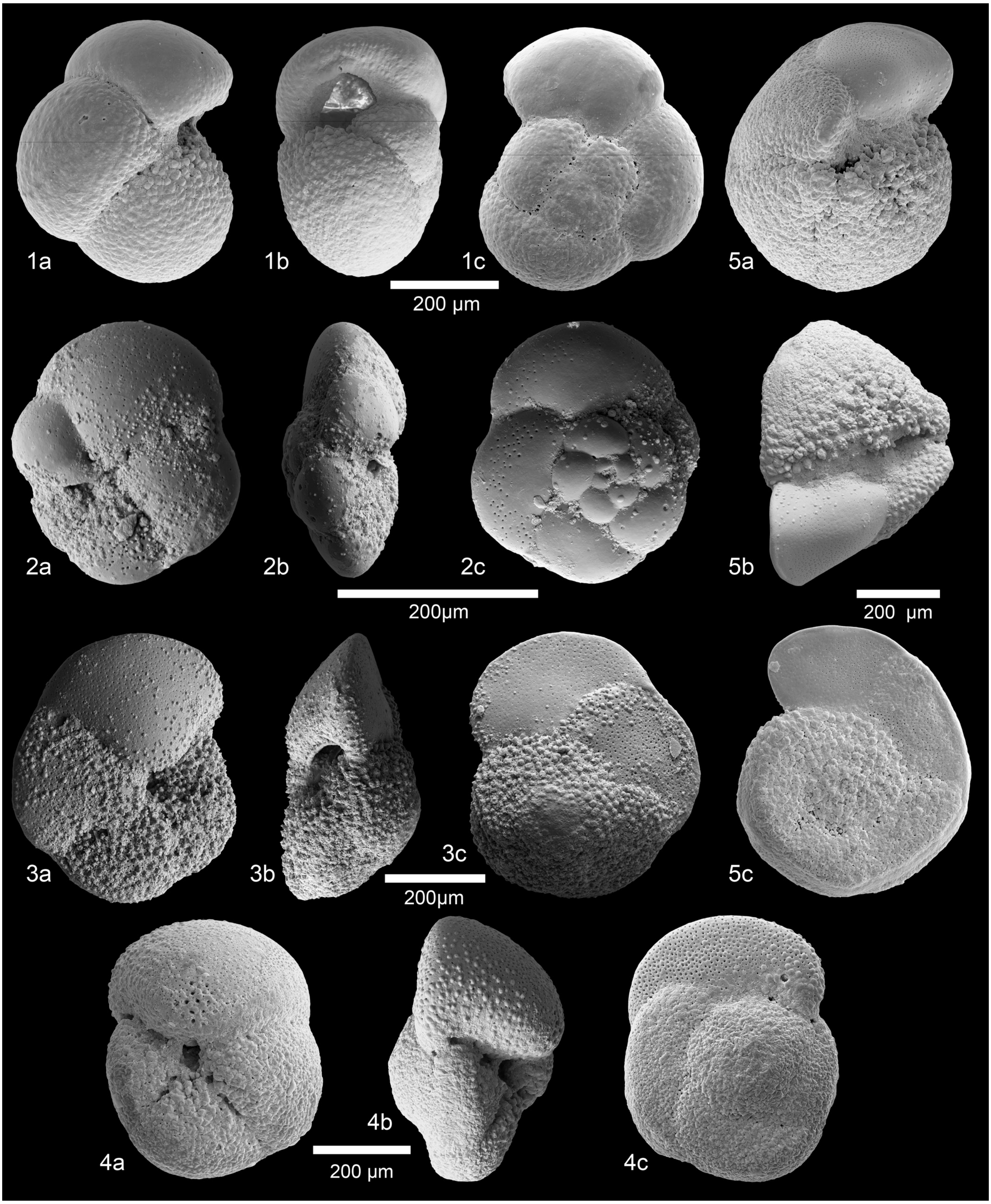
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Plate 22

1a-c *Pulleniatina obliquiloculata* (Parker and Jones, 1865), Hypotype from TTR17 MS411G 45
2a-c *Neogloboquadrina incompta* (Cifelli, 1961), Hypotype from PS70/011-1
3a-c *Neogloboquadrina pachyderma* (Ehrenberg, 1861), Hypotype from PS70/028-2
4a-b *Neogloboquadrina dutertrei* (d'Orbigny, 1839), Hypotype from PS70/011-1
5a-c *Berggrenia clarkei* (Rögl and Bolli, 1973), Hypotype from PS70/002-2

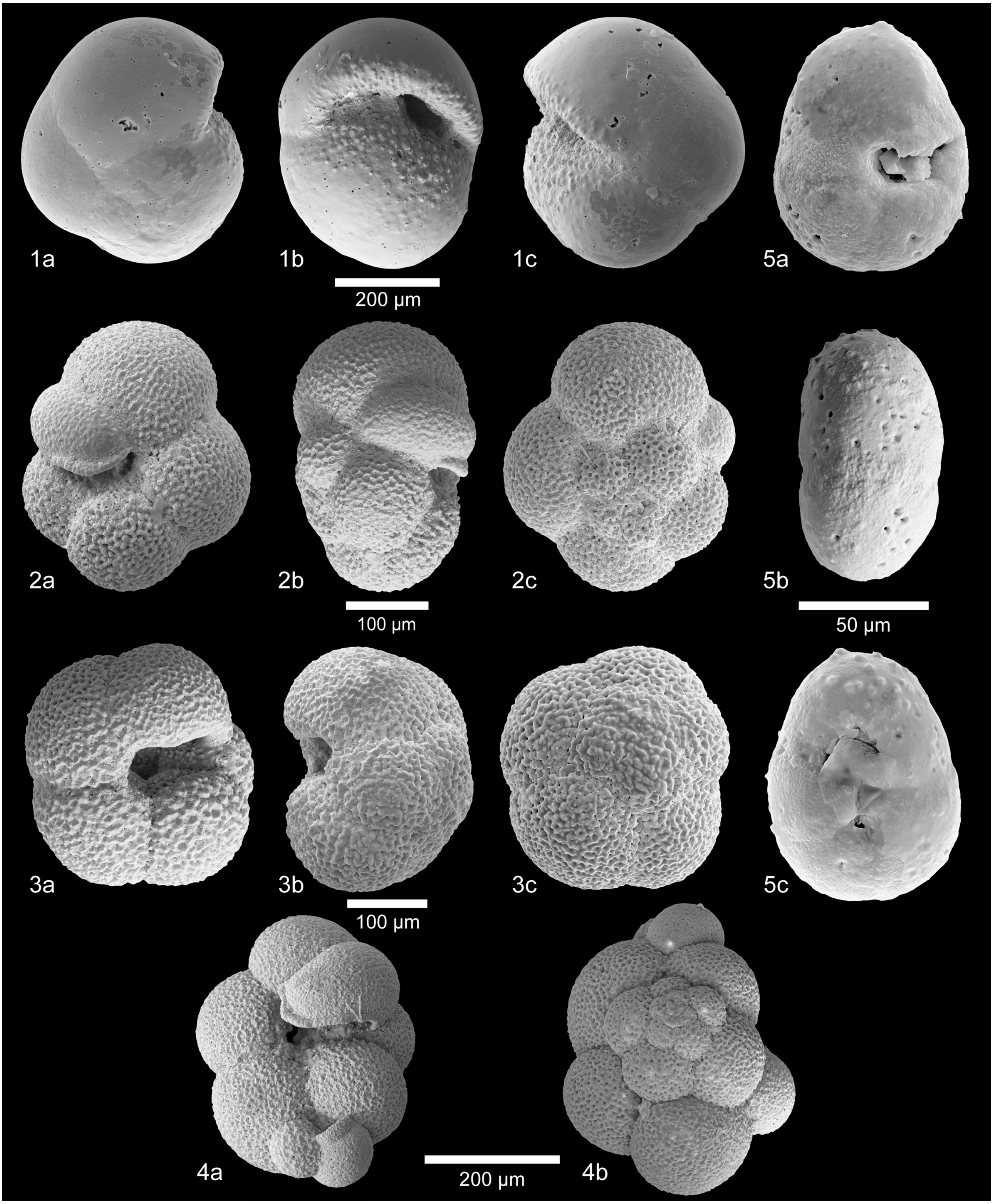
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Plate 23

1a-c *Turborotalita quinqueloba* (Natland, 1938), Hypotype from PS70/028-2

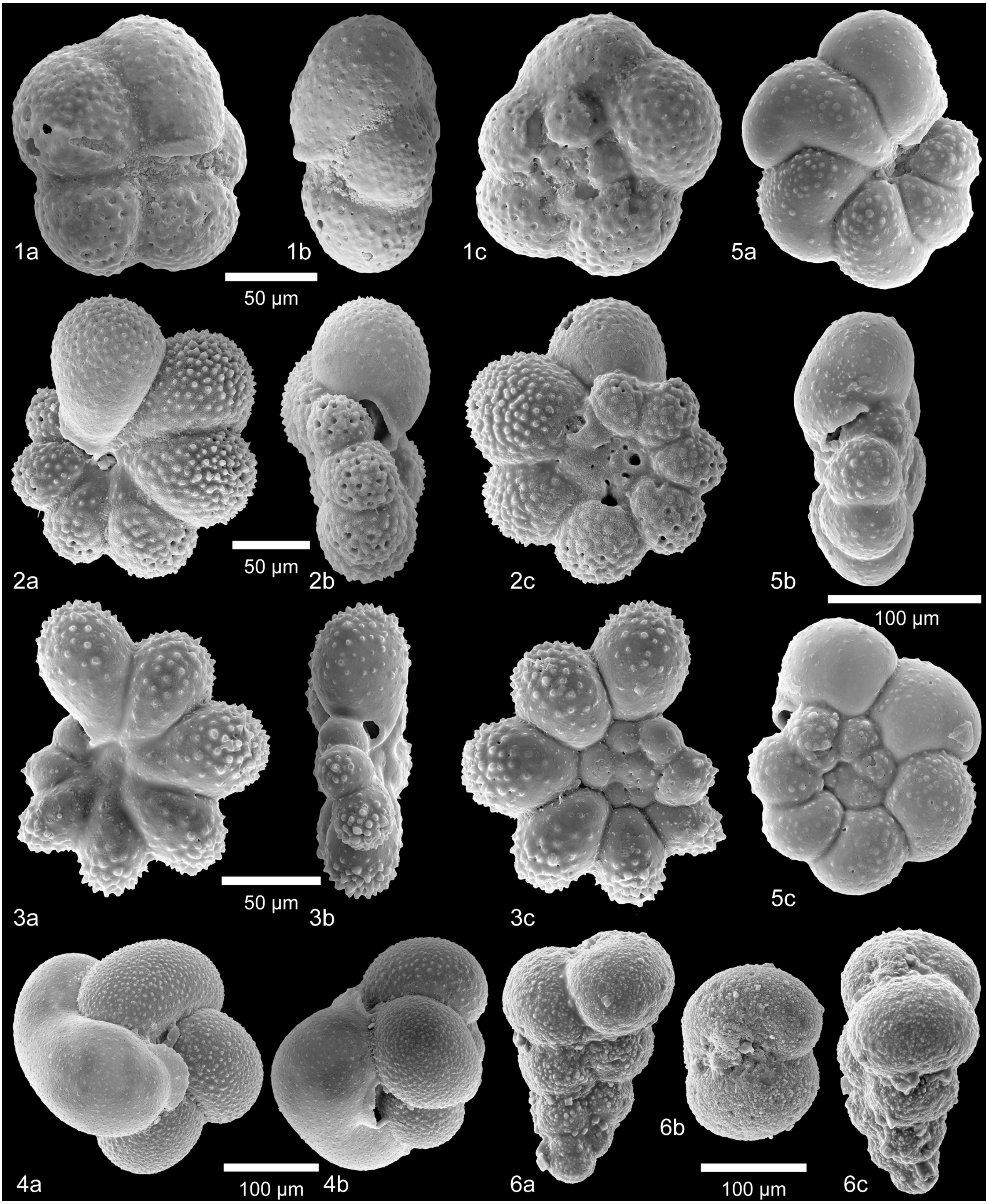
2a-c *Turborotalita humilis* (Brady, 1884), Hypotype from TTR17 MS411G 20

3a-c *Turborotalita cristata* (Heron-Allen and Earland, 1929), Hypotype from TTR17 MS411G 20

4a-b *Tenuitella iota* (Parker, 1962), Hypotype from TTR17 MS419G 25

5a-c *Tenuitella anfracta* (Parker, 1967), Hypotype from TTR17 MS419G 55

6a-c *Strepochilus tokelauae* (Boersma, 1969), Hypotype from TTR17 MS419G 25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100 µm
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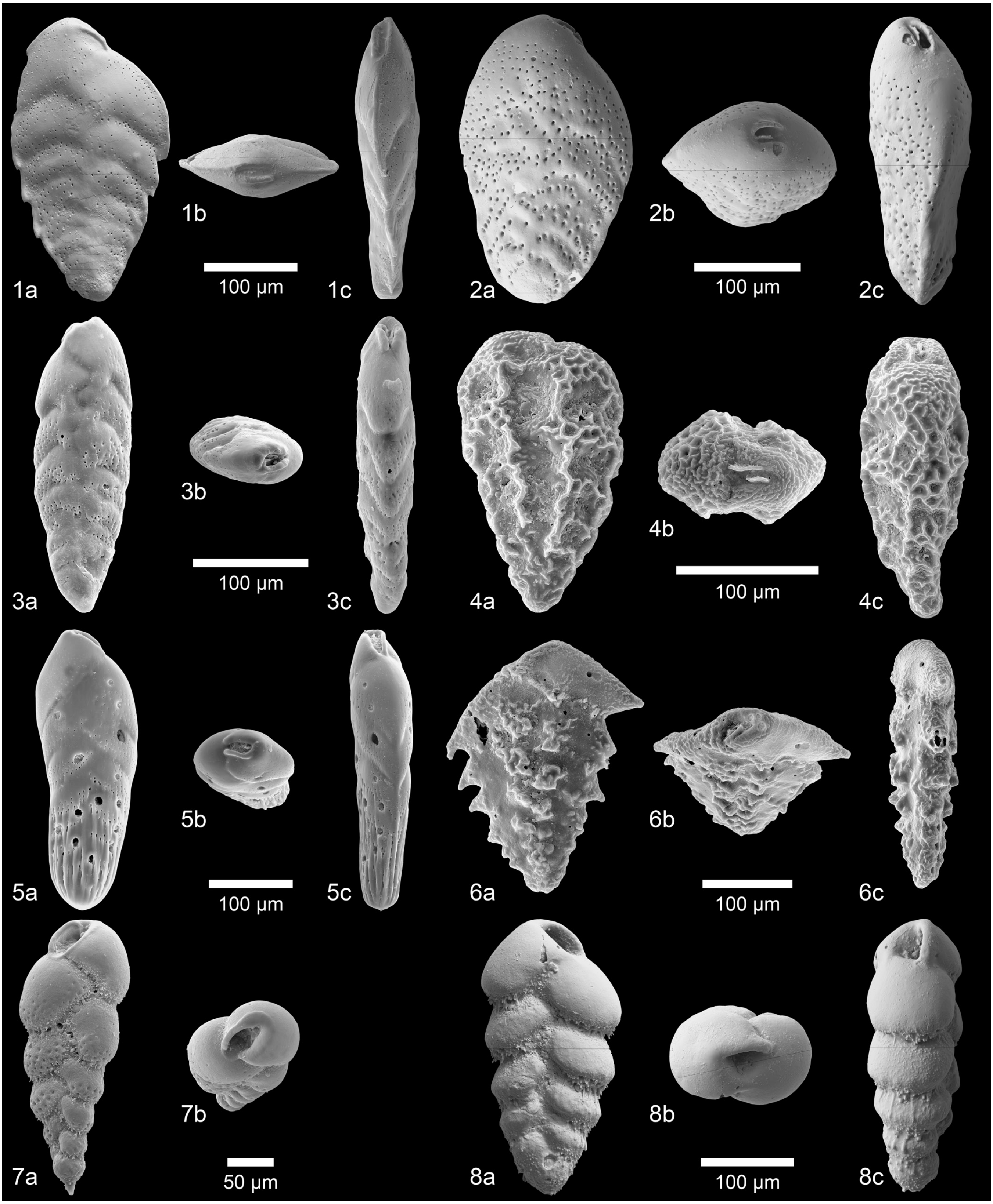
PLATE 24

1a-c *Bolivina alata* (Seguenza, 1862), Hypotype from TTR17 MS419G 25
2a-c *Bolivina dilatata* (Reuss, 1850), Hypotype from P292 577-1
3a-c *Bolivinellina pseudopunctata* (Höglund, 1947), Hypotype from GeoB9204-1
4a-c *Bolivina pseudoplicata* Heron-Allen and Earland, 1930, Hypotype from TTR17 MS411G 25
5a-c *Bolivinellina striatula* (Cushman, 1922), Hypotype from TTR17 MS411G 0
6a-c *Bolivina difformis* (Williamson, 1858), Hypotype from P292 576-1
7a-b *Bolivina spinescens* Cushman, 1911, Hypotype from POS391 555-1
8a-c *Bolivina subspinescens* Cushman, 1922, Hypotype from P292 580-1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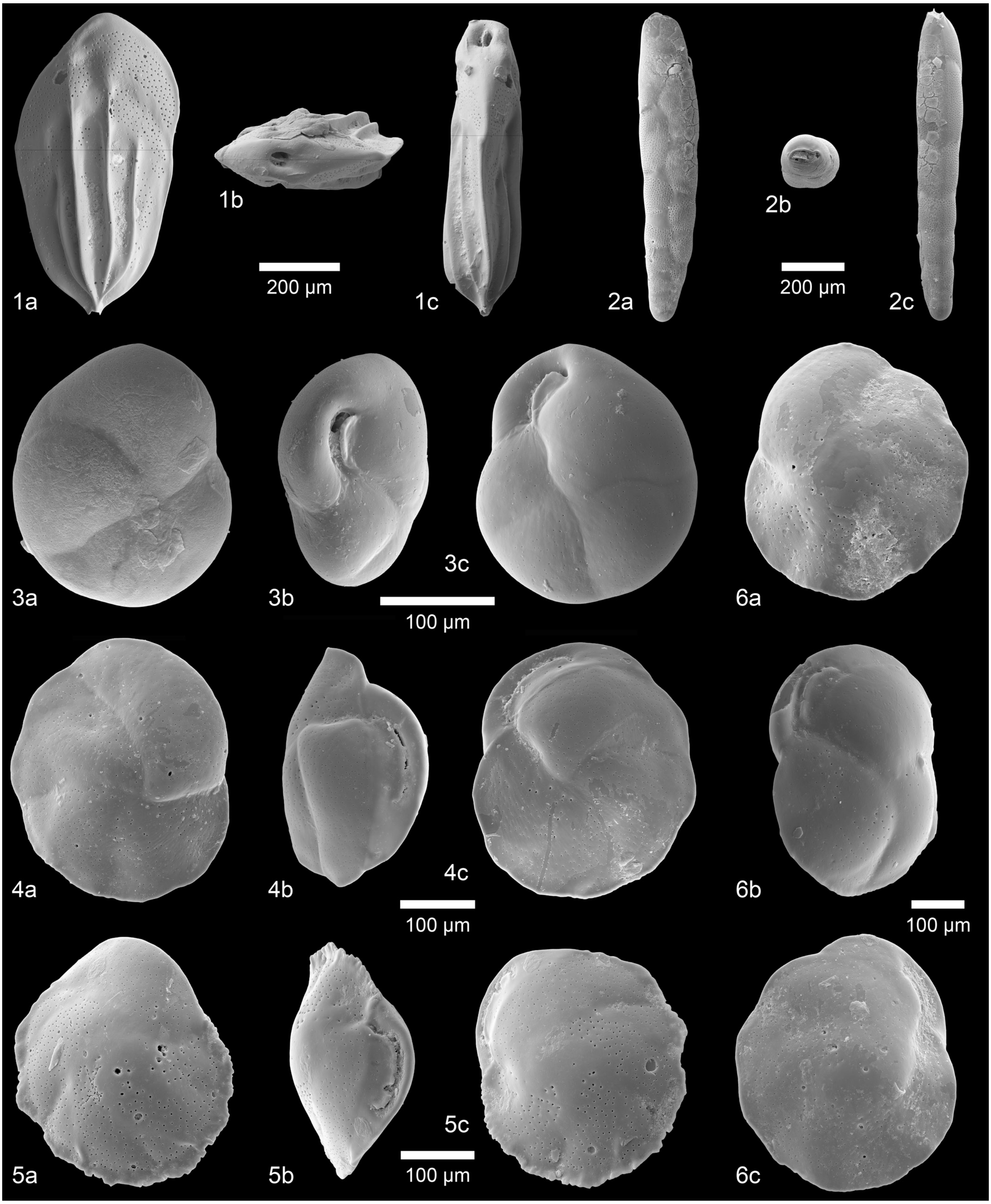
8b
100 µm
8c

Plate 25

1a-b *Brizalina subaenariensis* (Cushman, 1922), Hypotype from P292 580-1
2a-c *Parabrizalina porrectum* (Brady, 1881), Hypotype from AL232 1025
3a-c *Cassidulina reniforme* Nörvang, 1945, Hypotype from POS391 555-1
4a-c *Cassidulina laevigata* d'Orbigny, 1826, Hypotype from PS70/028-2
5a-c *Cassidulina carinata* Silvestri, 1896, Hypotype from PS70/011-1
6a-c *Cassidulina teretis* Tappan, 1951, Hypotype from PS70/038-2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5b
5c
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6c

Plate 26

1a-c	*Cassidulina neoteretis* Seidenkrantz, 1995, Hypotype from POS391 558-1
2a-c	*Takayanagia delicata* (Cushman, 1927), Hypotype from PS292 576-1
3a-c	*Cassidulina crassa* d’Orbigny, 1839, Hypotype from PS70/028-2
4a-c	*Globocassidulina subglobosa* (Brady, 1881), Hypotype from TTR17 MS411G 0
5a-c	*Islandiella norcrossi* (Cushman, 1933), Hypotype from POS391 555-1
6a-b	*Cassidulinoides bradyi* (Norman, 1881), Hypotype from TTR17 MS419G 75

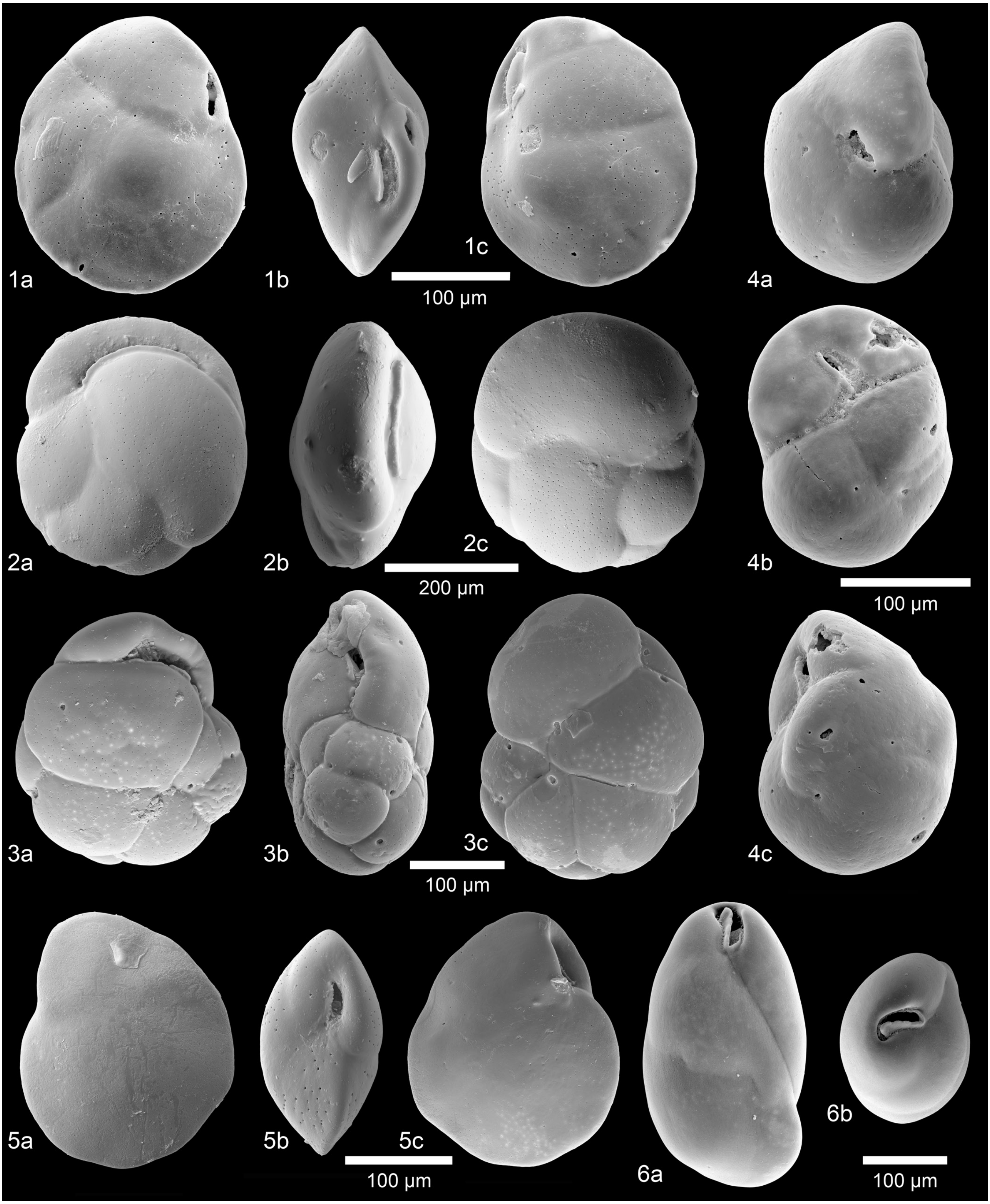
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Plate 27

1a-b *Ehrenbergina trigona* Goës, 1896, Hypotype from GeoB 9256-1
2a-c *Stainforthia fusiformis* (Williamson, 1858), Hypotype from AL232 1025
3a-c *Stainforthia loeblichi* (Feyling-Hanssen, 1954), Hypotype from POS391 555-1
4a-c *Fursenkoina complanata* (Egger, 1893), Hypotype from AL232 1025
5a-c *Stainforthia skagerakensis* (Höglund, 1947), Hypotype from AL232 1025
6a-c *Rectuvigerina elongatastriata* (Colom, 1952), Hypotype from TTR17 MS411G 10
7a-b *Siphogenerina columellaris* (Brady, 1881), Hypotype from TTR17 MS411G 15
8a-b *Bulimina aculeata* d'Orbigny, 1826, Hypotype from TTR17 MS419G 94
9a-b *Bulimina marginata* d'Orbigny, 1826, Hypotype from TTR17 MS411G 10
10a-c *Bulimina striata* d'Orbigny, 1826, Hypotype from TTR17 MS411G 15

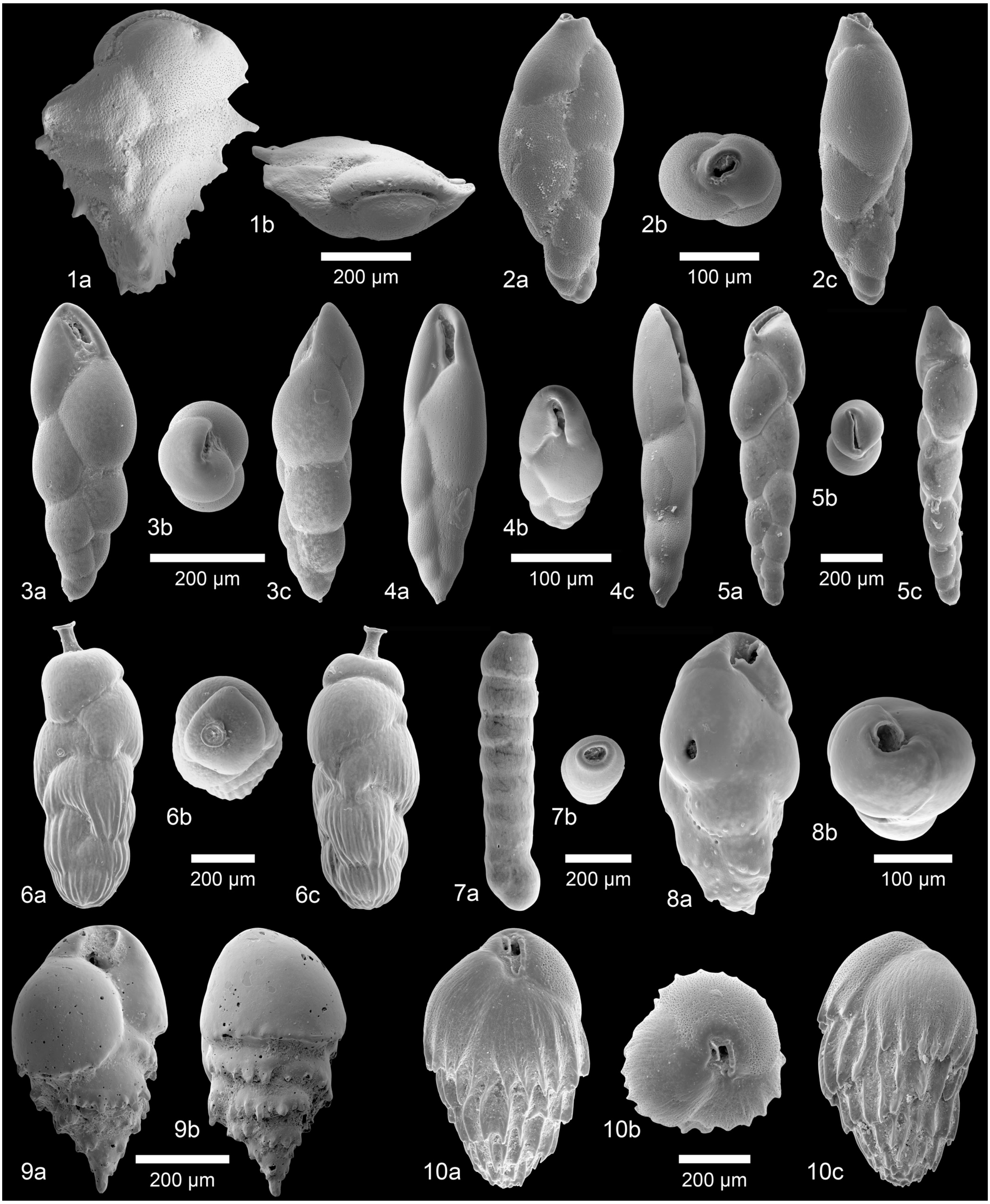
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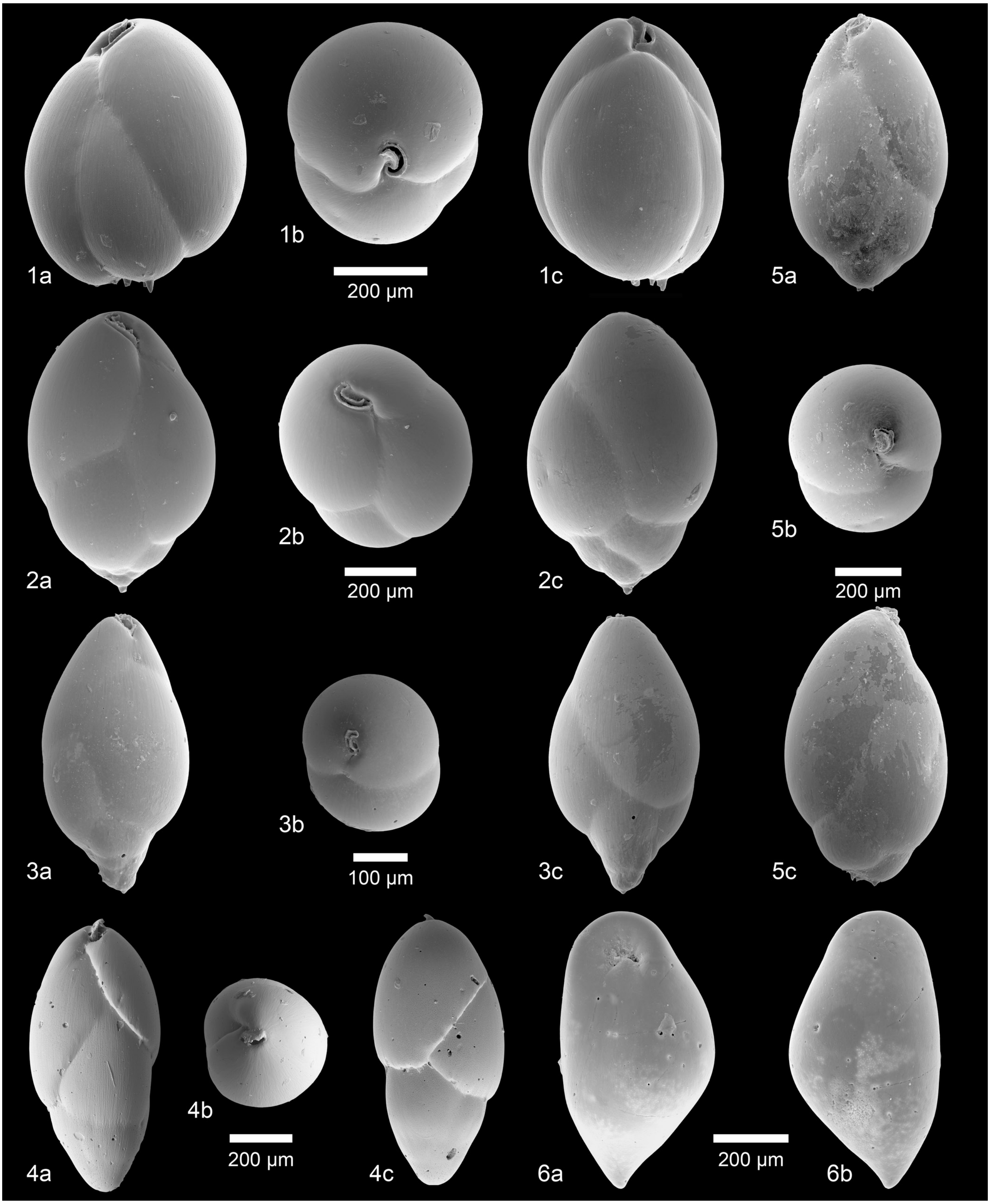
PLATE 28

1a-c	*Globobulimina turgida* (Bailey, 1851), Hypotype from AL232 1025
2a-c	*Globobulimina affinis* (d'Orbigny, 1839), Hypotype from AL232 1025
3a-c	*Globobulimina affinis* (d'Orbigny, 1839), Hypotype from AL232 1026
4a-c	*Praeglobobulimina ovata* (d'Orbigny, 1846), Hypotype from P292 580-1
5a-c	*Globobulimina doliolum* (Terquem and Terquem, 1886), Hypotype from POS391 550-1
6a-b	*Buliminella spinigera* Cushman, 1922, Hypotype from GeoB12722-1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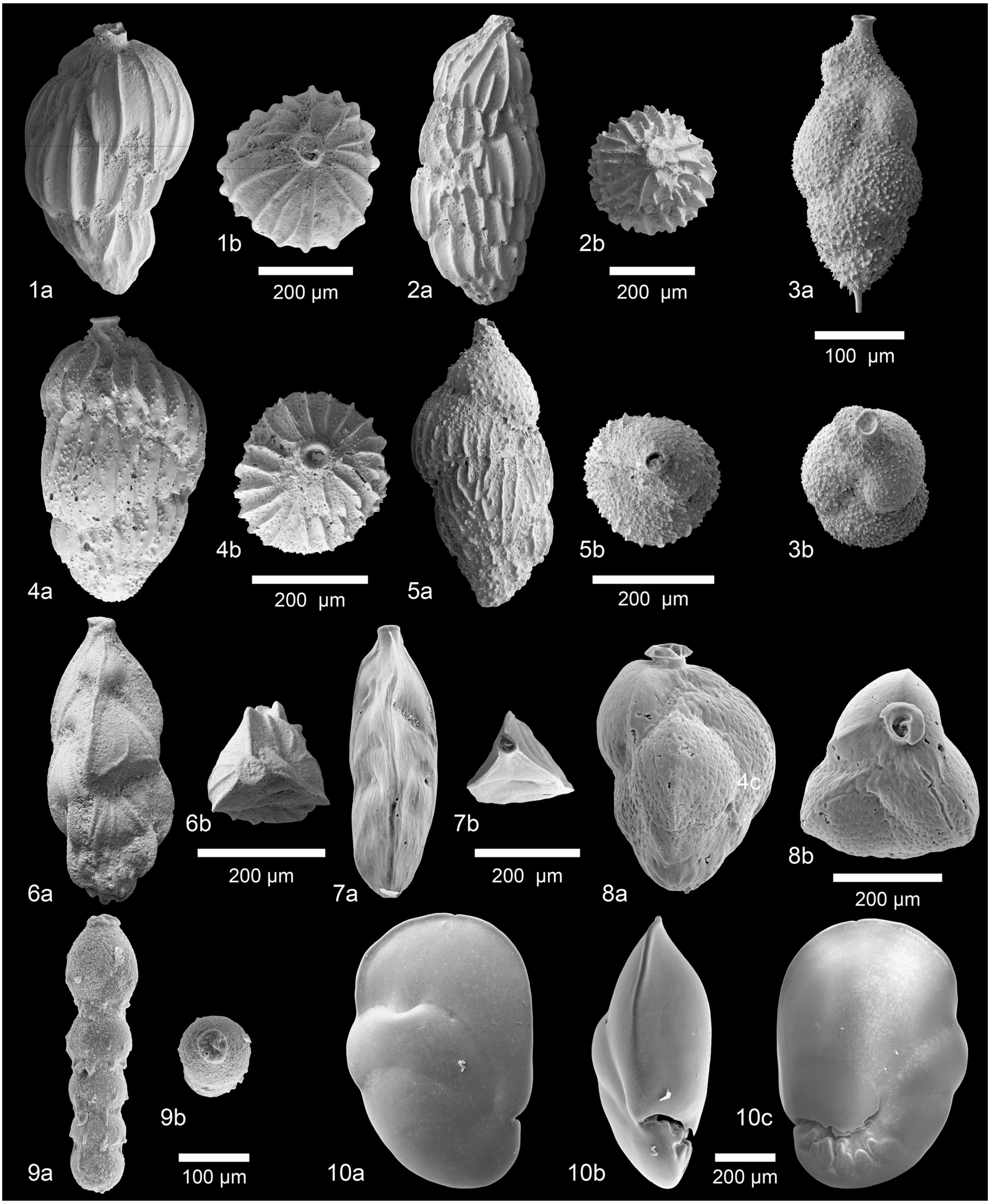
6a
200 µm
6b

Plate 29

1a-b *Uvigerina mediterranea* Hofker, 1932, Hypotype from P292 580-1
2a-b *Uvigerina peregrina* Cushman, 1923, Hypotype from P292 580-1
3a-b *Uvigerina auberiana* d'Orbigny, 1839, Hypotype from GeoB 6721-1
4a-b *Uvigerina peregrina parva* Lutze, 1986, Hypotype from GeoB 6721-1
5a-b *Uvigerina pigmaea* d'Orbigny, 1826, Hypotype from P292 576-1
6a-b *Angulogerina angulosa* (Williamson, 1858), Hypotype from P292 577-1
7a-b *Trifarina bradyi* (Cushman, 1923), Hypotype from TTR17 MS419G 107
8a-b *Trifarina fornasini* (Selli, 1948), Hypotype from TTR17 MS411G 25
9a-b *Nodogenerina virgula* (Brady, 1884), Hypotype from PS70/033-2
10a-c *Cancris auriculus* (Fichtel and Moll, 1798), Hypotype from TTR17 MS411G 40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10c
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Plate 30

1a-c	*Valvulineria bradyana* (Fornasini, 1900), Hypotype from TTR17 MS411G 15
2a-c	*Ioanella tumidula* (Brady, 1884), Hypotype from PS70/033-2
3a-c	*Stomatorbina concentrica* (Parker and Jones, 1864), Hypotype from GeoB9256-1
4a-c	*Hyrrokkin sarcophaga* Cedhagen, 1994, Hypotype from POS391 562-1
5a-c	*Hyrrokkin sarcophaga* Cedhagen, 1994, Hypotype from POS391 550-1

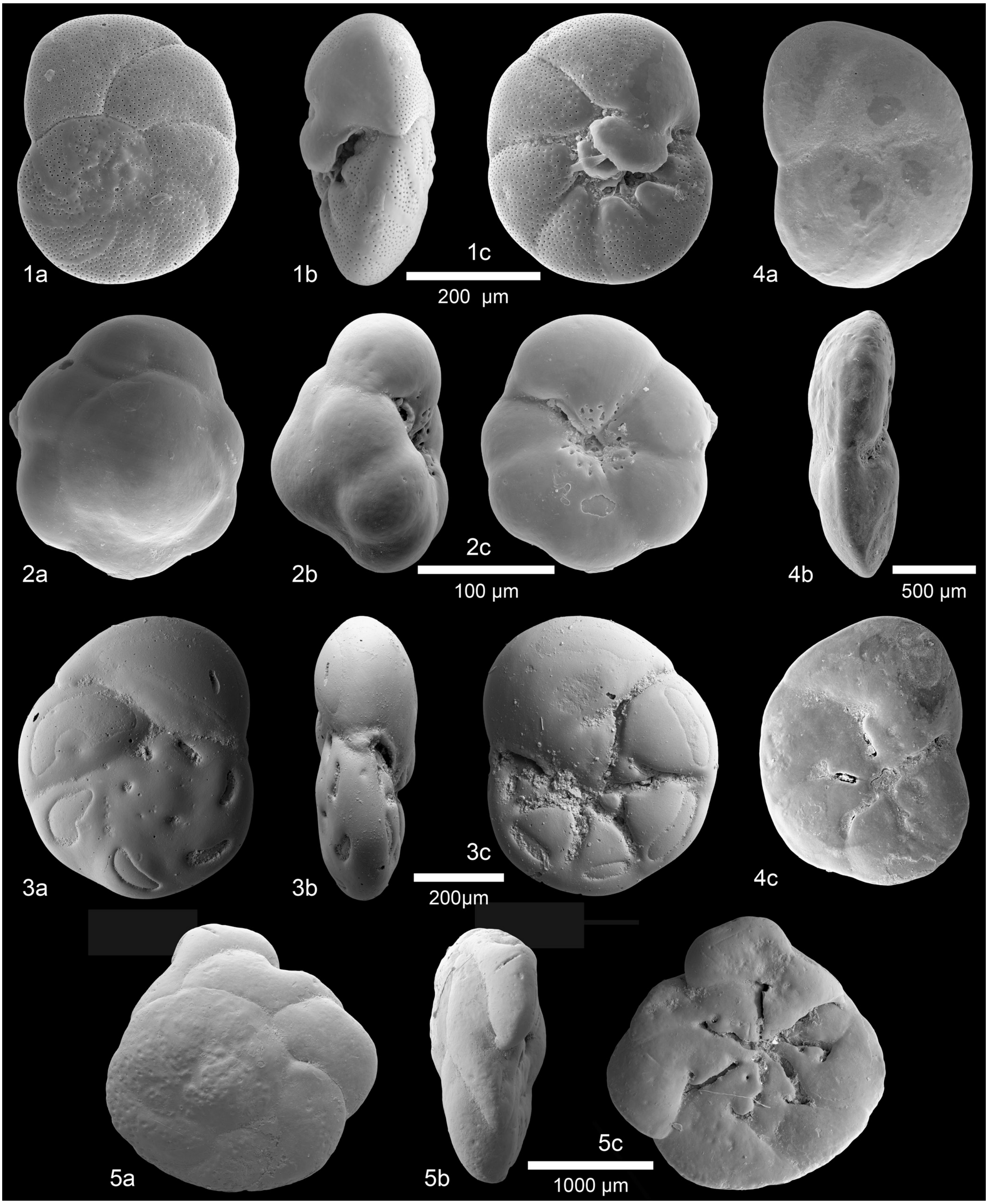
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PLATE 31

1a-c *Gavelinopsis nitida* (Williamson, 1858), Hypotype from POS391 555-1
2a-c *Gavelinopsis praegeri* (Heron-Allen and Earland, 1913), Hypotype from TTR17 MS411G 0
3a-c *Gavelinopsis caledonia* Murray and Whittaker, 2001, Hypotype from POS325 455
4a-c *Rosalina globularis* d’Orbigny, 1826, Hypotype from PS70/011-1
5a-c *Rosalina brady* (Cushman, 1915), Hypotype from PS70/011-1

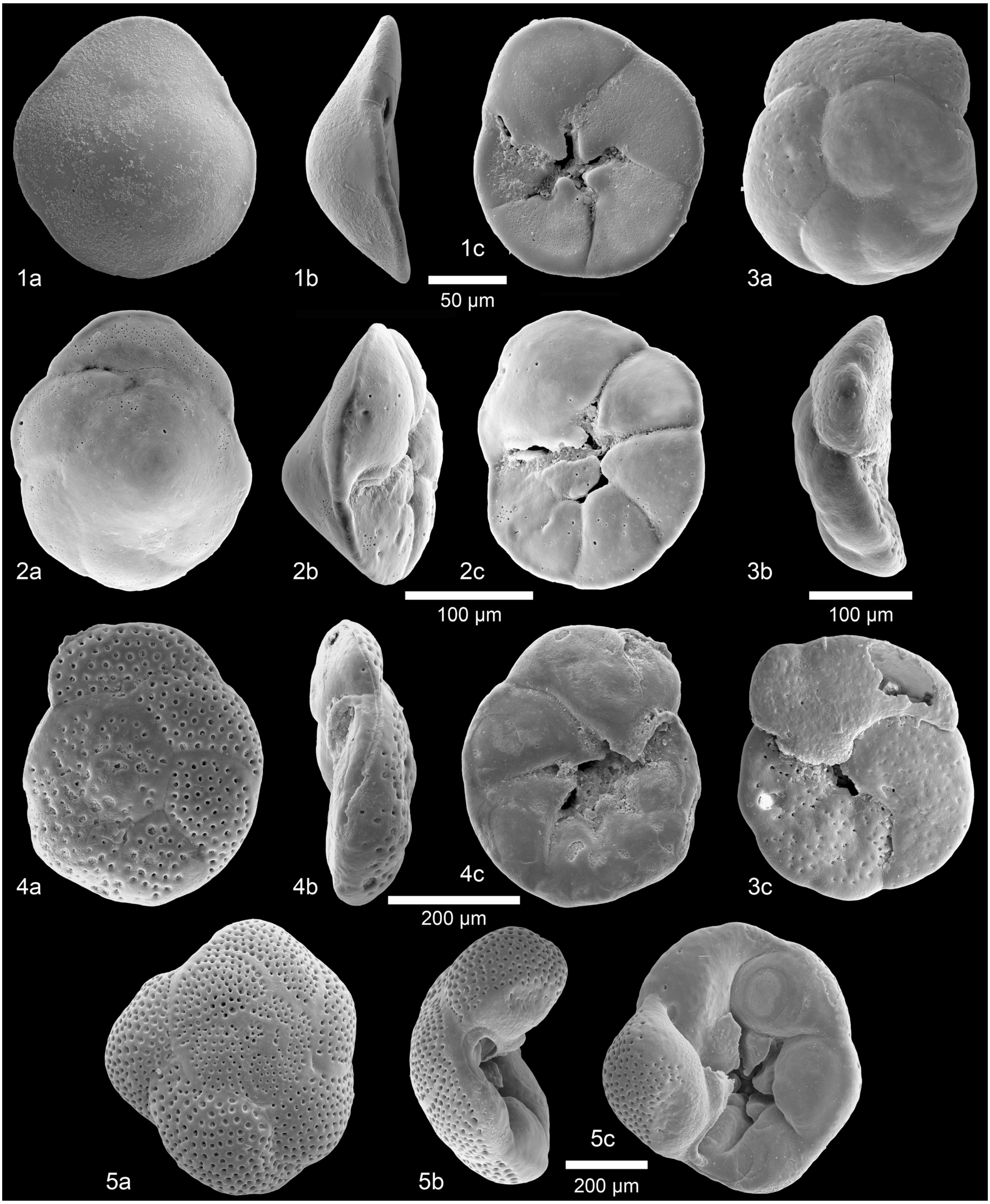
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PLATE 32

1a-c	*Rosalina semipunctata* (Bailey, 1851), Hypotype from GeoB9205-1
2a-c	*Sphaeroidina bulloides* d'Orbigny, 1826, Hypotype from TTR17 MS411G 0
3a-c	*Glabratella patelliformis* (Brady, 1884), Hypotype from TTR17 MS411G 0
4a-c	*Siphonina reticulata* (Czjzek, 1848), Hypotype from TTR17 MS411G 15
5a-c	*Heronallenita lingulata* (Burrows and Holland, 1895), Hypotype from TTR17 MS411G 25

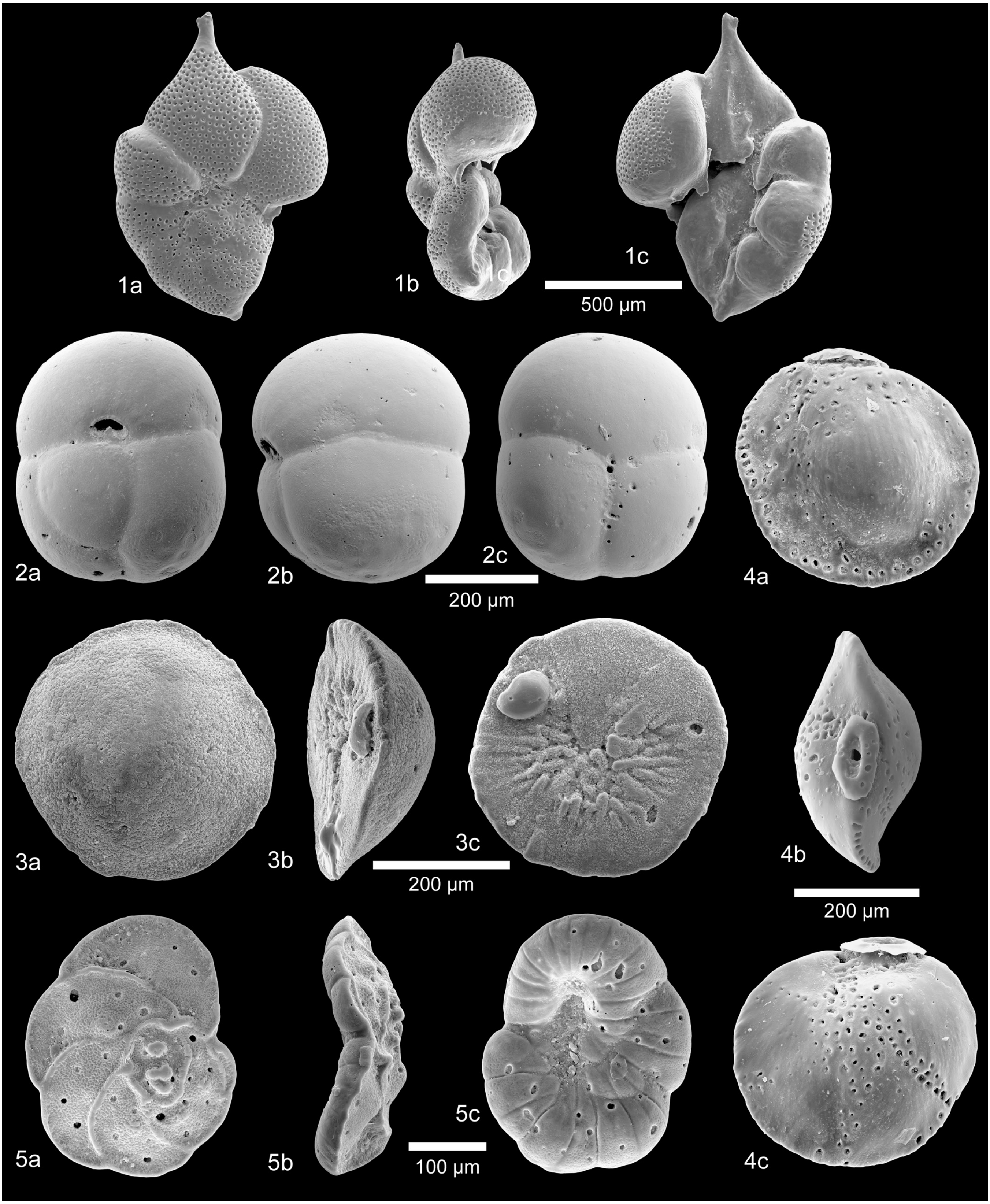
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PLATE 33

1a-c	*Cibicidoides mundulus* (Parker, 1953), Hypotype from TTR17 MS411G 0
2a-c	*Cibicidoides pachyderma* (Rzehak, 1886), Hypotype from TTR17 MS411G 0
3a-c	*Epistominella vitrea* Parker, 1953, Hypotype from AL316 321
4a-c	*Epistominella exigua* (Brady, 1884), Hypotype from TTR17 MS411G 15
5a-c	*Discorbinella bertheloti* (d'Orbigny, 1839), Hypotype from POS391 550-1

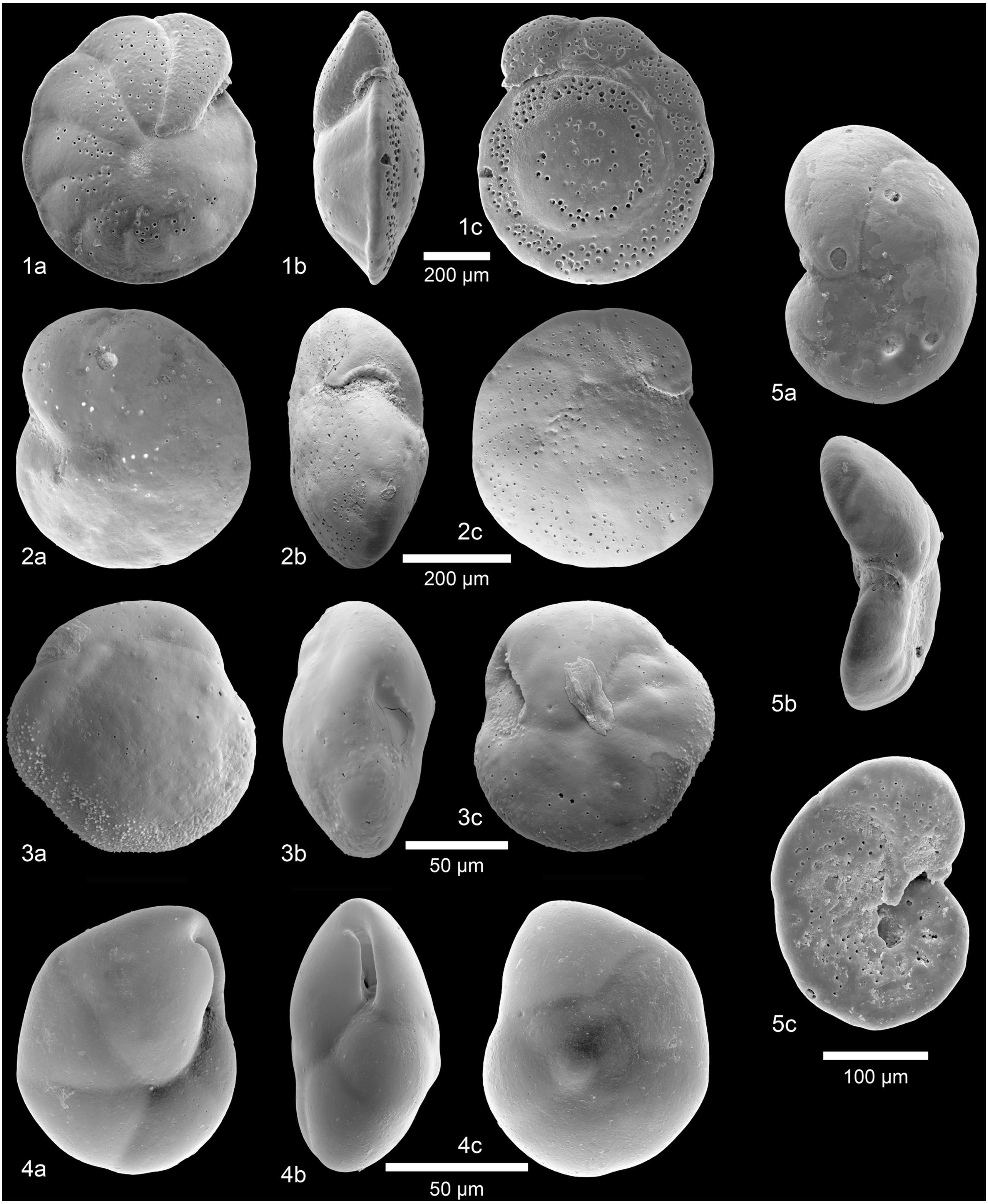
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PLATE 34

1a-c *Planulina ariminensis* d'Orbigny, 1826, Hypotype from M07-15
2a-c *Hyalinea balthica* (d'Orbigny, 1826), Hypotype from P292 576-1
3a-c *Cibicides ungerianus* (d'Orbigny, 1826), Hypotype from POS391 534-1
4a-c *Cibicides refulgens* de Montfort, 1808, Hypotype from P292 574-1
5a-c *Cibicides aravaensis* Perelis and Reiss, 1976, Hypotype from TTR17 MS411G 50

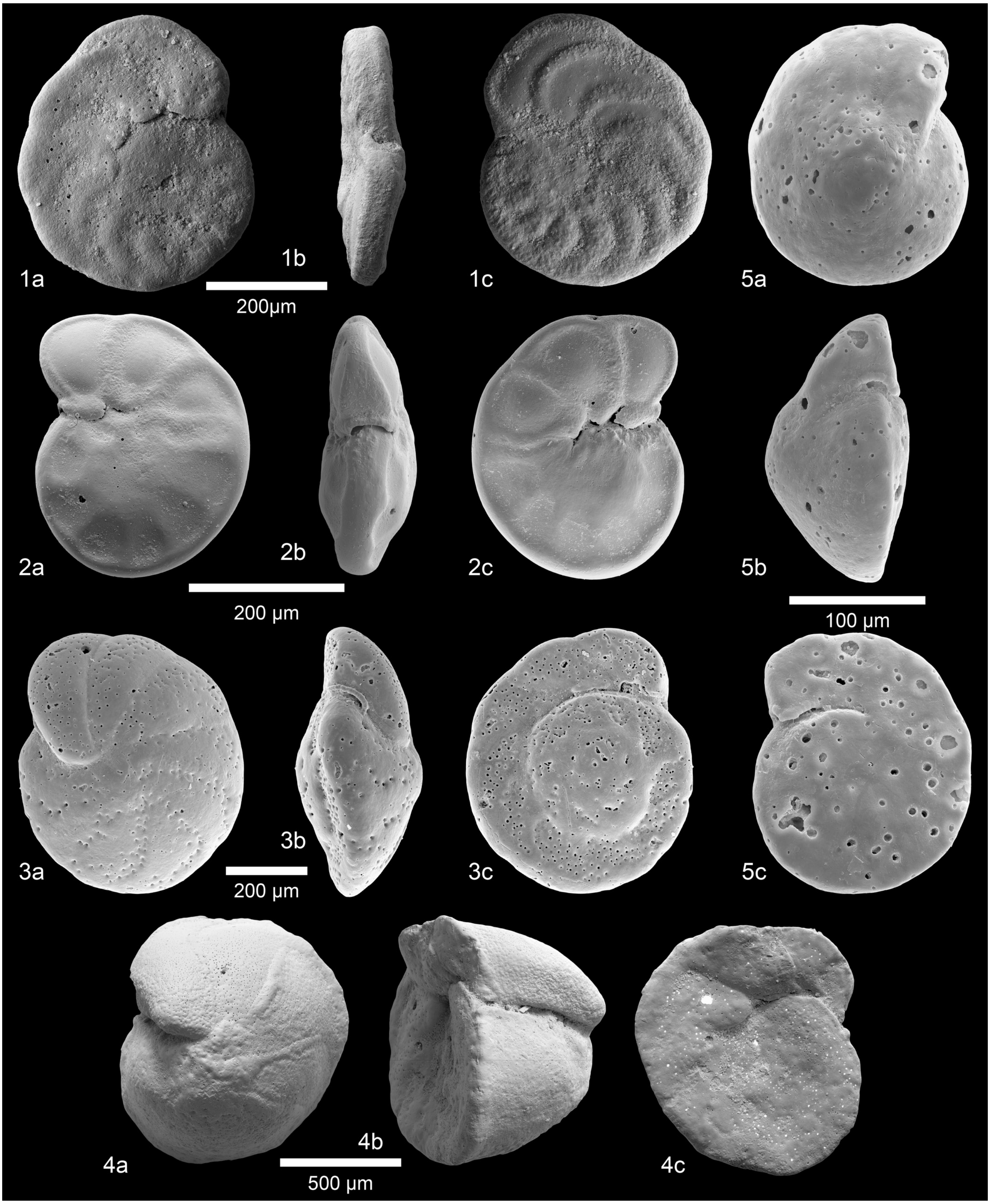
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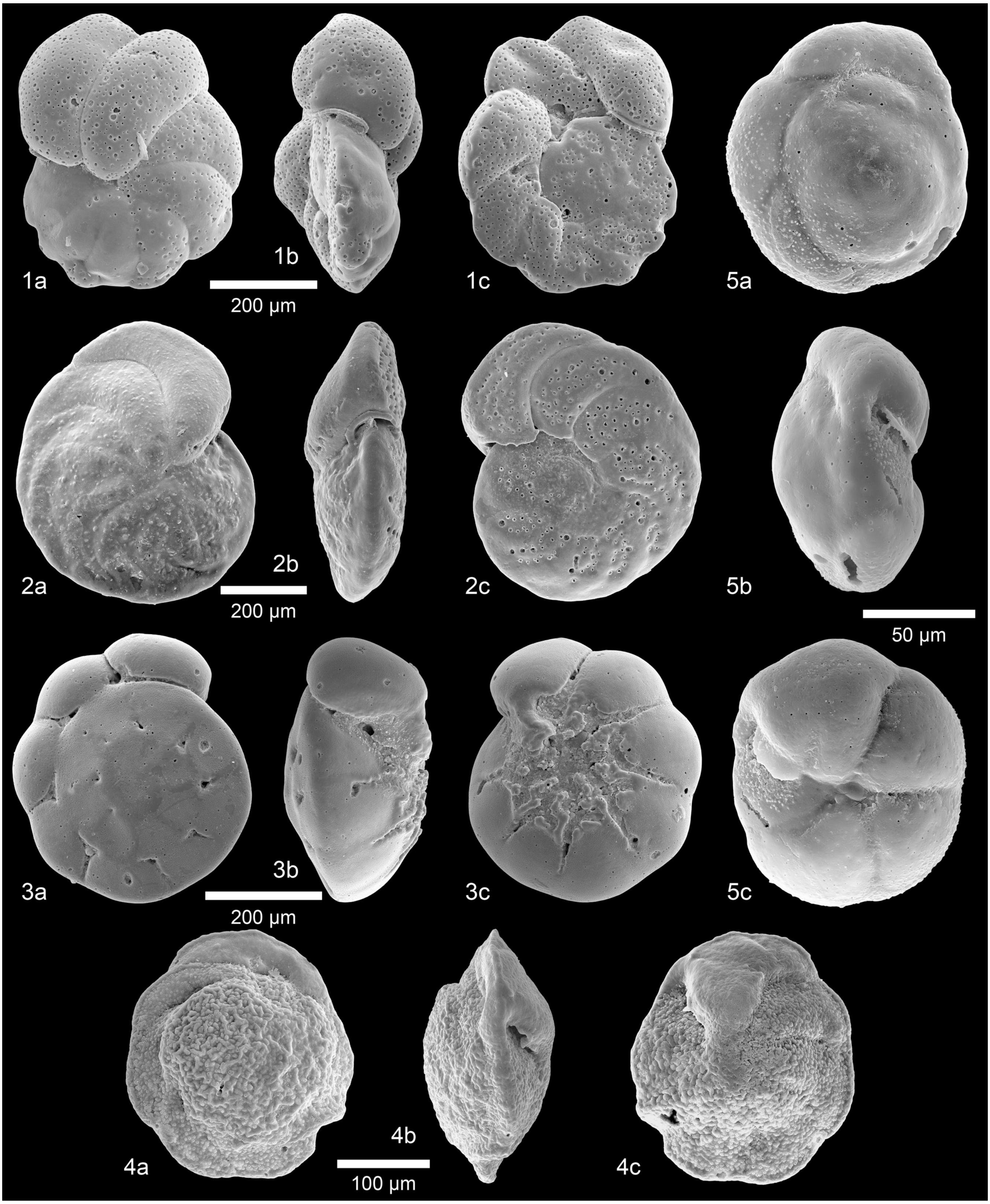
PLATE 35

1a-c	*Lobatula lobatula* (Walker and Jacob, 1798), Hypotype from TTR17 MS411G 35
2a-c	*Fontbotia wuellerstorfi* (Schwager, 1866), Hypotype from PS70/032-2
3a-c	*Pseudoeponides falsobeccarii* Rouvillois, 1974, Hypotype from TTR17 MS419G 126
4a-c	*Nuttallides umbonifera* (Rouvillois, 1974), Hypotype from TTR17 MS411G 20
5a-c	*Nuttallides decorata* (Phleger and Parker, 1951), Hypotype from TTR17 MS411G 10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4a
4b
4c
100 µm

PLATE 36

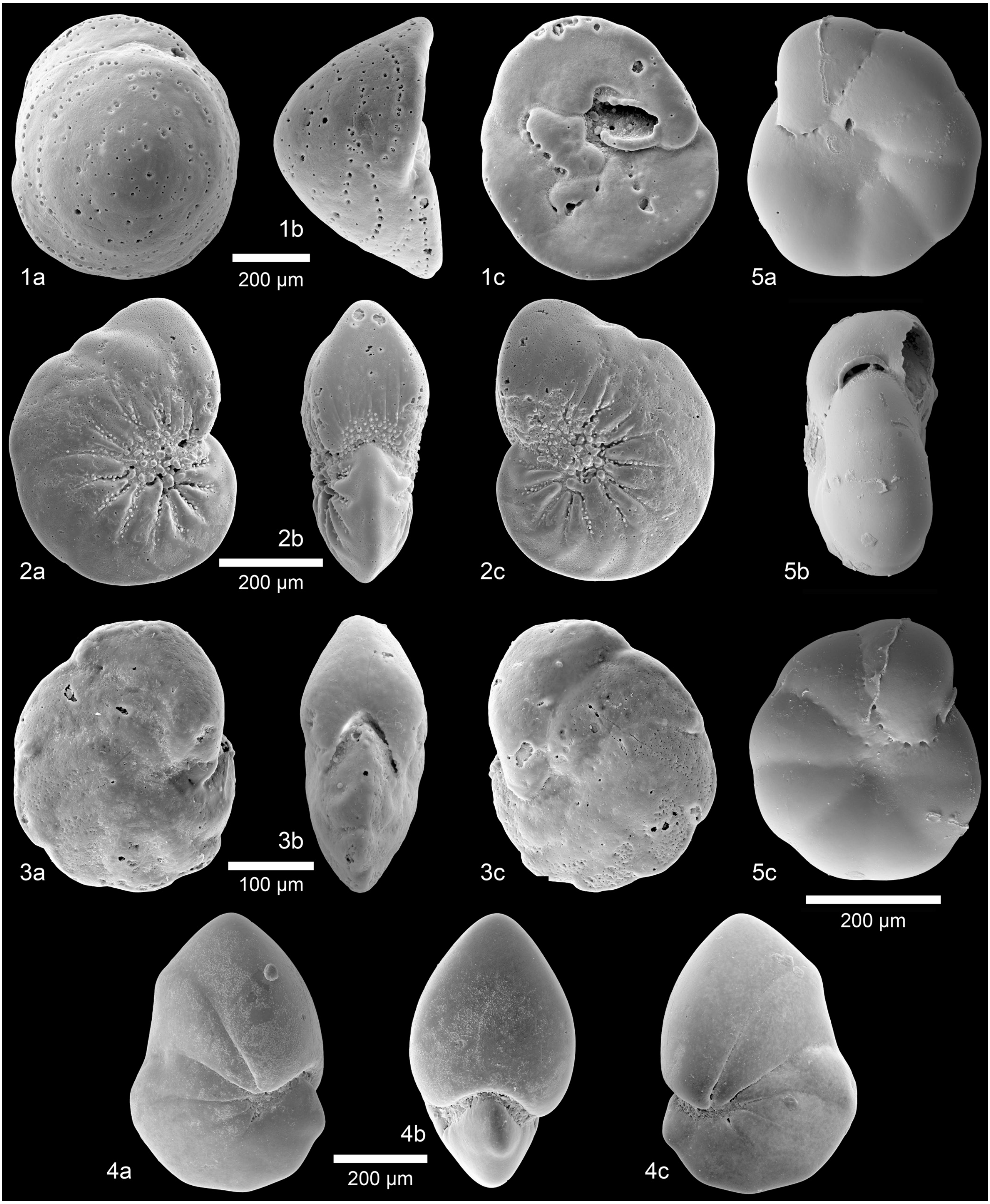
1a-c *Astigerinata mamilla* (Williamson, 1858), Hypotype from TTR17 MS419G 25

2a-c *Nonion fabum* (Fichtel and Moll, 1798), Hypotype from TTR17 MS419G 55

3a-c *Nonion pauperatus* (Balkwill and Wright, 1885), Hypotype from TTR17 MS419G 100

4a-c *Nonionellina labradorica* (Dawson, 1860), Hypotype from AL232 1026

5a-c *Nonion pauciloculum* (Cushman, 1944), Hypotype from PS70/033-2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3c
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4a
4b
200 µm
4c

Plate 37

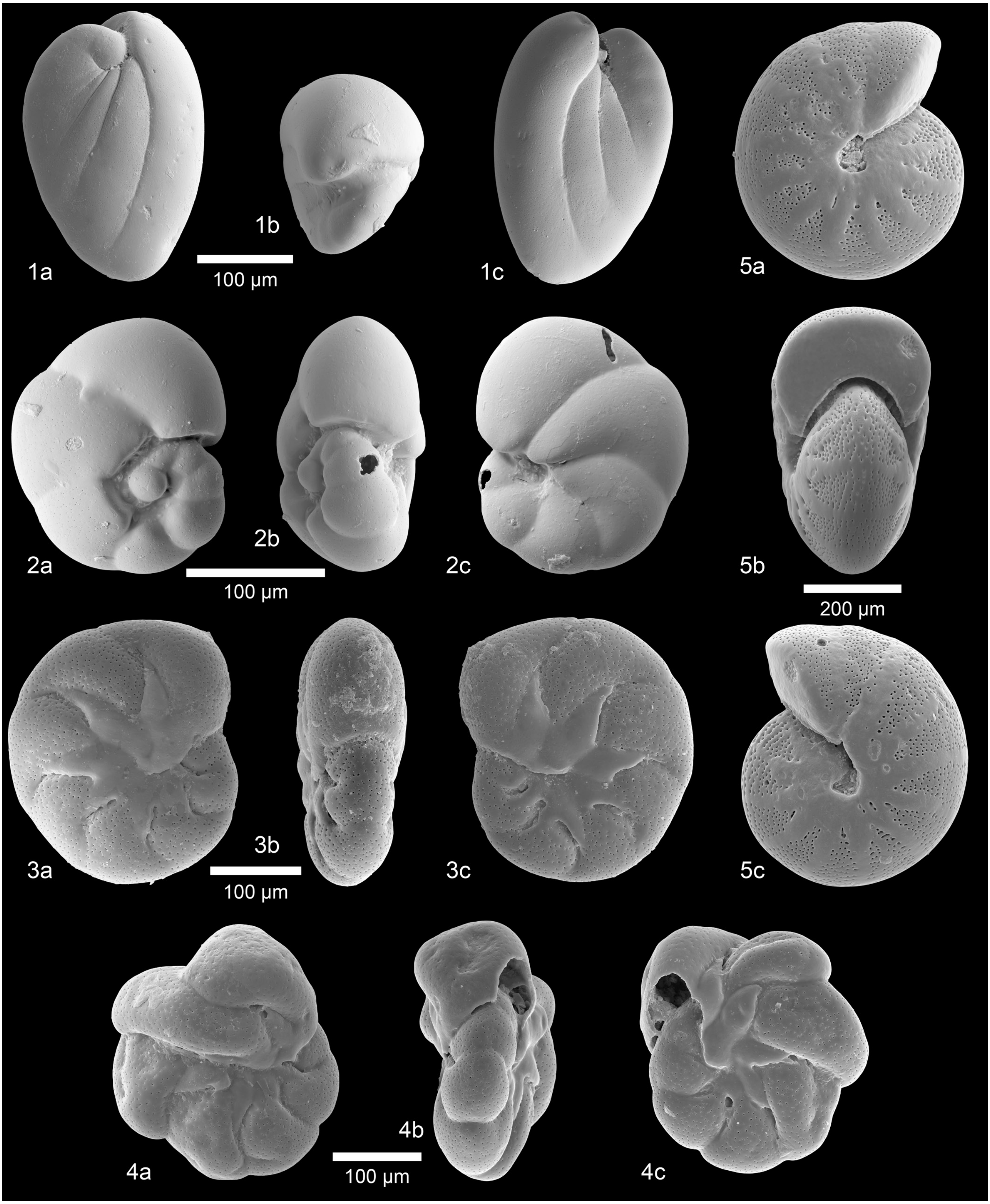
1a-c *Nonionella turgida* (Williamson, 1858), Hypotype from TTR17 MS411G 15

2a-c *Nonionella iridea* Heron-Allen and Earland, 1932, Hypotype from TTR17 MS419G 100

3a-c *Astrononion gallowayi* Loeblich and Tappan, 1953, Hypotype from POS325 455

4a-c *Astrononion antarcticus* Parr, 1950, Hypotype from POS325 455

5a-c *Melonis pompilioides* (Fichtel and Moll, 1798), Hypotype from TTR17 MS419G 98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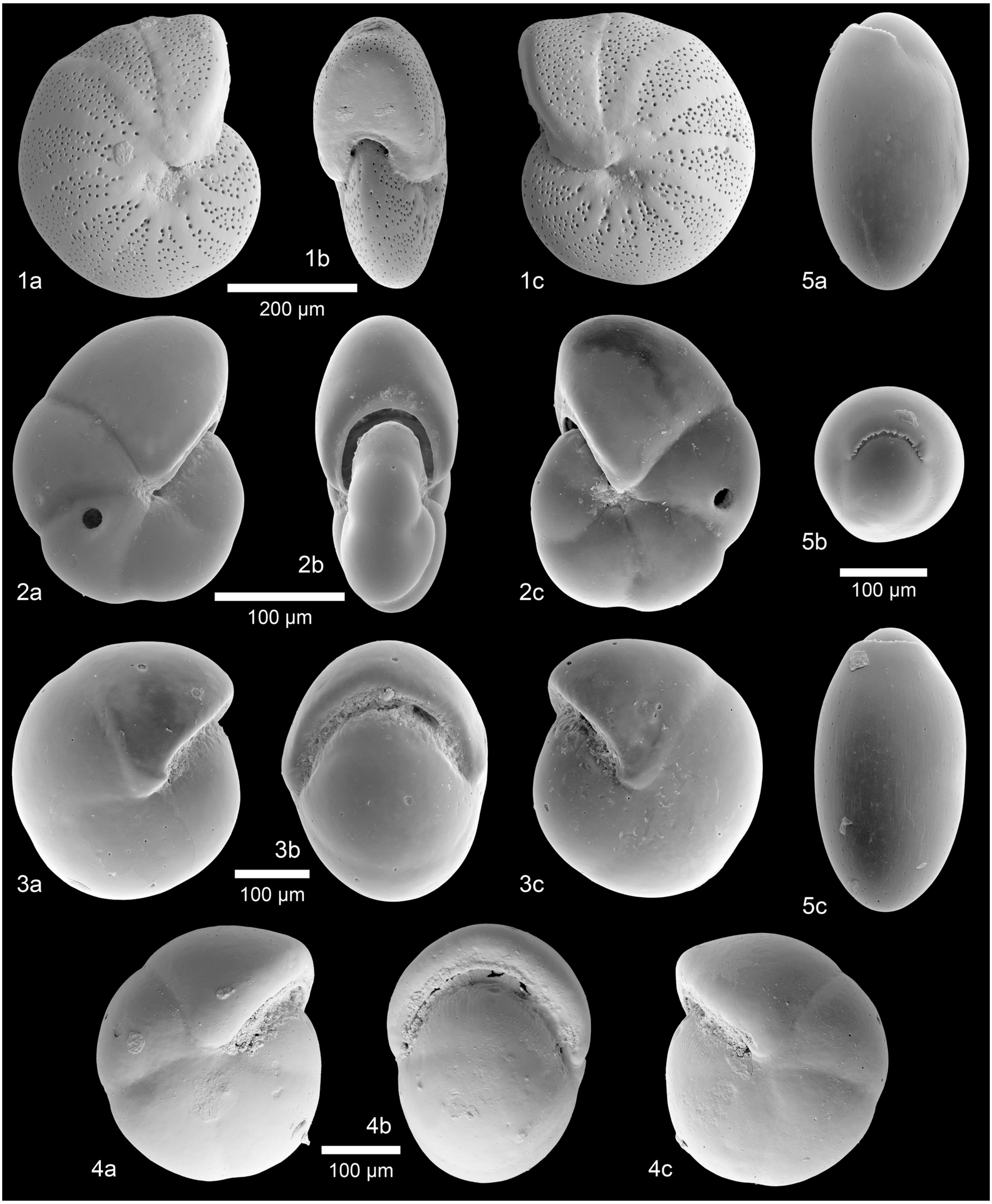
5c
4a
4b
100 µm
4c

PLATE 38

1a-c	*Melonis barleeanum* (Williamson, 1858), Hypotype from P292 581-1
2a-c	*Pullenia subcarinata* (d'Orbigny, 1839), Hypotype from PS70/023-3
3a-c	*Pullenia bulloides* (d'Orbigny, 1826), Hypotype from TTR17 MS419G 25
4a-c	*Pullenia bulloides* (d'Orbigny, 1826), Hypotype from Hermi1_1
5a-c	*Chilostomella oolina* Schwager, 1878, Hypotype from P292 580-1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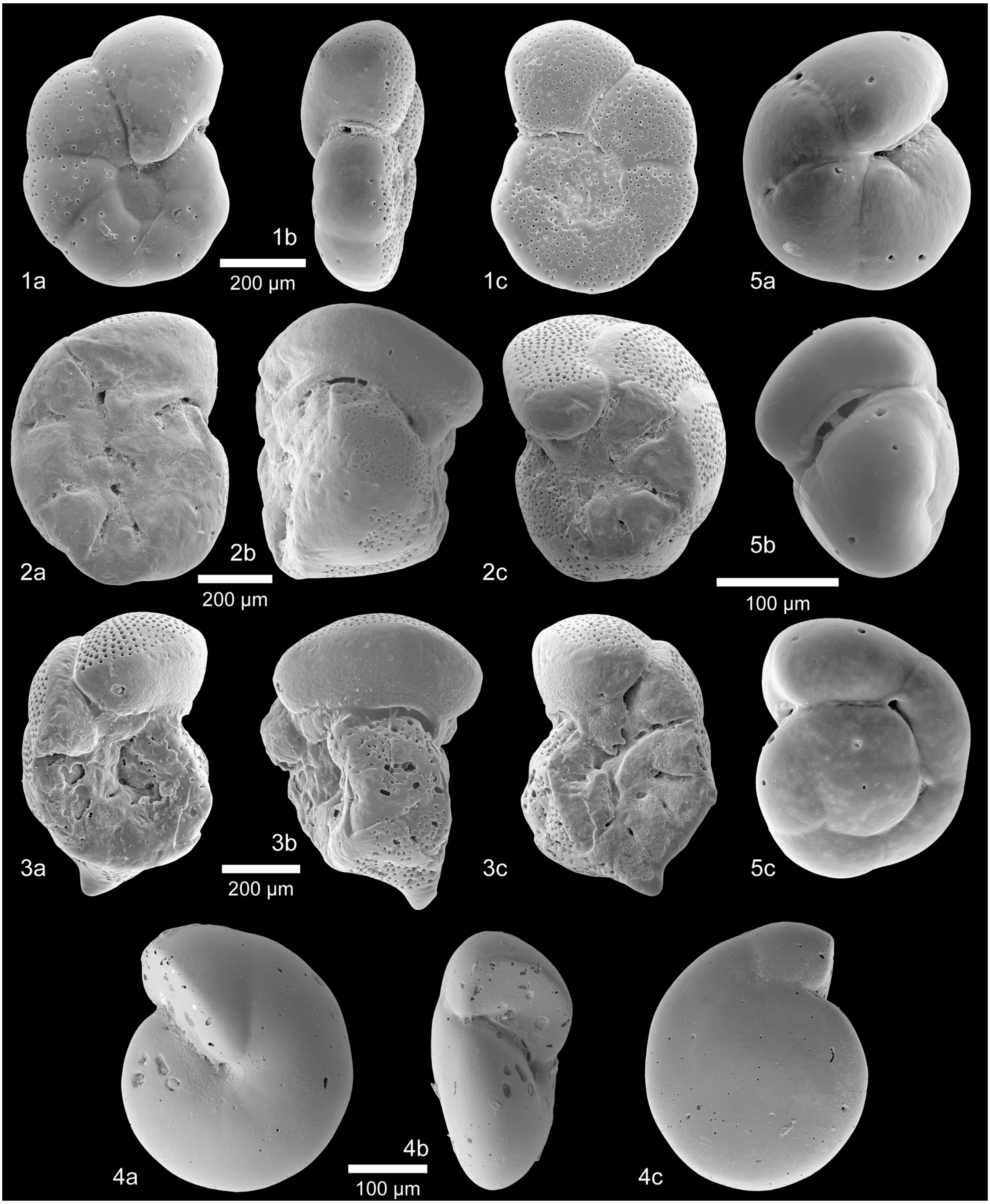
5c
4a
4b
100 µm
4c

PLATE 39

1a-c	*Anomalinoides globulosa* (Chapman and Parr, 1937), Hypotype from GeoB 9288
2a-c	*Discanomalina coronata* (Parker and Jones, 1857), Hypotype from GeoB9204-1
3a-c	*Discanomalina japonica* Asano, 1951, Hypotype from GeoB9205-1
4a-c	*Gyroidina laevigata* d’Orbigny, 1826, Hypotype from GeoB 6721-1
5a-c	*Gyroidina lamarckiana* (d’Orbigny, 1839), Hypotype from TTR17 MS411G 10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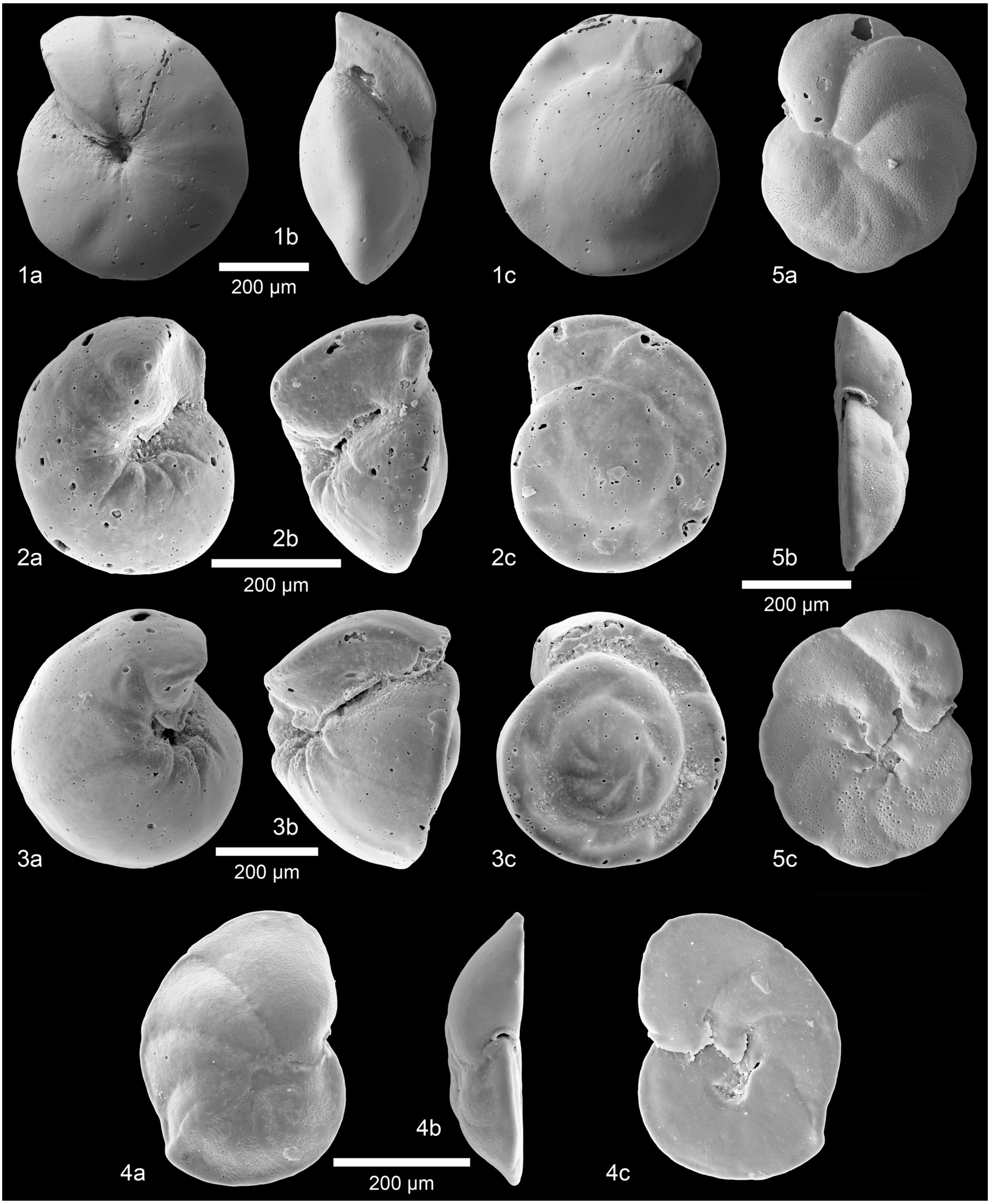
5c
4a
4b
100 µm
4c

PLATE 40

1a-c	*Gyroidina soldanii* d’Orbigny, 1839, Hypotype from GeoB 9220
2a-c	*Gyroidina neosoldanii* Brotzen, 1936, Hypotype from GeoB9220
3a-c	*Gyroidina altiformis* Steward and Steward, 1930, Hypotype from TTR17 MS419G 15
4a-c	*Hanzawaia boueana* (d’Orbigny, 1846), Hypotype from GeoB12748-1
5a-c	*Hanzawaia boueana* (d’Orbigny, 1846), Hypotype from POS391 558-1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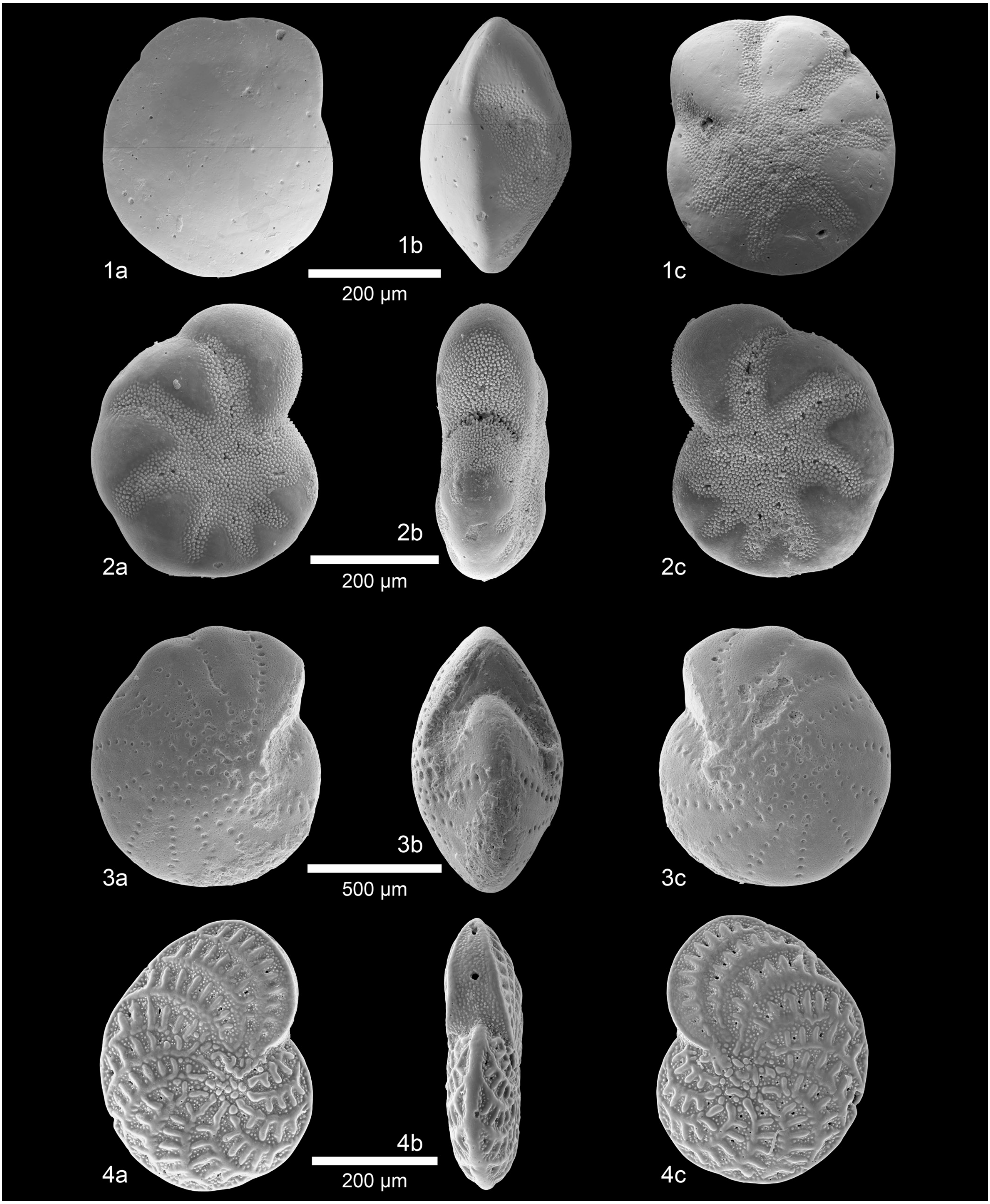
5c
4a
4b
200 µm
4c

Plate 41

1a-c *Buccella frigida* (Cushman, 1922), Hypotype from POS391 558-1
2a-c *Elphidium albiumbilicatum* (Weiss, 1954), Hypotype from POS391 571-1
3a-c *Elphidium groenlandicum* Cushman, 1933, Hypotype from PS70/039-2
4a-c *Elphidium hanzawai* Asano, 1939, Hypotype from TTR17 MS419G 45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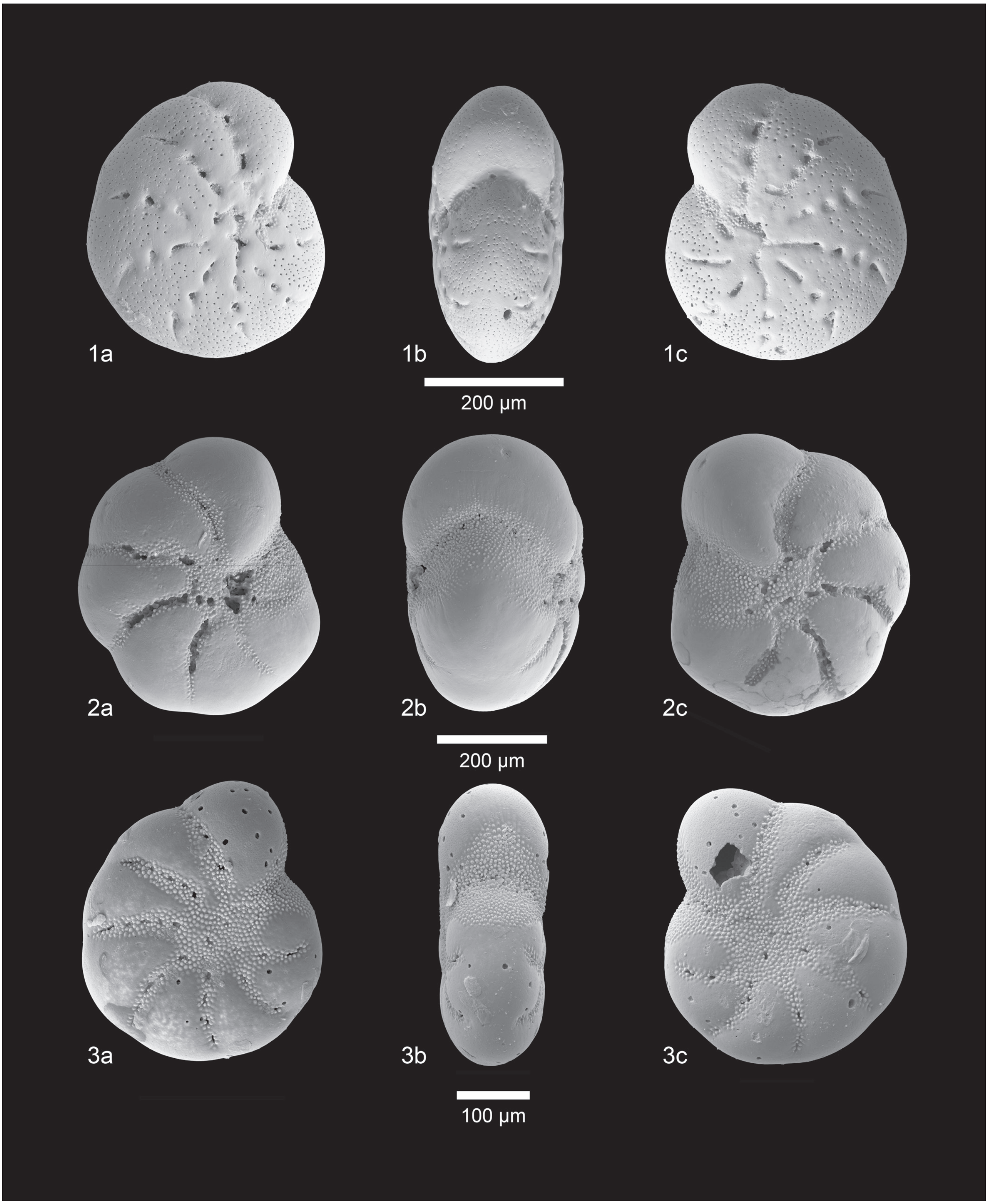
200 µm
2c
3a
3b
500 µm
3c
4a
4b
200 µm
4c

PLATE 42

1a-c *Elphidium incertum* (Williamson, 1858), Hypotype from P292 578-1
2a-c *Elphidium magellanicum* Heron-Allen and Earland, 1932, Hypotype from POS391 534-1
3a-c *Elphidium subarcticum* Cushman, 1944, Hypotype from POS391 534-1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3a
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100 μm

ANNEX

Appendix A. Species list and quantitative data of benthic foraminifera from the Porcupine/Rockall region (Chapter 2). Generic names are in accordance with Loeblich and Tappan (1987).

sample number	574-1	576-1	577-1	578-1	579-1	580-1	581-1
sum counts	430	595	627	605	502	375	266
Adercotryma wrightii Brönnimann and Whittaker, 1987	0	0	0	0	0	0	0
Ammonia beccarii Linné, 1758	0	0	2	3	0	0	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	3	0	0	0	0	0	0
Ammoscalaria pseudospiralis Williamson = *Proteonina pseudospiralis* Williamson, 1858	0	0	0	0	0	0	0
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	0	0	0	1	2	1	1
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	13	26	58	16	23	10	10
Anomalinoides granosa Hantken, 1875	0	0	0	0	0	0	0
Astacolus crepidulus Fichtel and Moll = *Nautilus crepidulus* Fichtel and Moll, 1798	0	0	2	0	0	0	0
Astrononion gallowayi Loeblich and Tappan, 1953	3	0	0	0	0	0	1
Astrononion stelligerum d'Orbigny = *Nonionina stelligera* d'Orbigny, 1839	0	6	2	1	0	3	0
Bigenerina nodosaria d'Orbigny, 1826	0	2	5	3	2	1	0
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	1	8	1	4	0	0	0
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	5	7	12	23	4	2	0
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	0	0	0	0	0	0	0
Bolivina pseudopunctata Höglund, 1947	0	0	1	1	1	0	0
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	6	1	0	0	0	0	0
Bolivina robusta Brady, 1881	0	0	0	0	0	1	0
Bolivina sp.	0	0	0	0	0	0	0
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	13	21	8	21	4	3	1
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	0	0	0	0	0	0	0
Bolivina subaenariensis Cushman = *Brizalina subaenariensis* Cushman, 1922	0	0	0	0	1	1	0
Bolivina subspinescens Cushman, 1922	0	0	3	2	0	2	0
Budashevaella multicamerata Voloshinova & Budasheva, 1961	0	0	0	0	0	0	0
Bulimina aculeata d'Orbigny, 1826	0	10	12	5	8	6	1
Bulimina marginata d'Orbigny, 1826	12	33	62	51	45	38	11
Bulimina striata d'Orbigny, 1843	0	0	1	0	0	0	0
Cassidulina carinata Silvestri = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896	215	148	67	34	12	15	20
Cassidulina laevigata d'Orbigny, 1826	3	8	33	30	6	20	3
Cibicides refulgens de Montfort, 1808	5	0	0	0	0	0	0
Cibicides ungerianus d'Orbigny = *Rotalia ungeriana* d'Orbigny, 1846	0	0	1	0	4	3	3
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	12	41	9	0	0	1	5
Cibicidoides pachyderma Rzehak, 1886	39	122	5	5	5	7	3
Cibicides/Cibicidoides juv.	0	0	2	0	15	21	10
Cibicidoides sp.	0	0	0	3	1	0	0
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	0	0	0	0	0	0	0
Cribrostomoides jeffreysii Williamson = *Nonionina jeffreysii* Williamson, 1858	0	0	0	0	0	0	0
Dentalina leguminiformis Batsch = *Nautilus (Orthoceras)* leguminiformis Batsch, 1791	1	0	0	0	0	0	1
Deuterammina rotaliformis Heron-Allen and Earland =*Trochammina rotaliformis* Heron-Allen and Earland, 1911	0	0	0	0	0	1	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	0	0	0	0	0	0	0
Discanomalina semipunctata Bailey = *Rotalina semipunctata* Bailey, 1851	0	0	0	0	0	0	0
Eggerella bradyi Cushman, 1911 = *Verneuilina bradyi* Cushman, 1911	0	0	0	0	0	0	0
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	0	0	0	0	0	0	0
Ehrenbergina trigona Goës = *Ehrenebrgina serrata* Brady var. *trigona* Goës, 1896	0	0	0	0	0	0	0

Appendix A (continued)

sample number	574-1	576-1	577-1	578-1	579-1	580-1	581-1
sum counts	430	595	627	605	502	375	266
Elphidium earlandi Cushman, 1936	0	0	0	0	0	0	0
Elphidium gerthi Van Voorthuysen, 1957	0	0	0	0	0	0	0
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	1	3	4	12	29	31	4
Epistominella vitrea Parker, 1953	0	1	4	4	20	26	28
Fissurina laevigata Reuss, 1850	0	0	0	0	0	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	0	0	0	0	0	0
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	0	0	0	0	0	0	0
Fissurina orbignyana Seguenza, 1862	0	0	0	0	0	0	0
Paliolatella semimarginata Reuss = *Fissurina semimarginata* Reuss, 1870	0	0	0	1	0	0	0
Fissurina sp.	0	0	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	0	3	0	4	0	0	0
Fursenkoina schreibersiana Carter, 1880 = *Virgulina schreibersiana* Carter	0	1	0	0	4	0	0
Gaudryina rudis Wright 1900	0	0	0	0	0	0	0
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	5	2	3	3	3	0	1
Globobulimina pupoides d'Orbigny = *Bulimina pupoides* d'Orbigny, 1846	0	0	0	0	0	1	0
Gavelinopsis sp.	0	0	0	0	0	0	0
Globocassidulina subglobosa group	64	45	58	39	12	4	4
Guttulina communis d'Orbigny = *Polymorphina (Guttulina) communis* d'Orbigny, 1826	0	0	0	0	0	0	0
Guttulina regina Brady, Parker and Jones = *Polymorphina regina* Brady, Parker and Jones, 1871	0	0	0	0	0	0	0
Gyroidina neosoldanii Brotzen, 1936	0	0	1	2	0	0	2
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	0	0	0	0	1	0	0
Gyroidina soldanii d'Orbigny, 1826	0	0	0	0	1	0	0
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	0	0	0	0	0	0	1
Heterolepa haidingeri d'Orbigny = *Rotalina haidingerii* d'Orbigny, 1846	0	0	0	0	0	0	0
Hoeglundina elegans d'Orbigny = *Rotalia (Turbinulina) elegans* d'Orbigny, 1826	0	1	0	0	0	0	1
Hopkinsina atlantica Cushman = *Hopkinsina pacifica* Cushman, 1933	1	0	4	4	1	9	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	16	30	42	54	51	33	24
Hyrrokkin sarcophaga Cedhagen, 1994	0	0	0	0	0	0	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	0	0	0	0	0	1	0
Lagena hispida Reuss, 1863	0	0	0	0	0	0	0
Lagena spicata Thiele, 1898	0	0	0	0	0	0	0
Lagena striata d'Orbigny, 1839	1	0	1	0	0	0	0
Lagena sulcata Walker and Jacob = *Serpula sulcata* Walker and Jacob, 1798	0	0	0	0	0	1	0
Lenticulina inornata d'Orbigny = *Robulina inornata* d'Orbigny, 1846	0	0	0	2	1	0	0
Lenticulina orbicularis d'Orbigny = *Robulina orbicularis* d'Orbigny, 1826	0	0	0	0	0	0	1
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	5	4	1	0	1	0	1
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	0	2	12	9	15	16	17
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	0	0	0	0	0	0	1
Melonis sp.	0	0	0	0	0	0	0
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	0	0	0	0	0	0	0
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	0	0	0	0	0	0
Nonionella iridea Heron-Allen and Earland, 1932	0	0	0	0	0	10	1
Nonionellina labradorica Dawson = *Nonionina labradorica* Dawson, 1860	0	1	0	0	0	0	0

Appendix A (continued)

sample number	574-1	576-1	577-1	578-1	579-1	580-1	581-1
sum counts	430	595	627	605	502	375	266
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	1	3	4	5	13	9	1
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	0	0	0	0	1	0	1
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	0	0	0	0	0	0	0
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	1	0	0	0
Ophthalmidium kilianensis Rhumbler, 1936	0	0	0	0	0	0	0
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	0	1	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	0	0	1	0	0	1	0
Paratrochammina murrayi Brönnimann and Zaninetti, 1984	0	0	1	0	0	0	0
Planulina ariminensis d’Orbigny, 1826	0	0	0	0	0	0	3
Porosononion ex gr. *Granosum* d'Orbigny = *Nonionina granosa* d'Orbigny, 1826	0	5	9	11	1	2	0
Pullenia bulloides d’Orbigny = *Nonionina bulloides* d’Orbigny, 1846	0	0	0	0	0	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	0	0	0	0	2	5	3
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	0	0	0	0	0	0	0
Pyrgo elongata d’Orbigny = *Biloculina elongata* d’Orbigny, 1826	0	0	0	0	0	0	0
Pyrgo inornata d’Orbigny = *Biloculina elongata* d’Orbigny, 1839	0	0	0	0	0	0	0
Pyrgo murrhina Schwager = *Biloculina murrhina* Schwager, 1866	0	0	0	0	0	0	0
Pyrgo subsphaerica d’Orbigny = *Biloculina subsphaerica* d’Orbigny, 1840	0	0	0	0	0	0	0
Quinqueloculina arctica Cushman, 1933	0	0	0	0	0	0	0
Cycloforina stalkeri Loeblich and Tappan, 1953	0	0	0	1	0	0	0
Reophax scorpiurus de Montfort, 1808	0	0	1	0	0	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	0	0	0	0	0	0
Rosalina sp.	0	1	0	0	0	0	0
Rosalina vilardeboana d’Orbigny, 1839	0	0	0	0	1	0	0
Saccammina sphaerica Sars, 1868	0	0	0	1	0	0	0
Saccorhiza ramosa Brady = *Hyperammina ramosa* Brady, 1879	0	0	0	0	0	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	0	0	0	1	1
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	0	0	1	1	0	0	6
Sphaeroidina bulloides d’Orbigny, 1826	0	0	0	2	0	1	0
Spirillina vivipara Ehrenberg, 1843	0	0	0	0	0	0	0
Spiroplectinella sagittula d'France, 1824	0	0	0	0	0	1	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	2	6	2	1	1	3	3
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	1	2	2	0	3	0	2
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	0	0	0	0	0	0
Textularia agglutinans d’Orbigny, 1839	0	0	0	2	2	1	1
Textularia bigenerinoides Lacroix, 1932	0	0	0	0	1	0	0
Textularia pseudogramen d’Orbigny, 1839	0	0	1	0	0	0	0
Textularia truncata Höglund, 1947	0	0	0	3	0	0	0
Tosaia hanzawai Takayanagi, 1953	0	0	0	0	0	0	0
Trifarina brady Cushman, 1923	0	0	0	0	0	0	0
Uvigerina auberiana d’Orbigny, 1839	0	0	0	0	0	0	2
Uvigerina mediterranea Hofker, 1932	0	8	32	43	32	36	17
Uvigerina peregrina Cushman, 1923	2	44	157	197	172	47	70
Vulvulina pennatula Batsch = *Nautilus (Orthoceras) pennatula* Batsch, 1791	0	0	0	0	0	0	0

Appendix A (continued)

sample number	GeoB6721-1	M07-15	M07-21	M07-23	M07-24	M07-25	9204-1	9205-1	9209-2	9216-1	9219-1
sum counts	188	116	88	119	103	345	58	39	62	85	121
Adercotryma wrightii Brönnimann and Whittaker, 1987	1	0	0	0	1	0	0	0	0	0	0
Ammonia beccarii Linné, 1758	0	0	0	0	0	0	0	0	0	1	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	0	0	0	0	0	0	0	0	0	0	0
Ammoscalaria pseudospiralis Williamson = *Proteonina pseudospiralis* Williamson, 1858	0	0	0	0	2	0	0	0	0	0	0
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	0	0	2	0	1	0	1	0	0	0	5
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	4	0	17	7	8	8	1	0	0	3	0
Anomalinoides granosa Hantken, 1875	0	0	0	0	0	0	0	0	0	0	0
Astacolus crepidulus Fichtel and Moll = *Nautilus crepidulus* Fichtel and Moll, 1798	0	0	0	0	0	0	0	0	0	0	0
Astrononion gallowayi Loeblich and Tappan, 1953	0	0	0	0	0	1	0	0	0	0	4
Astrononion stelligerum d'Orbigny = *Nonionina stelligera* d'Orbigny, 1839	3	0	0	0	0	16	0	1	4	3	0
Bigenerina nodosaria d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	0	2	0	0	0	0	0	1	1	2	3
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	0	0	0	3	5	8	7	3	1	0	0
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	0	0	0	0	0	0	0	1	0	0	0
Bolivina pseudopunctata Höglund, 1947	0	0	0	0	0	0	2	0	0	0	5
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	0	0	0	0	0	0	0	0	1	3	0
Bolivina robusta Brady, 1881	0	0	0	0	0	0	0	0	0	0	0
Bolivina sp.	1	1	0	0	0	0	0	0	0	0	5
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	0	0	0	0	0	0	0	0	0	0	0
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	0	0	0	1	0	0	0	0	0	1	1
Bolivina subaenariensis Cushman = *Brizalina subaenariensis* Cushman, 1922	0	0	0	0	0	0	0	0	0	0	0
Bolivina subspinescens Cushman, 1922	0	0	0	0	0	0	0	0	0	0	0
Budashevaella multicamerata Voloshinova & Budasheva, 1961	0	0	0	0	1	0	0	0	0	0	9
Bulimina aculeata d'Orbigny, 1826	0	0	0	0	1	7	0	0	0	0	0
Bulimina marginata d'Orbigny, 1826	6	2	0	2	4	21	1	0	1	2	0
Bulimina striata d'Orbigny, 1843	0	0	0	0	0	0	0	0	0	0	0
Cassidulina carinata Silvestri = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896	5	8	5	5	9	29	3	1	5	0	21
Cassidulina laevigata d'Orbigny, 1826	3	3	1	4	0	0	9	1	4	7	1
Cibicides refulgens de Montfort, 1808	0	1	2	4	0	0	1	0	5	0	4
Cibicides ungerianus d'Orbigny = *Rotalia ungeriana* d'Orbigny, 1846	7	1	0	3	2	3	0	1	1	1	0
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	0	6	5	4	0	12	2	0	0	0	1
Cibicidoides pachyderma Rzehak, 1886	4	0	0	0	0	0	0	0	0	0	0
Cibicides/Cibicidoides juv.	0	0	0	0	0	0	0	0	0	0	0
Cibicidoides sp.	1	0	0	0	0	0	2	2	1	3	1
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0
Cribrostomoides jeffreysii Williamson = *Nonionina jeffreysii* Williamson, 1858	0	0	0	0	0	0	0	1	0	1	9
Dentalina leguminiformis Batsch = *Nautilus (Orthoceras)* leguminiformis Batsch, 1791	0	0	0	0	0	0	0	0	0	0	0
Deuterammina rotaliformis Heron-Allen and Earland =*Trochammina rotaliformis* Heron-Allen and Earland, 1911	0	0	0	0	0	0	0	0	0	0	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	4	32	2	0	1	0	5	0	11	2	0
Discanomalina semipunctata Bailey = *Rotalina semipunctata* Bailey, 1851	0	0	0	0	0	0	0	2	0	0	0
Eggerella bradyi Cushman, 1911 = *Verneuilina bradyi* Cushman, 1911	0	0	0	0	0	0	0	0	0	0	0
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	0	0	2	0	1	0	0	0	0	0	1
Ehrenbergina trigona Goës = *Ehrenebrgina serrata* Brady var. *trigona* Goës, 1896	0	1	0	0	0	0	0	0	0	0	0

Appendix A (continued)

sample number	GeoB6721-1	M07-15	M07-21	M07-23	M07-24	M07-25	9204-1	9205-1	9209-2	9216-1	9219-1
sum counts	188	116	88	119	103	345	58	39	62	85	121
Elphidium earlandi Cushman, 1936	0	0	0	0	0	0	0	0	0	1	0
Elphidium gerthi Van Voorthuysen, 1957	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	12	0	0	0	0	0	0	0	0	0	0
Epistominella vitrea Parker, 1953	33	11	9	18	15	13	1	0	5	2	1
Fissurina laevigata Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	0	0	0	0	0	0	0	0	0	0
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	0	0	0	0	0	0	0	0	1	0	2
Fissurina orbignyana Seguenza, 1862	0	0	0	0	0	0	0	0	0	1	0
Paliolatella semimarginata Reuss = *Fissurina semimarginata* Reuss, 1870	0	0	0	0	0	0	0	0	0	0	0
Fissurina sp.	0	1	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	4	0	0	0	0	0	0	0	0	0	0
Fursenkoina schreibersiana Carter, 1880 = *Virgulina schreibersiana* Carter	2	0	0	0	0	0	0	0	0	0	0
Gaudryina rudis Wright 1900	0	0	0	0	0	0	2	0	0	0	1
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	0	0	0	0	0	0	1	0	0	1	0
Globobulimina pupoides d'Orbigny = *Bulimina pupoides* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	32
Gavelinopsis sp.	0	0	0	0	0	0	0	2	0	0	0
Globocassidulina subglobosa group	12	29	11	5	9	1	5	8	7	21	0
Guttulina communis d'Orbigny = *Polymorphina (Guttulina) communis* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0
Guttulina regina Brady, Parker and Jones = *Polymorphina regina* Brady, Parker and Jones, 1871	0	0	0	0	0	0	0	0	0	0	0
Gyroidina neosoldanii Brotzen, 1936	0	0	0	0	0	0	0	0	0	2	0
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	2	4	0	1	0	0	1	0	0	0	0
Gyroidina soldanii d'Orbigny, 1826	1	0	0	0	0	0	0	0	1	0	2
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	2	0	2	3	4	0	0	0	1	2	1
Heterolepa haidingeri d'Orbigny = *Rotalina haidingerii* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0
Hoeglundina elegans d'Orbigny = *Rotalia (Turbinulina) elegans* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0
Hopkinsina atlantica Cushman = *Hopkinsina pacifica* Cushman, 1933	0	0	0	0	0	0	0	0	0	0	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	3	2	0	2	2	32	0	1	0	0	0
Hyrrokkin sarcophaga Cedhagen, 1994	0	2	0	0	2	0	0	0	0	0	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	1	0	1	3	0	0	1	0	2	1	0
Lagena hispida Reuss, 1863	0	0	0	0	1	2	0	0	0	0	0
Lagena spicata Thiele, 1898	0	0	1	0	0	0	0	0	0	0	0
Lagena striata d'Orbigny, 1839	1	0	0	1	1	4	0	0	0	0	0
Lagena sulcata Walker and Jacob = *Serpula sulcata* Walker and Jacob, 1798	0	0	0	0	0	0	0	0	0	0	0
Lenticulina inornata d'Orbigny = *Robulina inornata* d'Orbigny, 1846	1	1	0	3	3	1	0	0	0	2	0
Lenticulina orbicularis d'Orbigny = *Robulina orbicularis* d'Orbigny, 1826	2	0	0	0	0	0	0	0	0	0	3
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	1	0	2	0	2	0	2	1	2	3	0
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	8	0	1	4	3	1	0	1	1	0	0
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	0	0	0	0	0	0	0	0	0	0	0
Melonis sp.	0	0	0	0	0	0	0	2	0	0	0
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	0	0	0	0	1	0	0	1	0	0	1
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	0	0	0	0	0	0	0	0	0	0
Nonionella iridea Heron-Allen and Earland, 1932	0	0	0	0	0	0	0	0	0	0	0
Nonionellina labradorica Dawson = *Nonionina labradorica* Dawson, 1860	0	0	0	0	0	0	0	0	0	0	0

Appendix A (continued)

sample number	GeoB6721-1	M07-15	M07-21	M07-23	M07-24	M07-25	9204-1	9205-1	9209-2	9216-1	9219-1
sum counts	188	116	88	119	103	345	58	39	62	85	121
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	2	0	0	0	0	0	0	0	0	0	0
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	0	0	0	0	0	0	0	1	0	1	0
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	0	0	0	0	0	0	0	0	0	0	0
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	0	0	0	0	0	0	0	0
Ophthalmidium kilianensis Rhumbler, 1936	0	0	0	1	0	0	0	1	0	0	1
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	0	0	0	0	0	0	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	0	0	0	0	0	0	0	0	0	0	0
Paratrochammina murrayi Brönnimann and Zaninetti, 1984	0	0	0	0	0	0	0	0	0	0	0
Planulina ariminensis d'Orbigny, 1826	4	3	3	0	1	0	3	2	3	1	0
Porosononion ex gr. *Granosum* d'Orbigny = *Nonionina granosa* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	3	1
Pullenia bulloides d'Orbigny = *Nonionina bulloides* d'Orbigny, 1846	0	0	0	0	0	0	0	0	1	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	0	1	1	0	1	2	1	1	0	2	0
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	0	0	0	0	0	0	0	0	0	0	0
Pyrgo elongata d'Orbigny = *Biloculina elongata* d'Orbigny, 1826	0	0	0	0	1	0	0	0	0	0	0
Pyrgo inornata d'Orbigny = *Biloculina elongata* d'Orbigny, 1839	0	0	0	0	0	0	1	0	0	0	0
Pyrgo murrhina Schwager = *Biloculina murrhina* Schwager, 1866	0	0	0	0	0	0	0	0	0	0	0
Pyrgo subsphaerica d'Orbigny = *Biloculina subsphaerica* d'Orbigny, 1840	0	1	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica Cushman, 1933	0	0	0	0	1	0	0	0	0	0	0
Cycloforina stalkeri Loeblich and Tappan, 1953	0	0	0	0	0	0	0	0	0	0	1
Reophax scorpiurus de Montfort, 1808	0	0	0	0	0	0	0	0	0	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	1	0	0	0	0	0	0	0	0	0
Rosalina sp.	0	0	0	0	0	0	0	0	0	0	0
Rosalina vilardeboana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0
Saccammina sphaerica Sars, 1868	0	0	0	0	0	0	0	0	0	0	0
Saccorhiza ramosa Brady = *Hyperammina ramosa* Brady, 1879	0	0	0	0	0	0	0	0	0	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	0	0	0	0	0	0	0	0	0
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	5	0	0	1	0	2	0	0	0	2	0
Sphaeroidina bulloides d'Orbigny, 1826	2	0	0	0	1	4	0	0	0	1	2
Spirillina vivipara Ehrenberg, 1843	0	0	0	0	0	0	1	0	0	1	0
Spiroplectinella sagittula d'France, 1824	0	0	0	0	0	0	0	0	0	0	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	1	0	6	1	4	2	0	0	0	0	1
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	2	0	0	0	1	0	0	0	0	0	0
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	0	0	0	0	0	0	0	0	0	0
Textularia agglutinans d'Orbigny, 1839	0	3	1	1	0	6	0	0	0	0	0
Textularia bigenerinoides Lacroix, 1932	0	0	0	0	0	0	0	0	0	0	0
Textularia pseudogramen d'Orbigny, 1839	1	0	0	0	0	0	0	0	0	0	0
Textularia truncata Höglund, 1947	0	0	0	0	0	1	0	0	0	0	1
Tosaia hanzawai Takayanagi, 1953	0	0	1	0	0	0	0	0	0	0	0
Trifarina brady Cushman, 1923	0	0	0	0	0	0	1	1	1	1	0
Uvigerina auberiana d'Orbigny, 1839	9	0	0	0	0	0	0	1	1	1	1
Uvigerina mediterranea Hofker, 1932	12	0	4	24	6	134	3	0	1	4	0
Uvigerina peregrina Cushman, 1923	25	0	9	18	8	35	1	2	0	3	0
Vulvulina pennatula Batsch = *Nautilus (Orthoceras) pennatula* Batsch, 1791	1	0	0	0	0	0	0	0	0	0	0

Appendix A (continued)

sample number	9220	9256-1	9271	9287	9257	9260	9268	9269	9288
sum counts	124	131	79	123	95	63	118	68	81
Adercotryma wrightii Brönnimann and Whittaker, 1987	0	0	0	2	0	0	0	0	0
Ammonia beccarii Linné, 1758	0	0	0	0	0	0	0	0	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	0	0	0	0	0	0	0	0	0
Ammoscalaria pseudospiralis Williamson = *Proteonina pseudospiralis* Williamson, 1858	0	0	0	0	0	0	0	0	0
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	0	0	0	0	0	0	0	0	0
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	0	2	3	13	2	3	10	2	9
Anomalinoides granosa Hantken, 1875	0	0	0	0	0	0	0	0	1
Astacolus crepidulus Fichtel and Moll = *Nautilus crepidulus* Fichtel and Moll, 1798	0	0	0	0	0	0	2	0	0
Astrononion gallowayi Loeblich and Tappan, 1953	0	0	0	0	0	0	0	0	0
Astrononion stelligerum d'Orbigny = *Nonionina stelligera* d'Orbigny, 1839	3	1	2	4	2	1	2	0	0
Bigenerina nodosaria d’Orbigny, 1826	0	0	0	0	0	0	0	0	0
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	0	0	0	0	0	0	0	0	0
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	3	0	0	5	0	0	1	0	1
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	0	0	0	0	0	0	0	0	0
Bolivina pseudopunctata Höglund, 1947	0	0	0	1	0	0	1	1	0
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	0	1	0	5	0	0	0	1	0
Bolivina robusta Brady, 1881	0	0	0	0	0	0	0	0	0
Bolivina sp.	0	0	0	0	0	0	0	0	0
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	0	1	0	3	1	0	0	0	0
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	0	0	0	0	0	0	0	0	0
Bolivina subaenariensis Cushman = *Brizalina subaenariensis* Cushman, 1922	0	0	0	0	0	0	0	0	0
Bolivina subspinescens Cushman, 1922	0	0	0	0	1	0	0	1	0
Budashevaella multicamerata Voloshinova & Budasheva, 1961	0	0	0	0	0	0	0	0	0
Bulimina aculeata d’Orbigny, 1826	0	0	0	0	0	0	0	0	0
Bulimina marginata d’Orbigny, 1826	1	1	4	2	3	5	7	2	3
Bulimina striata d'Orbigny, 1843	0	0	0	0	0	0	0	0	0
Cassidulina carinata Silvestri = *Cassidulina laevigata* d’Orbigny var. *carinata* Silvestri, 1896	1	0	0	2	1	0	0	4	3
Cassidulina laevigata d’Orbigny, 1826	6	1	3	5	6	1	11	10	3
Cibicides refulgens de Montfort, 1808	1	4	0	6	0	2	1	0	0
Cibicides ungerianus d’Orbigny = *Rotalia ungeriana* d’Orbigny, 1846	2	1	1	0	0	0	0	0	0
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	0	0	0	0	3	1	1	0	3
Cibicidoides pachyderma Rzehak, 1886	22	0	3	0	0	2	0	2	3
Cibicides/Cibicidoides juv.	0	0	0	0	0	0	0	0	0
Cibicidoides sp.	0	0	2	3	10	3	1	5	10
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	0	1	0	0	0	0	0	0	0
Cribrostomoides jeffreysii Williamson = *Nonionina jeffreysii* Williamson, 1858	0	0	0	0	0	0	0	0	0
Dentalina leguminiformis Batsch = *Nautilus (Orthoceras)* leguminiformis Batsch, 1791	0	0	0	0	0	0	0	0	0
Deuterammina rotaliformis Heron-Allen and Earland =*Trochammina rotaliformis* Heron-Allen and Earland, 1911	0	0	0	0	0	0	0	0	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	13	2	0	4	1	0	6	0	0
Discanomalina semipunctata Bailey = *Rotalina semipunctata* Bailey, 1851	0	1	0	0	0	0	0	0	0
Eggerella bradyi Cushman, 1911 = *Verneuilina bradyi* Cushman, 1911	0	0	0	0	0	0	0	0	0
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	5	0	0	0	0	0	3	0	0
Ehrenbergina trigona Goës = *Ehrenebrgina serrata* Brady var. *trigona* Goës, 1896	0	1	0	1	0	0	0	0	0

Appendix A (continued)

sample number	9220	9256-1	9271	9287	9257	9260	9268	9269	9288
sum counts	124	131	79	123	95	63	118	68	81
Elphidium earlandi Cushman, 1936	0	0	0	0	0	0	0	0	0
Elphidium gerthi Van Voorthuysen, 1957	0	0	0	0	0	0	0	0	1
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	0	0	0	0	0	0	0	0	0
Epistominella vitrea Parker, 1953	5	31	14	15	12	1	23	9	5
Fissurina laevigata Reuss, 1850	0	0	0	0	0	0	0	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	2	0	0	0	0	0	0	0
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	0	1	0	0	0	0	0	0	1
Fissurina orbignyana Seguenza, 1862	0	0	0	0	0	0	0	0	0
Paliolatella semimarginata Reuss = *Fissurina semimarginata* Reuss, 1870	0	0	0	0	0	0	0	0	0
Fissurina sp.	0	1	2	0	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	0	0	0	0	0	0	0	0	0
Fursenkoina schreibersiana Carter, 1880 = *Virgulina schreibersiana* Carter	0	0	0	0	0	0	0	0	0
Gaudryina rudis Wright 1900	1	0	0	0	0	2	0	0	0
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	2	1	0	1	0	1	1	1	1
Globobulimina pupoides d'Orbigny = *Bulimina pupoides* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0
Gavelinopsis sp.	0	1	0	2	1	0	0	0	0
Globocassidulina subglobosa group	16	46	20	16	37	23	31	16	20
Guttulina communis d'Orbigny = *Polymorphina (Guttulina) communis* d'Orbigny, 1826	1	0	0	0	0	0	0	0	0
Guttulina regina Brady, Parker and Jones = *Polymorphina regina* Brady, Parker and Jones, 1871	0	0	0	0	1	0	0	1	0
Gyroidina neosoldanii Brotzen, 1936	2	0	0	3	0	0	0	0	0
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0
Gyroidina soldanii d'Orbigny, 1826	4	0	2	0	1	0	2	1	0
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	2	2	0	3	1	1	3	0	0
Heterolepa haidingeri d'Orbigny = *Rotalina haidingerii* d'Orbigny, 1846	0	0	0	0	0	0	0	0	5
Hoeglundina elegans d'Orbigny = *Rotalia (Turbinulina) elegans* d'Orbigny, 1826	1	0	0	0	0	0	0	0	0
Hopkinsina atlantica Cushman = *Hopkinsina pacifica* Cushman, 1933	0	0	0	0	0	0	0	0	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	1	0	0	0	1	0	0	0	0
Hyrrokkin sarcophaga Cedhagen, 1994	0	0	0	0	0	0	0	0	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	2	0	0	0	1	1	0	0	0
Lagena hispida Reuss, 1863	0	0	0	0	0	0	0	0	0
Lagena spicata Thiele, 1898	0	0	0	0	0	0	0	0	0
Lagena striata d'Orbigny, 1839	0	0	0	0	0	0	0	0	0
Lagena sulcata Walker and Jacob = *Serpula sulcata* Walker and Jacob, 1798	0	0	0	2	0	0	0	0	0
Lenticulina inornata d'Orbigny = *Robulina inornata* d'Orbigny, 1846	0	0	0	0	0	1	1	0	1
Lenticulina orbicularis d'Orbigny = *Robulina orbicularis* d'Orbigny, 1826	0	0	0	0	0	0	1	0	0
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	2	1	1	1	1	1	1	1	2
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	3	4	1	2	0	1	0	2	3
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	0	0	0	0	0	0	0	0	0
Melonis sp.	2	0	0	0	0	0	0	0	0
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	0	2	0	0	0	1	0	0	1
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	0	0	1	0	0	0	1	0
Nonionella iridea Heron-Allen and Earland, 1932	0	0	0	0	0	0	0	0	0
Nonionellina labradorica Dawson = *Nonionina labradorica* Dawson, 1860	0	0	0	0	0	0	0	0	0

Appendix A (continued)

sample number	9220	9256-1	9271	9287	9257	9260	9268	9269	9288
sum counts	124	131	79	123	95	63	118	68	81
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	0	1	0	0	0	0	0	0	1
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	0	0	0	0	0	0	0	0	0
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	0	1	0	0	0	0	0	0	0
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	0	0	0	0	0	0
Ophthalmidium kilianensis Rhumbler, 1936	0	0	0	0	0	0	0	0	0
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	0	0	0	0	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	0	0	0	0	1	0	0	0	0
Paratrochammina murrayi Brönnimann and Zaninetti, 1984	0	0	0	0	0	0	0	0	0
Planulina ariminensis d'Orbigny, 1826	0	12	0	4	1	3	6	2	2
Porosononion ex gr. *Granosum* d'Orbigny = *Nonionina granosa* d'Orbigny, 1826	1	0	0	0	0	0	0	0	0
Pullenia bulloides d'Orbigny = *Nonionina bulloides* d'Orbigny, 1846	0	0	0	1	0	0	0	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	1	0	0	0	0	0	0	0	0
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	1	0	0	0	0	0	0	0	0
Pyrgo elongata d'Orbigny = *Biloculina elongata* d'Orbigny, 1826	0	0	0	1	0	0	0	0	0
Pyrgo inornata d'Orbigny = *Biloculina elongata* d'Orbigny, 1839	0	0	0	1	0	0	0	0	0
Pyrgo murrhina Schwager = *Biloculina murrhina* Schwager, 1866	0	0	0	0	0	0	1	0	0
Pyrgo subsphaerica d'Orbigny = *Biloculina subsphaerica* d'Orbigny, 1840	0	0	0	0	0	0	0	0	0
Quinqueloculina arctica Cushman, 1933	0	0	0	0	1	0	0	0	1
Cycloforina stalkeri Loeblich and Tappan, 1953	0	0	0	0	0	0	0	0	0
Reophax scorpiurus de Montfort, 1808	0	0	0	0	0	0	0	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	2	0	0	0	0	0	0	0
Rosalina sp.	0	0	0	0	0	0	0	0	0
Rosalina vilardeboana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0
Saccammina sphaerica Sars, 1868	0	0	0	0	0	0	0	0	0
Saccorhiza ramosa Brady = *Hyperammina ramosa* Brady, 1879	0	1	0	0	0	0	0	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	0	0	0	0	0	0	0
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	8	0	2	3	1	1	0	0	0
Sphaeroidina bulloides d'Orbigny, 1826	0	0	0	1	0	0	0	0	0
Spirillina vivipara Ehrenberg, 1843	0	0	0	0	0	1	0	0	0
Spiroplectinella sagittula d'France, 1824	0	0	0	0	0	0	0	0	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	0	0	0	1	0	0	0	0	0
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	0	0	0	0	0	0	1	0	0
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	2	0	0	0	0	0	0	0
Textularia agglutinans d'Orbigny, 1839	0	0	0	0	0	0	0	0	0
Textularia bigenerinoides Lacroix, 1932	0	0	0	0	0	0	0	0	0
Textularia pseudogramen d'Orbigny, 1839	0	0	0	0	0	0	0	0	0
Textularia truncata Höglund, 1947	0	0	0	1	0	0	0	0	0
Tosaia hanzawai Takayanagi, 1953	0	0	0	0	0	0	0	0	0
Trifarina brady Cushman, 1923	0	0	0	0	0	0	0	0	0
Uvigerina auberiana d'Orbigny, 1839	1	0	0	2	0	0	0	0	0
Uvigerina mediterranea Hofker, 1932	10	3	19	3	4	0	0	0	0
Uvigerina peregrina Cushman, 1923	1	0	0	3	1	7	1	6	1
Vulvulina pennatula Batsch = *Nautilus (Orthoceras) pennatula* Batsch, 1791	0	0	0	0	0	0	0	0	0

Appendix B. Species list and quantitative data of benthic foraminifera from the Norwegian Margin (Chapter 3). Generic names are in accordance with Loeblich and Tappan (1987).

sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
sum counts	540	450	518	552	266	537	270	317	528	373	628	626	376	291	370	821
Adercotryma wrightii Brönnimann and Whittaker, 1987	0	4	0	0	0	0	0	4	0	2	0	0	0	1	8	2
Ammobaculites agglutinans d'Orbigny = *Spirolina agglutinans* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ammodiscus incertus d'Orbigny = *Operculina incerta* d'Orbigny, 1839	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammolagena clavata Jones and Parker = *Trochammina irregularis* d'Orbigny var. *clavata* Jones and Parker, 1860	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	31	13	61	87	32	32	36	27	16	8	4	0	51	71	5	0
Astrononion gallowayi Loeblich and Tappan, 1953	16	49	9	1	3	0	1	2	0	1	1	0	1	3	7	2
Bathysiphon filiformis M. Sars, 1872	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Bigenerina cylindrica Cushman, 1922	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	37
Bigenerina nodosaria d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0
Biloculinella depressa Wiesner = *Biloculina labiata* Schlumberger var. *depressa* Wiesner, 1923	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biloculinella globula Bornemann = *Biloculina globulus* Bornemann, 1855	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	1	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0
Bolivina pseudopunctata Höglund, 1947	2	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Bolivina spinescens Cushman, 1911	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bolivina subspinescens Cushman, 1922	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Botellina labyrinthica Brady, 1881	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
Buccella frigida Cushman = *Pulvinulina frigida* Cushman, 1922	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Buccella tenerrima Bandy = *Rotalia tenerrima* Bandy, 1950	1	0	0	0	0	1	0	0	1	0	0	2	0	0	0	0
Bulimina aculeata d'Orbigny, 1826	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Bulimina marginata d'Orbigny, 1826	0	0	0	5	1	3	0	0	0	1	0	1	2	0	28	8
Cassidulina carinata Silvestri = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896	13	4	29	13	3	11	4	1	23	0	9	1	24	13	11	69
Cassidulina laevigata group	8	7	11	1	1	6	34	31	52	90	2	3	1	5	16	8
Cassidulinoides oblonga Reuss = *Cassidulina oblonga* Reuss, 1850	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cibicides refulgens de Montfort, 1808	9	0	17	37	6	78	4	0	0	0	1	0	17	12	3	0
Cibicides ungerianus d'Orbigny = *Rotalia ungeriana* d'Orbigny, 1846	12	1	0	1	1	7	0	1	0	0	0	0	2	3	1	1
Cibicides/Cibicidoides juv	42	0	12	13	0	1	0	0	1	0	0	0	0	0	0	0
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	0	0	0	14	1	17	7	0	0	0	0	0	12	17	0	0
Cibicidoides sp.	3	16	31	2	13	7	0	0	0	0	0	0	3	15	10	0
Cibicidoides pachyderma Rzehak, 1886	192	85	113	88	33	191	17	6	18	1	1	0	32	11	49	0
Cibicidoides pseudoungerianus Cushman =*Truncatulina pseudoungeriana* Cushman, 1922	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Clavulina primaeva Cushman, 1913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Cornuspira foliacea Philippi = *Orbis foliaceus* Philippi, 1844	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	0	1	4	0	0	0	0	0	0	1	0	0	0	0	0	0
Cribroelphidium excavatum Terquem = *Polystomella excavata* Terquem, 1875	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cribrostomoides jeffreysii Williamson = *Nonionina jeffreysii* Williamson, 1858	0	10	3	0	0	1	0	0	0	0	0	0	0	0	0	0
Cribrostomoides subglobosum Cushman = *Haplophragmoides subglobosum*, Cushman, 1910	0	0	0	0	2	0	2	6	41	49	174	111	0	0	0	14
Cushmania plumigera Brady = *Lagena plumigera* Brady, 1881	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Appendix B (continued)

sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
sum counts	540	450	518	552	266	537	270	317	528	373	628	626	376	291	370	821
Cycloforina angularis d'Orbigny = *Quinqueloculina angularis* d'Orbigny, 1905	0	0	0	0	0	0	0	2	1	0	4	4	0	0	0	0
Cycloforina laevigata d'Orbigny, 1839	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cycloforina stalkeri Loeblich and Tappan, 1953	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dentalina advena Cushman = *Nodosaria advena* Cushman, 1923	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Discammina compressa Goes, 1882	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	48	47	14	6	15	18	1	0	0	0	0	0	0	6	1	0
Discorbinella bertheloti d'Orbigny = *Rosalina bertheloti* d'Orbigny, 1839	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eggerella bradyi Cushman = *Verneuilina bradyi* Cushman, 1911	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	91
Elphidiella hannai Cushman and Grant = *Elphidium hannai* Cushman and Grant, 1927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Elphidiella albiumbilicata Weiss = *Nonion pauciloculum* Cushman subsp. *albiumbilicatum* Weiss, 1954	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidium clavatum Cushman = *Elphidium incertum* Williamson var. *clavatum* Cushman, 1930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidium frigidum Cushman, 1933	1	1	0	0	2	10	0	0	0	0	0	2	0	0	8	1
Elphidium groenlandicum Cushman, 1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidium incertum Williamson = *Polystomella umbilicata* Walker var. *incerta* Williamson, 1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidium subarcticum Cushman, 1944	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	4	2	8	27	6	4	6	22	23	36	53	20	1	2	13	4
Epistominella vitrea Parker, 1953	8	0	11	38	30	16	18	11	19	16	5	9	20	37	1	0
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	0	1	2	0	0	1	0	0	0	0	0	0	1	0	1	0
Favulina melo d'Orbigny = *Oolina melo* d'Orbigny, 1839	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0
Favulina squamosa Montagu = *Vermiculum squamosum* Montagu, 1803	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Fissurina annectens Burrows and Holland = *Lagena annectens* Burrows and Holland, 1895	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina clathrata Brady = *Lagena clathrata* Brady, 1884	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Fissurina curvitubulosa McCulloch, 1977	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Fissurina derogata McCulloch, 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina eburnea Buchner, 1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina inflatiperforata McCulloch, 1977	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0
Fissurina kerguelensis Parr, 1950	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Fissurina laevigata Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	1	1	0	2	0	0	0	0	1	2	0	0	0	2	1
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	2	11	1	1	1	1	0	1	2	1	2	5	0	0	1	0
Fissurina orbignyana Seguenza, 1862	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Fissurina pseudorbignyana Buchner = *Lagena pseudoorbignyana* Buchner, 1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina quadricostulata Reuss = *Lagena quadricostulata* Reuss, 1870	0	0	0	1	0	2	0	1	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	2	0	0	0	0	0	0	0	24	33	244	376	0	0	0	0
Gaudryina rudis Wright 1900	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
Gavelinopsis caledonia Murray and Whittaker, 2001	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gavelinopsis nitida Williamson = *Rotalina nitida*, Williamson 1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	4	7	12	0	6	2	1	0	3	0	0	0	0	0	8	1
Glandulina laevigata d'Orbigny = *Nodosaria laevigata* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Glandulina rotundata Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Globobulimina affinis d'Orbigny = *Bulimia affinis* d'Orbigny, 1839	1	1	0	1	0	0	0	0	0	1	0	0	0	0	1	231
Globocassidulina subglobosa group	41	14	46	23	15	9	14	30	70	46	30	4	21	33	3	0

Appendix B (continued)

sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
sum counts	540	450	518	552	266	537	270	317	528	373	628	626	376	291	370	821
Glomospira gordialis Parker and Jones = *Trochammina squamata* Jones and Parker var. *charoides Jones & Parker, 1860*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidina neosoldanii Brotzen, 1936	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidina soldanii d'Orbigny, 1826	0	1	1	0	2	4	0	0	0	0	0	0	0	0	0	0
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	0	0	1	0	4	5	0	0	0	0	12	0	0	0	0	0
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	0	0	11	14	7	0	0	2	0	0	0	0	6	14	0	0
Hanzawaia concentrica Cushman = *Truncatulina concentrica* Cushman, 1918	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplophragmoides membranaceum Höglund, 1947	0	0	0	0	3	2	2	0	0	0	0	0	0	0	0	0
Hoeglundina elegans d'Orbigny = *Rotalia (Turbinulina) elegans* d'Orbigny, 1826	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Homalohedra apiopleura Loeblich and Tappan = *Lagena apiopleura* Loeblich and Tappan, 1953	1	1	2	0	0	0	0	0	0	0	0	0	0	0	2	0
Homalohedra borealis Loeblich and Tappan = *Entosolenia costata* Williamson, 1954	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hopkinsina atlantica Cushman = *Hopkinsina pacifica* Cushman, 1933	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	69
Hormosinella guttifera Brady = *Lituola guttifera* Brady, 1881	0	0	1	0	0	0	0	1	1	9	5	2	0	0	0	0
Hormosina globulifera Brady, 1879	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	1	0	4	34	2	8	2	0	0	0	0	0	27	4	7	43
Hyperammina sp.	1	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0
Hyrrokkin sarcophaga Cedhagen, 1994	0	0	0	0	2	1	0	0	0	0	0	0	0	1	0	0
Ioanella tumidula Brady = *Truncatulina tumidula* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Labrospira canariensis d'Orbigny = *Nonionina canariensis* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labrospira crassimargo Norman = *Haplophragmoides crassimargo* Norman, 1892	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	4
Lagena lateralis Cushman, 1913	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Lagena meridionalis Wiesner = *Lagena gracilis* Williamson var. *meridionalis* Wiesner, 1931	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lagena sulcata Walker and Jacob = *Serpula sulcata* Walker and Jacob, 1798	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lagena trigonabicarinata Balkwill and Millett, 1884	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Lagenosolenia bradyiformata McCulloch, 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lenticulina gibba d'Orbigny = *Cristellaria gibba* d'Orbigny, 1826	0	1	0	0	0	0	0	0	0	1	0	0	0	0	2	0
Lenticulina inornata d'Orbigny = *Robulina inornata* d'Orbigny, 1846	1	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0
Lenticulina orbicularis d'Orbigny = *Robulina orbicularis* d'Orbigny, 1826	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Lenticulina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	26	90	53	23	6	35	17	3	3	2	8	5	0	3	48	2
Marginulina striata d'Orbigny, 1852	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Marsipella elongata Norman, 1878	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	17	16	8	18	9	4	35	60	72	8	2	0	11	14	27	16
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	0	0	2	7	0	0	7	0	0	0	0	0	0	0	34	13
Miliolinella elongata Kruit = *Miliolinella circularis* Bornemann var. *elongata* Kruit, 1955	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	1	10	3	0	6	0	0	0	0	0	0	0	0	0	1	0
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Neoeponides haidingerii d'Orbigny = *Rotalina haidingerii* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonion depressulus Walker and Jacob = *Nautilus depressulus* Walker and Jacob, 1798	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nonion fabum Fichtel and Moll = *Nautilus faba* Fichtel and Moll, 1798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonion pauperatus Balkwill and Wright = *Nonionina pauperata* Balkwill and Wright, 1885	2	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0
Nonionella iridea Heron-Allen and Earland, 1932	1	4	2	7	4	4	2	1	7	2	1	2	0	0	5	0

Appendix B (continued)

sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
sum counts	540	450	518	552	266	537	270	317	528	373	628	626	376	291	370	821
Nonionellina labradorica Dawson = *Nonionina labradorica* Dawson, 1860	2	0	1	0	0	1	0	0	0	0	0	0	1	0	0	2
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	4	0	0	10	1	0	0	0	1	2	0	0	2	1	1	3
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Oolina globosa Montagu = *Vermiculum globosum* Montagu, 1803	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	5	0	0	0	1	1	0	12	15	0	0	0	0
Ovulina striata Seguenza, 1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paliolatella semimarginata Reuss = *Fissurina semimarginata* Reuss, 1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parafissurina botteliformis Brady = *Lagena botelliformis* Brady, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parafissurina felsinea Fornasini = *Lagena felsinea* Fornasini, 1894	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Parafissurina marginoradiata McCulloch, 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parafissurina subquadrata Parr = *Fissurina subquadrata* Parr, 1945	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	0	0	0	1	1	1	1	6	2	4	4	0	0	0	1	3
Patellina corrugata Williamson, 1858	5	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Pelosina cylindrica Brady, 1884	0	0	0	1	0	1	0	7	0	0	0	0	0	0	0	0
Planulina ariminensis d'Orbigny, 1826	0	0	0	0	1	5	3	0	0	0	0	0	5	0	0	0
Procerolagena gracilis Costa = *Amphorina gracilis* Costa, 1856	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Protelphidium anglicum Murray, 1965	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
Psammosphaera fusca Schulze, 1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia bulloides d'Orbigny = *Nonionina bulloides* d'Orbigny, 1846	2	0	0	1	1	1	0	0	3	1	1	0	3	4	0	0
Pullenia osloensis Feyling-Hanssen = *Pullenia quinqueloba* Reuss var. *minuta* Feyling-Hanssen, 1954	0	3	0	3	2	1	2	1	0	0	0	0	0	1	0	1
Pullenia quadriloba Reuss = *Pullenia compressiuscula* Reuss var. *quadriloba* Reuss, 1867	2	1	1	2	0	3	5	6	8	0	0	0	0	0	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	10	7	0	1	3	0	2	1	3	11	1	1	0	0	0	0
Pullenia subcarinata d'Orbigny = *Nonionina subcarinata* d'Orbigny, 1839	0	1	0	4	7	2	1	1	4	0	5	2	0	0	6	59
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Pyrgo constricta Costa = *Biloculina constricta* Costa, 1856	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo elongata d'Orbigny = *Biloculina elongata* d'Orbigny, 1826	1	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Pyrgo lucernula Schwager = *Biloculina lucernula* Schwager, 1866	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo oblonga d'Orbigny = *Biloculina oblonga* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo rotalaria Loeblich and Tappan, 1953	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Pyrgo sarsi Schlumberger = *Biloculina sarsi* Schlumberger, 1891	0	0	0	0	0	0	0	0	0	0	9	52	0	0	0	0
Pyrgo subsphaerica d'Orbigny = *Biloculina subsphaerica* d'Orbigny, 1840	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo williamsoni Silvestri = *Biloculina williamsoni* Silvestri, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pyrulina gutta d'Orbigny = *Polymorphina* (*Pyruline*) *gutta* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina lamarckiana d'Orbigny, 1839	2	3	0	0	0	2	1	1	0	0	2	0	0	0	0	0
Quinqueloculina arctica Cushman, 1933	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Quinqueloculina cuvieriana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina seminula Linnaeus = Serpula seminulum Linnaeus, 1758	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Quinqueloculina viennensis Le Calvez and Le Calvez, 1958	8	0	0	0	3	5	0	0	0	0	0	0	0	0	0	0
Recurvoides trochamminiformis Höglund, 1947	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Reophax difflugiformis Brady, 1879	1	1	0	0	0	0	0	53	59	12	0	1	0	0	2	0
Reophax nodulosa Brady, 1879	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Reophax scorpiurus de Montfort, 1808	1	0	0	0	0	0	8	6	61	19	5	0	0	0	1	1

Appendix B (continued)

sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
sum counts	540	450	518	552	266	537	270	317	528	373	628	626	376	291	370	821
Rhabdammina abyssorum Sars, 1869	0	0	0	0	1	1	0	4	2	4	9	3	0	0	0	4
Robertinoides brady Cushman and Parker, 1936	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Robertinoides pumilum Höglund, 1947	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosalina anomala Terquem, 1875	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rosalina brady Cushman = *Discorbina globularis* d'Orbigny var. *bradi* Cushman, 1915	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosalina globularis d'Orbigny, 1826	0	4	5	0	1	0	1	0	0	0	0	0	0	2	0	0
Rosalina vilardeboana d'Orbigny, 1839	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0
Rupertina stabilis Wallich, 1877	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Saccammina sphaerica Sars, 1868	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	4
Saccorhiza ramosa Brady = *Hyperammina ramosa* Brady, 1879	1	0	0	1	0	0	21	6	0	0	0	0	0	0	0	0
Sigmoidella elegantissima Parker and Jones = *Polymorphina elegantissima* Parker and Jones, 1865	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	0	0	0	0	0	7	0	0	0	0	0	0	2	2	0	0
Sphaeroidina bulloides d'Orbigny, 1826	0	0	0	1	0	0	0	0	0	0	0	0	3	2	0	0
Spirillina vivipara Ehrenberg, 1843	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Spiroloculina excavata d'Orbigny, 1846	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroloculina tenuiseptata Brady, 1884	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	0	0	8	4	3	1	0	0	0	0	0	0	0	0	3	1
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	2	0	2	0	0	0	0	4	0	1	2	0	0	0	7	12
Stainforthia loeblichi Feyling-Hanssen = *Virgulina loeblichi* Feyling-Hanssen, 1954	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia schreibersiana Carter = *Virgulina schreibersiana* Carter, 1880	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5
Stainforthia skagerakensis Höglund = *Virgulina skagerakensis* Höglund, 1947	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	7
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia agglutinans d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Textularia pseudogramen d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia tenuissima Earland, 1933	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	57
Textularia truncata Höglund, 1947	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Trifarina brady Cushman, 1923	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Triloculina tricarinata d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0
Trisegmentina compressa Wiesner, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tritaxis fusca Williamson = *Rotalina fusca* Williamson, 1858	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1
Trochammina inflata Montagu = *Nautilus inflatus* Montagu, 1808	0	0	0	1	3	3	2	3	0	0	0	0	0	0	0	0
Trochammina robertsoni Brady, 1887	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	12
Trochammina squamata Jones and Parker, 1860	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Usbekistania charoides Jones and Parker = *Trochammina squamata* Jones and Parker var. *charoides* Jones and Parker, 1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uvigerina auberiana d'Orbigny, 1839	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Uvigerina mediterranea Hofker, 1932	0	0	0	0	0	0	0	0	0	0	0	0	17	1	0	0
Uvigerina peregrina Cushman, 1923	0	0	0	42	0	5	3	0	1	0	0	0	104	4	0	9
Valvulineria bradyana Fornasini = *Discorbina bradyana* Fornasini, 1900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Verneulina propinqua Brady, 1884	1	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0

Appendix B (continued)

sample number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
sum counts	426	333	404	303	242	272	403	465	310	487	438	335	315	301	407	342
Adercotryma wrightii Brönnimann and Whittaker, 1987	0	5	0	0	0	0	1	0	0	0	0	0	1	0	10	4
Ammobaculites agglutinans d'Orbigny = *Spirolina agglutinans* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammodiscus incertus d'Orbigny = *Operculina incerta* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammolagena clavata Jones and Parker = *Trochammina irregularis* d'Orbigny var. *clavata* Jones and Parker, 1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	3	18	1	24	3	26	9	24	11	38	23	42	5	6	3	0
Astrononion gallowayi Loeblich and Tappan, 1953	4	10	19	1	1	2	16	8	2	2	6	2	2	4	15	1
Bathysiphon filiformis M. Sars, 1872	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bigenerina cylindrica Cushman, 1922	21	5	0	0	0	0	0	0	0	0	0	0	2	0	0	9
Bigenerina nodosaria d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Biloculinella depressa Wiesner = *Biloculina labiata* Schlumberger var. *depressa* Wiesner, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biloculinella globula Bornemann = *Biloculina globulus* Bornemann, 1855	0	0	1	0	0	1	0	1	0	0	1	1	0	0	0	0
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	0	1	0	1	0	1	1	0	0	3	1	0	0	0	0	0
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	6	2	0	0	0	0	0	0	0	0	0	0	4	0	0	15
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	0	2	0	0	0	0	2	0	2	1	0	0	0	0	0	0
Bolivina pseudopunctata Höglund, 1947	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	3	2	0	0	0	0	0	0	0	0	0	0	4	0	1	20
Bolivina spinescens Cushman, 1911	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bolivina subspinescens Cushman, 1922	0	0	0	1	0	0	1	3	0	1	5	0	2	0	1	2
Botellina labyrinthica Brady, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buccella frigida Cushman = *Pulvinulina frigida* Cushman, 1922	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0
Buccella tenerrima Bandy = *Rotalia tenerrima* Bandy, 1950	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulimina aculeata d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Bulimina marginata d'Orbigny, 1826	15	26	0	0	0	0	0	0	0	2	0	2	37	15	4	21
Cassidulina carinata Silvestri = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896	28	26	0	1	0	0	4	0	0	2	1	1	1	1	7	1
Cassidulina laevigata group	8	3	11	9	5	4	8	18	17	62	28	15	28	24	21	25
Cassidulinoides oblonga Reuss = *Cassidulina oblonga* Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cibicides refulgens de Montfort, 1808	0	17	14	26	45	29	19	99	36	7	66	20	11	27	7	2
Cibicides ungerianus d'Orbigny = *Rotalia ungeriana* d'Orbigny, 1846	5	0	25	1	0	0	1	0	0	4	1	0	0	0	0	0
Cibicides/Cibicidoides juv	0	0	11	11	0	1	13	0	4	0	2	0	1	1	2	4
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	0	0	1	0	0	0	8	0	0	1	0	3	0	1	0	0
Cibicidoides sp.	0	12	27	13	3	8	40	10	11	4	1	4	4	8	4	1
Cibicidoides pachyderma Rzehak, 1886	5	31	103	76	73	77	17	97	81	45	80	30	34	37	13	4
Cibicidoides pseudoungerianus Cushman =*Truncatulina pseudoungeriana* Cushman, 1922	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clavulina primaeva Cushman, 1913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cornuspira foliacea Philippi = *Orbis foliaceus* Philippi, 1844	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cribroelphidium excavatum Terquem = *Polystomella excavata* Terquem, 1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cribrostomoides jeffreysii Williamson = *Nonionina jeffreysii* Williamson, 1858	0	0	0	0	0	0	0	0	3	0	2	0	2	2	14	3
Cribrostomoides subglobosum Cushman = *Haplophragmoides subglobosum*, Cushman, 1910	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cushmania plumigera Brady = *Lagena plumigera* Brady, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B (continued)

sample number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
sum counts	426	333	404	303	242	272	403	465	310	487	438	335	315	301	407	342
Cycloforina angularis d'Orbigny = *Quinqueloculina angularis* d'Orbigny, 1905	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cycloforina laevigata d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cycloforina stalkeri Loeblich and Tappan, 1953	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Dentalina advena Cushman = *Nodosaria advena* Cushman, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discammina compressa Goes, 1882	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	0	0	18	59	86	24	35	31	19	0	64	33	0	1	0	0
Discorbinella bertheloti d'Orbigny = *Rosalina bertheloti* d'Orbigny, 1839	0	0	1	5	0	3	9	5	1	10	3	7	4	5	4	1
Eggerella bradyi Cushman = *Verneuilina bradyi* Cushman, 1911	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	18	6	0	0	0	0	0	0	0	0	0	0	1	0	12	16
Elphidiella hannai Cushman and Grant = *Elphidium hannai* Cushman and Grant, 1927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidiella albiumbilicata Weiss = *Nonion pauciloculum* Cushman subsp. *albiumbilicatum* Weiss, 1954	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Elphidium clavatum Cushman = *Elphidium incertum* Williamson var. *clavatum* Cushman, 1930	0	0	14	1	1	0	0	0	0	0	0	0	2	0	2	0
Elphidium frigidum Cushman, 1933	3	0	0	0	0	0	0	0	0	0	0	0	3	0	4	1
Elphidium groenlandicum Cushman, 1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidium incertum Williamson = *Polystomella umbilicata* Walker var. *incerta* Williamson, 1858	0	0	1	0	2	0	0	0	0	0	0	0	0	1	0	0
Elphidium subarcticum Cushman, 1944	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	1	10	1	0	0	7	5	5	9	10	1	9	3	12	5	6
Epistominella vitrea Parker, 1953	3	2	0	7	1	2	12	9	6	21	9	20	0	0	0	0
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	0	1	0	0	0	0	1	1	0	2	0	1	0	0	0	0
Favulina melo d'Orbigny = *Oolina melo* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Favulina squamosa Montagu = *Vermiculum squamosum* Montagu, 1803	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Fissurina annectens Burrows and Holland = *Lagena annectens* Burrows and Holland, 1895	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
Fissurina clathrata Brady = *Lagena clathrata* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina curvitubulosa McCulloch, 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina derogata McCulloch, 1977	0	0	0	0	0	1	1	0	2	0	0	1	0	0	1	0
Fissurina eburnea Buchner, 1940	0	0	0	0	0	1	3	1	0	4	3	2	0	0	1	1
Fissurina inflatiperforata McCulloch, 1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina kerguelensis Parr, 1950	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina laevigata Reuss, 1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	0	0	0	0	0	0	2	1	3	1	1	1	2	2	0
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	0	0	4	2	0	2	5	7	1	4	4	1	1	0	9	0
Fissurina orbignyana Seguenza, 1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina pseudorbignyana Buchner = *Lagena pseudoorbignyana* Buchner, 1940	0	0	2	1	0	0	0	1	1	0	0	1	0	0	0	0
Fissurina quadricostulata Reuss = *Lagena quadricostulata* Reuss, 1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaudryina rudis Wright 1900	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0
Gavelinopsis caledonia Murray and Whittaker, 2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gavelinopsis nitida Williamson = *Rotalina nitida*, Williamson 1858	0	0	0	0	2	0	0	2	0	0	1	0	0	0	0	0
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	0	10	1	1	0	7	5	8	3	4	4	0	5	1	13	0
Glandulina laevigata d'Orbigny = *Nodosaria laevigata* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glandulina rotundata Reuss, 1850	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
Globobulimina affinis d'Orbigny = *Bulimia affinis* d'Orbigny, 1839	46	3	0	0	0	0	2	0	0	1	0	0	0	2	3	85
Globocassidulina subglobosa group	3	3	19	18	5	19	32	31	27	55	49	24	1	7	9	0

Appendix B (continued)

sample number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
sum counts	426	333	404	303	242	272	403	465	310	487	438	335	315	301	407	342
Glomospira gordialis Parker and Jones = *Trochammina squamata* Jones and Parker var. *charoides Jones & Parker, 1860*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidina neosoldanii Brotzen, 1936	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gyroidina soldanii d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	0	0	0	1	0	2	15	9	5	8	6	8	6	3	8	0
Hanzawaia concentrica Cushman = *Truncatulina concentrica* Cushman, 1918	0	0	0	4	0	0	8	6	6	6	12	4	3	3	10	0
Haplophragmoides membranaceum Höglund, 1947	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hoeglundina elegans d'Orbigny = *Rotalia (Turbinulina) elegans* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Homalohedra apiopleura Loeblich and Tappan = *Lagena apiopleura* Loeblich and Tappan, 1953	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Homalohedra borealis Loeblich and Tappan = *Entosolenia costata* Williamson, 1954	0	0	1	0	0	0	3	1	0	0	0	3	0	0	1	0
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0
Hopkinsina atlantica Cushman = *Hopkinsina pacifica* Cushman, 1933	13	3	0	0	0	0	0	0	0	0	0	0	1	5	2	0
Hormosinella guttifera Brady = *Lituola guttifera* Brady, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hormosina globulifera Brady, 1879	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	11	8	0	0	0	0	3	0	1	44	2	9	34	9	5	63
Hyperammina sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Hyrrokkin sarcophaga Cedhagen, 1994	0	0	0	0	0	0	1	0	0	0	0	4	0	1	1	0
Ioanella tumidula Brady = *Truncatulina tumidula* Brady, 1884	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Labrospira canariensis d'Orbigny = *Nonionina canariensis* d'Orbigny, 1839	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Labrospira crassimargo Norman = *Haplophragmoides crassimargo* Norman, 1892	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagena lateralis Cushman, 1913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagena meridionalis Wiesner = *Lagena gracilis* Williamson var. *meridionalis* Wiesner, 1931	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Lagena sulcata Walker and Jacob = *Serpula sulcata* Walker and Jacob, 1798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagena trigonabicarinata Balkwill and Millett, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagenosolenia bradyiformata McCulloch, 1977	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lenticulina gibba d'Orbigny = *Cristellaria gibba* d'Orbigny, 1826	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lenticulina inornata d'Orbigny = *Robulina inornata* d'Orbigny, 1846	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Lenticulina orbicularis d'Orbigny = *Robulina orbicularis* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lenticulina sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	4	34	89	14	6	26	41	37	16	19	19	10	24	53	82	2
Marginulina striata d'Orbigny, 1852	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marsipella elongata Norman, 1878	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	20	19	20	2	2	6	27	10	12	15	15	10	19	10	18	8
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	48	17	1	0	0	1	3	3	0	25	2	0	35	22	42	4
Miliolinella elongata Kruit = *Miliolinella circularis* Bornemann var. *elongata* Kruit, 1955	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	0	0	4	4	2	3	8	0	0	0	2	1	0	0	1	1
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neoeponides haidingerii d'Orbigny = *Rotalina haidingerii* d'Orbigny, 1846	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1
Nonion depressulus Walker and Jacob = *Nautilus depressulus* Walker and Jacob, 1798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonion fabum Fichtel and Moll = *Nautilus faba* Fichtel and Moll, 1798	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nonion pauperatus Balkwill and Wright = *Nonionina pauperata* Balkwill and Wright, 1885	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Nonionella iridea Heron-Allen and Earland, 1932	0	8	1	1	1	2	3	3	3	4	1	0	5	2	14	3

Appendix B (continued)

sample number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
sum counts	426	333	404	303	242	272	403	465	310	487	438	335	315	301	407	342
Nonionellina labradorica Dawson = *Nonionina labradorica* Dawson, 1860	5	1	1	1	2	0	1	1	0	1	0	0	0	0	2	2
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	4	2	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oolina globosa Montagu = *Vermiculum globosum* Montagu, 1803	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ovulina striata Seguenza, 1862	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Paliolatella semimarginata Reuss = *Fissurina semimarginata* Reuss, 1870	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Parafissurina botteliformis Brady = *Lagena botelliformis* Brady, 1881	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Parafissurina felsinea Fornasini = *Lagena felsinea* Fornasini, 1894	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parafissurina marginoradiata McCulloch, 1977	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0
Parafissurina subquadrata Parr = *Fissurina subquadrata* Parr, 1945	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Patellina corrugata Williamson, 1858	0	0	2	1	0	1	9	1	3	7	0	1	0	2	3	0
Pelosina cylindrica Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planulina ariminensis d'Orbigny, 1826	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Procerolagena gracilis Costa = *Amphorina gracilis* Costa, 1856	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Protelphidium anglicum Murray, 1965	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psammosphaera fusca Schulze, 1875	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Pullenia bulloides d'Orbigny = *Nonionina bulloides* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia osloensis Feyling-Hanssen = *Pullenia quinqueloba* Reuss var. *minuta* Feyling-Hanssen, 1954	0	0	0	3	0	5	1	13	11	10	6	6	5	3	15	14
Pullenia quadriloba Reuss = *Pullenia compressiuscula* Reuss var. *quadriloba* Reuss, 1867	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia subcarinata d'Orbigny = *Nonionina subcarinata* d'Orbigny, 1839	56	0	0	0	0	0	5	1	0	6	0	5	0	1	3	0
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pyrgo constricta Costa = *Biloculina constricta* Costa, 1856	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo elongata d'Orbigny = *Biloculina elongata* d'Orbigny, 1826	0	0	0	0	0	0	1	0	0	0	2	0	0	0	1	0
Pyrgo lucernula Schwager = *Biloculina lucernula* Schwager, 1866	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Pyrgo oblonga d'Orbigny = *Biloculina oblonga* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Pyrgo rotalaria Loeblich and Tappan, 1953	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo sarsi Schlumberger = *Biloculina sarsi* Schlumberger, 1891	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo subsphaerica d'Orbigny = *Biloculina subsphaerica* d'Orbigny, 1840	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0
Pyrgo williamsoni Silvestri = *Biloculina williamsoni* Silvestri, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrulina gutta d'Orbigny = *Polymorphina* (*Pyruline*) *gutta* d'Orbigny, 1826	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Quinqueloculina lamarckiana d'Orbigny, 1839	0	0	2	0	0	0	0	0	0	0	0	3	1	0	1	0
Quinqueloculina arctica Cushman, 1933	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Quinqueloculina cuvieriana d'Orbigny, 1839	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0
Quinqueloculina seminula Linnaeus = Serpula seminulum Linnaeus, 1758	0	2	0	0	0	1	0	0	0	0	0	0	1	1	1	0
Quinqueloculina viennensis Le Calvez and Le Calvez, 1958	0	2	0	0	1	0	2	3	6	1	1	0	0	1	0	1
Recurvoides trochamminiformis Höglund, 1947	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0
Reophax difflugiformis Brady, 1879	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0
Reophax nodulosa Brady, 1879	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax scorpiurus de Montfort, 1808	4	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0

Appendix B (continued)

sample number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
sum counts	426	333	404	303	242	272	403	465	310	487	438	335	315	301	407	342
Rhabdammina abyssorum Sars, 1869	4	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
Robertinoides brady Cushman and Parker, 1936	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Robertinoides pumilum Höglund, 1947	0	0	0	0	0	0	1	1	0	0	0	2	0	2	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Rosalina anomala Terquem, 1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosalina brady Cushman = *Discorbina globularis* d'Orbigny var. *bradi* Cushman, 1915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosalina globularis d'Orbigny, 1826	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0
Rosalina vilardeboana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rupertina stabilis Wallich, 1877	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saccammina sphaerica Sars, 1868	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
Saccorhiza ramosa Brady = *Hyperammina ramosa* Brady, 1879	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Sigmoidella elegantissima Parker and Jones = *Polymorphina elegantissima* Parker and Jones, 1865	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	2	2	0	0	0	0	0	0	0	0	0	3	0	2	0	0
Sphaeroidina bulloides d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	9	0	4	0	0	0	0
Spirillina vivipara Ehrenberg, 1843	0	0	0	0	0	4	3	0	1	0	0	0	0	0	0	0
Spiroloculina excavata d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroloculina tenuiseptata Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	0	6	1	3	0	1	1	1	0	0	1	2	3	3	7	0
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	11	2	0	0	0	0	0	0	0	0	0	0	1	2	0	3
Stainforthia loeblichi Feyling-Hanssen = *Virgulina loeblichi* Feyling-Hanssen, 1954	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Stainforthia schreibersiana Carter = *Virgulina schreibersiana* Carter, 1880	5	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Stainforthia skagerakensis Höglund = *Virgulina skagerakensis* Höglund, 1947	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Textularia agglutinans d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Textularia pseudogramen d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0	0
Textularia tenuissima Earland, 1933	30	11	0	0	0	0	0	0	0	0	0	0	1	1	0	4
Textularia truncata Höglund, 1947	0	1	0	0	0	0	0	0	0	0	0	0	2	0	4	0
Trifarina brady Cushman, 1923	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0
Triloculina tricarinata d'Orbigny, 1826	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Trisegmentina compressa Wiesner, 1923	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0
Tritaxis fusca Williamson = *Rotalina fusca* Williamson, 1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trochammina inflata Montagu = *Nautilus inflatus* Montagu, 1808	0	0	0	0	0	0	0	0	0	1	0	0	1	1	4	0
Trochammina robertsoni Brady, 1887	9	3	0	0	0	0	0	0	1	0	0	0	2	1	0	2
Trochammina squamata Jones and Parker, 1860	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Usbekistania charoides Jones and Parker = *Trochammina squamata* Jones and Parker var. *charoides* Jones and Parker, 1860	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
Uvigerina auberiana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uvigerina mediterranea Hofker, 1932	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uvigerina peregrina Cushman, 1923	23	3	0	0	0	0	0	1	1	19	0	19	5	1	1	3
Valvulineria bradyana Fornasini = *Discorbina bradyana* Fornasini, 1900	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5
Verneulina propinqua Brady, 1884	0	0	0	0	0	0	1	1	0	0	5	1	0	1	0	0

Appendix C. Species list and quantitative data of planktonic foraminifera from the Norwegian Margin (Chapter 3). Generic names are in accordance with Loeblich and Tappan (1987).

sample number	3	4	5	6	7	8	9	10	11	12	13	14	19	20	22	23	24	25	26	27
sum counts	802	664	383	602	875	809	870	831	950	1164	188	832	24	47	43	117	101	122	189	55
Globigerina bulloides d'Orbigny, 1826	91	78	10	62	128	43	86	67	139	218	28	42	3	1	1	0	1	1	3	1
Globigerinella calida Parker = *Globigerina calida* Parker, 1926	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Globigerinella siphonifera d'Orbigny = *Globigerina siphonifera* d'Orbigny, 1839	2	1	0	2	2	0	1	0	4	0	1	5	0	0	0	0	0	0	0	0
Globigerinita glutinata Egger = *Globigerina glutinata* Egger, 1893	98	35	22	19	43	74	73	221	51	43	32	69	1	24	12	79	67	87	74	25
Globigerinita uvula Ehrenberg = *Pylodexia uvula* Ehrenberg, 1861	192	176	192	136	176	213	180	66	157	181	30	113	0	0	0	10	7	17	13	6
Globigerinoides ruber d'Orbigny = *Globigerina rubra* d'Orbigny, 1839	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Globigerinoides sacculifer Brady = *Globigerina sacculifera* Brady, 1877	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Globorotalia inflata d'Orbigny = *Globigerina inflata* d'Orbigny, 1839	3	0	1	9	7	8	20	23	13	19	0	2	0	0	0	0	0	0	0	0
Globorotalia scitula Brady = *Pulvinulina scitula* Brady, 1882	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Neogloboquadrina dutertrei d'Orbigny = *Globigerina dutertrei* d'Orbigny, 1839	5	1	0	0	2	3	8	5	19	15	0	0	0	0	0	0	0	0	0	0
Neogloboquadrina incompta Cifelli = *Globigerina incompta* Cifelli, 1961	302	262	46	144	275	220	326	200	249	290	63	473	1	2	23	1	13	6	48	14
Neogloboquadrina pachyderma Ehrenberg = *Aristospira pachyderma* Ehrenberg, 1861	18	17	4	17	39	25	96	69	82	286	6	6	6	2	0	0	0	2	0	0
Orbulina universa d'Orbigny, 1839	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Tenuitella iota Parker = *Globigerinita iota* Parker, 1962	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Tenuitella parkerae Brönnimann and Resig = *Globorotalia parkerae* Brönnimann and Resig, 1971	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Truncorotalia truncatulinoides d'Orbigny = *Rotalina truncatulinoides* d'Orbigny, 1839	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turborotalita cristata Heron-Allen and Earland = *Globigerina cristata* Heron-Allen and Earland, 1929	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Turborotalita humilis Brady = *Truncatulina humilis* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1
Turborotalita quinqueloba Natland = *Globigerina quinqueloba* Natland, 1938	89	94	108	213	201	221	80	176	236	112	26	121	11	17	7	27	13	8	51	8

Appendix D. Indicator species for phytodetritus flux, organic carbon flux, oxygen level, and current strength on the Norwegian margin according to Murray (2006) and Margreth et al. (2009) and the references cited therein.

phytodetritus indicator species	organic carbon flux indicator species	oxygen level indicator species	current strength indicator species
Epistominella spp.	*Bathysiphon filiformis* M. Sars, 1872	*Bathysiphon filiformis* M. Sars, 1872	*Angulogerina angulosa* Williamson, 1858
Globocassidulina spp.	*Bolivina* spp.	*Cassidulina* spp.	*Cassidulina* spp.
Hormosinella guttifera Brady, 1881	*Bulimina* spp.	*Cassidulinoides oblonga* Reuss, 1850	*Cassidulinoides oblonga* Reuss, 1850
Nonion depressulus Walker and Jacob, 1798	*Cribrostomoides* spp.	*Cibicides* spp.	*Cibicides refulgens* de Montfort, 1808
Nonionella iridea Heron-Allen and Earland, 1932	*Elphidiella* spp.	*Cibicidoides* spp.	*Cornuspira* spp.
Spiroloculina spp.	*Elphidium* spp.	*Discanomalina coronata* Parker and Jones, 1857	*Cribrostomoides* spp.
Triloculina tricarinata d'Orbigny, 1826	*Epistominella* spp.	*Elphidiella* spp.	*Discanomalina coronata* Parker and Jones, 1857
Uvigerina mediterranea Hofker, 1932	*Globobulimina affinis* d'Orbigny, 1839	*Elphidium* spp.	*Discorbinella bertheloti* d'Orbigny, 1839
Uvigerina peregrina Cushman, 1923	*Globocassidulina* spp.	*Fontbotia wuellerstorfi* Schwager, 1866	*Elphidiella albiumbilicata* Weiss, 1954
	Hyalinea balthica Schröter, 1783	*Globocassidulina* spp.	*Elphidium clavatum* Cushman, 1930
	Lagena spp.	*Lenticulina* spp.	*Elphidium frigidum* Cushman, 1933
	Lenticulina spp.	*Lobatula lobatula* Walker and Jacob, 1798	*Elphidium groenlandicum* Cushman, 1933
	Melonis spp.	*Pyrgo* spp.	*Elphidium incertum* Williamson, 1858
	Nonion spp.	*Quinqueloculina* spp.	*Elphidium subarcticum* Cushman, 1944
	Nonionella spp.	*Robertinoides* spp.	*Fontbotia wuellerstorfi* Schwager, 1866
	Pullenia spp.	*Triloculina tricarinata* d'Orbigny, 1826	*Gaudryina rudis* Wright 1900
	Robertinoides spp.		*Gavelinopsis* spp.
	Stainforthia spp.		*Hanzawaia* spp.
	Uvigerina spp.		*Hyperammina* sp.
	Valvulineria bradyana Fornasini, 1900		*Lobatula lobatula* Walker and Jacob, 1798
			Miliolinella spp.
			Paratrochammina challengeri Brönnimann and Whittaker, 1988
			Patellina corrugata Williamson, 1858
			Planulina ariminensis d'Orbigny, 1826
			Psammosphaera fusca Schulze, 1875
			Reophax spp.
			Rosalina spp.
			Rupertina stabilis Wallich, 1877
			Saccammina sphaerica Sars, 1868
			Saccorhiza ramosa Brady, 1879
			Spiroloculina spp.
			Spiroplectinella wrighti Silvestri, 1903
			Triloculina tricarinata d'Orbigny, 1826
			Tritaxis fusca Williamson, 1858
			Trochammina spp.

Appendix E. Species list and quantitative data of benthic foraminifera from the Alboran Sea (Chapter 4). Generic names are in accordance with Loeblich and Tappan (1987).

sample number	M25	M35	M45	M55	M65	M75	M84	M94	M98	M100	M102	M107	M115	M126
sum counts	422	327	328	250	243	273	274	319	240	184	301	235	364	434
Allassoida virgola Brady = *Sagrina virgola* Brady, 1879	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	16	8	13	13	5	12	6	13	9	5	14	5	9	6
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	1	2	1	1	0	1	2	1	2	4	0	1	1	0
Archimerismus subnodosus Brady = *Hyperammina subnodosa* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Astacolus patens Brady = *Vaginulina patens* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Asterigerinata mamilla Williamson = *Rotalina mamilla* Williamson, 1858	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Asterigerinata planorbis d'Orbigny = *Asterigerina planorbis* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astrononion stelligerum d'Orbigny = *Nonionina stelligera* d'Orbigny, 1839	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Bigenerina nodosaria d'Orbigny, 1826	16	11	9	3	6	2	5	4	6	2	5	2	1	3
Biloculinella globula Bornemann = *Biloculina globulus* Bornemann, 1855	0	1	0	0	0	0	1	1	1	3	0	0	0	0
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	3	2	7	3	4	2	0	0	0	0	2	1	2	1
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	17	15	24	5	11	6	7	6	6	4	5	2	3	14
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	3	8	7	3	4	0	2	2	3	4	2	3	7	3
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	1	0	0	0	1	0	0	0	0	1	1	2	2	2
Bolivina pseudopunctata Höglund, 1947	2	2	0	1	0	2	3	2	2	1	2	1	2	6
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	15	5	7	6	3	1	4	2	4	1	3	4	6	11
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	0	0	0	1	1	0	2	3	1	5	3	2	1	5
Bolivina subaenariensis Cushman = *Brizalina subaenariensis* Cushman, 1922	2	0	0	0	0	0	0	1	1	2	5	0	1	4
Bolivina subspinescens Cushman, 1922	2	5	3	3	4	1	0	2	3	2	3	5	2	3
Bulimina aculeata d'Orbigny, 1826	1	0	6	0	1	2	2	4	2	4	2	4	11	6
Bulimina marginata d'Orbigny, 1826	25	19	26	15	15	21	24	26	21	15	19	27	26	25
Bulimina striata d'Orbigny, 1843	1	1	3	3	2	4	6	6	6	12	9	6	8	11
Cancris auriculatus Fichtel and Moll= *Nautilus acutauricularis* Fichtel and Moll, 1798	0	0	0	0	0	0	0	1	1	0	0	0	1	0
Cassidulina carinata Silvestri = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896	32	16	17	14	10	13	7	11	7	4	9	2	17	16
Cassidulina laevigata d'Orbigny, 1826	8	11	7	4	7	8	3	1	4	0	2	5	8	13
Cassidulinoides oblonga Reuss = *Cassidulina oblonga* Reuss, 1850	0	0	1	1	1	3	1	0	1	1	0	1	0	1
Chilostomella oolina Schwager, 1878	3	2	2	5	1	0	3	0	0	2	0	0	0	0
Cibicides refulgens de Montfort, 1808	0	0	0	0	0	0	0	0	2	0	1	1	3	3
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	4	3	2	1	1	1	4	1	0	1	2	1	4	4
Cibicidoides pachyderma Rzehak, 1886	0	3	3	2	0	0	0	1	0	0	0	0	2	1
Cibicidoides pseudoungerianus Cushman =*Truncatulina pseudoungeriana* Cushman, 1922	13	11	10	9	7	5	6	5	6	2	7	5	9	9
Cibicidoides sp.	7	11	3	3	5	2	5	4	0	1	5	4	4	7
Clavulina parisiensis d'Orbigny, 1826	5	4	1	2	1	3	0	2	0	0	1	1	1	0
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cycloforina laevigata d'Orbigny, 1839	0	1	0	2	2	2	5	1	2	1	1	0	7	1
Cycloforina laevigata d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dentalina communis d'Orbigny = *Nodosaria communis* d'Orbigny, 1826	0	0	1	1	0	1	0	2	0	0	0	1	0	0
Dentalina flintii Cushman, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dentalina guttifera d'Orbigny, 1846	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	0	0	0	0	0	0	0	0	0	0	2	1	4	2
Discorbinella bertheloti d'Orbigny = *Rosalina bertheloti* d'Orbigny, 1839	0	0	0	0	0	1	6	6	3	1	1	1	1	2
Edentostomina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eggerella bradyi Cushman = *Verneuilina bradyi* Cushman, 1911	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix E (continued)

sample number	M25	M35	M45	M55	M65	M75	M84	M94	M98	M100	M102	M107	M115	M126
sum counts	422	327	328	250	243	273	274	319	240	184	301	235	364	434
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	1	1	2	2	2	3	2	0	0	2	0	0	0	0
Elphidium fichtelianum d'Orbigny = *Polystomella fichtelliana* d'Orbigny, 1846	0	1	2	0	1	0	0	0	1	1	4	0	3	2
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	0	0	0	0	0	0	0	1	0	1	0	0	0	1
Epistominella vitrea Parker, 1953	0	1	0	0	0	0	0	0	0	0	0	0	3	1
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	0	1	2	2	1	0	0	0	0	0	0	0	0	1
Favulina melo d'Orbigny = *Oolina melo* d'Orbigny, 1839	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Favulina squamosa Montagu = *Vermiculum squamosum* Montagu, 1803	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Fissurina kerguelensis Parr, 1950	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Fissurina laevigata Reuss, 1850	0	0	3	1	0	0	1	1	0	0	0	0	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	0	0	0	1	2	0	0	0	0	0	0	0	0
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Fissurina orbignyana Seguenza, 1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina piriformis Buchner = *Lagena piriformis* Buchner, 1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina quadricostulata Reuss = *Lagena quadricostulata* Reuss, 1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	0	1	0	0	0	0	1	0	0	0	0	0	2	1
Gaudryina rudis Wright 1900	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	10	6	9	5	3	5	1	5	4	1	1	3	2	7
Glabratella torrei Bermúdez = *Discorbis torrei* Bermúdez, 1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glandulina ovula d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Globobulimina affinis d'Orbigny = *Bulimia affinis* d'Orbigny, 1839	9	5	8	4	1	5	3	1	0	0	2	3	3	4
Globocassidulina subglobosa group	89	57	48	50	56	46	55	46	26	20	54	33	30	29
Gordiospira fragilis Heron-Allen and Earland, 1932	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guttulina communis d'Orbigny = *Polymorphina (Guttulina) communis* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidina altiformis Steward and Steward = *Gyroidina soldanii* d'Orbigny var. *altiformis* Steward and Steward, 1930	2	0	4	1	1	2	5	5	1	0	1	3	1	16
Gyroidina neosoldanii Brotzen, 1936	2	4	1	6	7	7	4	4	1	1	0	1	4	3
Gyroidina soldanii d'Orbigny, 1826	6	5	1	1	0	3	2	1	0	0	0	0	5	3
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	0	1	0	0	0	2	2	1	0	0	0	0	2	2
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	1	5	2	0	1	0	2	2	1	1	2	0	0	4
Hanzawaia concentrica Cushman = *Truncatulina concentrica* Cushman, 1918	1	2	1	1	1	0	1	2	1	0	1	1	1	0
Hoeglundina elegans d'Orbigny = *Rotalia (Turbinulina) elegans* d'Orbigny, 1826	4	3	6	0	1	5	4	3	5	3	7	2	3	5
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	15	18	10	9	9	18	10	19	11	7	26	19	32	44
Hyrrokkin sarcophaga Cedhagen, 1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Lagena gibbera Buchner, 1940	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lagena meridionalis Wiesner = *Lagena gracilis* Williamson var. *meridionalis* Wiesner, 1931	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lagena striata d'Orbigny, 1839	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lagena williamsoni Harvey and Bailey, 1854	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lenticulina calcar Linné = *Nautilus calcar* Linné, 1758	0	0	0	0	0	0	0	1	0	0	0	1	0	1
Lenticulina gibba d'Orbigny = *Cristellaria gibba* d'Orbigny, 1826	2	0	1	1	1	0	0	1	0	0	0	0	0	1
Lenticulina inornata d'Orbigny = *Robulina inornata* d'Orbigny, 1846	1	0	1	1	1	2	0	0	1	0	0	2	1	0
Lenticulina orbicularis d'Orbigny = *Robulina orbicularis* d'Orbigny, 1826	0	0	0	0	1	0	3	1	1	2	2	1	0	3
Lenticulina peregrina Schwager = *Cristellaria peregrina* Schwager, 1866	1	0	1	0	2	1	0	0	0	0	2	0	2	1

Appendix E (continued)

sample number	M25	M35	M45	M55	M65	M75	M84	M94	M98	M100	M102	M107	M115	M126
sum counts	422	327	328	250	243	273	274	319	240	184	301	235	364	434
Lenticulina vortex Fichtel and Moll = *Nautilus vortex* Fichtel and Moll, 1798	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	1	3	3	2	1	3	2	2	5	0	8	2	6	7
Marginulina striata d'Orbigny, 1852	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	12	12	7	11	13	8	2	11	10	3	19	9	16	18
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	4	0	1	0	2	1	1	4	6	1	3	2	5	4
Miliolinella elongata Kruit = *Miliolinella circularis* Bornemann var. *elongata* Kruit, 1955	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	0	0	0	0	0	0	1	0	0	0	1	1	3	0
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nonion pauperatus Balkwill and Wright = *Nonionina pauperata* Balkwill and Wright, 1885	0	0	0	0	0	0	0	0	0	2	0	0	2	2
Nonion sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nonionella iridea Heron-Allen and Earland, 1932	0	1	0	1	1	2	3	2	1	4	0	1	1	1
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	0	2	0	0	0	0	1	1	1	0	0	0	1	1
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	3	0	0	2	1	0	0	0	0	0	0	0	0	0
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paratrochammina murrayi Brönnimann and Zaninetti, 1984	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Planulina ariminensis d'Orbigny, 1826	4	0	4	4	6	2	3	3	4	3	1	2	3	2
Porosononion ex gr. *granosum* d'Orbigny = *Nonionina granosa* d'Orbigny, 1826	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	0	1	0	0	0	0	0	1	3	1	0	1	0	3
Pseudonodosaria aequalis d'Orbigny = *Nodosaria aequalis* d'Orbigny, 1908	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotriloculina oblonga Montagu = *Vermiculum oblongum* Montagu, 1803	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia bulloides d'Orbigny = *Nonionina bulloides* d'Orbigny, 1846	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia quadriloba Reuss = *Pullenia compressiuscula* Reuss var. *quadriloba* Reuss, 1867	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	2	1	0	0	0	0	0	1	0	0	0	1	0	0
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Pyrgo depressa d'Orbigny = *Biloculina depressa* d'Orbigny, 1826	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Pyrgo elongata d'Orbigny = *Biloculina elongata* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgo inornata d'Orbigny = *Biloculina elongata* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrgoella sphaera d'Orbigny = *Biloculina sphaera* d'Orbigny, 1839	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Quinqueloculina padana Perconig, 1954	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Quinqueloculina seminula Linné = Serpula seminulum Linné, 1758	0	0	2	0	0	0	1	0	2	0	2	0	2	3
Quinqueloculina viennensis Le Calvez and Le Calvez, 1958	3	1	1	0	0	0	2	2	0	0	1	2	3	2
Quniqueloculina pseudobuchiana Luczkowska, 1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rectuvigerina elongatastriata Colom = *Angulogerina elongatastriata* Colom, 1952	6	6	3	5	4	3	0	0	0	0	1	0	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosalina globularis d'Orbigny, 1826	0	1	2	2	0	1	1	3	3	0	1	0	3	1
Rosalina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosalina vilardeboana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Sigmoilina sigmoidea Brady = *Planispirina sigmoides* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	13	7	8	5	2	5	4	8	4	4	6	3	10	12
Siphogenerina columellaris Brady = *Uvigerina columellaris* Brady, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonina reticulata Czjzek = *Rotalia reticulata* Czjzek, 1848	0	0	1	0	1	3	0	1	0	0	3	0	0	0

Appendix E (continued)

sample number	M25	M35	M45	M55	M65	M75	M84	M94	M98	M100	M102	M107	M115	M126
sum counts	422	327	328	250	243	273	274	319	240	184	301	235	364	434
Siphotextularia fretensis Vella, 1957	0	2	0	0	0	0	0	0	0	2	0	0	0	0
Sphaeroidina bulloides d'Orbigny, 1826	2	1	2	3	5	14	8	8	3	6	6	6	4	4
Spirillina vivipara Ehrenberg, 1843	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Spiroloculina depressa d'Orbigny, 1826	0	0	0	0	0	0	0	1	1	1	1	2	0	0
Spiroloculina excavata d'Orbigny, 1846	2	0	0	1	0	0	1	0	0	0	0	0	0	0
Spiroloculina tenuiseptata Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	4	2	0	0	3	3	4	5	4	3	3	4	0	7
Stainforthia concava Höglund = *Virgulina concava* Höglund, 1947	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia agglutinans d'Orbigny, 1839	0	1	1	1	0	0	1	0	0	0	0	0	0	1
Textularia laevigata d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia lateralis Lalicker,1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia pseudogramen d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Textularia truncata Höglund, 1947	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Trifarina brady Cushman, 1923	0	0	1	0	0	0	0	0	0	0	0	2	1	1
Trifarina fornasinii Selli = *Angulogerina fornasinii* Selli, 1948	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Triloculina marioni Schlumberger, 1893	0	0	1	1	0	1	0	1	0	0	0	0	0	0
Triloculina tricarinata d'Orbigny, 1826	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Triloculina trigonula Lamarck = *Miliolites trigonula* Lamarck, 1804	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Trochammina conica Earland, 1934	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uvigerina auberiana d'Orbigny, 1839	0	0	0	0	0	1	1	3	0	3	0	1	0	0
Uvigerina mediterranea Hofker, 1932	29	22	19	12	10	11	13	12	14	4	6	4	7	9
Uvigerina peregrina Cushman, 1923	13	6	14	11	9	19	22	43	30	28	28	31	54	57
Valvulineria bradyana Fornasini = *Discorbina bradyana* Fornasini, 1900	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Appendix E (continued)

sample number	D0	D10	D15	D20	D25	D30	D35	D40	D45	D50	D55	D60	D150
sum counts	367	347	372	281	309	412	433	330	293	412	245	130	136
Allassoida virgola Brady = *Sagrina virgola* Brady, 1879	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphicoryna scalaris Batsch =*Nautilus scalaris* Batsch, 1791	5	6	7	4	3	14	17	15	2	3	4	1	0
Angulogerina angulosa Williamson = *Uvigerina angulosa* Williamson, 1858	2	3	2	5	4	0	8	4	3	12	9	2	1
Archimerismus subnodosus Brady = *Hyperammina subnodosa* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0
Astacolus patens Brady = *Vaginulina patens* Brady, 1884	0	0	0	0	0	0	0	0	0	0	0	0	0
Asterigerinata mamilla Williamson = *Rotalina mamilla* Williamson, 1858	0	0	0	0	0	0	0	0	1	2	0	0	0
Asterigerinata planorbis d'Orbigny = *Asterigerina planorbis* d'Orbigny, 1846	1	0	0	0	0	0	0	0	0	0	0	1	0
Astrononion stelligerum d'Orbigny = *Nonionina stelligera* d'Orbigny, 1839	0	1	2	3	4	0	0	1	3	2	0	0	0
Bigenerina nodosaria d'Orbigny, 1826	8	5	9	8	6	11	7	6	3	0	1	0	2
Biloculinella globula Bornemann = *Biloculina globulus* Bornemann, 1855	2	1	0	0	2	1	2	0	1	0	1	1	1
Bolivina alata Seguenza = *Vulvulina alata* Sequenza, 1862	0	0	2	0	0	0	2	2	0	1	1	1	1
Bolivina difformis Williamson = *Textularia variabilis* var. *difformis* Williamson, 1858	23	25	25	12	20	20	14	13	12	14	17	9	9
Bolivina dilatata Reuss = *Brizalina dilatata* Reuss, 1850	1	2	1	4	1	1	0	2	0	3	4	2	2
Bolivina pseudoplicata Heron-Allen and Earland = *Bolivina pseudo-plicata* Heron-Allen and Earland, 1930	0	0	0	0	2	0	2	0	1	1	1	0	0
Bolivina pseudopunctata Höglund, 1947	5	4	1	2	1	0	4	3	0	2	0	1	2
Bolivina spathulata Williamson = *Textularia variabilis* var. *spathulata* Williamson, 1858	2	8	4	1	5	6	0	3	4	0	7	0	0
Bolivina striatula Cushman = *Brizalina striatula* Cushman, 1922	3	0	0	2	1	3	3	0	1	2	0	1	0
Bolivina subaenariensis Cushman = *Brizalina subaenariensis* Cushman, 1922	0	0	0	0	0	0	1	0	2	13	4	3	0
Bolivina subspinescens Cushman, 1922	0	2	0	0	0	1	1	1	0	0	0	0	0
Bulimina aculeata d'Orbigny, 1826	1	0	0	0	3	1	1	3	3	14	2	1	1
Bulimina marginata d'Orbigny, 1826	8	16	17	9	8	11	22	13	8	5	6	4	5
Bulimina striata d'Orbigny, 1843	2	1	5	1	0	3	6	2	3	4	3	0	0
Cancris auriculatus Fichtel and Moll= *Nautilus acutauricularis* Fichtel and Moll, 1798	0	0	0	0	0	0	0	2	1	0	0	0	0
Cassidulina carinata Silvestri = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896	14	3	7	7	9	15	10	7	4	17	4	2	7
Cassidulina laevigata d'Orbigny, 1826	12	3	4	0	10	3	1	2	0	23	4	2	1
Cassidulinoides oblonga Reuss = *Cassidulina oblonga* Reuss, 1850	0	0	0	1	0	0	0	0	0	5	0	0	0
Chilostomella oolina Schwager, 1878	1	1	1	0	1	1	1	1	0	0	1	0	1
Cibicides refulgens de Montfort, 1808	2	5	0	2	1	7	4	2	14	10	5	0	0
Cibicidoides kullenbergi Parker = *Cibicides kullenbergi* Parker, 1953	8	4	4	1	4	16	2	2	0	2	5	2	3
Cibicidoides pachyderma Rzehak, 1886	6	4	8	2	8	1	15	2	6	21	7	4	3
Cibicidoides pseudoungerianus Cushman =*Truncatulina pseudoungeriana* Cushman, 1922	4	2	2	0	0	1	2	0	5	4	6	2	4
Cibicidoides sp.	8	9	17	4	6	11	14	12	11	19	7	17	7
Clavulina parisiensis d'Orbigny, 1826	5	2	5	3	0	5	0	2	2	0	0	0	0
Cornuspira involvens Reuss = *Operculina involvens* Reuss, 1850	0	0	2	0	0	0	0	1	0	0	0	0	1
Cycloforina laevigata d'Orbigny, 1839	0	3	0	0	0	0	0	0	0	0	0	1	0
Cycloforina laevigata d'Orbigny, 1839	0	0	0	0	1	0	0	0	0	0	0	0	0
Dentalina communis d'Orbigny = *Nodosaria communis* d'Orbigny, 1826	2	0	1	0	0	0	0	0	0	0	0	0	0
Dentalina flintii Cushman, 1923	0	0	0	0	0	1	0	0	0	0	0	0	0
Dentalina guttifera d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0
Discanomalina coronata Parker and Jones = *Anomalina coronata* Parker and Jones, 1857	0	0	1	1	0	1	18	6	18	56	23	12	2
Discorbinella bertheloti d'Orbigny = *Rosalina bertheloti* d'Orbigny, 1839	2	3	1	0	3	1	1	1	2	1	1	1	0
Edentostomina sp.	0	0	4	2	0	0	0	0	0	0	0	0	0
Eggerella bradyi Cushman = *Verneuilina bradyi* Cushman, 1911	0	0	0	0	0	0	0	0	0	0	0	1	0

Appendix E (continued)

sample number	D0	D10	D15	D20	D25	D30	D35	D40	D45	D50	D55	D60	D150
sum counts	367	347	372	281	309	412	433	330	293	412	245	130	136
Eggerelloides scabra Williamson = *Bulimina scabrum* Williamson, 1958	0	2	4	4	0	0	2	0	0	1	1	0	0
Elphidium fichtelianum d'Orbigny = *Polystomella fichtelliana* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0
Epistominella exigua Brady = *Pulvinulina exigua* Brady, 1884	0	3	6	2	1	1	0	0	0	0	0	0	1
Epistominella vitrea Parker, 1953	0	2	0	0	0	1	0	0	0	1	1	1	3
Favulina hexagona Williamson = *Entosolenia squamosa* Montagu var. *hexagona* Williamson, 1858	1	0	0	1	1	0	0	1	0	0	1	0	1
Favulina melo d’Orbigny = *Oolina melo* d’Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	1
Favulina squamosa Montagu = *Vermiculum squamosum* Montagu, 1803	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina kerguelensis Parr, 1950	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina laevigata Reuss, 1850	0	0	0	0	1	1	1	0	0	0	0	0	0
Fissurina lucida Williamson = *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848	0	0	0	0	0	0	1	0	0	0	2	0	0
Fissurina marginata Montagu = *Vermiculum marginatum* Montagu, 1803	1	2	0	0	0	0	0	1	1	1	1	2	0
Fissurina orbignyana Seguenza, 1862	0	1	1	2	1	0	1	2	2	1	2	1	0
Fissurina piriformis Buchner = *Lagena piriformis* Buchner, 1940	0	1	0	0	0	0	0	0	0	0	1	0	0
Fissurina quadricostulata Reuss = *Lagena quadricostulata* Reuss, 1870	0	0	0	0	0	0	0	1	0	0	0	0	0
Fontbotia wuellerstorfi Schwager = *Anomalina wüllerstorfi* Schwager, 1866	0	0	0	0	0	0	0	0	1	0	0	0	0
Gaudryina rudis Wright 1900	0	0	0	0	0	1	0	0	4	1	1	1	1
Gavelinopsis praegeri Heron-Allen and Earland = *Discorbina praegeri* Heron-Allen and Earland, 1913	19	16	16	14	14	17	20	14	3	9	6	4	2
Glabratella torrei Bermúdez = *Discorbis torrei* Bermúdez, 1935	0	0	0	0	1	0	0	0	0	0	0	0	0
Glandulina ovula d'Orbigny, 1846	1	0	0	0	0	0	0	0	0	0	0	0	0
Globobulimina affinis d’Orbigny = *Bulimia affinis* d’Orbigny, 1839	2	1	1	1	0	2	1	1	2	0	1	0	0
Globocassidulina subglobosa group	85	86	54	48	61	88	75	57	50	30	27	14	30
Gordiospira fragilis Heron-Allen and Earland, 1932	0	0	0	0	0	0	0	0	1	0	0	0	0
Guttulina communis d'Orbigny = *Polymorphina (Guttulina) communis* d'Orbigny, 1826	0	0	0	0	0	0	0	1	0	0	0	0	0
Gyroidina altiformis Steward and Steward = *Gyroidina soldanii* d'Orbigny var. *altiformis* Steward and Steward, 1930	0	1	5	4	3	7	4	4	0	0	0	0	1
Gyroidina neosoldanii Brotzen, 1936	1	0	2	3	5	3	1	1	2	5	2	0	1
Gyroidina soldanii d’Orbigny, 1826	3	4	0	1	1	1	0	1	0	7	2	0	1
Gyroidinoides laevigatus d'Orbigny = *Gyroidina laevigata* d'Orbigny, 1826	1	2	0	0	0	0	0	1	3	0	0	0	0
Hanzawaia boueana d'Orbigny = *Rotalina boueana* d'Orbigny, 1846	5	7	4	3	3	3	7	4	3	3	6	2	1
Hanzawaia concentrica Cushman = *Truncatulina concentrica* Cushman, 1918	0	0	0	0	0	0	0	0	3	1	2	0	0
Hoeglundina elegans d’Orbigny = *Rotalia (Turbinulina) elegans* d’Orbigny, 1826	10	11	7	6	0	11	9	4	8	1	7	2	2
Homalohedra williamsoni Alcock = *Entosolenia williamsoni* Alcock, 1865	0	0	0	0	0	0	0	0	1	0	0	0	0
Hyalinea balthica Schröter = *Nautilus balthicus* Schröter, 1783	6	4	6	5	7	3	5	4	2	13	8	3	4
Hyrrokkin sarcophaga Cedhagen, 1994	0	1	0	0	0	1	0	0	0	0	0	0	0
Karreriella bradyi Cushman = *Gaudryina bradyi* Cushman, 1911	0	0	0	0	0	0	0	0	1	0	0	0	0
Lagena gibbera Buchner, 1940	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagena meridionalis Wiesner = *Lagena gracilis* Williamson var. *meridionalis* Wiesner, 1931	0	0	0	0	0	0	0	0	0	0	1	0	0
Lagena striata d'Orbigny, 1839	1	0	0	0	0	0	0	1	1	0	1	0	0
Lagena williamsoni Harvey and Bailey, 1854	0	0	0	0	0	0	2	0	0	0	0	0	0
Lenticulina calcar Linné = *Nautilus calcar* Linné, 1758	0	0	0	0	0	0	0	0	0	1	0	0	0
Lenticulina gibba d’Orbigny = *Cristellaria gibba* d’Orbigny, 1826	0	2	0	0	0	0	0	0	0	0	0	0	0
Lenticulina inornata d’Orbigny = *Robulina inornata* d’Orbigny, 1846	4	6	2	2	4	0	4	5	2	0	0	1	0
Lenticulina orbicularis d’Orbigny = *Robulina orbicularis* d’Orbigny, 1826	1	1	4	4	1	8	2	3	4	0	2	0	0
Lenticulina peregrina Schwager = *Cristellaria peregrina* Schwager, 1866	0	0	0	0	0	2	0	0	0	0	0	0	0

Appendix E (continued)

sample number	D0	D10	D15	D20	D25	D30	D35	D40	D45	D50	D55	D60	D150
sum counts	367	347	372	281	309	412	433	330	293	412	245	130	136
Lenticulina vortex Fichtel and Moll = *Nautilus vortex* Fichtel and Moll, 1798	0	1	0	0	0	0	0	0	0	0	0	0	0
Lobatula lobatula Walker and Jacob = *Nautilus lobatulus* Walker and Jacob, 1798	4	5	9	6	1	4	11	6	11	9	9	1	1
Marginulina striata d'Orbigny, 1852	0	0	0	1	1	0	0	0	0	0	0	0	0
Melonis barleeanum Williamson = *Nonionina barleeana* Williamson, 1858	6	2	14	9	7	13	11	10	2	13	5	4	3
Melonis pompilioides Fichtel and Moll, 1798 = *Nautilus pompilioides* Fichtel and Moll, 1798	0	0	0	1	1	0	1	0	3	3	0	0	2
Miliolinella elongata Kruit = *Miliolinella circularis* Bornemann var. *elongata* Kruit, 1955	0	0	0	0	0	0	0	0	0	1	0	0	1
Miliolinella subrotunda Montagu, 1803 = *Vermiculum subrotundum* Montagu, 1803	1	0	3	4	4	9	1	1	2	4	2	3	0
Neoconorbina terquemi Rzehak = *Discorbina terquemi* Rzehak, 1888	0	0	0	0	0	0	1	0	0	0	1	0	0
Nonion pauperatus Balkwill and Wright = *Nonionina pauperata* Balkwill and Wright, 1885	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonion sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Nonionella iridea Heron-Allen and Earland, 1932	0	0	0	0	2	1	1	0	0	1	0	2	0
Nonionella turgida Williamson = *Rotalina turgida* Williamson, 1858	1	0	2	1	1	0	1	0	0	0	0	0	1
Nuttallides umboniferus Cushman = *Pulvinulina umbonifera* Cushman, 1933	1	1	2	7	3	3	7	0	3	1	0	0	1
Oridorsalis umbonatus Reuss = *Rotalina umbonatus* Reuss, 1851	0	0	0	0	0	0	0	0	2	0	0	0	0
Paratrochammina challengeri Brönnimann and Whittaker, 1988	1	1	0	0	0	0	0	0	0	0	1	0	0
Paratrochammina murrayi Brönnimann and Zaninetti, 1984	0	0	0	0	0	0	0	1	0	1	0	0	0
Planulina ariminensis d'Orbigny, 1826	2	0	1	2	0	2	3	0	0	1	0	0	0
Porosononion ex gr. *granosum* d'Orbigny = *Nonionina granosa* d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudoeponides falsobeccarii Rouvillois = *Ammonia falsobeccarii* Rouvillois, 1974	0	0	0	0	0	1	0	0	0	0	0	0	0
Pseudonodosaria aequalis d'Orbigny = *Nodosaria aequalis* d'Orbigny, 1908	0	0	0	0	0	0	0	1	0	1	0	0	1
Pseudotriloculina oblonga Montagu = *Vermiculum oblongum* Montagu, 1803	0	0	0	0	1	0	0	0	0	0	0	0	0
Pullenia bulloides d'Orbigny = *Nonionina bulloides* d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0
Pullenia quadriloba Reuss = *Pullenia compressiuscula* Reuss var. *quadriloba* Reuss, 1867	0	0	0	0	0	0	0	0	0	1	0	0	0
Pullenia quinqueloba Reuss = *Nonionina quinqueloba* Reuss, 1851	0	0	1	1	1	0	0	1	0	0	0	0	0
Pyrgo anomala Schlumberger = *Biloculina anomala* Schlumberger, 1891	0	1	0	0	2	1	0	0	1	0	2	4	0
Pyrgo depressa d'Orbigny = *Biloculina depressa* d'Orbigny, 1826	0	0	0	0	1	0	0	0	0	0	0	0	0
Pyrgo elongata d'Orbigny = *Biloculina elongata* d'Orbigny, 1826	0	0	1	0	1	0	0	0	0	3	0	0	0
Pyrgo inornata d'Orbigny = *Biloculina elongata* d'Orbigny, 1839	0	0	0	1	0	0	0	0	0	0	1	0	0
Pyrgoella sphaera d'Orbigny = *Biloculina sphaera* d'Orbigny, 1839	0	0	0	0	0	0	0	0	1	0	0	0	0
Quinqueloculina padana Perconig, 1954	0	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina seminula Linné = Serpula seminulum Linné, 1758	0	1	2	0	0	3	0	0	1	2	1	0	0
Quinqueloculina viennensis Le Calvez and Le Calvez, 1958	14	6	7	6	5	4	13	4	8	9	0	0	2
Quniqueloculina pseudobuchiana Luczkowska, 1974	0	0	0	0	0	0	0	0	0	0	1	0	0
Rectuvigerina elongatastriata Colom = *Angulogerina elongatastriata* Colom, 1952	1	4	2	2	2	3	2	2	1	0	0	0	0
Robertinoides subcylindrica Brady =*Bulimia subcylindrica* Brady, 1881	0	0	0	0	0	0	0	1	0	0	0	0	0
Rosalina globularis d'Orbigny, 1826	1	3	2	2	5	4	9	3	0	4	1	1	0
Rosalina sp.	0	0	0	0	0	0	0	1	3	1	0	0	0
Rosalina vilardeboana d'Orbigny, 1839	0	1	2	0	1	0	0	0	0	0	0	0	1
Sigmoilina sigmoidea Brady = *Planispirina sigmoides* Brady, 1884	1	0	1	1	2	2	0	2	0	1	1	0	0
Sigmoilinita tenuis Czjzek = *Quinqueloculina tenuis* Czjzek, 1848	0	0	0	0	1	1	0	1	0	0	0	0	1
Sigmoilopsis schlumbergeri Silvestri = *Sigmoilina schlumbergeri* Silvestri, 1904	4	5	2	5	0	7	5	6	1	2	0	0	0
Siphogenerina columellaris Brady = *Uvigerina columellaris* Brady, 1881	0	0	2	0	0	0	0	2	0	0	0	0	0
Siphonina reticulata Czjzek = *Rotalia reticulata* Czjzek, 1848	0	0	2	1	0	1	0	0	1	0	0	0	1

Appendix E (continued)

sample number	D0	D10	D15	D20	D25	D30	D35	D40	D45	D50	D55	D60	D150
sum counts	367	347	372	281	309	412	433	330	293	412	245	130	136
Siphotextularia fretensis Vella, 1957	0	0	0	0	0	0	1	2	0	0	0	0	0
Sphaeroidina bulloides d'Orbigny, 1826	2	2	7	1	3	3	9	3	4	0	1	2	1
Spirillina vivipara Ehrenberg, 1843	1	1	0	0	1	3	1	0	0	0	0	0	0
Spiroloculina depressa d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	1	0	0
Spiroloculina excavata d'Orbigny, 1846	1	2	2	0	2	1	2	3	3	1	2	2	1
Spiroloculina tenuiseptata Brady, 1884	0	0	0	0	0	1	0	0	0	1	0	0	0
Spiroplectinella wrighti Silvestri = *Spiroplecta wrighti* Silvestri, 1903	7	4	9	1	10	7	9	3	4	0	0	1	0
Stainforthia concava Höglund = *Virgulina concava* Höglund, 1947	0	0	0	0	0	0	0	0	0	0	0	0	0
Stainforthia fusiformis Williamson = *Bulimina pupoides* var. *fusiformis* Williamson, 1858	0	0	0	0	0	0	0	0	0	0	0	0	0
Stomatorbina concentrica Parker and Jones = *Pulvinulina concentrica* Parker and Jones, 1864	0	0	0	0	0	0	1	0	0	0	0	0	0
Textularia agglutinans d'Orbigny, 1839	8	7	6	4	2	1	0	3	1	0	0	0	1
Textularia laevigata d'Orbigny, 1826	0	1	0	0	0	0	1	7	0	0	0	0	0
Textularia lateralis Lalicker,1935	0	0	0	3	0	0	0	0	0	0	0	0	0
Textularia pseudogramen d'Orbigny, 1839	0	0	0	0	1	0	0	2	2	0	0	0	0
Textularia truncata Höglund, 1947	1	2	6	1	1	0	3	0	1	0	0	0	0
Trifarina brady Cushman, 1923	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifarina fornasinii Selli = *Angulogerina fornasinii* Selli, 1948	1	3	0	1	3	3	2	4	1	0	2	0	0
Triloculina marioni Schlumberger, 1893	0	0	1	1	0	0	0	0	0	0	0	0	0
Triloculina tricarinata d'Orbigny, 1826	0	0	1	0	0	0	0	0	0	0	0	0	0
Triloculina trigonula Lamarck = *Miliolites trigonula* Lamarck, 1804	0	4	0	0	0	0	1	0	0	2	1	0	0
Trochammina conica Earland, 1934	0	0	0	0	0	1	0	0	0	0	0	0	0
Uvigerina auberiana d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0
Uvigerina mediterranea Hofker, 1932	33	13	32	24	18	33	31	35	15	0	5	0	9
Uvigerina peregrina Cushman, 1923	8	8	5	19	17	14	13	12	17	21	10	8	6
Valvulineria bradyana Fornasini = *Discorbina bradyana* Fornasini, 1900	0	0	1	1	0	0	0	0	0	0	0	0	1

Appendix F. Species list and quantitative data of planktonic foraminifera from the Alboran Sea (Chapter 4). Generic names are in accordance with Loeblich and Tappan (1987).

sample number	M25	M35	M45	M55	M65	M75	M84	M94	M98	M100	M102	M107	M115	M126
sum counts	994	1216	1226	1115	1122	1068	1066	1103	1027	816	1058	854	918	946
Beella digitata Brady = *Globigerina digitata* Brady, 1879	0	0	0	0	0	1	1	1	2	1	0	0	0	0
Globigerina bulloides d'Orbigny, 1826	97	88	86	71	78	51	34	38	37	24	51	31	46	48
Globigerinella calida Parker = *Globigerina calida* Parker, 1926	4	3	3	4	4	3	3	2	2	6	1	2	0	2
Globigerinella siphonifera d'Orbigny = *Globigerina siphonifera* d'Orbigny, 1839	0	7	15	13	8	13	12	8	8	3	6	0	4	1
Globigerinita glutinata Egger = *Globigerina glutinata* Egger, 1893	205	333	231	200	185	201	198	186	123	113	168	117	141	110
Globigerinita uvula Ehrenberg = *Pylodexia uvula* Ehrenberg, 1861	11	26	7	17	10	12	13	20	16	10	11	12	21	10
Globigerinoides conglobatus Brady, 1879	0	0	0	0	0	0	2	0	0	1	0	0	0	0
Globigerinoides elongatus d'Orbigny = *Globigerina elongata* d'Orbigny, 1826	15	14	25	18	8	25	20	13	13	6	10	12	6	11
Globigerinoides immaturus Le Roy = *Globigerinoides sacculiferus* Brady var. *Immatura* Le Roy, 1939	4	5	9	5	5	10	3	4	6	0	0	0	0	0
Globigerinoides ruber d'Orbigny = *Globigerina rubra* d'Orbigny, 1839	47	74	89	93	115	106	122	89	75	56	67	58	31	24
Globigerinoides sacculifer Brady = *Globigerina sacculifera* Brady, 1877	9	10	6	5	4	7	2	0	1	1	8	0	0	0
Globorotalia hirsuta d'Orbigny = *Rotalina hirsua* d'Orbigny, 1839	2	3	0	0	0	0	0	0	0	0	1	1	0	2
Globorotalia inflata d’Orbigny = *Globigerina inflata* d’Orbigny, 1839	270	328	276	266	236	209	144	80	41	34	42	31	47	53
Globorotalia scitula Brady = *Pulvinulina scitula* Brady, 1882	9	4	4	1	0	3	2	1	0	0	1	0	1	12
Globoturborotalita rubescens Hofker = *Globigerina rubescens* Hofker, 1956	19	34	42	35	51	47	38	22	19	4	14	11	4	7
Hastigerina pelagica d'Orbigny = *Nonionina pelagica* d'Orbigny, 1839	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Hastigerinopsis riedeli Rögl and Bolli = *Hastigerinella riedeli* Rögl and Bolli, 1973	0	0	2	1	0	0	0	0	0	0	0	0	2	0
Neogloboquadrina dutertrei d'Orbigny = *Globigerina dutertrei* d'Orbigny, 1839	0	0	1	0	0	0	0	0	2	16	0	4	9	5
Neogloboquadrina incompta Cifelli = *Globigerina incompta* Cifelli, 1961	25	41	69	69	99	105	168	239	307	230	320	245	287	372
Neogloboquadrina pachyderma Ehrenberg = *Aristospira pachyderma* Ehrenberg, 1861	2	1	1	0	0	1	3	1	1	0	1	2	5	0
Orbulina universa d'Orbigny, 1839	7	7	7	3	8	5	4	0	4	1	4	4	3	0
Pulleniatina obliquiloculata Parker and Jones = *Pullenia sphaeroides* d'Orbigny var. *Obliquiloculata* Parker and Jones, 1865	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tenuitella anfracta Parker = *Globorotalia anfracta* Parker, 1967	0	0	1	2	1	4	0	0	0	2	0	1	1	0
Tenuitella iota Parker = *Globigerinita iota* Parker, 1962	11	6	5	3	5	0	2	0	1	1	0	0	0	0
Tenuitella parkerae Brönnimann and Resig = *Globorotalia parkerae* Brönnimann and Resig, 1971	0	0	0	0	0	0	0	0	2	0	1	1	3	0
Truncorotalia crassaformis Galloway and Wissler = *Globigerina crassaformis* Galloway and Wiessler, 1927	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Truncorotalia truncatulinoides d'Orbigny = *Rotalina truncatulinoides* d'Orbigny, 1839	10	9	7	12	7	2	3	1	3	3	2	3	2	9
Turborotalita cristata Heron-Allen and Earland = *Globigerina cristata* Heron-Allen and Earland, 1929	1	0	3	1	2	0	0	0	1	0	2	0	0	1
Turborotalita humilis Brady = *Truncatulina humilis* Brady, 1884	20	21	22	7	13	12	5	1	4	13	4	4	1	6
Turborotalita quinqueloba Natland = *Globigerina quinqueloba* Natland, 1938	224	200	315	289	283	251	287	397	359	291	344	315	304	271

Appendix F (continued)

sample number	D0	D10	D15	D20	D25	D30	D35	D40	D45	D50	D55	D60	D65	D70	D75	D150
sum counts	1049	1042	1079	1092	1072	1062	942	919	780	964	806	599	824	837	732	724
Beella digitata Brady = *Globigerina digitata* Brady, 1879	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Globigerina bulloides d'Orbigny, 1826	165	169	125	73	60	110	50	75	49	87	54	38	34	29	47	36
Globigerinella calida Parker = *Globigerina calida* Parker, 1926	8	6	7	2	4	2	7	4	2	4	4	2	5	0	1	3
Globigerinella siphonifera d'Orbigny = *Globigerina siphonifera* d'Orbigny, 1839	4	4	8	12	7	13	5	5	4	1	1	1	3	1	4	5
Globigerinita glutinata Egger = *Globigerina glutinata* Egger, 1893	89	59	171	132	128	146	126	154	93	120	106	140	176	221	162	182
Globigerinita uvula Ehrenberg = *Pylodexia uvula* Ehrenberg, 1861	16	21	38	22	20	39	28	14	0	19	20	10	18	20	21	19
Globigerinoides conglobatus Brady, 1879	0	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Globigerinoides elongatus d'Orbigny = *Globigerina elongata* d'Orbigny, 1826	16	15	26	31	27	14	12	10	11	1	5	3	18	5	13	0
Globigerinoides immaturus Le Roy = *Globigerinoides sacculiferus* Brady var. *Immatura* Le Roy, 1939	7	11	16	14	3	7	3	3	10	1	4	0	6	3	7	10
Globigerinoides ruber d'Orbigny = *Globigerina rubra* d'Orbigny, 1839	72	72	82	78	80	70	69	71	63	27	23	8	84	61	61	40
Globigerinoides sacculifer Brady = *Globigerina sacculifera* Brady, 1877	11	7	5	9	5	12	0	1	3	1	0	1	1	0	2	3
Globorotalia hirsuta d'Orbigny = *Rotalina hirsua* d'Orbigny, 1839	6	3	1	4	1	2	2	0	1	0	1	0	1	0	0	5
Globorotalia inflata d'Orbigny = *Globigerina inflata* d'Orbigny, 1839	327	293	272	370	304	231	98	172	191	24	33	8	129	42	105	91
Globorotalia scitula Brady = *Pulvinulina scitula* Brady, 1882	2	26	8	4	1	9	8	7	1	8	7	3	1	1	2	4
Globoturborotalita rubescens Hofker = *Globigerina rubescens* Hofker, 1956	7	3	8	3	1	4	0	13	10	6	6	6	7	9	19	7
Hastigerina pelagica d'Orbigny = *Nonionina pelagica* d'Orbigny, 1839	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Hastigerinopsis riedeli Rögl and Bolli = *Hastigerinella riedeli* Rögl and Bolli, 1973	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Neogloboquadrina dutertrei d'Orbigny = *Globigerina dutertrei* d'Orbigny, 1839	3	0	5	5	2	1	2	3	3	0	3	0	0	4	3	2
Neogloboquadrina incompta Cifelli = *Globigerina incompta* Cifelli, 1961	78	102	100	74	121	105	210	126	245	426	303	136	113	191	100	117
Neogloboquadrina pachyderma Ehrenberg = *Aristospira pachyderma* Ehrenberg, 1861	3	7	12	16	7	9	8	13	7	6	5	13	13	10	9	16
Orbulina universa d'Orbigny, 1839	7	11	9	13	5	9	2	7	7	4	0	2	2	3	2	7
Pulleniatina obliquiloculata Parker and Jones = *Pullenia sphaeroides* d'Orbigny var. *Obliquiloculata* Parker and Jones, 1865	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Tenuitella anfracta Parker = *Globorotalia anfracta* Parker, 1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tenuitella iota Parker = *Globigerinita iota* Parker, 1962	0	0	0	0	0	0	0	0	0	0	0	0	1	4	4	0
Tenuitella parkerae Brönnimann and Resig = *Globorotalia parkerae* Brönnimann and Resig, 1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Truncorotalia crassaformis Galloway and Wissler = *Globigerina crassaformis* Galloway and Wiessler, 1927	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Truncorotalia truncatulinoides d'Orbigny = *Rotalina truncatulinoides* d'Orbigny, 1839	11	6	4	13	7	7	1	10	5	5	1	0	6	2	2	3
Turborotalita cristata Heron-Allen and Earland = *Globigerina cristata* Heron-Allen and Earland, 1929	1	1	2	6	2	3	7	1	0	1	2	1	0	1	0	0
Turborotalita humilis Brady = *Truncatulina humilis* Brady, 1884	12	2	28	12	15	18	12	11	4	9	5	4	10	13	7	13
Turborotalita quinqueloba Natland = *Globigerina quinqueloba* Natland, 1938	204	221	149	198	271	251	292	218	70	214	223	223	195	217	160	160

CURRICULUM VITAE

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Education

October 2006 – September 2010
    PhD thesis, Department of Geosciences, University of Fribourg.
    Titel of the thesis: Benthic foraminifera associated to cold-water coral ecosystems
October 2000 - July 2006
    Diploma (MSc equivalent) in Geography, University of Zurich.
    Diploma work: Particle flux and sedimentation in Upper Engadin lakes.
March 1996 – June 1999
    High school graduation, in-service training, ISME Interkantonal School for Adults
August 1991 – July 1994
    Apprenticeships as a Laboratory Technician, Chemistry Laboratory of Kanton Graubünden, Switzerland

Work experience

October 2006 – September 2010
    Graduate Assistant for general Micropaleotology, Micropaleontology Stratigraphy and Paleoceanography, practice courses, Department of Geosciences, University of Fribourg.
October 2003 – January 2006
    Assistant in Soil Science and Geobiology, practice course, Department of Geography, University of Zurich.
January 2004 – August 2004
    Organisation of Baikal-Excursion 2004, Department of Geography, University of Zurich.
February 2003 – April 2003
    Work placement in water monitoring, Environmental Agency of Kanton Graubünden, Switzerland.
August 1994 – July 2000
    Laboratory Technician in Environment Analytic, Chemistry Laboratory of Kanton Graubünden, Switzerland.

Oceanographic Cruises

30 August – 29 September 2009
    FS POSEIDON POS391, Bremerhaven – Tromsø – Kiel
2 April – 6 April 2009
    RV G.O. SARS Hermi-1, Tromsø – Tromsø
6 März – 24 März 2008
    FS ALKOR AL316, Kiel – Ålesund – Kiel
30 September – 22 Oktober 2007
    RV PELAGIA 64PE276, Galway – Galway

Workshop Participation

Mesozoic Planktonic Foraminifera Working Group Meeting: 27 – 28 June 2009, Fribourg, Switzerland

Oligocene Planktonic Foraminifera Working Group Meeting: 23 – 25 June 2009, Fribourg, Switzerland

Cold-Water Carbonate Reservoir System in Deep Environments (COCARDE) – A pilot Industry - Academia Partnership in Marine Research Drilling – Magellan Workshop Series, 21-24 January, Fribourg, Switzerland.

Cold-water Coral Ecosystems in a Changing World; 17 – 18 January 2008, Gent, Belgium.

Oligocene Planktonic Foraminifera Working Group Meeting; 13 – 16 December 2007, Tübingen, Germany.

Exploring Escarpment Mud Mound Systems and Mud Volcanoes with New European Strategies for Sustainable Mid-Depth Coring - Magellan Workshop Series, 26 – 29 April 2007, Murten, Switzerland.

Workshop on Mesozoic Planktonic Foraminiferal Taxonomy; 10 September 2006, Natal, Brasil.

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published:

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Raddatz, J., Rüggeberg, A., Margreth, S., Dullo, W., and IODP Expedition 307 Scientific Party, submitted. Paleoenvironmental reconstruction of deep-water carbonate mound initiation in the Porcupine Seabight, NE Atlantic. Mar. Geol.

Reviewer for:

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Margreth, S., Rüggeberg, A., Gennari, G., Spezzaferri, G., 2010. Identifying cold-water coral ecosystem by using benthic foraminiferal indicators: from active reefs to the geological record. European Gesciences Union, General Assembly 2010. European Gesciences Union, Wien, Austria. Geophysical Research Abstracts, EGU2010-4167-1, 2010.

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Margreth, S., Spezzaferri, S., Tamburini, F., Rüggeberg, A., de Haas, H., 2008. Cold water coral mounds from the Porcupine area: On-off mound characterization based on planktonic and benthic foraminifera and phosphorus content in the sediments, AAPG International Conference and Exhibition, Cape Town, South Africa.

Margreth, S., Spezzaferri, S., Tamburini, F., de Haas, H., Party, P.C.S., 2008. Benthic foraminifera as bioindicators for active cold-water coral mounds: Results from the Porcupine and Rockall Banks in the North Atlantic. The micropalaeontological society's foraminifera and nannofossil group's joint spring meeting, Tübingen, Germany, 35.

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