

Eocene/Oligocene deep-water agglutinated foraminifers (DWAF) assemblages from the Madonie Mountains (Sicily, Southern Italy)

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ABSTRACT

Quantitative and qualitative analysis of deep-water agglutinated foraminifer (DWAF) assemblages from Portella Colla (Madonie Mts.) reveal a variation of the trophic continuum in late Eocene and early Oligocene times. Twenty-nine samples were processed obtaining 138 agglutinated species, 59 of which are in open nomenclature, belonging to 46 genera attributed to four functional morphogroups according to their life position and feeding strategies. Faunal density increases upsection, whereas specific diversity fluctuates and reaches its minimum within the E/O transition. In the uppermost Eocene, cyclamminids, *Haplophragmoides* and *Repmantina charoides*, epifaunal and lower infaunal forms which prefer well-oxygenated bottom water and a normal food supply, prevail. Within the E/O transition the DWAF abundance broadly decreases and the assemblages are dominated by opportunistic taxa such as *Repmantina charoides*. In the lower Rupelian, suspension-feeders and assemblages rich in *Paratrochamminoides* are present, and hyaline taxa disappear. At the end of the lower Rupelian, *Nothia*, ammodiscids and hyaline foraminifers reappear, and deep infaunal morphogroup becomes dominant marking low-oxygen bottom water conditions. In the upper Rupelian, deep infaunal communities (rheophacids and *Caudammmina*) dominate the assemblages, and epifaunal surface-dwelling foraminifers decrease. The LO of *Caudammmina gutta* coincides with an increase in sand deposition (transition from Calvaturo Fm. to Portella Colla Clays), a decrease in suspension feeders and surface-dwellers, and the dominance of oligotypic assemblages by *Reticulophragmium rotundidorsatum*. The oxygenation of bottom waters return to levels similar to those of the upper Eocene, with a medium to high nutrient supply as inferred from the abundance of cyclamminids.

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INTRODUCTION

Deep water agglutinated foraminifer (DWAF) assemblages are well known in the Carpathians flysch (e.g., Grzybowski, 1896, 1898, 1901; Geröch, 1960, 1966), from deep water core exploration (e.g., Gradstein and Berggren, 1981; Kuhnt and Collins, 1996; Kaminski et al., 2006; Kender et al., 2008), and are well documented from the Apennine (Montanaro Gallitelli, 1943, 1955, 1958; Petters and Gandolfi, 1948; Lipparini, 1951; Nicosia, 1952; Emiliani, 1954; Accordi, 1958; Dallan, 1962; Coltro, 1963; Wezel, 1966; Dallan Nardi, 1968; Morlotti and Kuhnt, 1992; Morlotti, 1998a, 1998b). Such faunal assemblages were described by Brouwer (1965) under the name “*Rhabdammina* faunas” for the Cretaceous-Paleogene flysches. The record of late Eocene and early Oligocene DWAF assemblages in Italy are very scarce (Lipparini, 1951; Bellagamba and Coccioni, 1990; Morlotti and Kuhnt, 1992), whereas a more complete record is available for the Atlantic Ocean Drilling Program (ODP) exploration (e.g., Osterman and Spiegler, 1996; Kaminski et al., 2006, 2009; Kender et al., 2008, 2009; Kaminski and Ortiz, 2014).

The Eocene-Oligocene transition (EOT) was characterized by a glacial climatic and oceanographic change (e.g., Coxall and Pearson, 2007) from the shallow water seas to the deep ocean. An extended period of global cooling is widely documented (e.g., Zachos et al., 2001; Katz et al., 2008) and extinctions are recognized in different phyletic lineages (Wade and Pearson, 2008; Ortiz and Kaminski, 2012; Prothero et al., 2013; Kaminski and Ortiz, 2014).

With respect to shallow-water environments, where an abrupt change in benthic communities is well documented (Benedetti, 2010; Cotton and Pearson, 2011), deep-sea benthic foraminifers underwent a gradual extinction from the middle-late Eocene (Kaminski, 2005; Ortiz and Kaminski, 2012). The EOT was characterized by a faunal turnover among DWAF (Kaminski and Gradstein, 2005; Kaminski, 2005; Kaminski and Ortiz, 2014), possibly reflecting an abrupt drop in the calcite compensation depth (CCD) (Coxall et al., 2005); this results in a poorly documented record of DWAF from the early Oligocene (Kaminski, 2005; Kaminski and Gradstein, 2005; Cetaan and Kaminski, 2011).

Some poorly investigated assemblages have been identified and preliminarily described (Benedetti and Pignatti, 2008; 2009; Benedetti, 2010) from the uppermost Eocene and lower Oligocene clays of the Caltavuturo Formation cropping out at Por-

tella Colla (Madonie Mts., Sicily). These previous works provided new evidence of diverse Oligocene DWAF assemblages containing 74 species and defined three faunal assemblages: 1, a *Cyclammina* assemblage, characterized by the dominance of cyclamminids, ammodiscids, *Paratrochamminoides*, with some *Cibicidoides*, but few elongated and cylindrical forms; 2, a *Rhabdammina* assemblage, characterizing the lower Rupelian sediments, and dominated by tubular suspension feeding forms; 3, a *Caudammina* assemblages dominated by elongated and seriate infaunal forms (Benedetti and Pignatti, 2008). In the sediments of Caltavuturo Fm., Benedetti and Pignatti (2008, 2009) described some taxa that are usually known from the Cretaceous to the Eocene. In particular the new species *Caudammina gutta* Benedetti and Pignatti, 2009 represents the first documentation of this genus after the middle Eocene. These studies excluded the possibility of mixture among different-age taxa, because none of the recovered foraminifers shows signs of reworking (except isolated tests of Late Cretaceous orbitoids within few interbedded calcarenites). All the foraminifers indicate an Eocene-Oligocene age, because the DWAF assemblages show a coherent vertical distribution, and according to the biometric study, this reveals the occurrence of a complex evolutionary trend (Benedetti and Pignatti, 2009). In addition, agglutinated foraminifers considered extinct from the Eocene, were recently recovered and recognized in Miocene sediments by Kaminski et al. (2006, 2009) and Kender et al. (2009), thus suggesting strict environmental and ecological controls on the disappearance of such taxa from different areas. The aim of this work is to provide a taxonomic identification of the investigated taxa, and to give a paleoenvironmental interpretation of the foraminiferal assemblages, with particular regards to the faunal turnover at the EOT.

MATERIALS AND METHODS

The Caltavuturo Formation (Schmidt di Friedberg et al., 1960) belongs to the Imerese Domain and is generally described as red or green calcilutites and marls with intercalated resedimented larger foraminiferal biocalcarenes (Basilone, 2012). This sedimentary succession crops out discontinuously in northeastern Sicily, and spans from the Cretaceous to the lower Oligocene (Basilone, 2012). The Caltavuturo Fm. at Portella Colla (Figure 1) is about 30 m thick, and consists of red to dark greenish clays and marly-clays, with low calcium carbonate content, with some interbedded

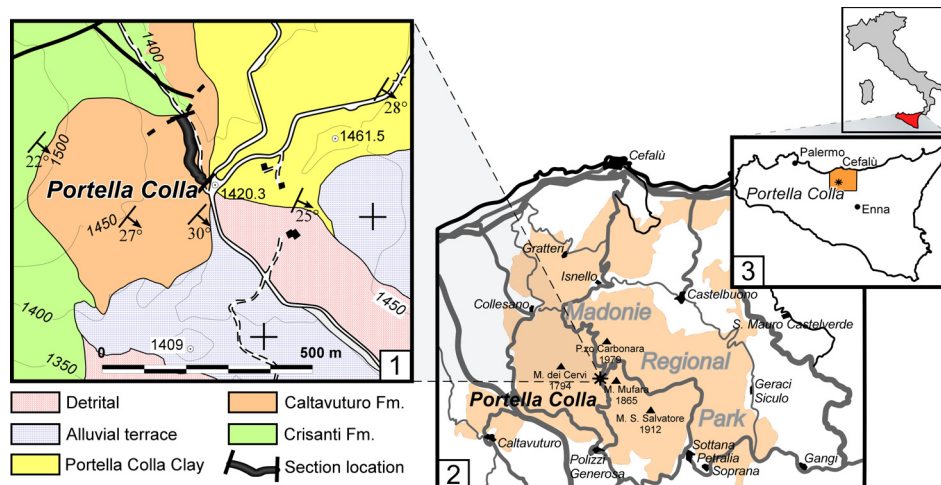


FIGURE 1. Schematic geological map with location of the investigated section (1). The study section is located at Portella Colla (2) in the Madonie Mountains, Sicily (3).

turbiditic levels dominated by numulitids and orbitoidiforms (Figure 2). The investigated succession unconformably overlies the light-grey limestone of the Crisanti Formation, and it is covered without any hiatuses by the silty-clay of the Portella Colla member of the Numidian Flysch (Wezel, 1966).

A total of 29 samples were collected at variable intervals, from 10 cm to 2 m. The sampling intervals were spaced closer near the suspected Eocene/Oligocene boundary, following the preliminary results in Benedetti (2010) and Benedetti and Pignatti (2008). The age control of Portella Colla section was previously based on the distribution of larger foraminifers in the resedimented layers (Benedetti, 2010), because the planktonic foraminifers are scarce and not useful to biostratigraphic characterization. Upsection the larger foraminifer assemblages appear to be diachronous and stratigraphically continuous, but some reworked Cretaceous orbitoids occur. The biometrical analysis of megalospheric specimens of *Nephrolepidina* reveals a direct evolutionary progression of the measured populations (Benedetti and Pignatti, 2013). The foraminifers in the clayey levels can be instead considered autochthonous in comparison to those of the calcareous levels. The macrofossils are extremely rare and essentially represented by small teeth of fish; radiolarians are absent. In the clayey samples of the Caltavuturo Fm., the assemblages are primarily composed of DWAF (Benedetti and Pignatti, 2008, 2009); hyaline foraminifers, both benthic and planktic, are rare and often absent. The scarce planktic foraminifers are poorly preserved and dominated by taxa with low stratigraphic resolution, so they are not useful for a

detailed biostratigraphic reconstruction of the investigated succession. Only two samples contain recognizable taxa: single specimens of *Turborotalia ampliapertura*, *Subbotina corpulenta*, *S. eocaena*, and *Dentoglobigerina cf. galavisi* occur in PC060601 (suggesting a late Eocene-early Oligocene age), whereas *Subbotina gortanii*, *Dentoglobigerina tripartita*, *D. tapuriensis* and *Globigerina venezuelana* were extracted from PC8 (Oligocene s.l.).

In this work new biostratigraphic data are added from poorly preserved calcareous nannofossils, although several samples were barren of recognizable taxa (Figure 2). The oldest sediments recovered from the investigated succession are referred to the late Eocene (biozones NP19-20 of Martini, 1971) based on the occurrence of *Dictyocites bisectus*, *Coccolithus formosus*, *Reticulofenestra umbilicus*, *Discoaster tanii*, *D. nodifer*, *D. deflandrei* (about 80%), and rosette-shaped discoasters (about 20%). Latest Eocene sediments occur at least up to samples PC0606067 and PC3, which contains nannofossil assemblage of *Dictyocites bisectus*, *Coccolithus formosus*, *Reticulofenestra umbilicus*, *Isthmolithus recurvus*, *Sphenolithus radians*, and common *Discoaster saipanensis*. In the absence of more precise data, these levels are referred to the biozone NP19-NP20 of Martini (1971). A more accurate attribution according to the biozonal scheme of Agnini et al. (2014) is not possible because of the preservation of the material. Based on the occurrence of *Dictyocites bisectus*, *D. scrippsae*, *Isthmolithus recurvus*, *Reticulofenestra umbilicus*, *Clausicoccus obrutus*, *Discoaster tanii*, *D. nodifer*, *D. deflandrei*,

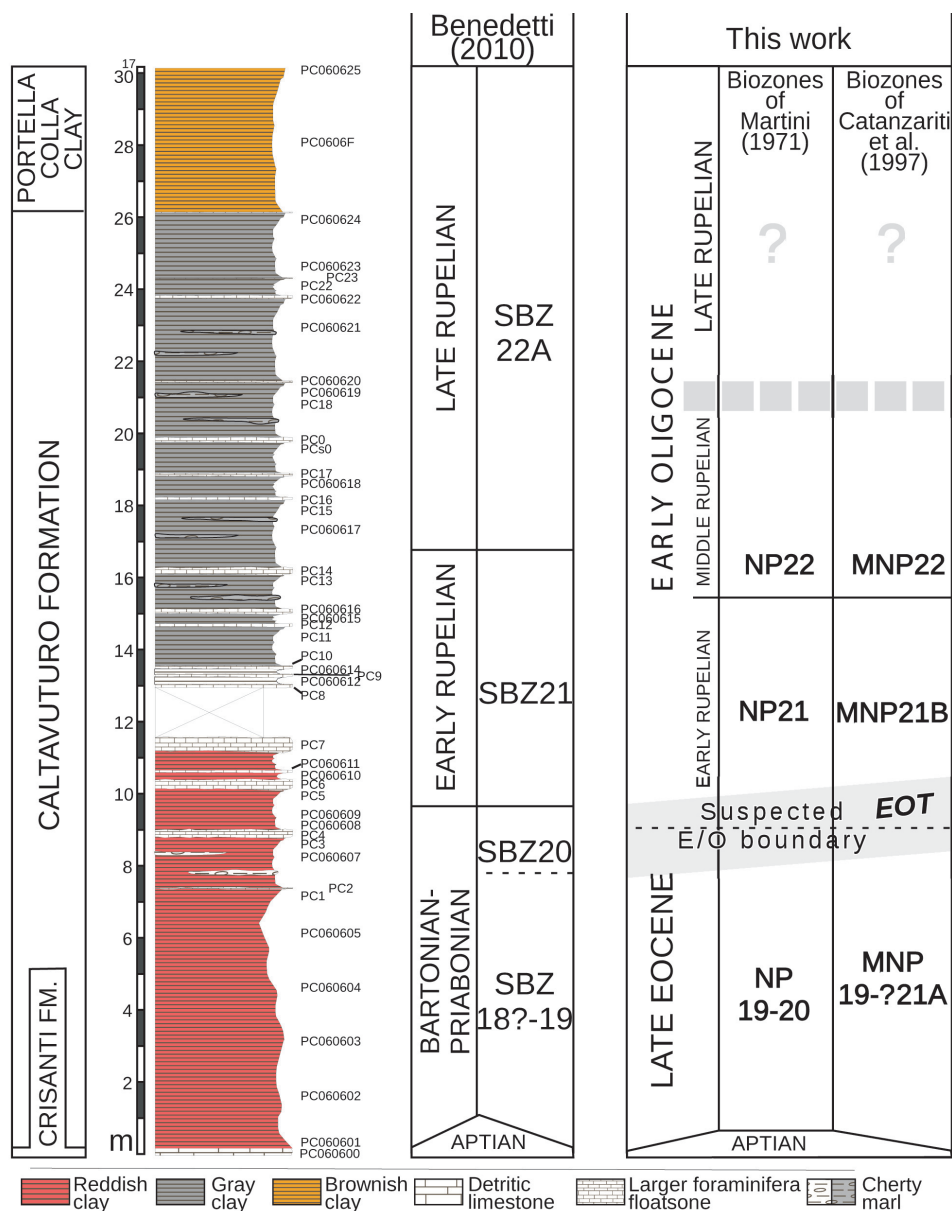


FIGURE 2. Biostratigraphic interpretation of the investigated section. According to Benedetti (2010), the distribution of the main larger foraminifers in the displaced layers allows the recognition of four biozones in the Paleogene succession. The presence of SBZ 18 (late Bartonian) at the base of Paleogene succession is uncertain. The E/O boundary is here redefined by the study of poorly-preserved nanofossils occurring only in some levels, and following the biozonal schemes of Martini (1971), and Catanzariti et al. (1997).

and the absence of rosette-shaped *Discoaster*, the sample PC060609 is dated as early Oligocene, zone MP21B of Catanzariti et al. (1997) corresponding to the upper part of NP21 of Martini (1971). A middle Rupelian age is assigned from the sample PC13 by the occurrence of *Dictyocites bisectus*, *Reticulofenestra umbilicus*, *Ismolithus recurvus*, *Sphenolithus predistentus*, *Cyclicargolithus floridanus*, *Discoaster tanii*, *D. nodifer*, *D. deflandrei*, and by the absence of *Coccolithus for-*

mosus marking the MNP22 of Catanzariti et al. (1997), or more simply NP22 of Martini (1971). The upper part of the section is barren in recognizable calcareous nanofossils and is assigned to the late Rupelian according to the study of resedimented larger foraminifers (Benedetti, 2010; Benedetti and Pignatti, 2013).

Samples were weighed, disaggregated by peroxide hydrogen solution, sieved over a 63 µm mesh, and all foraminifers were picked from each

dry residue to determine the total abundance per gram. Foraminifers were mounted in standard micropaleontological slides. Selected specimens were photographed at a FEI QUANTA 400 MK2 scanning electron microscope (SEM), and the plates were assembled by the vectorial imaging software Canvas 11. The number of species per sample, the percentages of epifaunal and infaunal forms, the specific diversity, richness, and the index of evenness were calculated using the software PAST (Hammer et al., 2001; Hammer and Harper, 2006). The content in calcium carbonate in the investigated samples was determined with a Dietrich-Fruhling calcimeter in the Laboratory of Sedimentology of the University of Rome "La Sapienza".

FACTORS CONTROLLING THE DWAF ASSEMBLAGES

According to Stainforth (1952), water turbidity is the main factor controlling the distribution of the arenaceous agglutinated foraminifers, reducing the activity of symbionts typical of calcareous organisms. The living agglutinated foraminifers occur in a great variety of environments: in shallow waters, lagoons, transitional environments, in proximity of river deltas, and in deep waters. A progressive increase in agglutinating taxa diversity from marginal marine to deep sea has been recorded (Nagy et al., 2000; Murray and Alve, 2011). In particular, modern taxa with organo-agglutinated walls are exclusively found in environments where the water is under-saturated in carbonate, such as in high intertidal marshes, and in the deep sea below the CCD (Murray and Alve, 2011), but also in fjords (Murray et al., 2003), and on deep continental shelves (Murray and Pudsey, 2004). The increase in arenaceous foraminifers with depth usually corresponds to a decrease in calcareous-walled foraminifers (Nagy et al., 2000).

Living DWAF assemblages have been reported from depths of 11 km (Akimoto et al., 2001), therefore, the temperature should be another dominant factor in the distribution of the DWAF. Comparing the "*Rhabdammina* faunas" with recent agglutinated foraminifer-dominated assemblages described by Brady (1884) and Saidova (1961), Brouwer (1965) held this kind of assemblage typical of abyssal depth below the CCD. Consequently Gradstein and Berggren (1981) found that the availability of calcium carbonate is the main factor controlling the benthic foraminifer distribution. A lot of agglutinants have organic cement resistant to the corrosion of the

deep seawater enriched in carbon dioxide. This would explain why DWAF are predominant in waters unsaturated in calcium carbonate, as well as in low salinity and low temperature conditions, or in oxygen depleted or pH fluctuating waters, such as in brackish environments. The organic cement typical of DWAF, however, tends to degrade after death and burial, so a limited number of specimens are preserved in the fossil record (Corliss, 1985). More likely, therefore, is that a single dominant factor does not exist, and DWAF distribution is influenced by bathymetry, oxygenation of the bottom- and interstitial waters, sedimentary input, nutrients, availability of calcium carbonate, type of substrate, hydrodynamic effects, and other factors that rule the equilibrium of the communities (Kuhnt et al., 1989).

FUNCTIONAL MORPHOGROUPS

The analysis of functional morphogroups of agglutinated foraminifers is a fundamental tool for paleoenvironmental interpretations; the relative frequency of different trophic groups in a sample is dependent on environmental factors such as the organic productivity and the bottom-water oxygenation. The different agglutinated foraminifer taxa can be divided in morphotypes on the basis of test morphology that reflects the life position and the feeding strategies (Jones and Charnock, 1985; Nagy et al., 1995, 1997; Bağ et al., 1997; van den Akker et al., 2000; Kaminski et al., 2006) (Figures 3-4). The morphotypes can be combined into morphogroups according to the preferred habitat, and the life position respect to the sediment/water interface (infaunal or epifaunal).

In this work four principal morphogroups, subdivided into seven morphotypes, are distinguished (Figure 4). Morphogroup M1 includes tubular and branched forms living in erect position, perpendicular to the substrate. These foraminifers are suspension feeders that filter bottom waters with extroflexed pseudopoda at the end of the tubular chambers. They are abundant in bathyal and abyssal environments without strong currents under stable conditions (Kaminski and Schröder, 1987; Kuhnt and Kaminski, 1989; Nagy et al., 2000). This morphogroup is composed of mostly astrophorids and bathysiphonids. Kaminski et al. (2006) also inserted *Arthrodendron subnodosiformis*, but not *A. grandis*, in M1 in association with tubular branched forms; however, Kaminski et al. (2006) did not provide support for this placement, and so this hypothesis is herein rejected.

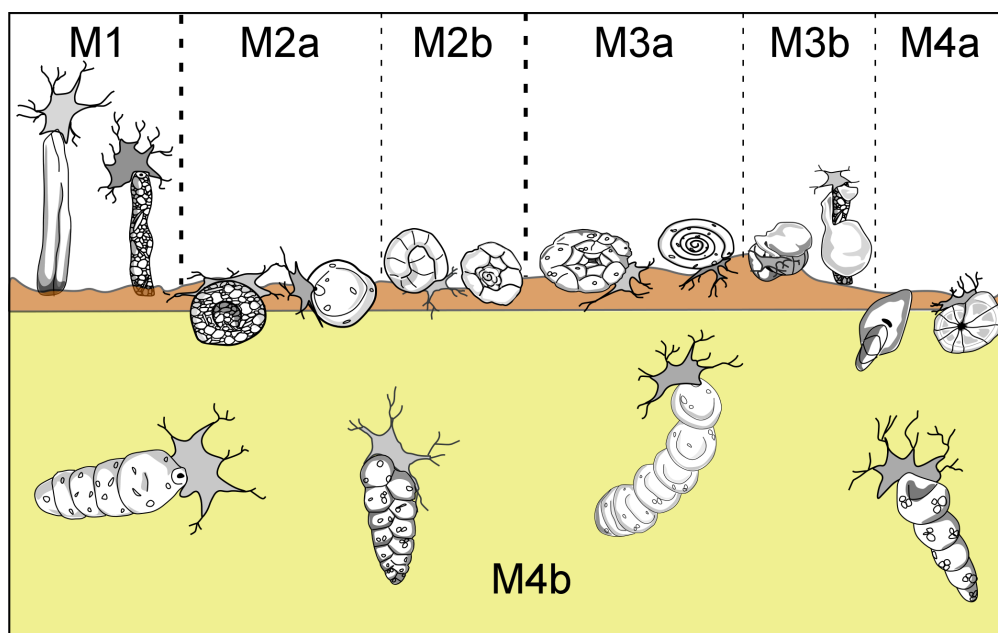


FIGURE 3. Representative forms of foraminifera belonging to the six different functional morphogroups (redrawn after Jones and Charnock, 1985, figure 2).

The morphogroup M2, predominantly characterized by deposit feeders, globular taxa living on or just below the substrate, is subdivided in two subgroups. The morphotype M2a includes spherical or subspherical forms and the saccamminids, among which is *Psammospaera*, a globular form without evident aperture that lives just under the water/sediment boundary (Kaminski et al., 1995). The thick-walled tubular *Nothia* is here considered a deposit feeder as suggested by Geroch and Kaminski (1993), even if it is classified as suspension feeder by Jones and Charnock (1985) and Kaminski et al. (2006). *Nothia* is placed in M2a rather than in M1 on the basis of data collected in this work, that show that *Nothia* distribution is directly proportional to deposit feeders rather than to tubular suspension feeders. Van den Akker et al. (2000) also included the genera *Arthrodendron* and *Caudamina* in M2a. In this study, however, these taxa are instead referred to the morphogroup M4b (Figure 4). The morphotype M2b comprises both rounded trochospiral and streptospiral forms (*Recurvoides* and *Thalmanamina*), in addition to some planoconvex trochospiral forms (*Trochammina*). Following Bağ et al. (1997), Galeotti et al. (2004), and Kaminski et al. (2006), *Cribrostomoides* is also included in M2b.

The morphogroup M3 consists of two morphotypes. M3a includes flattened forms with planispiral (*Ammodiscus*) trochospiral (*Trochamminoides*) or streptospiral coiling (*Paratrochamminoides*, *Rep-*

manina). Morphotype M3b includes all the sessile, agglutinated foraminifera referred to Tolypammininae, passive herbivores and deposit feeders that live fixed to the substrate or other organisms, such as tests of other foraminifera. *Ammolagena clavata* is the unique representative of M3b recovered in this work. *Ammolagena* is a cosmopolitan epibiont species common in various deep water assemblages from upper bathyal to abyssal environments, but it has also been found in shallow environments and in tropical seas (Cushman, 1928). *Ammolagena clavata* is, however, usually common in sediments deposited above the CCD, selecting the tests of other agglutinated foraminifera as a substrate for settlement (Waśkowska, 2014).

The morphogroup M4 comprises all the shallow or deep infaunal taxa, which are split into two different morphotypes. These taxa tolerate high organic matter flux (Kaminski et al., 1995). The planispirally coiled *Cyclammina*, *Haplophragmoides*, and *Reticulophragmium* belong to the morphotype M4a; these taxa live in the sediment near the water/sediment boundary. They are herbivores or active deposit feeders able to resort to more omnivorous feeding in answer to environmental modifications (Jones and Charnock, 1985). *Haplophragmoides* lives up to 4 cm deep in the sediment (Kaminski et al., 1995), and is a generalist form adapted to a wide variety of environments (Nagy et al., 2000) indicative of low oxygenation in the bot-








Morphogroup	Morphotype	Test shape	Life position	Feeding habit	Environment	Main genera
M1		Tubular and branching	Erect epifauna	Suspension feeding	Bathyal and abyssal with low organic matter flux	<i>Hyperammina</i> <i>Psammosiphonella</i> <i>Rhabdammina</i> <i>Rhizammina</i> <i>Kalamopsis</i>
M2a		Globular and tubular	Shallow infauna	Suspension feeding - Passive deposit feeding	Bathyal and abyssal	<i>Nothia</i> <i>Placentammina</i> <i>Saccammina</i> <i>Psammosphaera</i>
M2b		Rounded trochospiral and streptospiral	Surficial epifauna	Active deposit feeding	Shelf to deep marine	<i>Cribrostomoides</i> <i>Recurvoidella</i> <i>Recurvoides</i> <i>Thalmannammina</i> <i>Trochammina</i>
M3a		Flattened planispiral, low-trochospiral or streptospiral	Surficial epifauna	Active or passive deposit feeding	Lagoon to abyssal	<i>Ammodiscus</i> <i>Glomospira</i> <i>Trochamminoides</i> <i>Paratrochamminoides</i> <i>Repmanina</i>
M3b		Flattened irregular	Surficial epifauna	Passive deposit feeding	Upper bathyal to abyssal	<i>Ammolagena</i>
M4a		Rounded planispiral	Surficial epifauna - Shallow infauna	Active deposit feeding	Inner shelf to bathyal	<i>Cyclammina</i> <i>Haplophragmoides</i> <i>Reticulophragmium</i>
M4b		Elongated tapered and subcylindrical	Deep infauna	Active deposit feeding	Inner shelf to bathyal with increased organic matter flux	<i>Ammobaculites</i> <i>Arthrodendron</i> <i>Caudammina</i> <i>Hormosina</i> <i>Karrerulina</i> <i>Pseudonodosinella</i> <i>Reophax</i> <i>Subreophax</i>

FIGURE 4. Summarizing scheme of the DWAf functional morphogroups and morphotypes described in this work (redrawn and modified after van den Akker et al., 2000, figure 6).

tom waters (Green et al., 2004). The M4a abundance, therefore, is dependent on changes in organic productivity rather than bathymetry (Kaminski et al., 2006). All the plurilocular, lengthened, seriate, cylindrical, or flattened forms belong to the morphotype M4b; the lengthened tests are particularly adapted to a deep infaunal life position and these foraminifers are passive deposit feeders. As an example, *Karrerulina* lives 10 to 20 cm deep in the sediment, and its abundance indicates a low rate of sedimentation and low oxygenation of the bottom water under oligotrophic conditions (Kender et al., 2005). Intermediate and deep infaunal dominated assemblages are usually directly proportional to the organic matter content of the sea-floor sediments and to the oxygenation of the bottom waters (Van der Zwaan et al., 1999) and, even in case of parity in the oxygen content of the waters, infaunal-dominated assemblages are common in samples with higher organic carbon content (Kaminski et al., 1995). On the contrary, epifaunal- and shallow infaunal-dominated assemblages are typical of environments with normal oxygenation, although in this condition all the morphogroups are usually represented (Kaminski et al., 1995).

In unstable environments, benthic communities are “physically controlled” and consist of infaunal r-strategists that live at the limit of the environmental tolerance (Kaminski et al., 1995; Preece et al., 1999). Under these conditions the specific diversity is controlled by the frequency of the reduction of the stressed populations (such as after periodic events of anoxia). In the most extreme environments, the specific diversity and the number of foraminifers decrease to those occurring under abiotic conditions (Kuhnt and Kaminski, 1993; Kaminski et al., 1995). Under oligotrophic conditions all the morphogroups are represented, and accordingly the DWAf diversity is high and the organisms are typically K-strategists. Under eutrophic conditions the specific diversity generally decreases, and hyaline benthic foraminifers dominate the assemblages. Moreover, the whole fauna is primarily concentrated in the upper few centimeters and on the surface of the sediment (Kuhnt et al., 1996). Bottom waters depleted in oxygen are usually the result of epipelagic, eutrophic conditions. A high epipelagic productivity contributes to a fall of nutrients and induces deficiency of oxygen in the sediment/water interface. An ele-

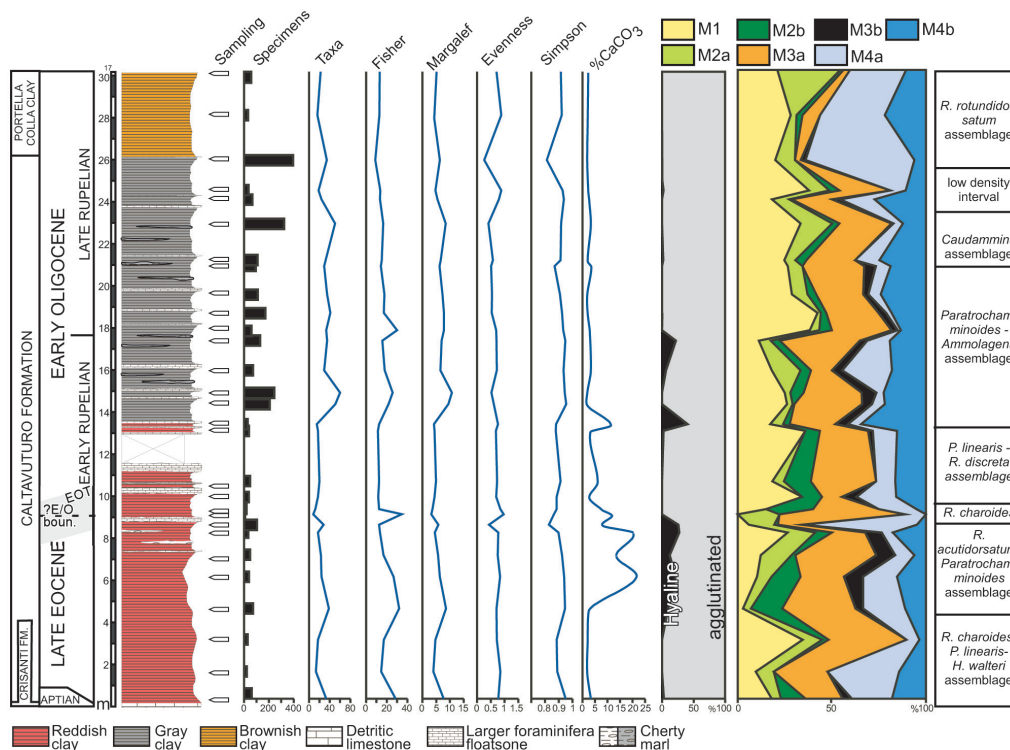


FIGURE 5. Results of the micropaleontological analysis along the investigated section cropping out at Portella Colla (Sicily). Vertical distribution of individuals counted per sample, number of taxa, Fisher's Alpha diversity, species richness, evenness index, Simpson's index, and percentage of CaCO₃ within the samples. The three boxes represent the relative abundances of agglutinated and calcareous hyaline taxa, the DWAF morphogroups, and the recognized assemblages.

ivated organic matter flux favors two groups of benthic foraminifers: 1) specialized forms, such as infaunal taxa tolerating low oxygenation; 2) opportunist forms that quickly (or seasonally) respond to elevated organic matter supply, which may tolerate oxygen content below the normal concentration (Kuhnt et al., 1996). The position of the "redox boundary", representing the limit of the benthic activity in the sediment, is fundamental, and it is due to the consumption of the oxygen in the interstitial waters by the activity of aerobic bacteria. In absence of burrowing macrofauna, which may rework the sediments, the position of the redox boundary depends, therefore, on the rate of organic flux. Under oligotrophic conditions the redox boundary can be several meters deep or even absent. Under very elevated rates of organic flux, the boundary can be close to the water/sediment interface, and tends to devastate the niches occupied by infaunal foraminifers (Kuhnt et al., 1996). Deep infaunal taxa and *Haplophragmoides* fully exploit the whole infaunal area between the sediment surface and the redox boundary (Goody, 1996). Under extremely eutrophic conditions, epifaunal morphogroups dominate, with especially

Ammodiscus and *Glomospira* (Kaminski et al., 1996), the infaunal taxa survive and live within the sediment.

RESULTS

A total of 138 species, of which 59 are in open nomenclature, have been isolated from the marly-clays of the Portella Colla section; additional taxa have been recognized only at generic rank (see Appendix for complete list). Many of the recognized species, particularly *Ammolagena clavata*, *Psammosiphonella cylindrica*, *P. linearis*, *Repmantina charoides*, and *Rhabdammina discreta*, are cosmopolitan and have a wide stratigraphic range. A total of eight assemblages have been identified according to the functional morphogroup analysis, the specific diversity, and the faunal density (Figures 5-8).

***Repmantina charoides*-*Psammosiphonella linearis*-*Haplophragmoides walteri* Assemblage (Upper Eocene)**

The red clays at the base of the investigated succession have a low calcium carbonate content,

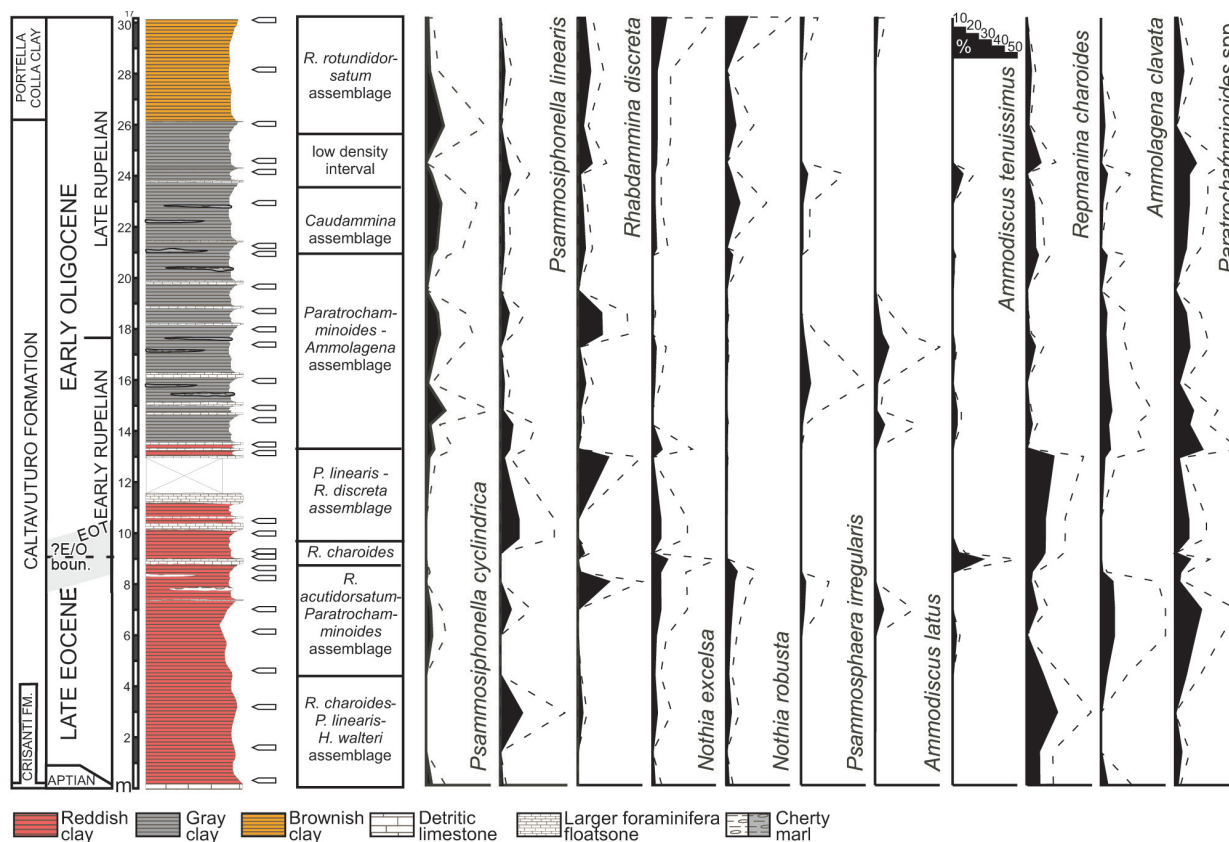


FIGURE 6. Stratigraphic distribution (in percentage) of selected DWAF taxa (solid line). The abundances have been exaggerated (dashed lines) in order to show also the minimal fluctuations.

and low faunal density; whereas the specific diversity reaches discrete values and all the morphogroups are represented, although M2b and M3b are subordinate. The assemblages are dominated by *Haplophragmoides walteri*, *Repmanina charoides*, and *Psammosiphonella linearis*. With the exception of the latter species, the tubular morphotypes belonging to M1 are rare. M4b is represented above all by *Karrerulina horrida*. This assemblage suggests good oxygenation of the seafloor, according to the rarity or absence of deep infaunal morphotypes and the occurrence of oligotrophic conditions.

***Reticulophragmium acutidorsatum*-*Paratrochamminoides* spp. Assemblage (uppermost Eocene)**

In the upper Eocene red clay, the specific diversity and density tend to decrease, the CaCO₃ content increases up to 20%, and hyaline taxa typical of deep environments are present, including *Cibicidoides havanensis* and *C. grimsdalei* (van Morkhoven et al., 1986). Among the DWAF, cyclamminids, *Haplophragmoides*, *Ammodiscus latus*,

Ammolagena clavata, *Paratrochamminoides*, and *Pseudonodosinella elongata* dominate. Parisi and Coccioni (1988) and Molina et al. (2006) described peaks in *R. amplectens* (or cyclamminids in general) in assemblage with *C. havanensis* and *C. grimsdalei* near the E/O boundary. These assemblages resemble the “*Paratrochamminoides* assemblages” of Kuhnt and Kaminski (1989), typical of red clays with a low number of tubular taxa (Kender et al., 2005), and characterizing oligotrophic environments (Kaminski et al., 1996).

***Repmanina charoides*-*Ammodiscus tenuissimus* Assemblage (Eocene/Oligocene transition)**

Near the hypothesized E/O boundary, the number of taxa abruptly decreases; the assemblages are dominated by opportunist taxa such as *Repmanina charoides*. The reduced carbon matter flux is reflected by the disappearance of the M1 and M3b morphogroups. Infaunals are instead rare, and M4b is not represented in this interval. The specific diversity registers a peak because most of the recovered taxa, although very few

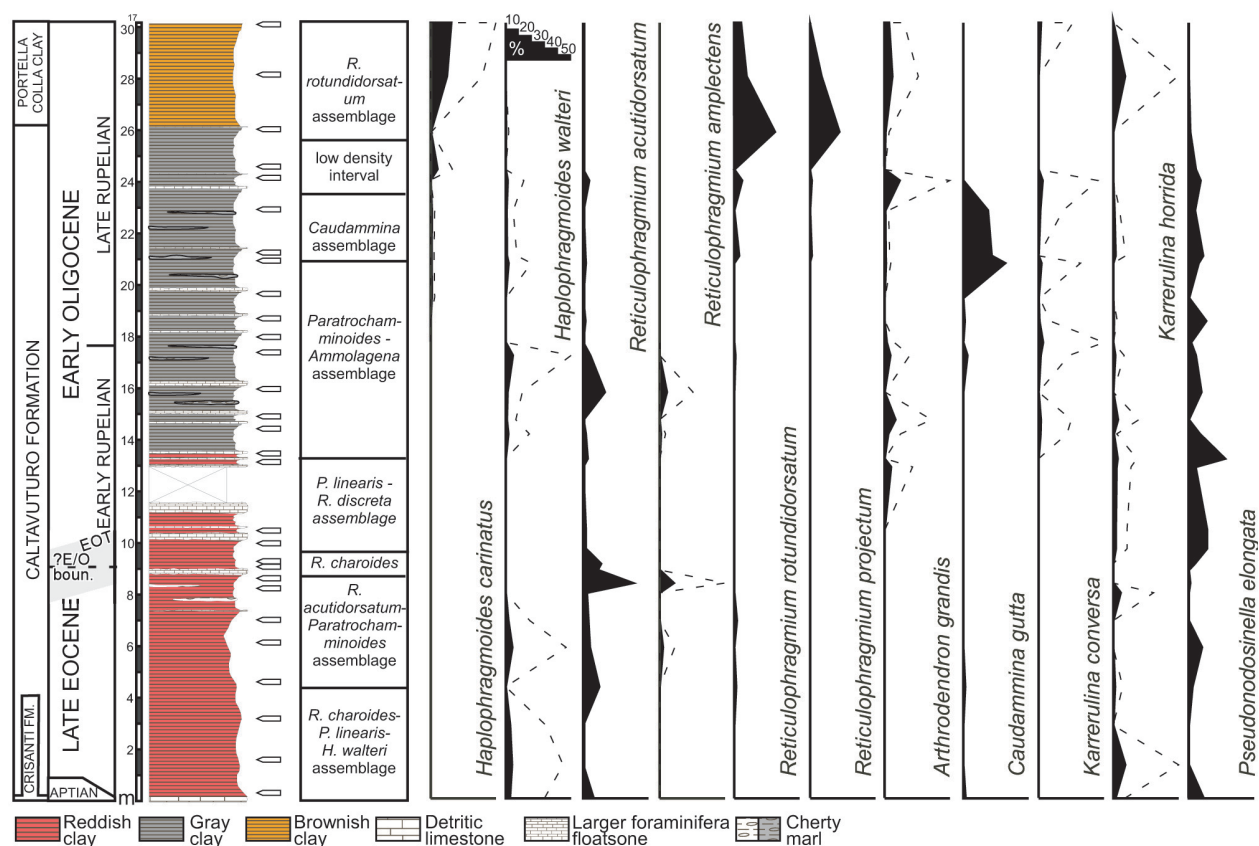


FIGURE 7. Stratigraphic distribution (in percentage) of selected DWAF taxa (solid line). The abundances have been exaggerated (dashed lines) in order to show also the minimal fluctuations.

($n=7-9$), are represented only by one or two individuals. The CaCO_3 content reaches 12%, but no calcareous foraminifers have been recovered in the autochthonous assemblages. The calcium carbonate is probably linked to the occurrence of reworked late Eocene larger foraminifers, such as *Nummulites incrassatus*, *Discocyclusa dispansa* and *Orbitoclypeus varians*, within the sample PC060608 described in Benedetti (2010).

Opportunists survive, such as *Ammosiphonella tenuissimus*, *Reticulophragmium acutidorsatum*, and especially *Repmanina charoides*, an epifaunal taxon that quickly responds to elevated flux of organic matter and to rapid changes of seafloor conditions (Arreguin-Rodriguez et al., 2014). The morphogroups M2, M3a, and M4a dominate within the interval, and robust taxa, such as *Nothia robusta*, disappear. *Haplophragmoides* disappears before the E/O boundary, and the infaunal taxa are absent, suggesting a sudden fall of the organic productivity. The causes of this change in the faunal content may be related to some alteration in the water mass characteristics, or more likely to the

global cooling recognized at the base of the Oligocene (Miller et al., 1987).

***Psammosiphonella linearis-Rhabdammina discreta* Assemblage (lowermost Rupelian)**

In the lowermost Rupelian, suspension-feeding tubular taxa (*Psammosiphonella* and *Rhabdammina*) become abundant, but the specific density and diversity are low. *Paratrochamminoides* and *Repmanina charoides* dominate, whereas *Cibicidoides*, *Haplophragmoides*, and *Reticulophragmium* disappear. Among the infaunal forms *Arthrodendron grandis* appears in association with *Karrerulina horrida* and *Pseudonodosinella elongata*. The presence of these taxa, especially *Arthrodendron*, could reflect elevated rate of organic matter input to the seafloor (Kaminski et al., 1996). The clay color is greenish gray recording decrease in the oxygenation of the bottom-waters. This assemblage is similar to the “*Rhabdammina* faunas” of Kuhnt and Kaminski (1989), typical of flysch-type sedimentation. At the base of the Oligocene, the turbiditic supply becomes more signifi-

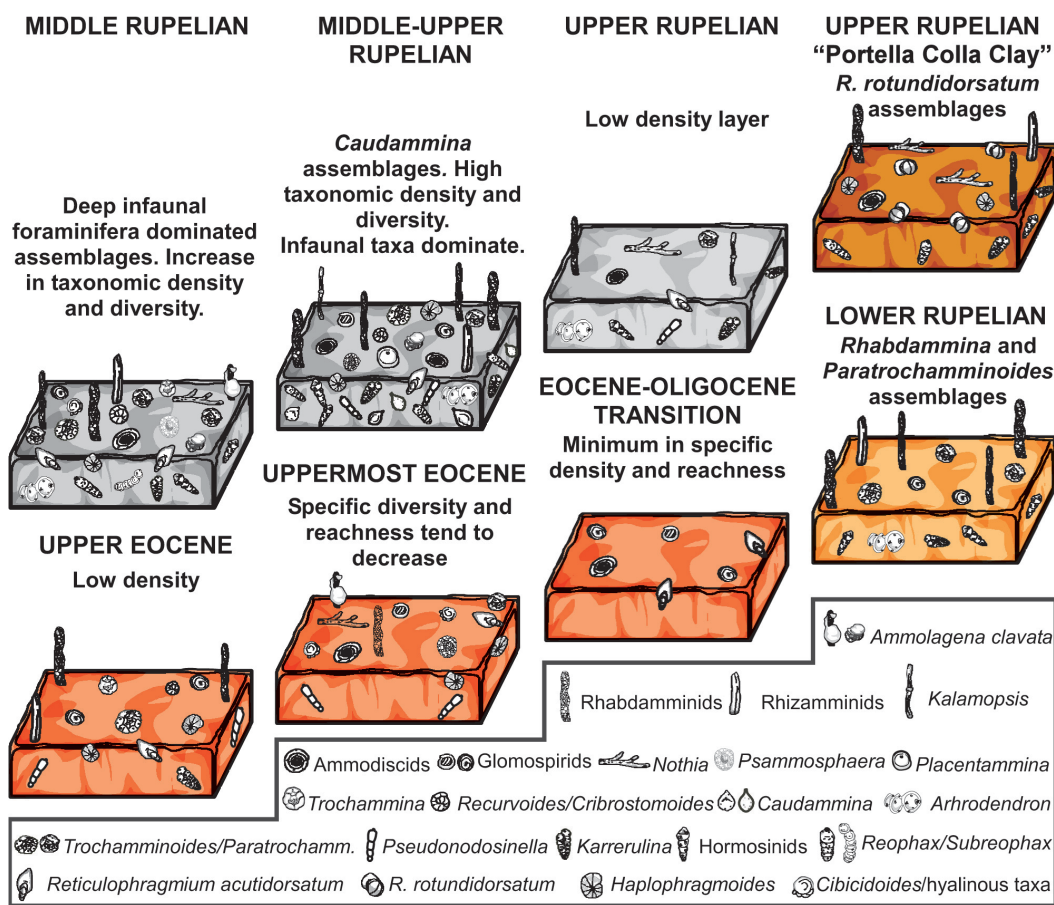


FIGURE 8. Environmental interpretation of the investigated succession. Block diagrams schematically show the presence/absence of main taxa and the faunal density.

cant, and the larger foraminifer-bearing layers increase in frequency and thickness.

***Paratrochamminoides*-*Ammolagena clavata* Assemblage (lower-middle Rupelian)**

At the transition from the lower to the upper Rupelian, the faunal density increases considerably, whereas the CaCO_3 content decreases. The assemblages are composed of suspension-feeding taxa, and deep infaunal, elongate forms indicating continuous flows enriched in organic matter and nutrients. Hyaline taxa are present (*Cibicidoides* and stilostomellids). *Arhrodendron grandis*, *Karrerulina horrida*, and *Karrerulina conversa* suggest an elevated supply of organic matter. *Haplophragmoides walteri*, *Reticulophragmium acutidorsatum*, *Ammolagena clavata*, *Paratrochamminoides*, *Ammodiscus latus*, *Psammosphaera irregularis*, and rhabdamminids are abundant. In addition, the FO of *Caudamina* in the Oligocene is recorded. The specific diversity is high, and the assemblages

are similar to the “*Rhabdammina* assemblages” described by Kender et al. (2005).

***Caudamina* Assemblage (middle-upper Rupelian)**

Beginning at the upper Rupelian, the assemblages are dominated by M4, whereas deposit-feeding epifaunal taxa tend to decrease. The assemblages are dominated by reophacids and, above all, by *Caudamina gutta*, a species described from the Portella Colla outcrop (Benedetti and Pignatti, 2009). Rhabdamminids are common and *Nothia robusta* becomes common. The occurrence of *Reticulophragmium projectum*, a species described for the Oligocene of the Beaufort-Mackenzie basin from Schröder-Adams and McNeil (1994), characterizes the first occurrence of this taxon in the Mediterranean area. The high organic carbon flux rate is proved by an increase in the faunal density, and by the abundance of deep and intermediate infaunal taxa. In particular deep

infaunal taxa dominate in low-oxygen environments and are adapted to live in areas with a high level of organic flux (Kaminski and Gradstein, 2005).

Low-density Interval (upper Rupelian)

In the uppermost clay layers of the Caltavuturo Fm., a low-diversity interval occurs. The assemblages are characterized by very rare DWAF, and are mainly composed of rhabdamminids and cyclamminids. This interval marks a return to oligotrophic conditions, preceding the deposition of the Portella Colla Clay where *Reticulophragmium rotundidorsatum*-dominated assemblages occur.

Reticulophragmium rotundidorsatum Assemblage (upper Rupelian, Portella Colla Clay)

Passing into the Portella Colla Clays, the faunas suffer a further change. *Caudammina* disappears, suspension-feeding and epifaunal deposit-feeding taxa decrease, and the assemblages become oligotopic, dominated by *Reticulophragmium rotundidorsatum* and *R. projectum*. Hyaline foraminifers are absent. *Arthrodendron* and *Karrerulina* dominate among the infaunals; *Haplophragmoides walteri* is replaced by *H. carinatum*, the suspension feeders decrease considerably responding to the increase of siliciclastic sedimentation rate flux. The fragmented specimens of *Nothia robusta*, occurring within this assemblage, show a very thick test characterized by coarse agglutination. In the Portella Colla Clay, there is a marked increase in the siliciclastic contribution; the quartz grains become more frequent in the clayey and especially in the turbiditic layers, the tubular forms have a coarser agglutination, and, among these, dominate large specimens of *N. robusta*. The occurrence of M4 marks high productivity without increase in sedimentation flux, since deep infaunal forms, such as *Karrerulina*, numerous in the uppermost samples, cannot tolerate high rates of sedimentation.

DISCUSSION

The Investigated Assemblages

The DWAF assemblages studied in the Portella Colla section represent a unicum in the Mediterranean Oligocene, and they are here compared to ODP projects. The ODP sites 643 (Norwegian Sea, North Atlantic; Kaminski et al., 1990) and 647 (Southern Labrador Sea, North Atlantic; Kaminski

et al., 1989; Kaminski, 2005; Kaminski and Ortiz, 2014) constitute the most complete Paleogene successions from high latitude available for DWAF analysis, and their zonations are compared with the assemblages recovered at Portella Colla (Figure 9). Late Eocene sediments are characterized by the occurrence of *Reticulophragmium* and *Haplophragmoides*-dominated assemblages. The species *R. amplectens*, poorly documented in the upper Eocene Portella Colla sediments, dominates the middle to late Eocene North Atlantic and is also common in the Arctic Ocean (Schröder-Adams and McNeil, 1994; McNeil, 1996). *Reticulophragmium acutidorsatum*, commonly recorded from the Eocene to Miocene (e.g., Kender et al., 2005, 2009), at Portella Colla occurs in the whole the Caltavuturo Fm., with a peak in the latest Eocene (sample PC3). *Reticulophragmium rotundidorsatum*, a species common throughout the Oligocene to the Miocene (e.g., Kaminski, 2005; Kaminski et al., 2006), and dominating the uppermost samples in the investigated section, marks the latest Eocene in the Carpathians (Geroch and Nowak, 1984). *Haplophragmoides carinatum*, which spans from the late Eocene to the Oligocene in the Arctic Ocean, at Portella Colla appears to be restricted to the Oligocene. The lower Oligocene generally contains impoverished DWAF assemblages, especially in the Tethys realm, whereas the *Spirosigmoilinella* assemblage appears to be restricted to the North Atlantic area (Kaminski and Gradstein, 2005).

A faunal turnover of DWAF taxa has been observed at the E/O boundary (Kaminski, 2005; Ortiz and Kaminski, 2012; Kaminski and Ortiz, 2014), and it generally linked to a drop in the CCD (Coxall et al., 2005; Ortiz and Kaminski, 2012). In particular, the late Eocene assemblages are usually dominated by *Pseudonodosinella elongata* (e.g., Kaminski and Huang, 1991), *Reticulophragmium amplectens*, *Ammodiscus latus* and *Spiroplectammina trinitatensis* (Kaminski and Ortiz, 2014), whereas the earliest Oligocene assemblages consist mainly of Ammodiscids and glomospirids (Kaminski et al., 1989). In the investigated section, red clays from the upper Eocene to the lower Oligocene levels suggest that the seafloor and deep-waters were well-oxygenated. The relatively high specific diversity of the first recognized assemblage also reflects oxygenation of bottom water. In the uppermost Eocene, the specific diversity and richness tend to decrease and cyclamminids dominate the assemblages in association with *Ammodiscus latus*, *Pseudonodosinella elongata*, *Ammolagena clavata*, and *Paratrochamminoides*.

	High latitude			Western Tethys	
	Southern Labrador Sea (North Atlantic)	Norwegian Sea (North Atlantic)	Beaufort-Mackenzie Basin (Arctic Ocean)	Carpathians	Portella Colla (Sicily, Italy)
	Kaminski et al. (1989); Kaminski (2005); Kaminski and Ortiz, (2014)	Kaminski et al. (1990); Osterman and Spiegler (1996); Kaminski and Austin (1999)	Schröder-Adams and McNeil (1994); McNeil, 1997	Geroch and Nowak (1984); Olszewska (1997)	Benedetti (2010); this study
Early Oligocene	<i>Turrilina alsatica</i> – <i>Spirosigmoilinella</i> assemblage <i>Spirosigmoilinella compressa</i> , <i>Psammimopelta gradsteini</i> , <i>Cribrostomoides subglobosus</i> , and <i>Rhabdammina</i> spp.	<i>Spirosigmoilinella compressa</i> assemblage <i>Bathysiphon</i> spp., <i>Verneuilinoides</i> sp., <i>Cystamina</i> sp., <i>Karrieriella siegliei</i> , and <i>Ammodiscus latus</i>	<i>Valvulineria dixonii</i> assemblage <i>Psammisiphonella cylindrica</i> , <i>Nothia robusta</i> , <i>Pseudonodosinella nodulosa</i> , <i>Ammodiscus tenuissimus</i> , <i>Glomospira charoides</i> , <i>Spirosigmoilinella compressa</i> , <i>Haplophragmoides carinatus</i> , <i>Recurvoides contortus</i> , <i>Adercotryma agterbergi</i> , <i>Spiroplectammina navarroana</i> , and <i>R. rotundidorsatum</i>	Gradual disappearance of agglutinated taxa	<i>R. rotundidorsatum</i> assemblage low density interval <i>Caudamina</i> assemblage <i>Paratrochamminoides</i> - <i>Ammolagena</i> assemblage
	Earliest Oligocene				<i>Ammodiscus latus</i> - <i>Turrilina alsatica</i> assemblage <i>R. charoides</i> , <i>G. irregularis</i> , <i>Bathysiphon</i> sp., <i>A. cretaceus</i> , and <i>Reophax</i> sp.
E/O Transition	Decrease in DWAF absolute abundance, species diversity and richness.				<i>R. charoides</i> assemblage
Late Eocene	<i>Spiroplectammina trinitatis</i> - <i>Reticulophragmium amplexens</i> assemblage <i>G. irregularis</i> , <i>K. coniformis</i> , <i>H. walteri</i> , <i>G. serpens</i> , <i>K. grzybowskii</i> , <i>A. clavata</i> , <i>S. grzybowskii</i> , and <i>Paratrochamminoides</i> spp.	<i>Reticulophragmium amplexens</i> assemblage <i>Budashevaella multicamerata</i> , <i>Ammosphaeroidina pseudopauciloculata</i> , and <i>Karrieriella chapapotensis</i>	<i>Haplophragmoides richardsensis</i> assemblage <i>Budashevaella multicamerata</i> , <i>Haplophragmoides carinatus</i> , <i>R. amplexens</i> , and <i>Ammosphaeroidina pseudopauciloculata</i>	<i>R.</i> <i>rotundidorsatum</i> assemblage <i>Reophax pilulifer</i> , <i>Recurvoides nucleolus</i> , and <i>Arenobulimina dorbignyi</i>	<i>R. acutidorsatum</i> - <i>Paratrochamminoides</i> assemblage <i>R. charoides</i> - <i>P. linearis</i> - <i>H. walteri</i> assemblage

FIGURE 9. Schematic zonal schemes of late Eocene-lower Oligocene successions described from different regions (redrawn and modified after Kaminski and Gradstein, 2005). The most common DWAF taxa are added.

Near the E/O boundary, the DWAF assemblages usually record an abrupt faunal turnover and a reduction of abundance and diversity (Kaminski et al., 1989; Kaminski and Huang, 1991; Kaminski, 2005; Kaminski and Ortiz, 2014). The DWAF assemblages are extremely impoverished, epifaunal opportunistic taxa survive, such as ammodiscids and glomospirids with smooth and well cemented tests (Kaminski et al., 1989).

The acme of *Ammodiscus latus* in the late Eocene and early Oligocene, with a hiatus in the lowermost Oligocene, is a global event with a high potential for correlation (Kaminski and Ortiz, 2014). Also at Portella Colla, *A. latus* disappears before the EOT up to the middle Rupelian sediments. *Pseudonodosinella elongata* commonly occurs along the entire section, but it disappears before the suspected EO boundary. *Reticulophragmium amplexens* is usually recorded as abundant in the late Eocene, and its last occurrence coincides with the Eocene/Oligocene boundary (e.g., Kaminski, 2005). The last occurrence of at least 10 DWAF

species is well-documented at the end of the Eocene (Ortiz and Kaminski, 2012; Kaminski and Ortiz, 2014), some of which were not recovered along the Portella Colla section (see below). *Ammolagena clavata* disappears at the EOT, and reappears in the lower-middle Rupelian; its occurrence is indicative of favourable environmental conditions (i.e., a high supply of organic matter, well oxygenated bottom sediment, and low-energy water) (Waśkowska, 2014). Overall, the faunal assemblage recovered in the upper Eocene clays reflects an oligotrophic environment in well-oxygenated seafloor waters.

The DWAF assemblages suffer a decrease in abundance in the EOT where some ammodiscid and glomospirids such as *Ammodiscus tenuissimus* and *Repamina charoides* survive. Suspension feeders belonging to the morphogroup M1 and deep-infaunal taxa of M4 disappear within this interval. The glomospirid *Repamina charoides* builds its wall by agglutinating particles with organic cement (Arreguin-Rodriguez et al., 2014),

and their abundance is traditionally interpreted as controlled by the dissolution of CaCO_3 , and by the changes in the CCD and carbonate availability (e.g., Kuhnt and Urqhart, 2001). Arreguin-Rodriguez et al. (2014) argued that the CaCO_3 dissolution is not the only cause of the dominance of glomospirids, which instead act as opportunists under stressed conditions due to their ability to feed on refractory organic matter. During the EOT at ODP site 647 an increase in the deep infaunal taxa of morphogroup M4b has been observed (Kaminski and Ortiz, 2014), suggesting an intensified productivity (Ortiz and Kaminski, 2012). The assemblages are diverse and indicative of well-oxygenated bottom waters. This datum contrasts with the assemblages described here, which document a decrease in deep infaunal taxa and the number of taxa. The *R. charoides*-*A. tenuissimus* assemblage is the result of a short-term event reflecting eutrophic conditions in which opportunistic forms with an epifaunal mode of life, such as *Ammodiscus* and *Glomospira*, survive during an abrupt change of the organic matter supply to the seafloor (e.g., Kaminski et al., 1996). The absence of deep infaunal taxa and the rarity of shallow-infaunal taxa could reflect a shift in the redox boundary, thus limiting the benthic activity in the sediments (Kuhnt et al., 1996). The calcareous taxa disappear within this interval confirming a change in the trophic conditions.

The dominance of morphogroups M1, M2b, and M4b in the lowermost Oligocene (*Psammosiphonella linearis*-*Rhabdammina discreta* assemblage) suggests an intensified organic supply at the seafloor and an increase in productivity. The diversity increases in the *Paratrochamminoides*-*Ammolagena clavata* assemblage, in which tubular forms, M1, M3a, and M4 morphogroups dominate. In this assemblage peaks in abundance of *Haplophragmoides walteri*, *Reticulophragmium acutidorsatum*, *Pseudonodosinella elongata*, *Ammodiscus latus*, *Arthrodendron grandis*, *A. clavata*, and *Paratrochamminoides* are observed. Peaks in *R. acutidorsatum* and *P. elongata* are known from the Oligocene of the Celebes Sea (Kaminski and Huang, 1991), but are rare in scaglia-type formations (Kaminski and Gradstein, 2005). The acme of *A. latus* is generally recorded in the lower Oligocene sediments of the Carpathians, where it defines a partial range zone from the FO of the nominate taxon to the FO of *Reticulophragmium rotundidorsatum* (Kaminski, 2005). At Portella Colla, *A. latus* disappears before the first common

occurrence of *R. rotundidorsatum* and reappears in the uppermost samples. *Ammolagena clavata* has been described from high diversity flysh-type assemblages indicating favourable environmental conditions such as high supply of organic matter, low energy water conditions, and well-oxygenated bottom sediments (Waškowa, 2014).

The *Caudammina* assemblage represents a unicum for the Oligocene DWAF assemblages, being this taxon unknown for this time interval since the erection of the species *C. gutta* Benedetti and Pignatti, 2009. The high occurrence of M4b marks a high organic carbon flux rate and low-oxygen, whereas the robust tubular forms of M1 could indicate currents strong enough to resuspend the surficial sediments. *Caudammina* is typical of bathyal to abyssal environments (Kaminski and Gradstein, 2005), and its high occurrence in the upper part of the investigated section suggests a deepening of the basin. The uppermost sediments of the Caltavuturo Fm. are characterized by a low density interval in which the number of taxa, their diversity, and the morphogroups M4a and M4b decrease, marking oligotrophic conditions. A peak in abundance of *R. charoides*, *P. linearis*, and *Paratrochamminoides* spp. is noteworthy, and indicates a new short-time phase of cooling (Pälike et al., 2006). Unfortunately, as stated above, no accurate biostratigraphic data are available for the upper part of the investigated section.

The assemblages in the Portella Colla Clay are dominated by *Haplophragmoides* and *Reticulophragmium* belonging to morphotype M4a, and suggesting low oxygenation (Green et al., 2004), with subordinate deep infaunal of M4b and tubular forms of M1. In the investigated samples, *Haplophragmoides carinatus* replaces the typical *H. walteri* forms, whereas *Reticulophragmium rotundidorsatum* seems to substitute for *R. acutidorsatum*. Although *R. rotundidorsatum* is known from the late Eocene (Kaminski and Gradstein, 2005), its highest occurrence usually marks middle late Miocene of the Norwegian-Greenland Sea (Osterman and Spiegler, 1996; Kaminski et al., 2006) and the Oligocene-Miocene of the Beaufort-MacKenzie Basin (Schröder-Adams and McNeil, 1994). The species *R. projectum*, described from the Oligocene of the Beaufort-MacKenzie Basin (Schröder-Adams and McNeil, 1994) and previously dubitatively recognized (Benedetti and Pignatti, 2008), is herein described from the late Rupelian of the Mediterranean area.

Bathymetry

The sedimentary successions of the Caltavuturo Formation have been described as having been deposited along the slope, between the platform margin and the basin, where turbidity currents reworked the carbonates from the Panormid carbonate platform (Abate et al., 1988; Pescatore et al., 1987). Calderone et al. (1980) and Dongarrà and Ferla (1982) provided a different environmental interpretation of the deposits cropping out at Portella Colla according to the analysis of the clay minerals. They suggested that the clays were deposited in a restricted depositional environment enriched in iron and organic matter. The premature diagenesis caused a modification in the sediments chemical composition with the dissolution of calcium carbonate, due to hyperaline bottom waters (Calderone et al., 1980). Such scenario is implausible, however, according to the micropaleontological interpretation of the assemblages occurring in the Caltavuturo Fm. and in the Portella Colla Clay. In addition, the analysis of resedimented larger foraminifers excludes high salinity values or other stress conditions in the basin (Benedetti, 2015). The bathymetric interpretation of the investigated faunas is challenging because of some common glauconitic layers (glauconite does not exceed 800 meters in depth according to Odin and Matter, 1981), the abundance of the displaced larger foraminiferal tests, and the absence of significant biosiliceous component testifying the occurrence of taxa living under the CCD.

DWAF assemblages are usually described as typical of epibathyal to abyssal environments (e.g., Kaminski and Gradstein, 2005). Their abundance is linked to the water depth, but is also dependent on factors such as water circulation and acidification (e.g., Gradstein and Berggren, 1981; Kuhnt et al., 1989). At Portella Colla, hyaline tests are uncommon and planktonic foraminifers are rare or absent, thus reflecting dissolution of calcium carbonate at depth below the CCD. In particular, the planktonic foraminiferal tests tend to be greatly affected by dissolution (Zachos et al., 1996). Kuhnt and Kaminski (1989) and Kuhnt et al. (1989) proposed a paleobathymetric distribution of DWAF assemblages: 1) the middle-slope assemblages (500-1500 m) are constituted by flysch-type agglutinated foraminifers with common ataxophragmiids, and variable number of planktonic foraminifers (0–99%) and of calcareous-walled benthic taxa; 2) the lower slope assemblages (from 1500 m to more than 2500 m) are dominated by *Rhabdammina* and

other tubular taxa, whereas hyaline taxa are rare or often absent, fragmented, and corroded; 3) the abyssal assemblages are characterized by high diversity, are dominated by *Recurvoides* and *Paratrochamminoides*, and are deprived of autochthonous calcareous foraminifers.

The bathymetric range of selected and frequent taxa from the investigated deposits is schematized in Figure 10. The percentage abundance of *Recurvoides* in the Caltavuturo Fm. is low in each sample and, although the *Caudammina* and *Reticulophragmium rotundidorsatum* assemblages could reflect an abyssal environment, it is likely that the true depositional environment was the middle slope. We must take into account that recent foraminiferal assemblages show a bathymetric distribution strictly dependent on the water temperature with a shallower limit for some species at the highest latitudes (Milam and Anderson, 1981), and bathymetric migrations (recorded even stagionally) are linked to the cooling of the ocean waters. Near the E/O boundary a global cooling is well documented on the strength of isotopic analyses on benthic foraminifers (Miller et al., 1987, Zachos et al., 1996) linked to an abrupt > 1 km drop of the CCD (Haq, 1981; Zachos et al., 1996; Rea and Lyle, 2005; Katz et al., 2008). Local rises of the CCD are possible and DWAF dominated assemblages barren in calcareous taxa are described from the Congo's delta in a bathyal environment (Kender et al., 2008). The sea level drop is also registered in the Caltavuturo Fm. by the shallow-water taxa occurring in the turbiditic layers. The deposition of these calcarenites could represent a sea-level drop that activated erosion at shallow marine settings and transport of shallower elements towards deeper environment in the basin (e.g., Alegret et al., 2008).

In an outcrop 700 m north of Portella Colla (section FO), in the red clays of the Caltavuturo Fm., three volcanoclastic layers enriched in quartz were found (Figure 11). The clays above and below these levels have no carbonatic content. Volcanic activity can explain the acidification of the bottom water, and the absence of calcareous taxa in response to a local rise of the CCD, thus resulting in a migration of some taxa, such as *Caudammina*, from abyssal environments to shallower ones. Therefore, the Portella Colla assemblages were most likely deposited under the CCD from the middle to lower bathyal zone in a middle-lower slope setting, as evidenced by the shallower known distribution of selected taxa (Figure 10).

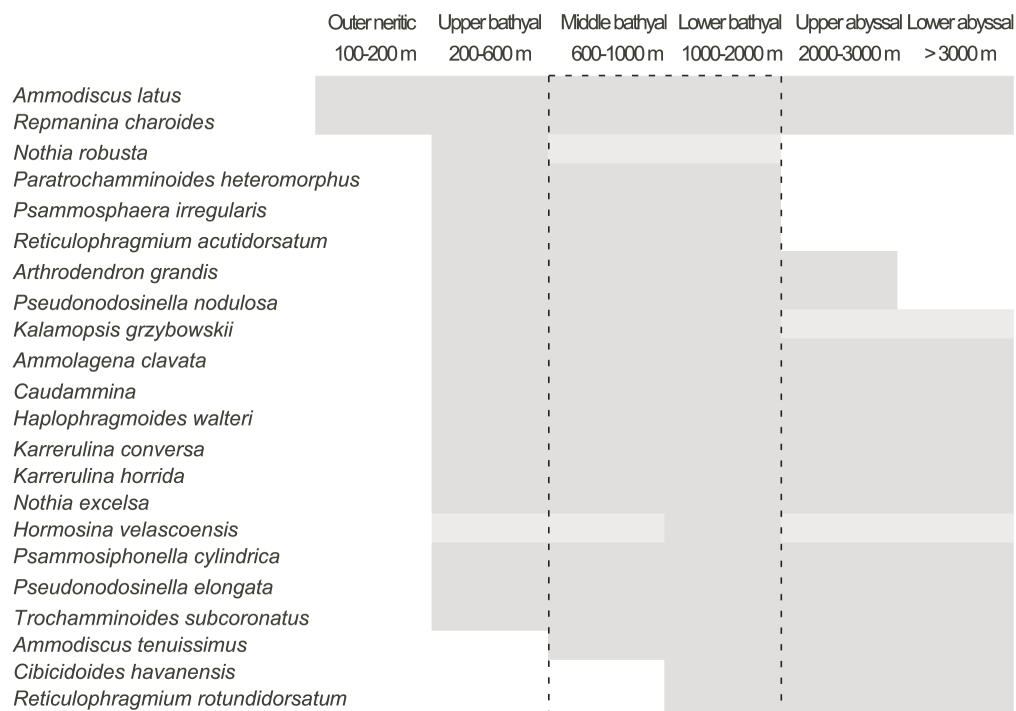


FIGURE 10. Depth distribution of some selected and frequent taxa according to data presented by van Morkhoven et al. (1986), Kaminski and Gradstein (2005) and Wařkowska (2014).

Remarks on the Taxonomic Composition of the Assemblages

Deep-sea Eocene to Miocene assemblages usually contain varying proportions of calcareous and agglutinated taxa (Kaminski and Gradstein, 2005). From the EOT, an increase in calcium-

cemented taxa and low DWAF density is usually described (Kaminski and Ortiz, 2014). In the early Oligocene organic-cemented agglutinated foraminifers dominate and diversity decreases (Kaminski and Gradstein, 2005). Although some poorly preserved bathyal hyaline foraminifers, such as *Cibicidoides*, occur along the investigated sec-

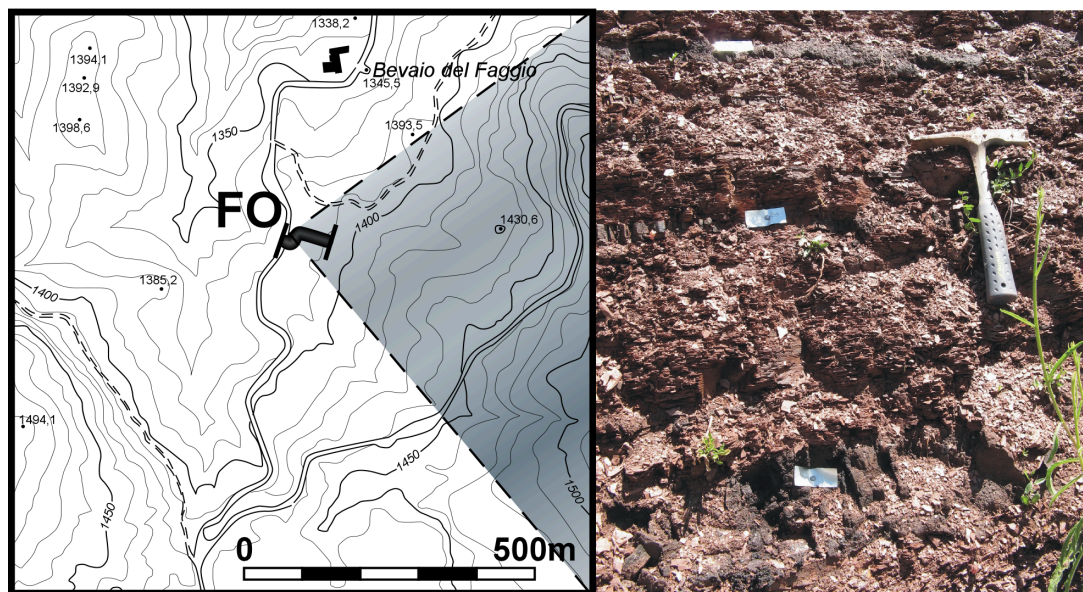


FIGURE 11. Location of the section FO; the reddish clay are interbedded by quartzose volcanic layers marked by the metallic labels.

tion (Benedetti and Pignatti, 2008, plate 2, figures 14-15), the faunal assemblages recovered in the samples of the Portella Colla section contain very peculiar deep-water faunas. In all the investigated samples, taxa with calcareous cement and with agglutinated calcitic grains are absent, such as *Dorothia*, *Karrerella*, *Tritaxia* and *Vulvulina* which are instead common in the coeval sediments of the Gratteri Formation cropping near Isnello (Benedetti and D'Amico, 2012), about 9 km north of the Portella Colla outcrop. In addition, in the sediments of Portella Colla, typical Eocene-Oligocene taxa, such as *Duquepsammina cubensis*, *Spiroplectamina trinitatensis*, *S. spectabilis*, and *Turrilina alsatica*, are absent. The Scaglia-type formations also contain calcareous-cemented forms such as *Remesella*, *Karrerella*, and *Spiroplectamina* (e.g., Kaminski and Gradstein, 2005). In the Numidian flysch of Morocco, *S. spectabilis* is very rare or absent because of the lack of organic matter or other nutrients (Kaminski et al., 1996). At Portella Colla, the frequency of species belonging to the morphogroup M4, except for the sample near the EOT, seems to be a good indicator of the abundance of organic matter reaching the seafloor. So, the absence of calcareous agglutinated taxa must be explained not as much on the trophic resources, but rather on the post-mortem dissolution of the tests, linked to the acidification of the water possibly due to the volcanic activity documented in the section FO (Figure 11).

SUMMARY

The taxonomic and stratigraphic importance of the uppermost Eocene and Oligocene DWAF assemblages, recovered at Portella Colla, is noteworthy; this work provides the most complete record of foraminifers in the clay of the Caltavuturo Fm., and several as yet unrecorded species are reported in open nomenclature. The cosmopolitan species described are well known from the Paleogene to Miocene of the North Atlantic region (Schroeder-Adams and McNeil, 1994; Osterman and Spiegler, 1996; Kaminski et al., 2006; Kaminski et al., 2009), but they are poorly described from the Mediterranean area, especially for the Oligocene. This study provides new data about the distribution of the poorly-known species *Caudammina gutta* and *Reticulophragmium projectum* in lower Oligocene sediments of Mediterranean area.

Nine assemblages were recognized according to the faunal content, faunal density, and species diversity. The DWAF assemblages suggest good

oxygenation in the uppermost Eocene samples, whereas during the EOT a minimum in the specific diversity has been recorded. The occurrence of opportunistic taxa, such as Ammodiscids and glomospirids (especially *Repmanina charoides*), and the absence of infaunal taxa indicate an upward migration of the redox boundary. At the base of the Rupelian, deep-infaunal foraminiferal assemblages suggest a decrease in bottom water oxygenation, and an increase in nutrients supply. *Repmanina charoides* is known as opportunistic species with an ecological advantage in the post-extinction benthic ecosystem (Arreguin-Rodriguez et al., 2014), since it is able to feed on less labile organic matter. In particular, glomospirids may reproduce rapidly and colonize the post-extinction empty niches. This study confirms that the EOT was a time of significant faunal turnover among DWAF, which responded to variations in the nutrient's availability, sea level fall, and climatic changes.

SYSTEMATIC PALAEOLOGY

The suprageneric classification of Loeblich and Tappan (1987, 1992) is followed and integrated with those of Kaminski (2004, 2014), Mikhalovich (2013), and Pawlowski et al. (2013). The specimens were investigated under an optic microscope and drawn using a camera lucida to detect details. Most taxa are illustrated with SEM photographs. For some specimens the generic or suprageneric classification is undetermined. The material is stored in the collection Benedetti in the micropaleontological laboratory of the University of Rome "La Sapienza".

Phylum FORAMINIFERA d'Orbigny, 1826
 Class ASTORRHIZATA Saidova, 1981
 Order ASTORRHIZIDA Lankester, 1885
 Superfamily ASTORRHIZOIDEA Brady, 1881
 Family RHABDAMMINIDAE Brady, 1884
 Subfamily RHABDAMMININAE Brady, 1884
 Genus RHABDAMMINA M. Sars in Carpenter, 1869

Rhabdammina discreta Brady, 1884
 Figure 12.1-2

- 1884 *Rhabdammina discreta*; Brady, p. 268, pl. 22, figs. 7, 8.
 1896 *Rhabdammina subdiscreta*; Grzybowski, p. 275, pl. 8, figs. 5, 6.
 1954 *Psammosiphonella discreta* (Brady); Avnimelech, p. 65.
 2005 *Psammosiphonella discreta* (Brady); Kaminski and Gradstein, p. 117, pl. 5/6, figs. 1-8.

Material. 134 specimens from 22 samples.

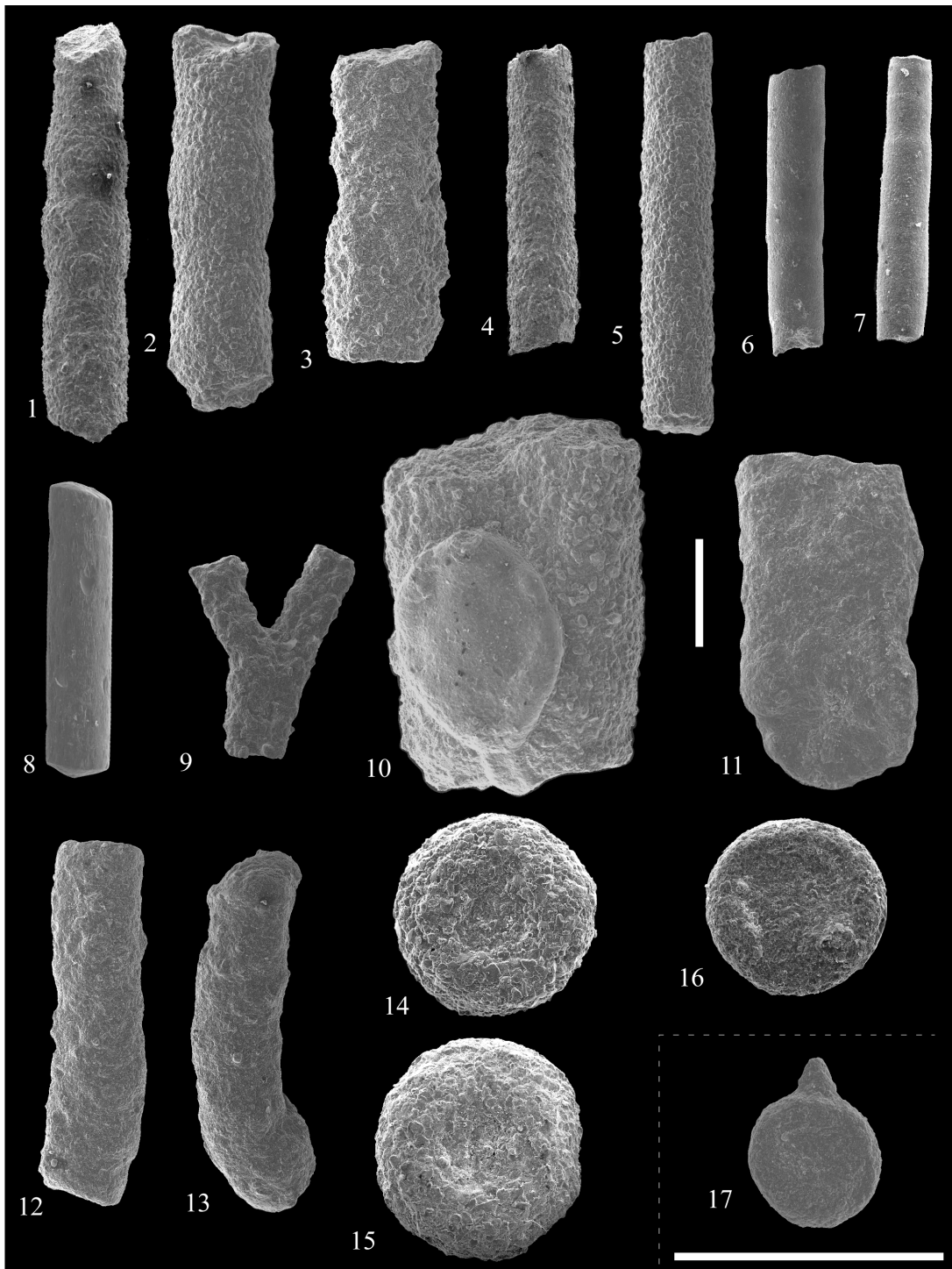


FIGURE 12. Scanning electron micrographs of Astrorhizida (**1-13**) and Saccamminidae (**14-15**) foraminifers from the Caltavuturo Formation cropping out at Portella Colla. **1-2**, *Rhabdammina discreta* Brady, 1884, PCs0 (**1**) and PC060618 (**2**). **3**, *Rhabdammina eocenica* Cushman and Hanna, 1927, PC060601. **4-5**, *Psammosiphonella cylindrica* (Glaessner, 1937), PC11 (**4**) and PCs0 (**5**). **6-7**, *Psammosiphonella linearis* (Brady, 1879), PC060618 (**6**) and PC11 (**7**). **8**, *Bathysiphon* sp., MM12. **9**, *Nothia excelsa* (Grzybowski, 1898), PC060603. **10**, *Nothia robusta* (Grzybowski, 1898) with *Ammolagena clavata* (Jones and Parker, 1860), PC060621. **11**, *Nothia* cf. *latissima* (Grzybowski, 1898), PC060624. **12-13**, *Rhizammina indivisa* Brady, 1884, PC060621. **14-15**, *Psammosphaera irregularis* (Grzybowski, 1896), PC13 (**14**) and PC22 (**15**). **16**, *Placentammina placenta* (Grzybowski, 1898), PCs0. **17**, *Saccammina grzybowskii* (Schubert, 1902), PC060621. Scale bar equals 0.5 mm.

Description. Tubular and rectilinear test, oval in outline. Thick wall with coarse agglutinated grains. The test presents irregularly distanced constrictions, aperture a simple terminal opening.

Distribution. From Cretaceous to recent, cosmopolitan.

Rhabdammina eocenica Cushman and Hanna, 1927

Figure 12.3

1927 *Rhabdammina eocenica*; Cushman and Hanna, p. 209, pl. 13, fig. 1.

1990 *Bathysiphon eocenicus*; Cushman and Hanna; Bellagamba and Coccioni, pl. 1, fig. 1.

Material. 21 specimens from 12 samples.

Description. Thick and weakly flattened test with an elliptical trasversal section.

Remarks. Differs from *R. rhabdammina* for the lack of constrictions and for the flattening of the test.

Rhabdammina spp.

Material. 17 specimens from 10 samples.

Description. Included in this group are all fragmentary and tubular specimens not assigned to any known species.

Subfamily BATHYSIPHONINAE Avnimelech, 1952

Genus BATHYSIPHON Sars, 1872

Bathysiphon spp.

Figure 12.8

Material. Three specimens from two samples.

Description. Tubular test with selective agglutination of sponge spicules.

Genus NOTHIA Pflaumann, 1964

Nothia excelsa (Grzybowski, 1898)

Figure 12.9

1898 *Dendrophrya excelsa*; Grzybowski, p. 272, pl. 10, figs. 1-4.

1960 *Dendrophrya excelsa* Grzybowski; Geroch, p. 121, pl. 1, figs. 1-11.

1993 *Nothia excelsa* (Grzybowski) emend. Geroch and Kaminski, 1993; Kaminski and Geroch, p. 245, pl. 1, figs. 2-6, 15a, b.

2009 *Nothia excelsa* (Grzybowski); Kender, Kaminski and Jones, p. 493, pl. 1, fig. 5.

Material. 57 specimens from 21 samples.

Description. Tubular and flattened test, rarely branched, usually straight or curved. Wall thick, moderately coarse agglutinated, composed of quartz grains.

Distribution. Well-known species from Cretaceous to the late Eocene of Carpathians; described from the Miocene by Osterman and Spiegler (1996) and Kender et al. (2009).

Paleoecology. *Nothia excelsa* was regarded as an epifaunal deposit-feeders form colonizing turbiditic deposit surfaces (Geroch and Kaminski, 1993); recently Kaminski et al. (2006) and Kender et al. (2008) set this species into the erect epifauna morphogroup M1.

Remarks. In the investigated samples this species usually occurs broken and fragmentated; only one branched specimen was found in the sample PC060603.

Nothia cf. *latissima* (Grzybowski, 1898)

Figure 12.11

cf. 1898 *Dendrophrya latissima*; Grzybowski, p. 273, pl. 10, fig. 8.

Material. Three specimens from the samples PC060624.

Description. Test tubular, flattened, compressed with wall thin composed of medium sized grains.

Distribution. *Nothia latissima* is a cosmopolitan taxon common in flysch-type assemblages from the Cretaceous to the Eocene (Kaminski and Gradstein, 2005); Kaminski et al. (2006) and Kender et al. (2009) signal this species in the Miocene of Greenland Sea and Angola.

Nothia robusta (Grzybowski, 1898)

Figure 12.10

1898 *Dendrophrya robusta*; Grzybowski, p. 273, pl. 10, fig. 7.

1993 *Rhabdammina robusta* (Grzybowski); Kaminski and Geroch, p. 247, pl. 1, figs. 7-9b, 16a, b.

1995 *Nothia robusta* (Grzybowski); Holbourn and Kaminski, p. 438, pl. 1, figs. 12, 13.

1996 *Rhabdammina robusta* (Grzybowski); Kaminski, Kuhnt, and Radley, p. 16, pl. 1, figs. 2-18.

2005 *Nothia robusta* (Grzybowski); Kaminski and Gradstein, p. 114, pl. 4.

2009 *Nothia robusta* (Grzybowski); Kender, Kaminski, and Jones, p. 493, pl. 1, fig. 7.

Material. 93 specimens from 16 samples.

Description. Test large, tubular, straight, compressed with a longitudinal furrow. Wall thick, coarse agglutinated with medium sized grains.

Remarks. Typical branched forms were absent, we have found only fragmented specimens. *Nothia robusta* differs from *N. excelsa* in having larger size and thicker wall.

Distribution. Cosmopolitan taxon known from the Late Cretaceous to the early Miocene (Kaminski and Gradstein, 2005).

Nothia spp.

Material. Eight specimens from three samples.

Description. Specimens with large tubular and flattened test not belonging to the listed species.

Genus PSAMMOSIPHONELLA Avnimelech, 1952
Psammosiphonella cylindrica (Glaessner, 1937)
 Figure 12.4-5

- 1937 *Rhabdammina cylindrica*; Glaessner, p. 354, pl. 1, fig. 1.
 1952 *Psammosiphonella cylindrica* (Glaessner); Avnimelech, p. 65.
 1992 *Rhabdammina cilindrica*; Glaessner; Morlotti and Kuhnt, p. 223, pl. 2, fig. 1.
 2005 *Psammosiphonella cylindrica* (Glaessner); Kaminski and Gradstein, p. 119, pl. 5/6, fig. 9-13.
 2009 *Rhabdammina cylindrica* (Glaessner); Kender, Kaminski and Jones, p. 492, pl. 1, fig. 1.

Material. 238 specimens from 21 samples.

Description. Test tubular with circular section. Wall thick, composed of quartz grains dispersed in siliceous cement. Surface rough, aperture a simple terminal opening. Against the light is clearly visible the central siphon.

Distribution. Known in flysh-type deposits from the Cretaceous.

Remarks. *Psammosiphonella cylindrica* differs from *Rhabdammina discreta* Brady, 1884 in the absence of constrictions, and in having smoother surface. *Psammosiphonella linearis* is smaller and thinner, and has a more evident siphon.

Psammosiphonella linearis (Brady, 1879)
 Figure 12.6-7

- 1879 *Rhabdammina linearis*; Brady, p. 37, pl. 3, figs. 10, 11.
 1952 *Oculosiphon linearis* (Brady); Avnimelech, p. 65, fig. 9.
 1987 *Oculosiphon linearis* (Brady); Loeblich and Tappan, p. 23, pl. 15, fig. 1.
 2005 *Rhabdammina linearis* (Brady); Kaminski and Gradstein, p. 122, pl. 7, figs. 1-8.
 2009 *Rhabdammina linearis* (Brady); Kender, Kaminski, and Jones, p. 493, pl. 1, fig. 2.

Material. 80 specimens from 19 samples.

Description. Test small, tubular, wall thin and finely agglutinated. Aperture a single terminal opening.

Distribution. From the Cretaceous to Recent (Kaminski and Gradstein, 2005).

Superfamily KOMOKIOIDEA Tendal and Hessler, 1977

Family RHIZAMMINIDAE Wiesner, 1931

Genus RHIZAMMINA Brady, 1879

Rhizammina indivisa Brady, 1884

Figure 12.12-13

- 1884 *Rhizammina indivisa*; Brady, p. 277, pl. 29, figs. 5-7.

- 1966 *Rhizammina indivisa* Brady; Geroch, p. 434, fig. 6 (1-7) (cum syn.).

- 1981 *Rhizammina indyvisa* Brady; Morgiel and Olszewska, p. 7, pl. 1, fig. 2.

- 1990 *Rhizammina indivisa* Brady; Bellagamba and Coccioni, pl. 1, fig. 5.

Material. 56 specimens from 19 samples.

Description. Test tubular, commonly flattened and curved.

Distribution. Jurassic–Recent.

Rhizammina spp.

Material. Seven specimens from four samples.

Description. Included in this group are all the fragmented forms with small size, test tubular and curved, with a wall thin, and irregular in outline.

Order SACCAMMININA Lankester, 1885
 Superfamily SACCAMMINOIDEA Brady, 1884
 Family SACCAMMINIDAE Brady, 1884
 Subfamily SACCAMMININAE Brady, 1884
 Genus PLACENTAMMINA Thalmann, 1947
Placentamina placenta (Grzybowski, 1898)
 Figure 12.16

- 1898 *Reophax placenta*; Grzybowski, p. 276, pl. 10, figs. 9, 10.

- 1943 *Placentamina placenta*; Majzon, p. 152, pl. 3, fig. 7a-c.

- 1954 *Saccamina placenta* (Grzybowski); Geroch and Gradzinski, p. 36.

- 1960 *Saccamina placenta* (Grzybowski); Geroch, p. 121, pl. 2, figs. 1-6.

- 1987 *Placentamina placenta* (Grzybowski); Loeblich and Tappan, p. 31, 32, pl. 21, figs. 12-19.

- 2005 *Placentamina placenta* (Grzybowski) emend. Geroch, 1960; Kaminski and Gradstein, p. 136, pl. 11, figs. 1-6.

Material. 11 specimens from eight samples

Description. Test medium size, single chamber circular in outline and compressed in both the sides. Wall composed of quartz grains of different size. Aperture small and circular on a raised neck in more or less eccentric position.

Distribution. Common in flysch-type deposits from the Late Cretaceous to the Eocene of Carpathians; signaled in the Oligo-Miocene flysches of Mediterranean areas.

Genus SACCAMMINA Carpenter, 1869
Saccamina grzybowskii (Schubert, 1902)
 Figure 12.17

- 1902 *Reophax grzybowskii*; Schubert, p. 20, pl. 1, fig. 13a, b.

- 2005 *Saccamina grzybowskii* (Schubert); Kaminski and Gradstein, p. 132, pl. 10, figs. 1-9.

Material. Two specimens from the sample PC060621.

Description. Unilocular test, circular in outline, and compressed. Peripheral aperture on a raised neck.

Distribution. Cretaceous–Neogene (Kaminski and Gradstein, 2005).

Superfamily PSAMMOSPHAEROIDEA Haeckel, 1894

Family PSAMMOSPHAERIDAE Haeckel, 1894

Subfamily PSAMMOSPHAERINAE Haeckel, 1894

Genus PSAMMOSPHAERA Schulze, 1875

Psammosphaera irregularis (Grzybowski, 1896)

Figure 12.14-15

- 1896 *Keramosphaera irregularis*; Grzybowski, p. 273, pl. 8, fig. 12, no fig. 13.

- 1966 *Psammosphaera levigata* White; Geroch, p. 436, pl. 7, figs. 18-20.

- cf. 1981 *Psammosphaera* sp. var. B; Gradstein and Berggren, p. 241, pl. I, fig. 16.

- 1995 *Psammosphaera irregularis* (Grzybowski); Bubík, p. 84, pl. 1, figs. 15, 16.

Material. 27 specimens from 12 samples.

Description. Test small to medium in size, single chamber, lenticular, circular in outline with raised peripheral margin. Wall thick composed of medium to coarse quartz grains, aperture not clearly visible. In some specimens a small aperture appears in between the grains.

Distribution. Known in flysh-type deposits from the Late Cretaceous to Eocene (Kaminski and Gradstein, 2005).

Psammosphaera cf. *laevigata* White, 1928

Figure 13.1

- cf. 1977 *Psammosphaera laevigata* White; Samuel, p. 24, pl. 2, fig. 11.

Material. Four specimens from three samples.

Description. Test globular to lenticular, with circular and rounded periphery. Wall thick composed of quartz grains. Aperture not visible.

Psammosphaera sp. 1

Figure 13.2

- cf. 1966 *Psammosphaera laevigata* White; Geroch, p. 436, fig. 7 (18, 20).

- ? 1972 *Psammosphaera laevigata* White; Hanzlíková, p. 33, pl. I, figs. 7, 8.

- 1995 *Psammosphaera* sp.1; Bubík, 84, pl. 1, figs. 11a-13b.

- 1995 *Psammosphaera fusca* Schulze; Rögl, p. 252, pl. 1, fig. 11.

Material. Five specimens from three samples.

Description. Test small, flattened, single chamber, circular in outline with a raised and rounded periphery.

Remarks. Differs from *P. irregularis* in having a smaller size.

Psammosphaera sp. 2

Figure 13.3

Material. One specimen from the sample PC060615.

Description. Test small to medium in size, single chamber, inflated, globular, subspherical. Wall thick, composed of quartz grains. Aperture is a small opening between grains.

Psammosphaera sp. 3

Figure 13.4

Material. One specimen from the sample PC060615.

Description. Test free, small, circular in outline with a central depression in both the sides. Wall thin, finely agglutinated.

Remarks. Differs from *Psammosphaera* sp. 1 in having smaller size and sparser agglutination.

Order AMMODISCIDA Mikhalevich, 1980

Suborder HIPPOCREPININA Saidova, 1981

Superfamily HIPPOCREPINOIDEA Rhumbler, 1895

Family HYPERAMMINIDAE Eimer and Fickert, 1899

Subfamily HYPERAMMININAE Eimer and Fickert, 1899

Genus HYPERAMMINA Brady, 1878

Hyperamina spp.

Figure 13.6

Material. Eight specimens from seven samples.

Description. This group includes all the tubular, straight or weakly curved flattened fragmented forms, with a large piriform or suboval proloculus.

Superfamily HORMOSINELLOIDEA Rauser and Reitlinger, 1986

Family AMMOLAGENIDAE Kaminski, Henderson, Cetaan, and Waškowska, 2009

Genus AMMOLAGENA Eimer and Fickert, 1899

Ammolagena clavata (Jones and Parker, 1860)

Figure 14.1-2

- 1860 *Trochamina irregularis* (d'Orbigny) var. *clavata*; Jones and Parker, p. 304.

- 1884 *Webbina clavata* Jones and Parker; Brady, p. 349-350, pl. 411, figs. 12-16 (cum syn.).

- 2004 *Ammolagena clavata* (Jones and Parker); Nigam, Mazumder, and Saraswat, p. 74, pl. 1, fig. a-d.

Material. 96 specimens from 20 samples.

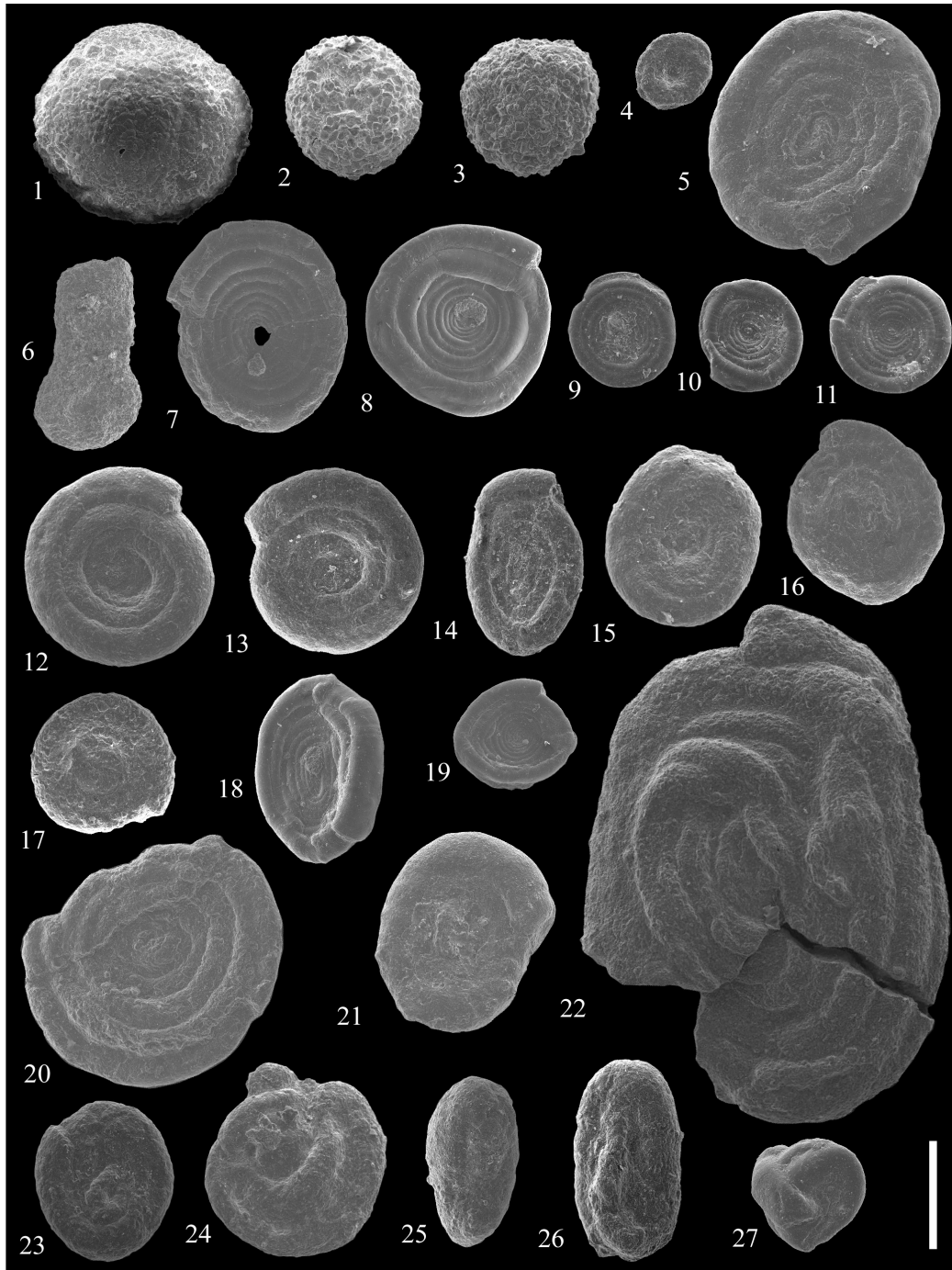


FIGURE 13. Scanning electron micrographs of Psammosphaeridae (1-4) and Ammodiscidae (5-27) from the Caltavuturo Formation cropping out at Portella Colla. **1**, *Psammosphaera* cf. *laevigata* White, 1928, PCs0. **2**, *Psammosphaera* sp. 1, PC13. **3**, *Psammosphaera* sp. 2, PC060615. **4**, *Psammosphaera* sp. 3, PC060625. **5**, *Ammodiscus cretaceus* (Reuss, 1845), PC22. **6**, *Hyperammia* sp., PC060625. **7-8**, *Ammodiscus incertus* (d'Orbigny, 1839), PC060603 (**7**) and PC13 (**8**). **9-11**, *Ammodiscus tenuisimus* (Gümbel, 1862), PC22 (**9**), PC060615 (**10**) and PC060615 (**11**). **12-13**, *Ammodiscus cf. latus* Grzybowski, 1898, PC11 (**12**) and PC11 (**13**). **14**, *Ammodiscus peruvianus* Berry, 1928, PC060617. **15-16**, *Ammodiscus cf. latus* Grzybowski, 1898, PC11. **17**, *Ammodiscus* sp. 1, PC11. **18**, *Ammodiscus* sp. 2, PC15. **19**, *Ammodiscus* sp. 3, PC060603. **20**, *Annectina biedai* Gradstein and Kaminski, 1997, PC060618. **21**, *Annectina* cf. *grzybowski* (Jurkiewicz, 1960), PC060617. **22**, *Glomospira* sp. 2, PC15. **23**, *Glomospira* sp. 1, PC11. **24**, *Glomospira* sp. 3, PC13. **25-26**, *Glomospira serpens* (Grzybowski, 1898), PC060617 (**25**) and PC060618 (**26**). **27**, *Glomospira irregularis* (Grzybowski, 1898), PC060618. Scale bar equals 0.5 mm.

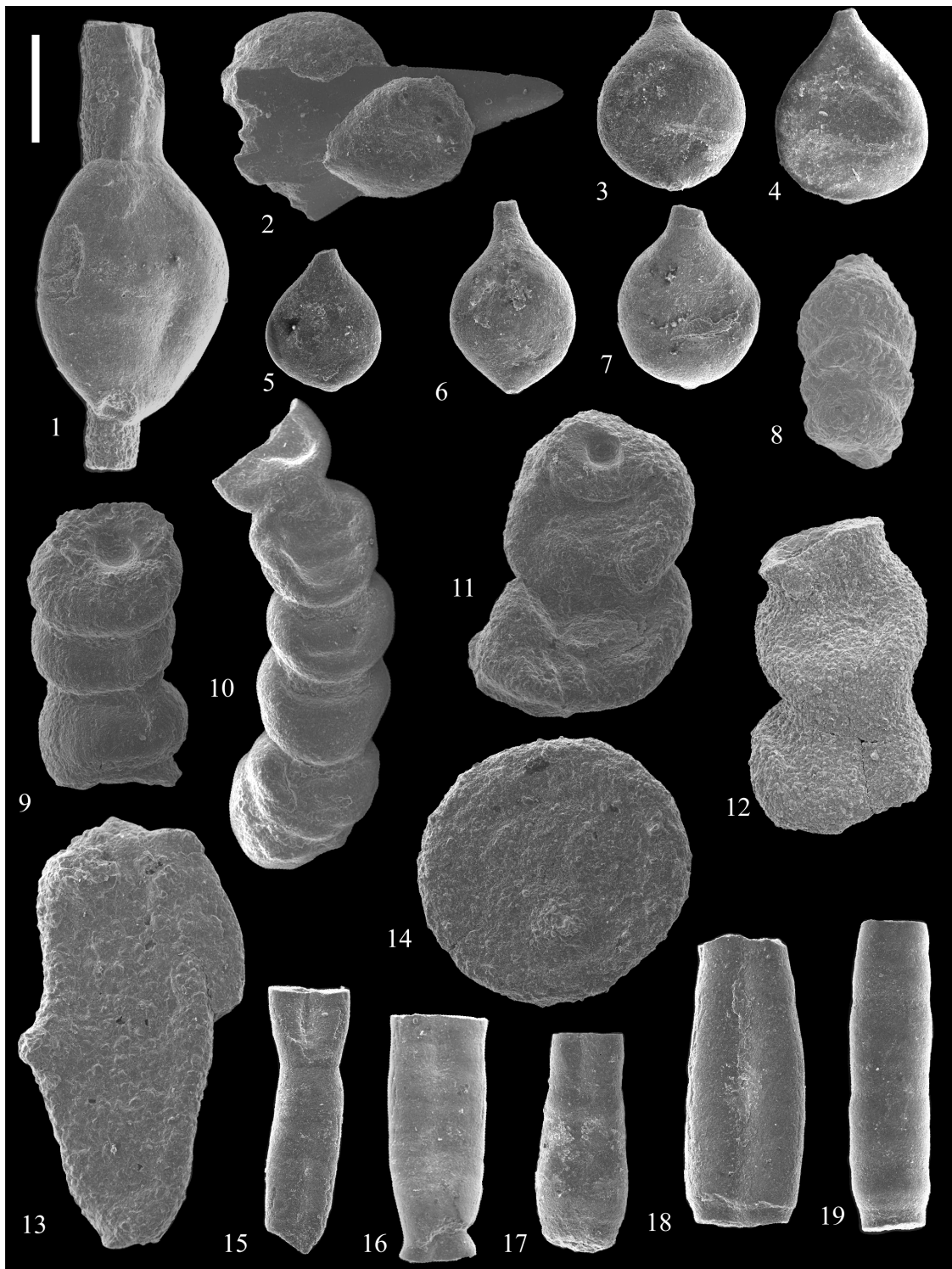


FIGURE 14. Scanning electron micrographs of Hormosinelloidea from the Caltavuturo Formation cropping out at Portella Colla. **1**, *Ammolagena clavata* (Jones and Parker, 1860) on a specimen of *Psammosiphonella cylindrica* (Glaessner, 1937), PCs0. **2**, *Ammolagena clavata* (Jones and Parker, 1860), PC060607. **3-7**, *Caudammina gutta* Benedetti and Pignatti, 2009, PC18. **8**, *Subreophax* cf. *guttifer* (Brady, 1881), PC15. **9**, *Subreophax* cf. *pseudoscalaris* (Samuel, 1977), PCs0. **10**, *Subreophax scalaris* (Grzybowski, 1896), PC11. **11-12**, *Subreophax splendidus* (Grzybowski, 1898), PC060624 (**11**) and PC11 (**12**). **13**, *Arthrodendron subnodosiformis* (Grzybowski, 1898), PC060615. **14**, *Arthrodendron grandis* (Grzybowski, 1898), PC050515. **15-19**, *Kalamopsis grzybowskii* (Dyłażanka, 1923), PC18 (**15**), PC11 (**16**), PC18 (**17**), PC060621 (**18**) and PC060621 (**19**). Scale bar equals 0.5 mm.

Description. Test attached, large inflated and ovoid proloculus, followed by an undivided elongate irregular tube-like chamber, not increasing in size. Wall smooth, thin, finely agglutinated. Two apertures, one at the base of the proloculus as a simple opening surrounded by a lip, one at the end of the tube-like chamber.

Distribution. Cosmopolitan, known from the Cretaceous to Recent, recently signaled in the Indian Ocean (Nigam et al., 2004).

Remarks. Attached form, sometimes encrusting Rhabdamminids, *Ammodiscus* or litoalids.

Family HORMOSINELLIDAE Rauser and Reitlinger, 1986

Genus CAUDAMMINA Montanaro-Gallitelli, 1955
Caudammina gutta Benedetti and Pignatti, 2009
Figure 14.3-7

2009 *Caudammina gutta*; Benedetti and Pignatti, p. 344, pl. 1, figs. 1-18.

Material. 126 specimens from nine samples.

Description. Test free, large, flask-like, originally plurilocular comprised of rounded or pyriform pseudochambers without internal partitions. Wall thick, imperforate, and finely agglutinated with a smooth surface. Aperture at the open end of the short neck.

Distribution. Late Eocene?–Oligocene.

Remarks. Mikhalevich (2013) erroneously includes the subfamily Caudammininae within the family Saccamminidae, since *Caudammina* is clearly not monothalamous.

Genus SUBREOPHAX Saidova, 1975
Subreophax cf. *guttifer* (Brady, 1881)
Figure 14.8

?1881 *Reophax guttifer*; Brady, p. 49.

?1977 *Reophax pseudoscalaria*; Samuel, p. 36, pl. 3, fig. 4a, b.

1992 *Subreophax* cf. *guttifer* (Brady); Morlotti and Kuhnt, p. 223, pl. 3, fig. 5.

Material. Two specimens from two samples.

Description. Test free, subcylindric, three flattened and subcircular chambers, interconnected and oblique respect the axis of growth. Aperture at the end of the last chamber.

Subreophax cf. *pseudoscalaris* (Samuel, 1977)
Figure 14.9

cf. 1977 *Reophax pseudoscalaria*; Samuel, p. 35, 36, pl. 3, fig. 4a, b.

cf. 2005 *Subreophax pseudoscalaris* (Samuel); Kaminski and Gradstein, p. 281, pl. 56, figs. 1-6 (partim).

Material. Five specimens from five samples.

Description. Test free, uniseriate, composed of discoidal, compressed chamber increasing gradually in size.

Distribution. *Subreophax pseudoscalaris* is described from the Senonian to Lower Eocene (Kaminski and Gradstein, 2005).

Subreophax scalaris (Grzybowski, 1896)
Figure 14.10

1896 *Reophax guttifer* Brady var. *scalaria*; Grzybowski, p. 277, pl. 8, fig. 26a, b.

1977 *Reophax scalaria* Grzybowski; Samuel, p. 35, 36, pl. 3, fig. 6a, b, pl. 19, fig. 4.

1992 *Subreophax scalaris* (Grzybowski); Morlotti and Kuhnt, p. 223, pl. 3, fig. 5.

2005 *Subreophax scalaris* (Grzybowski); Kaminski and Gradstein, p. 278, pl. 55, figs. 1-7.

2009 *Subreophax scalaris* (Grzybowski); Kender, Kaminski, and Jones, p. 497, pl. 3, figs. 3, 4.

Material. Six specimens from six samples.

Description. Test free, uniseriate, elongated, curved axis. Several discoidal and compressed chambers partially embraced increasing very slowly in size.

Distribution. Lowermost Cretaceous to Oligocene (Kaminski and Gradstein, 2005), more recently reported also from the Miocene by Kender et al. (2009).

Subreophax splendidus (Grzybowski, 1898)
Figure 14.11-12

1898 *Reophax splendidus*; Grzybowski, p. 278, pl. 10, fig. 16.

1993 *Subreophax splendidus* (Grzybowski); Kaminski and Geroch, p. 251, pl. 3, figs. 11a-12b.

2005 *Subreophax splendidus* (Grzybowski); Kender, Kaminski, and Cieszkowski, p. 262, fig. 11C.

Material. Eight specimens from five specimens.

Description. Test free, large, weakly curved. Chambers irregular flattened and elliptic, suture incise. Aperture wide and terminal. Wall coarsely agglutinated.

Suborder AMMODISCINA Mikhalevich, 1980
Superfamily AMMODISCOIDEA Reuss, 1862
Family AMMODISCIDAE Reuss, 1862
Subfamily AMMODISCINAE Reuss, 1862
Genus AMMODISCUS Reuss, 1862
Ammodiscus cretaceus (Reuss, 1845)
Figure 13.5

1845 *Operculina cretacea*; Reuss, p. 35, pl. 13, figs. 64, 65.

1860 *Comospira cretacea* Reuss; Reuss, p. 177, pl. 1, fig. 1.

- 1978 *Ammodiscus cretaceus* (Reuss); Krasheninikov and Pflaumann, p. 569, pl. 2, fig. 7.
 2005 *Ammodiscus cretaceus* (Reuss); Kaminski and Gradstein, p. 145, pl. 14, figs. 1-10.
 2009 *Ammodiscus cretaceus* (Reuss); Kender, Kaminski, and Jones, p. 495, pl. 1, fig. 16, pl. 2, fig. 5.

Material. 10 specimens from seven samples.

Description. Test large, circular, biconcave, composed of a spherical proloculus followed by a single tubular chamber planispirally coiled. The whorls (up to 11) increase gradually in size. Wall thin and finely agglutinated. Aperture at the end of the tubular chamber.

Distribution. Cosmopolitan taxon; known from the Cretaceous to the late Eocene (Kaminski and Gradstein, 2005). Signaled from the Oligocene of the Beaufort-Mackenzie Basin (Schröder-Adams and McNeil, 1994), and from the Miocene of the Congo Fan (Kender et al., 2008, 2009).

Ammodiscus incertus (d'Orbigny, 1839)
 Figure 13.7-8

- 1839 *Operculina incerta*; d'Orbigny, p. 49, pl. 6, figs. 16, 17.
 ?1884 *Ammodiscus incertus* d'Orbigny; Brady, p. 370, pl. 38, fig. 1-3.
 2004 *Ammodiscus incertus* d'Orbigny; Govindan, p. 225, pl. 4, figs. 17, 19.

Material. Four specimens from four samples.

Description. Test discoidal commonly biconcave, composed of a single tubular chamber.

Remarks. *Ammodiscus incertus* differs from *A. cretaceus* (Reuss, 1845) in having a constant height of the whorls, smaller size, and a typical biconvex test.

Ammodiscus latus Grzybowski, 1898
 Figure 13.12-13

- 1898 *Ammodiscus latus*; Grzybowski, p. 282, 283, pl. 10, figs. 27, 28.
 1898 *Ammodiscus umbonatus*; Grzybowski, p. 283, pl. 10, figs. 29, 30.
 1954 *Lituotuba lata* (Grzybowski); Geroch and Gradzinski, p. 39, tabl. 4, figs. 1, 2.
 1960 *Lituotuba lata* (Grzybowski); Geroch, p. 126, pl. 4, fig. 8.
 1992 *Ammodiscus latus* Grzybowski; Morlotti and Kuhnt, p. 221, pl. 1, fig. 3.
 2005 *Ammodiscus latus* Grzybowski; Kaminski and Gradstein, p. 150, pl. 16a, figs. 1-8, pl. 16b, figs. 1-6.
 2009 *Ammodiscus latus* Grzybowski; Kender, Kaminski, and Jones, p. 495, pl. 1, fig. 17.

Material. 42 specimens from nine samples.

Description. Spherical proloculus followed by a single tubular chamber planispirally coiled for 4.5 whorl increasing in size gradually. Wall thick and finely agglutinated, sutures depressed. The last portion of the tubular chamber is typically uncoiled. Aperture a simple terminal opening.

Distribution. Cosmopolitan taxon described from the Eocene to Miocene (Kender et al., 2009).

Remarks. The uncoiled stage is not visible in each specimen.

Ammodiscus cf. *latus* Grzybowski, 1898
 Figure 13.15-16

- cf. 1898 *Ammodiscus latus*; Grzybowski, p. 282, 283, pl. 10, figs. 27, 28.

Material. Four specimens from the sample PC11.

Remarks. Differs from *A. latus* in having a more flattened test, and for the lack of the uncoiled stage.

Ammodiscus tenuissimus (Gümbel, 1862)
 Figure 13.9-11

- 1862 *Spirillina tenuissima*; Gümbel, p. 214, pl. 13, fig. 2.
 1898 *Ammodiscus tenuissimus*; Grzybowski, p. 282, pl. 10, fig. 35.
 1966 *Ammodiscus tenuissimus* Gümbel; Geroch, p. 437, fig. 8 (1, 4).
 1993 *Ammodiscus tenuissimus* Grzybowski; Kaminski and Geroch, p. 253, figs. 1-3b.
 1995 *Ammodiscus tenuissimus* Gümbel; Holbourn and Kaminski, p. 442, pl. III, fig. 1.
 1996 *Ammodiscus tenuissimus* Grzybowski; Kaminski, Kuhnt, and Radley, p. 10, pl. 1, fig. 4.

Material. 25 specimens from eight samples.

Description. Test free, small size (less than 0.5 mm), very thin and flattened, circular or weakly elliptical, composed of a single chambers planispirally arranged in several closest whorls. Wall thin, finely agglutinated. Aperture terminal.

Distribution. Cosmopolitan species common from the Late Cretaceous to the Eocene (Kaminski and Gradstein, 2005). Recently signaled from the Miocene of the Greenland Sea (Kaminski et al., 2006).

Ammodiscus peruvianus Berry, 1928
 Figure 13.14

- 1928 *Ammodiscus peruvianus*; Berry, p. 342, pl. 27.
 1954 *Ammodiscus grzybowski*; Emiliani, p. 106.
 2006 *Ammodiscus peruvianus* (Berry); Kaminski, Silye, and Kender, p. 382, pl. 1, fig. 20.

Material. Five specimens in the sample PC060617.

Description. Test free, elliptical in outline, composed of a single chambers planispirally coiled. Wall thin, finely agglutinated. Aperture terminal.

Distribution. Cosmopolitan species common from the Cretaceous to the Eocene, and signaled from the Oligocene of the northern Appennines (Emiliani, 1954), and from the Miocene of Greenland Sea (Kaminski et al., 2006).

Remarks. *Ammodiscus peruvianus* differs from *A. cretaceus* for the elliptical outline.

Ammodiscus sp. 1
Figure 13.17

Material. One specimen from the sample PC060607.

Description. Test free, small in size, incomplete, composed of a large sized proloculus followed by a single tubular chamber for about two whorls. Wall thick, medium to coarse agglutinated.

Remarks. Differs from *A. latus* and *A. cf. latus* in having higher chamber and for the coarser agglutination of the wall.

Ammodiscus sp. 2
Figure 13.18

Material. Two specimens from two samples.

Description. Test free, planispirally coiled, biconcave, evolved with weakly embraced whorls. The single tubular chamber is arranged in seven whorls increasing gradually in size. Wall thin, finely agglutinated.

Ammodiscus sp. 3
Figure 13.19

Material. One single specimen from the sample PC060603.

Description. Test free, planispirally coiled, strictly biconcave, evolute with partially embraced whorls. The tubular chamber completes 11 whorls around the axis. Wall thin, finely agglutinated. Aperture single at the end of the chamber.

Remarks. Differs from *Ammodiscus* sp. 2 in having a higher number of whorls, and smaller size.

Ammodiscus spp.

Material. Six specimens from two samples.

Description. In this group are included all fragmented and compressed test unrecognizable at specific level.

Subfamily AMMOVERTELLININAE Saidova, 1981
Genus ANNECTINA Suleymanov, 1963
Annectina biedai Gradstein and Kaminski, 1997
Figure 13.20

1997 *Annectina biedai*; Gradstein and Kaminski, p. 218. figs. 2, 3, 1a-2c.

2005 *Annectina biedai* Gradstein and Kaminski; Kaminski and Gradstein, p. 195, pl. 29, figs. 1-5 (cum syn.).

Material. Two specimens from the sample PC060618.

Description. Test free, discoidal and flattened, circular or elliptic in outline. The short initial stage triloculina-like coiled is followed by several planispirally coiled whorls.

Distribution. Middle Eocene–late Oligocene (Kaminski and Gradstein, 2005).

Annectina cf. grzybowskii (Jurkiewicz, 1960)
Figure 13.21

cf. 1960 *Glomospira grzybowskii*; Jurkiewicz, p. 339, pl. 38, figs. 7, 10, 11.

cf. 1992 *Glomospirella biedai* Samuel; Morlotti and Kuhnt, p. 222, pl. 1, figs. 10, 11.

Material. Three specimens from the sample PC060617.

Description. Test elliptic or subcircular composed of a single chamber with an initial milioline-like stage followed by few planispirally coiled whorls. Wall thin, medium sized quartz grains immerse into abundant cement. Aperture a single opening at the end of the tubular chamber.

Remarks. Differs from *A. grzybowskii*, species describe from the Campanian to the Paleocene, in having smaller size.

Subfamily USBEKISTANIINAE Vyalov, 1968
Genus GLOMOSPIRA Rzehak, 1885
Glomospira extendens Emiliani, 1954
Figure 15.1

1954 *Glomospira charoides* (Jones and Parker), var. *extendens*; Emiliani, p. 133, pl. 22 (3), fig. 14a-c.

Material. One single specimen from the sample PC11.

Description. Test free, small, composed of a proloculus followed by a tubular undivided chamber initially arranged in 3–4 glomospirine whorls, whereas the last two whorls are coiled around an axis at 90°. Wall smooth and finely agglutinated. Aperture terminal at the end of the tube-like chamber.

Glomospira irregularis (Grzybowski, 1898)
Figure 13.27

1898 *Ammodiscus irregularis*; Grzybowski, p. 285, pl. 11, figs. 2, 3.

1966 *Glomospira irregularis* (Grzybowski); Geroch, p. 460, pl. 8, figs. 11, 12.

2005 *Glomospira irregularis* (Grzybowski); Kender, Kaminski, and Cieszkowski, p. 261, fig. 10Q.

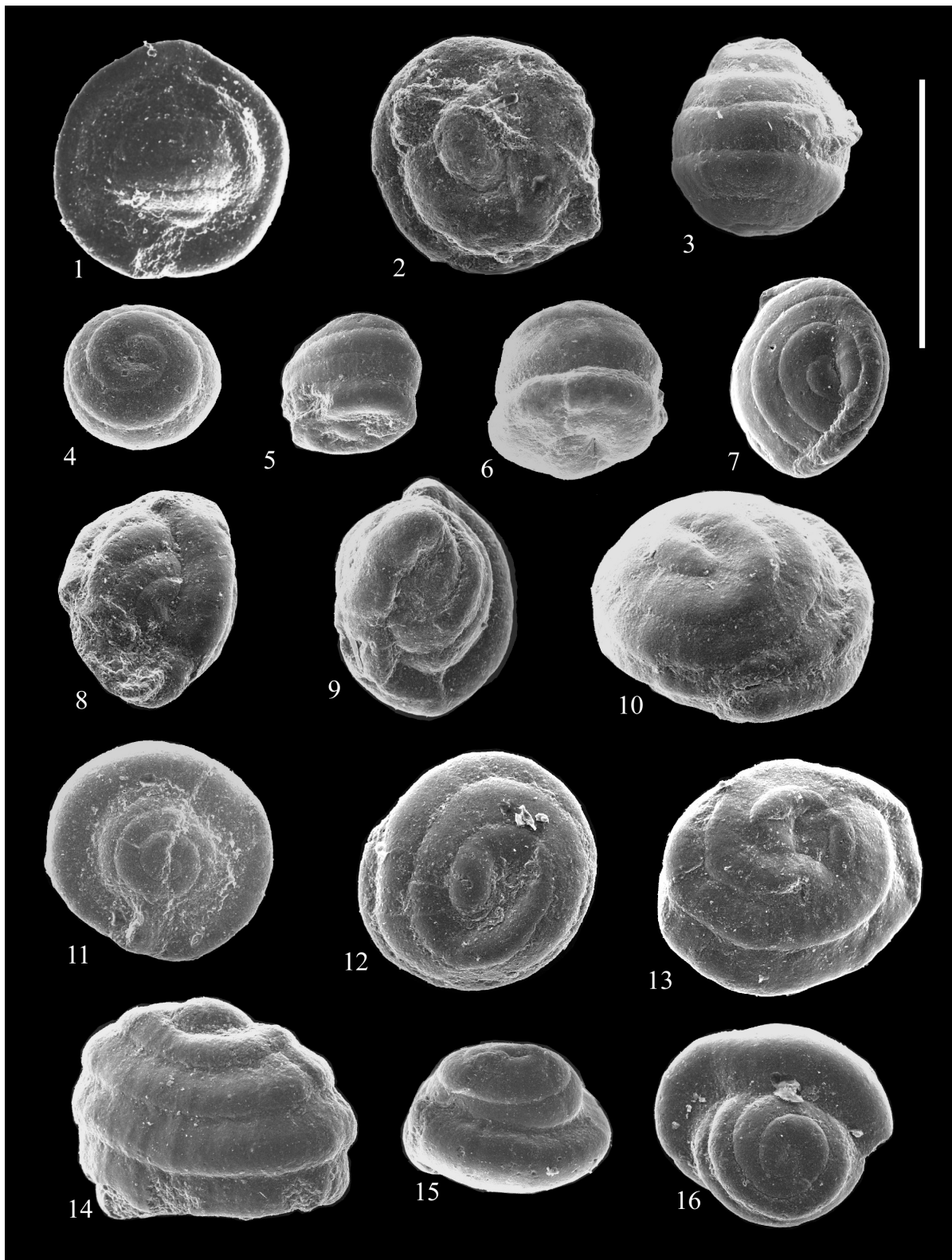


FIGURE 15. Scanning electron micrographs of Usbekistaniinae from the Caltavuturo Formation cropping out at Portella Colla. **1**, *Glomospira extendens* Emiliani, 1954, PC11. **2**, *Glomospira gordialis* (Jones and Parker, 1860), PC060604. **3-16**, *Repsmanina charoides* (Jones and Parker, 1860), PC060604 (**3**), PC060601 (**4**), PC060604 (**5**), PC060603 (**6**), PC060611 (**7**), PC060601 (**8**), PC060603 (**9**), PC060621 (**10**), PC060621 (**11**), PC060617 (**12**), PCs0 (**13**), PCs0 (**14**), PC060604 (**15**) and PCs0 (**16**). Scale bar equals 0.5 mm.

2009 *Glomospira irregularis* (Grzybowski); Kender, Kaminski, and Jones, p. 496, pl. 2, fig. 12.

Material. 10 specimens from six samples.

Description. Test free composed of a tube-like undivided chamber streptospirally coiled. Wall thick, finely agglutinated, smooth surface. Aperture at the end of the tubular chamber.

Distribution. Cosmopolitan species known from the Cretaceous to Recent (Kender et al., 2009).

Glomospira gordialis (Jones and Parker, 1860)
Figure 15.2

1860 *Trochammina squamata* Jones and Parker var. *charoides*; Jones and Parker, p. 304.

1884 *Ammodiscus gordialis* Jones and Parker; Brady, p. 333, pl. 38, figs. 7-9.

1995 *Glomospira gordialis* (Jones and Parker); Holbourn and Kaminski, p. 444, pl. 3, fig. 9.

2005 *Glomospira gordialis* (Jones and Parker); Kender, Kaminski, and Cieszkowski, p. 261, fig. 10P.

2009 *Glomospira gordialis* (Jones and Parker); Kender, Kaminski, and Jones, p. 496, pl. 2, fig. 11.

Material. 16 specimens from eight samples.

Description. Test free, small, circular in outline, comprised of a small proloculus followed by a single undivided chamber trochospirally enrolled in the early whorls, then glomospirally coiled along a general plane; last whorl deviates from the general coiling, embracing previous stage. Wall smooth, finely agglutinated; aperture simple opening at the end of the tube.

Distribution. Cosmopolitan species known from the Cretaceous to Recent (Kender et al., 2009).

Glomospira serpens (Grzybowski, 1898)
Figure 13.25-26

1898 *Ammodiscus serpens*; Grzybowski, p. 285, pl. 10, figs. 31-33.

1977 *Glomospirella serpens* (Grzybowski); Samuel, p. 30, pl. 4, figs. 2, 4.

1982 *Glomospira serpens* (Grzybowski); Miller, Gradstein, and Berggren, p. 20, pl. 1, fig. 13.

2005 *Glomospira serpens* (Grzybowski); Kender, Kaminski, and Cieszkowski, p. 261, fig. 10R.

Material. 21 specimens from six samples.

Description. Test flattened, ovate in outline, a single undivided chamber milioline-like coiled. Wall smooth, finely agglutinated; aperture is a simple opening at the end of the tube.

Distribution. Cosmopolitan species known from the Upper Cretaceous to the Eocene of Carpathians and Alps.

Glomospira sp. 1
Figure 13.23

Material. One single specimen from the sample PC11.

Description. Initial stage streptospirally coiled, followed by two planispirally enrolled whorls increasing rapidly in size.

Glomospira sp. 2
Figure 13.22

Material. One single specimen from the sample PC15.

Description. Test large, elliptic in outline, short initial stage glomospirine-like coiled followed by five planispirally coiled whorls weakly irregular. Wall thick with sparse agglutinated grains. Aperture at the end of the tubular chamber.

Glomospira sp. 3
Figure 13.24

Material. One single specimen from the sample PC13.

Description. Proloculus followed by an undivided tubular chamber with an initial stage streptospirally coiled; the diameter of the tube is constant and does not increase substantially in size. Last whorls are arranged in a subplanar coil perpendicular to the main direction of coiling of the glomospirine stage which results decentralized. Wall thick and finely agglutinated.

Genus REPMANINA Suleymanov in Arapova and Suleymanov, 1966

Repmanina charoides (Jones and Parker, 1860)
Figure 15.3-16

1860 *Trochammina squamata* Jones and Parker var. *charoides*; Jones and Parker, p. 304.

1884 *Ammodiscus charoides* (Jones and Parker); Brady, p.334, 335, pl. 38, figs. 10-16.

1928 *Glomospira charoides* (Jones and Parker), var. *corona*; Cushman and Jarvis, p. 89, pl. 12, figs. 9-11.

1989 *Repmanina charoides* (Jones and Parker); Coccioni, p. 95, pl. 3, fig. 22.

2005 *Glomospira charoides* (Jones and Parker); Kender, Kaminski, and Cieszkowski, p. 261, fig. 10M.

Material. 131 specimens from 24 samples.

Description. Test small, subspheric, circular in outline or flattened, composed of a long tube-like chamber streptospirally enrolled around the proloculus (never visible) about up to three different axes of coiling. Wall finely agglutinated, surface smooth.

Distribution. Cosmopolitan taxon known from the Jurassic to Recent (Kaminski and Gradstein, 2005).

Remarks. The outer morphology of *R. charoides* is widely variable, Berggren and Kaminski (1990) recognize a dozen of synonym subdivided into four groups.

Family LITUOTUBIDAE Loeblich and Tappan,
1984

Genus LITUOTUBA Rhumbler, 1895

Lituotuba lituiformis (Brady, 1879)

Figure 16.16

1879 *Trochammina lituiformis*; Brady, p. 59, pl. 5, Zfig. 16.

2005 *Lituotuba lituiformis* (Brady); Kaminski and Gradstein, p. 287, pl. 58, figs. 1-8.

Material. One single specimen from the sample PC060615.

Description. Test free, composed of a subspheric proloculus followed by a tube glomospirine or streptospirally coiled, which tends to uncoil and become rectilinear carrying on with the ontogeny. The tube is initially undivided, after some constrictions at irregular distance define the chambers.

Distribution. Cretaceous to Recent (Kaminski and Gradstein, 2005).

Genus PARATROCHAMMINOIDES Soliman, 1972

Paratrochamminoides acervulatus (Grzybowski,
1896)

Figure 16.14

1896 *Trochammina acervulata*; Grzybowski, p. 274, pl. 9, fig. 4.

2005 *Paratrochamminoides acervulatus* (Grzybowski); Kaminski and Gradstein, p. 290, pl. 59, figs. 1-7.

Material. Nine specimens from six samples.

Description. Test free, ovoid, the sack-shaped chambers are arranged in a conic and irregular trochospire. The ventral side shows a depressed umbellicus. Wall thick, finely agglutinated, aperture at the base of the last chamber.

Distribution. Late Cretaceous–Eocene (Kaminski and Gradstein, 2005).

Paratrochamminoides deflexiformis (Noth, 1912)
Figure 16.15

1912 *Trochammina deflexiformis*; Noth, p. 14, pl. 1, fig. 10.

2005 *Paratrochamminoides deflexiformis* (Noth); Kaminski and Gradstein, p. 293, pl. 60, figs. 1-4.

Material. Four specimens from four samples.

Description. Test free, subelliptic in outline, three glomospirine-like coiled whorls and open umbellicus.

Subspheric chambers increasing gradually in size, sutures incise. Wall finely agglutinated, thick, smooth surface.

Distribution. Maastrichtian–Eocene.

Paratrochamminoides draco (Grzybowski, 1901)
Figure 16.18

1901 *Trochammina draco*; Grzybowski, p. 280, pl. 8, fig. 10.

1995 *Paratrochamminoides draco* (Grzybowski); Bubík, p. 84, pl. 3, fig. 2a, b.

1996 *Paratrochamminoides draco* (Grzybowski); Kaminski, Kuhnt, and Radley, p. 16, pl. 3, fig. 8.

Material. One specimen from the sample PC11.

Description. Test free, large, elliptic in outline. Initially 2–3 glomospirine-like coiled whorls, followed by a reversed whorl of about 180°. Chambers elongated, sack-shaped, sutures very incise. Wall thick, medium to finely agglutinated. Aperture simple at the end of the last chamber.

Paratrochamminoides aff. *gorayskii* (Grzybowski,
1898)

Figure 17.12

aff. 1898 *Ammodiscus gorayskii*; Grzybowski, p. 286, pl. 11, fig. 5.

Material. Two specimens from the sample PC060615.

Description. Test small, elliptic in outline, trilobulate-like coiled. The chambers are subdivided by septa few evident. Wall finely agglutinated.

Remarks. The collected specimens resemble *P. gorayskii* (Grzybowski) differing in having a shorter spire.

Paratrochamminoides heteromorphus
(Grzybowski, 1898)

Figure 17.1-2

1898 *Trochammina heteromorpha*; Grzybowski, p. 286, pl. 11, fig. 16.

1943 *Trochamminoides koeroesmezoensis*; Majzon, p. 156, pl. 2, fig. 16a-c.

2005 *Paratrochamminoides heteromorphus* (Grzybowski); Kaminski and Gradstein, p. 298, pl. 62, figs. 1-10.

Material. 18 specimens from nine samples.

Description. Test free, large, initially trochospirally or streptospirally coiled, last chambers uncoiled. Chambers globose increasing in size in the uncoiled portions, where they become tubular and more or less compressed. Sutures incise. Wall finely agglutinated, smooth surface. Aperture simple at the end of the last chamber.

Distribution. Campanian–Eocene (Kaminski and Gradstein, 2005).

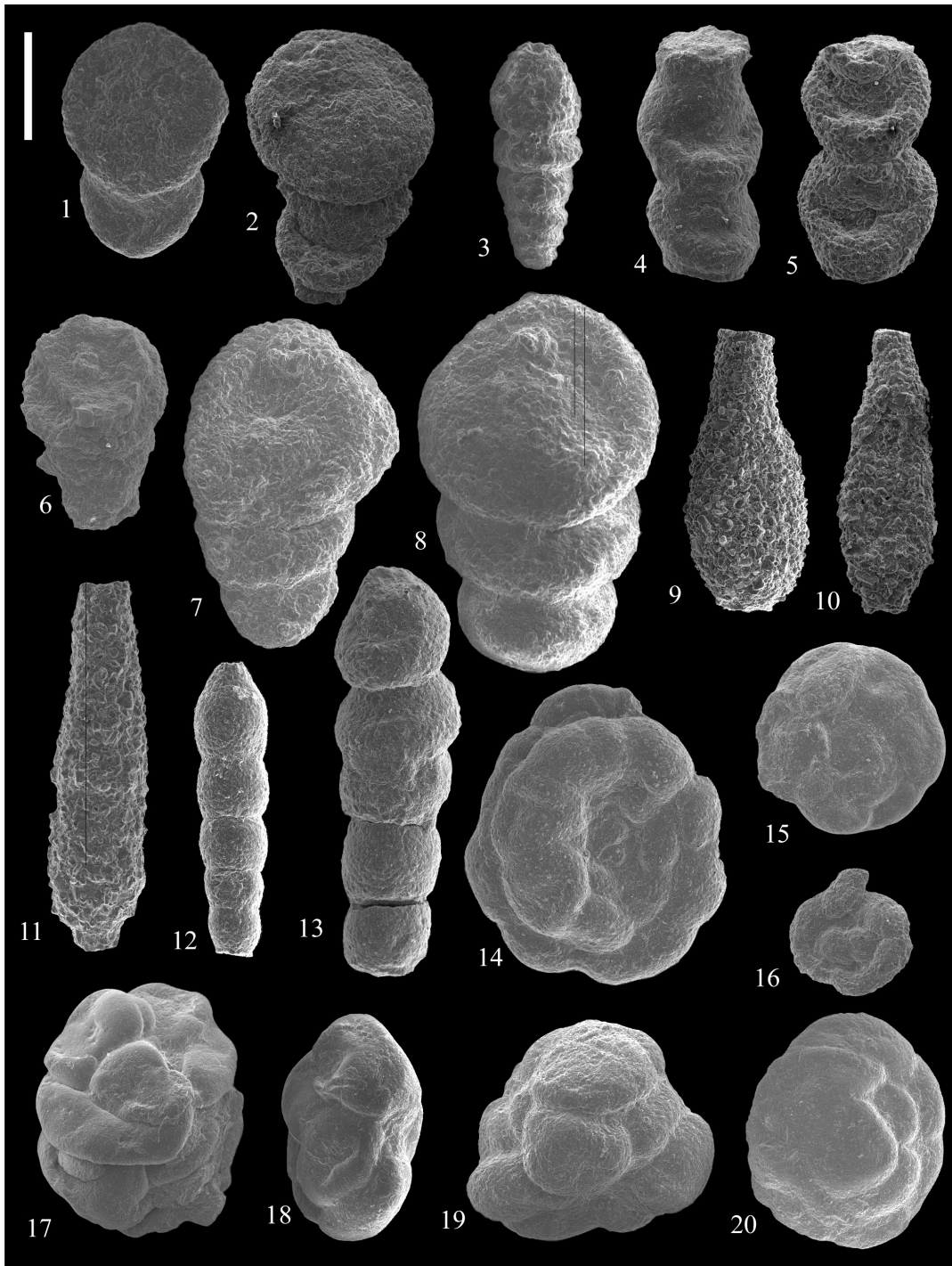


FIGURE 16. Scanning electron micrographs of Reophacidae (1-3), Hormosinidae (4-13), and Lituotubidae (14-20) from the Caltavuturo Formation cropping out at Portella Colla. 1, *Reophax duplex* Grzybowski, 1896, PC060624. 2, *Reophax pilulifer* Brady, 1884, PC13. 3, *Reophax* sp. 1, PC060615. 4-5, *Hormosina velascoensis* (Cushman, 1926), PC060617 (4) and PC11 (5). 6, *Hormosina trinitatensis* Cushman and Renz, 1946, PC11. 7, *Hormosina* sp. 1, PC060624. 8, *Hormosina* sp. 2, PC060615. 9-11, *Pseudonodosinella elongata* Grzybowski, 1898, PC11 (9), PC060601 (10) and PCs0 (11). 12-13, *Pseudonodosinella nodulosa* Brady, 1879, PC11 (12) and PC060617 (13). 14, *Paratrochamminoides acervulatus* (Grzybowski, 1896), PC13. 15, *Paratrochamminoides deflexiformis* (Noth, 1912), PC060615. 16, *Lituotuba lituiformis* (Brady, 1879), PC060615. 17, *Paratrochamminoides* sp. 1, PC060601. 18, *Paratrochamminoides draco* (Grzybowski, 1901), PC11. 19, *Paratrochamminoides mitratus* (Grzybowski, 1901), PCs0. 20, *Conglophragmium deforme* (Grzybowski, 1898), PC060623. Scale bar equals 0.5 mm.

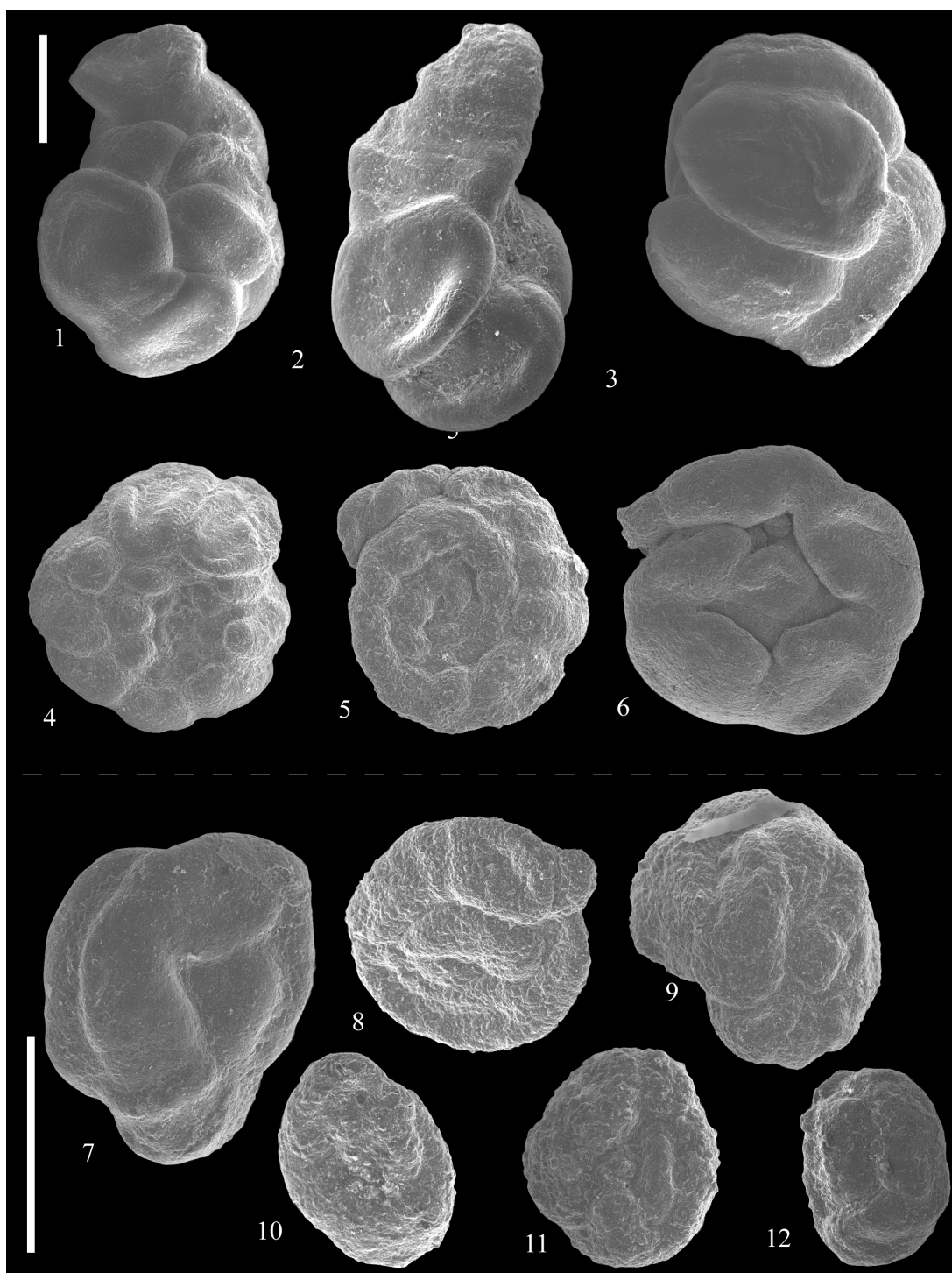


FIGURE 17. Scanning electron micrographs of Lituotubidae (1-3, 7, 9, 11-12) and Trochamminoidae (4-6, 8, 10) from the Caltavuturo Formation cropping out at Portella Colla. 1-2, *Paratrochamminoides heteromorphus* (Grzybowski, 1898), MM12 (1) and MM14 (2). 3, *Conglophragmium irregulare* (White, 1928), PCs0. 4, *Trochamminoides coronatus* (Brady, 1879), MM14. 5, *Trochamminoides grzybowskii* Kaminski and Geroch, 1992, MM1. 6, *Trochamminoides subcoronatus* (Grzybowski, 1896), MM1. 7, *Paratrochamminoides* cf. *olszewskii* (Grzybowski, 1898), PC060615. 8, *Trochamminoides dubius* (Grzybowski, 1901), PC060611. 9, *Paratrochamminoides olszewskii* (Grzybowski, 1898), PC11. 10, *Trochamminoides dubius* (Grzybowski, 1901), PC060611. 11, *Paratrochamminoides* aff. *olszewskii* (Grzybowski, 1898), PC060615. 12, *Paratrochamminoides* aff. *gorayskii* (Grzybowski, 1898), PC060615. Scale bars equal 0.5 mm.

Paratrochamminoides mitratus (Grzybowski, 1901)
Figure 16.19

1901 *Trochammina mitrata*; Grzybowski, p. 280, pl. 8, fig. 3.

2005 *Paratrochamminoides mitratus* (Grzybowski); Kaminski and Gradstein, p. 302, pl. 63, figs. 1-7.

Material. Four specimens from four samples.

Description. Test large, streptospirally coiled, composed of several chambers increasing slowly in size. The coiling plane abruptly changes. Wall finely agglutinated.

Distribution. Turonian–Oligocene (Kaminski and Gradstein, 2005).

Paratrochamminoides olszewskii (Grzybowski, 1898)
Figure 17.9

1898 *Trochammina olszewskii*; Grzybowski, p. 298, pl. 11, fig. 6.

2005 *Paratrochamminoides olszewskii* (Grzybowski); Kaminski and Gradstein, p. 305, pl. 64, figs. 1-7.

Material. Five specimens from five samples.

Description. Test free, oval in outline, glomospirine-like coiled, 2–3 whorls are externally visible. The initial stage is undivided, going on with the ontogeny some constrictions define the chambers. The last whorl tends to become planispiral or weakly irregular. Wall thin, finely agglutinated.

Distribution. Cenomanian–Eocene (Kaminski and Gradstein, 2005).

Paratrochamminoides cf. *olszewskii* (Grzybowski, 1898)
Figure 17.7

cf. 1898 *Trochammina olszewskii*; Grzybowski, p. 298, pl. 11, fig. 6.

Material. Three specimens from three samples.

Remarks. Differs from *P. olszewskii* in the lack of the planispiral final stage.

Paratrochamminoides aff. *olszewskii* (Grzybowski, 1898)
Figure 17.11

aff. 1898 *Trochammina olszewskii*; Grzybowski, p. 298, pl. 11, fig. 6.

Material. One specimen from the sample PC060615.

Description. Test free, small, glomospirine-like coiled. Initially a tubular undivided chambers, later constrictions subdivided the chambers with septa. Wall thin, finely agglutinated.

Remarks. Differs from *P. olszewskii* in having a shorter initial tube-like chamber and in the lack of the planispiral whorl.

Paratrochamminoides sp. 1
Figure 16.17

Material. One specimen from the sample PC060601.

Description. Test free, large, elliptic in outline, streptospirally coiled. Chambers large and compressed, sack-shaped, sutures incise. Wall finely agglutinated.

Paratrochamminoides spp.

Material. 139 specimens from 22 samples.

Description. In this group are included all the specimens not referred at any known species.

Genus CONGLOPHRAGMIUM Bermúdez and Rivero, 1963

Conglophragmium deforme (Grzybowski, 1898)
Figure 16.20

1898 *Trochammina deformatis*; Grzybowski, p. 288, pl. 11, figs. 20-22.

1995 *Paratrochamminoides deformatis* (Grzybowski); Rögl, p. 256, pl. 2, figs. 15-19.

2004 *Conglophragmium deformatis* (Grzybowski); Kaminski and Kuhnt, p. 279.

Material. One specimen from the sample PC060623.

Description. Test free, large, oval in outline. Initially streptospirally coiled, later an involute planispire with 5–6 globose, elongated and subrectangular chambers composing the last whorl. Aperture interiomarginal.

Conglophragmium irregulare (White, 1928)
Figure 17.3

1928 *Trochammina irregularis*; White, p. 307, pl. 42, fig. 1.

1937 *Trochamminoides irregularis* (White); Glaessner, p. 360, pl. 1, fig. 9a, b.

1990 *Paratrochamminoides irregularis* (White); Kuhnt, p. 320, pl. 5, fig. 10.

2004 *Conglophragmium irregularis* (White); Kaminski and Kuhnt, p. 279.

Material. 21 specimens from 10 samples.

Description. Test free, large, elliptic in outline. Chambers large, globose or sack-shaped, irregularly coiled. Coiling direction continuously alternating.

Distribution. From Cretaceous to Oligocene (Kaminski and Gradstein, 2005).

Family TROCHAMMINOIDEAE Haynes and Nwabufu-Ene, 1998

Genus TROCHAMMINOIDES Cushman, 1910
Trochamminoides coronatus (Brady, 1879)

Figure 17.4

- 1879 *Trochammina coronata*; Brady, p. 39, pl. 5, fig. 15.
1977 *Trochamminoides coronatus* Brady; Krashe-
ninnikov and Pflaumann, p. 570, pl. 4, fig. 4a,
b.

Material. 14 specimens from seven samples.

Description. Test free, large, biconcave, com-
posed of few whorls arranged in a low trochospire.
Chambers globose and elongated, sutures distinct,
periphery lobate. Aperture simple at the end of the
last chamber.

Trochamminoides dubius (Grzybowski, 1901)
Figure 17.8, 10

- 1901 *Ammodiscus dubius*; Grzybowski, p. 274, pl.
8, figs. 12, 14.
1993 *Trochamminoides dubius* (Grzybowski);
Kaminski and Geroch, p. 275, pl. 15, figs. 9-
12.
2005 *Trochamminoides dubius* (Grzybowski);
Kaminski and Gradstein, p. 308, pl. 65, figs. 1-
8.

Material. 10 specimens in six samples.

Description. Test free, small, compressed. Initial
coil glomospirine-like, becoming planispiral through
the ontogeny. The test is composed of four whorls,
in the last whorl 4 ½ tubular chambers occur. Wall
finely agglutinated.

Distribution. Maastrichtian–Oligocene (Kaminski
and Gradstein, 2005).

Trochamminoides grzybowskii Kaminski and
Geroch, 1992
Figure 17.5

- 1898 *Trochammina elegans* Rzehak; Grzybowski,
p. 287, pl. 11, fig. 10.
1977 *Trochamminoides elegans* (Grzybowski);
Samuel, p. 45, pl. 4, fig. 17.
1992 *Trochamminoides grzybowskii*; Kaminski and
Geroch, p. 64, fig. 1a, b.
2005 *Trochamminoides grzybowskii* Kaminski and
Geroch; Kaminski and Gradstein, p. 311, pl.
66, figs. 1-4.

Material. Four specimens from four samples.

Description. Test free, large, elliptic or subcircular
in outline, 2–3 whorls planispirally evolute coiled.
Chambers numerous, subspheric, sutures
depressed, well distinct at regular distance. Wall
finely agglutinated, smooth surface. Aperture small
at the base of the last chamber.

Distribution. Coniacian–Eocene (Kaminski and
Gradstein, 2005).

Trochamminoides intermedius (Grzybowski, 1896)
Figure 18.5

- 1896 *Trochammina intermedia*; Grzybowski, p. 282,
pl. 8, fig. 53a-c.

Material. Three specimens from two samples.

Description. Test free, oval, compressed, troco-
spirally coiled, with chambers flattened and
square-shaped. Sutures incise.

Trochamminoides proteus (Karrer, 1866)
Figure 18.2

- 1866 *Trochammina proteus*; Karrer, pl. 1, fig. 8.
1977 *Trochamminoides proteus* (Karrer); Samuel,
p. 46-47, pl. 5, fig. 5a, b.
2005 *Trochamminoides proteus* (Karrer); Kender,
Kaminski and Cieszkowski, p. 264, fig. 12E, F.

Material. Six specimens from five samples.

Description. Test free, large, oval in outline. Ini-
tially glomospirine-like coiled becoming planispiral
going on with the ontogeny. Chambers globose
increasing gradually in size. In the last whorl 6–9
chambers occur. Wall finely agglutinated.

Distribution. Cosmopolitan species known from
the Late Cretaceous to the late Eocene (Kender et
al., 2005).

Trochamminoides cf. proteus (Karrer, 1866)
Figure 18.3

- cf. 1866 *Trochammina proteus*; Karrer, pl. 1, fig. 8.

Material. One specimen from the sample
PC060624.

Description. A species referred to the genus *Tro-
chamminoides* with six subcircular and com-
pressed chambers in the last whorl. Periphery
lobate. Wall finely agglutinated with some medium
to large sized quartz grains.

Remarks. Differs from *T. proteus* in having less
chambers and a larger size.

Trochamminoides septatus (Grzybowski, 1898)
Figure 18.1

- 1898 *Ammodiscus septatus*; Grzybowski, p. 283, pl.
11, fig. 1.
1993 *Trochamminoides septatus* (Grzybowski);
Kaminski and Geroch, p. 255, pl. 5, fig. 9a-c.
2005 *Trochamminoides septatus* (Grzybowski);
Kender, Kaminski, and Cieszkowski, p. 264,
fig. 12G.

Material. One specimen from the sample
PC060604.

Description. Test free, large, planispirally ammo-
discine-type coiled, with constrictions forming
chambers. Wall thin, but coarsely agglutinated.

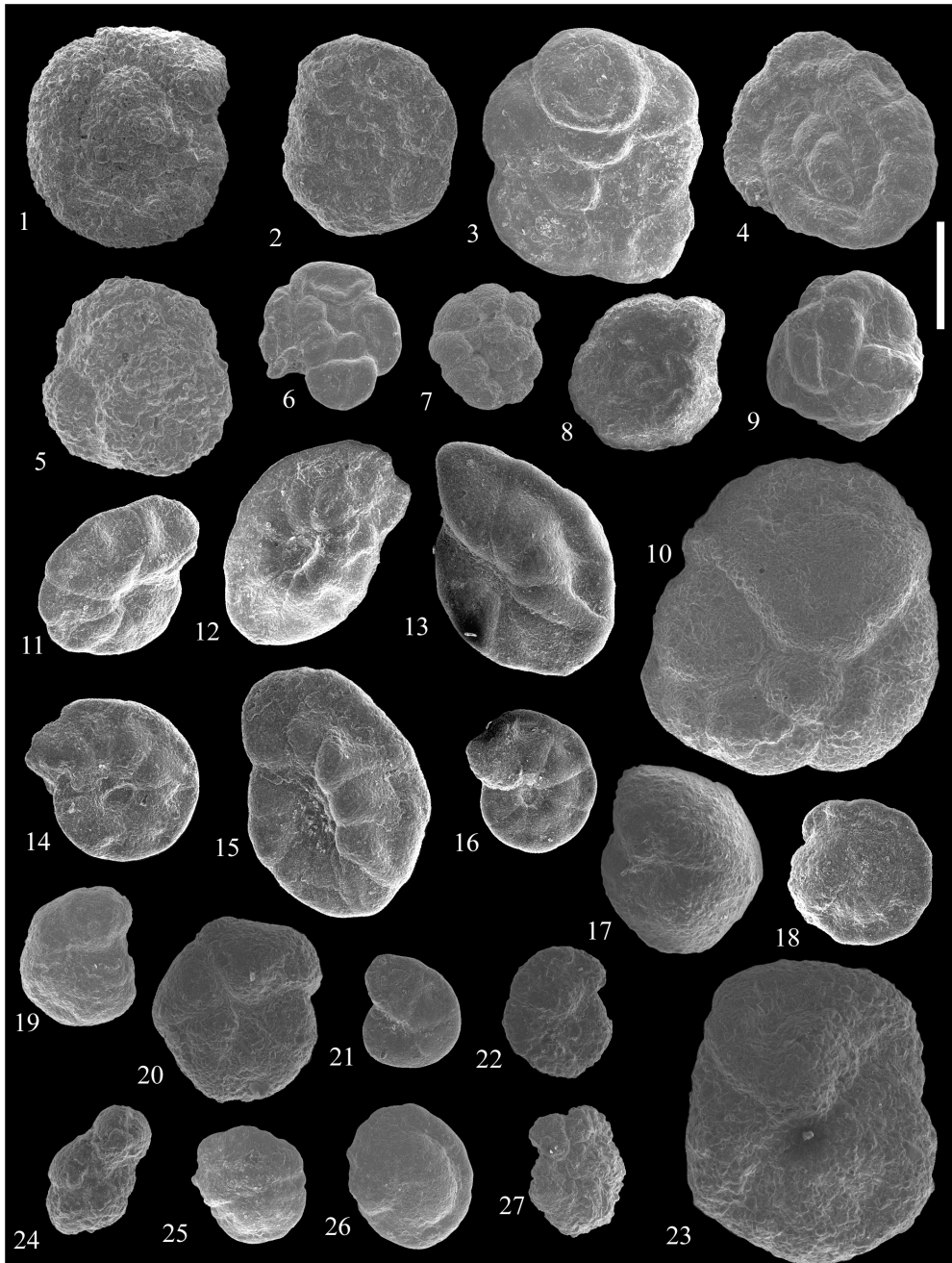


FIGURE 18. Scanning electron micrographs of Trochamminoidae (1-10) and Haplophragmoididae (11-27) from the Caltavuturo Formation cropping out at Portella Colla. **1**, *Trochamminoides septatus* (Grzybowski, 1898), PC060604. **2**, *Trochamminoides proteus* (Karrer, 1866), PC060621. **3**, *Trochamminoides* cf. *proteus* (Karrer, 1866), PC060624. **4**, *Trochamminoides velascoensis* Cushman, 1926, PC11. **5**, *Trochamminoides intermedius* (Grzybowski, 1896), PC060621. **6**, *Trochamminoides variolarius* (Grzybowski, 1898), MM14. **7**, *Trochamminoides* sp. 1, PC060603. **8**, *Trochamminoides* sp. 2, PC060604. **9**, *Trochamminoides* sp. 3, PC060618. **10**, *Trochamminoides* sp. 4, PC18. **11-13**, *Haplophragmoides carinatus* Cushman and Renz, 1941, PC060621 (**11**), PC060621 (**12**) and PC060624 (**13**). **14-16**, *Haplophragmoides walteri* (Grzybowski, 1898), PC18 (**14**), PC11 (**15**), PC5 (**16**). **17**, *Haplophragmoides eggeri* Cushman, 1926, PC060611. **18**, *Haplophragmoides excavatus* Cushman and Waters, 1927, PC060601. **19**, *Haplophragmoides* cf. *kirki* Wickenden, 1932, PC060602. **20**, *Haplophragmoides porrectus* Maslakova, 1955, PCs0. **21**, *Haplophragmoides* cf. *walteri* (Grzybowski, 1898), PC060621. **22**, *Haplophragmoides horridus* (Grzybowski, 1901), PC060601. **23**, *Haplophragmoides* cf. *horridus* (Grzybowski, 1901), PC060604. **24**, *Haplophragmoides* cf. *porrectus* Maslakova, 1955, PC060615. **25-26**, *Haplophragmoides* sp. 1, PC060602 (**25**) and PC060602 (**26**). **27**, *Haplophragmoides* sp. 2, PC060603. Scale bar equals 0.5 mm.

Trochamminoides subcoronatus (Grzybowski, 1896)

Figure 17.6

- 1896 *Trochammina subcoronata*; Grzybowski, p. 283, 284, pl. 9, fig. 3a-c.
- 1996 *Trochamminoides subcoronatus* (Grzybowski); Kuhnt and Collins, p. 214.
- 2001 *Trochamminoides subcoronatus* (Grzybowski); Kuhnt and Urquhart, p. 56, pl. 3, fig. 9 (cum syn.).

Material. 16 specimens from nine samples.**Description.** Test free, very large, subelliptic or circular in outline, planispirally coiled with 6–8 elongated sack-shaped chambers in the last whorl.**Remarks.** *Trochamminoides coronatus* has a higher number of chambers.*Trochamminoides variolarius* (Grzybowski, 1898)

Figure 18.6

- 1898 *Trochammina variolaria*; Grzybowski, p. 288, pl. 11, fig. 15.
- 1993 *Trochamminoides variolarius* (Grzybowski); Kaminski and Geroch, p. 261, pl. 9, figs. 5, 6.
- 2005 *Trochamminoides variolarius* (Grzybowski); Kender, Kaminski, and Cieszkowski, p. 264, fig. 12J.

Material. Six specimens from four samples.**Description.** Test free, small, subsquare in outline, composed of two whorls, with 4–5 chambers in the last whorl. Coiling planispiral or weakly trochospiral. Chambers triangular increasing rapidly in size. Wall finely agglutinated, smooth surface.*Trochamminoides velascoensis* Cushman, 1926

Figure 18.4

- 1926 *Trochamminoides velascoensis*; Cushman, p. 583, pl. 15, fig. 2a, b.
- 2005 *Trochamminoides velascoensis* (Cushman); Kender, Kaminski, and Cieszkowski, p. 264, fig. 12K.

Material. Three specimens from three samples.**Description.** Test free, subcircular in outline, planispirally coiled. Numerous subrectangular and flattened chambers (10 in the last whorl). Suture few evident.**Distribution.** *Trochamminoides velascoensis* was firstly described from the Velasco Formation of Mexico (Cushman, 1926), and recently signaled from the Eocene of Carpathians (Kender et al., 2005).*Trochamminoides* sp. 1

Figure 18.7

Material. One single specimen from the sample PC060603.**Description.** Test free, small, initially glomospirine-like coiled, becoming planispiral in the latest whorls. Chambers globose, sutures incise. Ten chambers in the last whorl.*Trochamminoides* sp. 2

Figure 18.8

Material. One specimen from the sample PC060604.**Description.** Very similar in shape to *T. velascoensis*, but the subdivision of the chambers is arranged as in *T. septatus*.*Trochamminoides* sp. 3

Figure 18.9

Material. Two specimens from the sample PC060618.**Description.** Test free, glomospirine-like coiled. Chambers flattened and subsquared. Periphery quadrangular and lobate.*Trochamminoides* sp. 4

Figure 18.10

Material. Two specimens from two samples.**Distribution.** Test free, very large, quadrangular in outline, low trochospirally coiled. Chambers subrectangular and very large increasing rapidly in size. In the dorsal side a low spire is visible, whereas three large chambers occur in the last whorl.*Trochamminoides* spp.**Material.** 22 specimens from 12 samples.**Description.** In this group are included all the broken or incomplete specimens with planispiral or low trochospiral mode of coiling, and chambers globose or flattened.

Order LITUOLIDA Lankester, 1885

Suborder HORMOSININA Mikhalevich, 1980
 Superfamily HORMOSINOIDEA Haeckel, 1894
 Family ASCHEMOCELLIDAE Vyalov, 1966
 Genus ARTHRODENDRON Ulrich, 1904
Arthrodendron grandis (Grzybowski, 1898)

Figure 14.14

- 1898 *Reophax grandis*; Grzybowski, p. 277, pl. 10, figs. 13-15.
- 1993 *Aschemocella grandis* (Grzybowski); Kaminski and Geroch, p. 249, pl. 2, figs. 8-10.
- 2005 *Aschemocella grandis* (Grzybowski); Kender, Kaminski, and Cieszkowski, p. 262, fig. 11D, E.
- 2008 *Arthrodendron grandis* (Grzybowski); Kaminski, Uchman, Neagu, and Cetean, p. 108.
- 2009 *Aschemocella grandis* (Grzybowski); Kender, Kaminski, and Jones, p. 497, pl.3, fig. 5.

Material. 56 specimens from 14 samples.

Description. Test free, large, uniseriate and curved, composed of discoidal and compressed chambers with raised periphery. Aperture single, peripheric, supported by a raised neck. Wall coarsely agglutinated.

Distribution. Species cosmopolitan known from the Campanian to the early Miocene (Kaminski and Gradstein, 2005).

Remarks. Only isolated chambers have been recovered.

Arthrodendron subnodosiformis (Grzybowski, 1898)
Figure 14.13

- 1898 *Hyperammia subnodosiformis*; Grzybowski, p. 274, pl. 10, figs. 5, 6.
1993 *Aschemocella subnodosiformis* (Grzybowski); Kaminski and Geroch, p. 248, pl. 1, figs. 10a-13.
2006 *Aschemocella subnodosiformis* (Grzybowski); Kaminski, Silye, and Kender, p. 384.
2008 *Arthrodendron subnodosiformis* (Grzybowski); Kaminski, Uchman, Neagu, and Cetean, p. 108.

Material. Eight specimens from four samples.

Description. Test free, large, uniseriate, flattened, consisting of single elongated, piriform, and compressed chambers increasing rapidly in size. Wall thin and finely agglutinated.

Distribution. Grzybowski (1898) described *A. subnodosiformis* from the Paleogene of the Polish Carpathians; Kaminski et al. (2006) signaled it from the Miocene of Greenland Sea.

Remarks. The chambers are usually isolated and fragmented.

Genus KALAMOPSIS de Folin, 1883
Kalamopsis grzybowskii (Dyłażanka, 1923)
Figure 14.15-19

- 1923 *Hyperammia grzybowskii*; Dyłażanka, p. 65.
1966 *Kalamopsis grzybowskii* (Dyłażanka); Geroch, p. 438, fig. 6.
1987 *Silicotuba grzybowskii* (Dyłażanka); Loeblich and Tappan, p. 26, pl. 16, figs. 10-13.
2002 *Kalamopsis grzybowskii* (Dyłażanka); Holbourn and Henderson, p. 11, figs. 2, 3.

Material. 47 specimens from 12 samples.

Description. Test free, bottle-like, elongated with constrictions, straight or curved, often tubular with longitudinal groove. Aperture terminal at the end of the open part of the chamber. Wall finely agglutinated, smooth surface.

Distribution. Flysh-type cosmopolitan taxon known from the lower Jurassic (?Oxfordian); Kuhnt

et al. (2002) signaled *K. grzybowskii* from the Oligocene of the Southern China Sea.

Family REOPHACIDAE Cushman, 1927
Genus REOPHAX de Montfort, 1808
Reophax duplex Grzybowski, 1896
Figure 16.1

- 1896 *Reophax duplex*; Grzybowski, p. 276, pl. 8, figs. 23-25.
2002 *Reophax duplex* Grzybowski; Kuhnt, Holbourn, and Zhao, p. 132, pl. 3, figs. 6, 7.

Material. 20 specimens from 11 samples.

Description. Test uniseriate composed of two subspherical chambers, sometimes more or less compressed. The first chamber is smaller and more globular than the second one. Aperture is a single opening on a raised neck. Wall thick and coarsely agglutinated.

Reophax pilulifer Brady, 1884
Figure 16.2

- 1884 *Reophax pilulifera*; Brady, p. 292, pl. 30, figs. 18-20.
1992 *Reophax pilulifer* Brady; Morlotti and Kuhnt, p. 223, pl. 2, figs. 10, 12.
1994 *Hormosina pilulifer* Brady; Schröder-Adams and McNeil, p. 37, pl. 4, fig. 3.
non 1995 *Reophax pilulifer* Brady; Bubík, p. 86, pl. 9, fig. 7.
2005 *Reophax pilulifer* Brady; Kender, Kaminski and Cieszkowski, p. 262, fig. 11F, G.
2009 *Reophax pilulifer* (Brady 1884); Kender, Kaminski, and Jones, p. 498, pl. 3, fig. 9.

Material. 14 specimens from 10 samples.

Description. Test free, uniseriate, straight, 2–4 circular and compressed chambers increasing in size gradually. Wall thick, coarsely agglutinated.

Distribution. Cosmopolitan taxon originally described from the Recent.

Reophax sp. 1
Figure 16.3

Material. One single specimen from the sample PC060615.

Description. Test free, uniseriate, straight axis, six chambers increasing gradually in size. Wall coarsely agglutinated. Aperture circular at the end of the last chamber.

Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894
Genus HORMOSINA Brady, 1879
Hormosina trinitatensis Cushman and Renz, 1946
Figure 16.6

- 1946 *Hormosina globulifera* Brady var. *trinitatensis*; Cushman and Renz, p. 14, pl. 1, figs. 15-19.

- 1995 *Hormosina trinitatis* Cushman and Renz; Bubík, p. 82, 83, pl. 9, fig. 3 (cum syn.).
 2005 *Hormosina trinitatis* Cushman and Renz; Kaminski and Gradstein, p. 241, pl. 43, figs. 1-11.

Material. Nine specimens from five samples.

Description. Test free, seriate, composed of 2–6 weakly embracing globular chambers increasing slowly in size. Wall medium to finely agglutinated.

Distribution. Late Campanian–Eocene (Kaminski and Gradstein, 2005).

Hormosina velascoensis (Cushman, 1926)
 Figure 16.4-5

- 1926 *Nodosinella velascoensis*; Cushman, p. 583, pl. 20, fig. 9.
 1981 *Nodellum velascoense* (Cushman); Morgiel and Olszewska, p. 7, pl. 1, fig. 1.
 2005 *Hormosina velascoensis* (Cushman); Kaminski and Gradstein, p. 243, pl. 44, figs. 1-8.

Material. 15 specimens from nine samples.

Description. Test free, robust, uniseriate; five or more subcylindric or fuse-like chambers sideways compressed. Wall medium to finely agglutinated, aperture is a single circular opening at the apex of the last chamber.

Distribution. Campanian–Oligocene (Kaminski and Gradstein, 2005).

Hormosina sp. 1
 Figure 16.7

Material. Two specimens from the sample PC060624.

Description. Test free, seriate, composed of three flattened weakly embracing chambers increasing rapidly in size. Wall thick, coarsely agglutinated; aperture is a circular opening in the peripheral zone of the last chamber.

Hormosina sp. 2
 Figure 16.8

Material. One specimen from the sample PC060615.

Description. Test free, uniseriate; composed of three flattened weakly embracing chambers increasing gradually in size. Wall thick, coarsely agglutinated; aperture is a circular opening in the peripheral zone of the last chamber.

Hormosina spp.

Material. Eight specimens from seven samples.

Description. In this group are included all the incomplete or bad preserved specimens, with uniseriate and straight test with partially embracing

chambers, not referred to the species above mentioned.

Genus PSEUDONODOSINELLA Saidova, 1970
Pseudonodosinella elongata Grzybowski, 1898
 Figure 16.9-11

- 1898 *Reophax elongatus*; Grzybowski, p. 279, pl. 10, figs. 19, 20.
 1960 *Reophax elongata* Grzybowski; Geroch, p. 123, pl. 3, figs. 8, 9.
 2005 *Pseudonodosinella elongata* Grzybowski; Kaminski and Gradstein, p. 256, pl. 48, figs. 1-9.

Material. 153 specimens from 21 samples.

Description. Test free, uniseriate, composed of elongated piriform chambers never found connected in this work. Wall thick, coarsely agglutinated.

Distribution. Geroch and Nowak (1984) restricted the range of *P. elongata* to the middle-late Eocene of Polish; Kaminski et al. (2006) signaled *P. elongata* from the Miocene of Greenland Sea.

Pseudonodosinella nodulosa Brady, 1879
 Figure 16.12-13

- 1879 *Reophax nodulosa*; Brady, p. 52, pl. 4, figs. 7, 8.
 1898 *Reophax subnodulosa* Grzybowski; p. 279, pl. 10, figs. 17, 18.
 1987 *Pseudonodosinella nodulosa* Brady; Loeblich and Tappan, p. 61, pl. 46, figs. 5, 6.
 2005 *Pseudonodosinella nodulosa* (Brady); Kaminski and Gradstein, p. 259, pl. 49, figs. 1-9.
 2009 *Pseudonodosinella nodulosa* (Brady); Kender, Kaminski, and Jones, p. 498, pl. 3, fig. 12.

Material. 23 specimens from 12 samples.

Description. Test free, elongated, uniseriate, straight or slightly curved; ovoid or piriform embracing chambers. Wall finely agglutinated with medium sized quartz grains. Sutures moderately incise, aperture terminal.

Distribution. Cosmopolitan taxon known from the Eocene to Recent (Kaminski and Gradstein, 2005).

Suborder LITUOLINA Lankester, 1885
 Superfamily LITUOLOIDEA de Blainville, 1827
 Family HAPLOPHRAGMOIDIDAE Maync, 1952
 Genus HAPLOPHRAGMOIDES Cushman, 1910
Haplophragmoides carinatus Cushman and Renz,
 1941

Figure 18.11-13

- 1941 *Haplophragmoides carinatum*; Cushman and Renz, p. 2, pl. 1, fig. 1.

2004 *Haplophragmoides carinatus* (Cushman and Renz); Green, Kaminski, and Sikora, p. 124, pl. 1, fig. 8.

Material. 21 specimens from seven samples.

Description. Test free, planispirally involute coiled, depressed in the umbelical zone, periphery lobate and carinate. Chambers triangular in shape increasing gradually in size, sutures incise and slightly curved. Wall finely agglutinated.

Distribution. At Portella Colla occurs only in the upper Rupelian.

Remarks. *Haplophragmoides carinatus* differs from *H. walteri* in having a transversal section more lenticular, and the last chamber elongated and strictly triangular.

Haplophragmoides eggeri Cushman, 1926
Figure 18.17

1926 *Haplophragmoides eggeri*; Cushman, p. 583, pl. 15, fig. 1a, b.

2005 *Haplophragmoides eggeri* Cushman; Kaminski and Gradstein, p. 342, pl. 75, figs. 1-6.

Material. Five specimens from four samples.

Description. Test free, oval in outline, planispirally coiled with depressed umbelicus. The chambers (6–7 in the last whorl) increase slowly in size. Sutures usually indistinct. Wall medium to coarsely agglutinated.

Distribution. Late Cretaceous–Eocene (Kaminski and Gradstein, 2005).

Haplophragmoides excavatus Cushman and Waters, 1927
Figure 18.18

1927 *Haplophragmoides excavatus*; Cushman and Waters, p. 82, pl. 10, fig. 3a-b.

2005 *Haplophragmoides excavatus* Cushman and Waters; Kaminski and Gradstein, p. 360, pl. 82, figs. 1-7.

Material. Four specimens from three samples.

Description. Test free, subcircular in outline, planispirally involute coiled with depressed umbilicus, lobate and carinate periphery. Chambers (12–13 in the last whorl) increase very slowly in size. Sutures few incise. Wall finely agglutinated, surface smooth.

Distribution. Late Cretaceous–Oligocene (Kaminski and Gradstein, 2005).

Remarks. *Haplophragmoides excavatus* differs from *H. carinatus* and *H. walteri* in having a more circular periphery, and a greater number of chambers in the last whorl.

Haplophragmoides cf. kirki Wickenden, 1932
Figure 18.19

cf. 1932 *Haplophragmoides kirki*; Wickenden, p. 85, pl. 1, fig. 1a-c.

Material. Three specimens from three samples.

Description. Test free, medium sized, planispirally coiled, rounded periphery, chambers weakly lobate. 3.5–4 chambers in the last whorl increasing slowly in size. Sutures distinct and depressed.

Remarks. *Haplophragmoides kirki* is smaller, and has 4–4.5 chambers in the last whorl.

Haplophragmoides horridus (Grzybowski, 1901)
Figure 18.22

1901 *Haplophragmium horridum*; Grzybowski, p. 270, pl. 7, fig. 12.

2005 *Haplophragmoides horridus* (Grzybowski); Kaminski and Gradstein, p. 347, pl. 77, figs. 1-6.

2009 *Haplophragmoides horridus* (Grzybowski); Kender, Kaminski, and Jones, p. 500, pl. 5, fig. 8.

Material. Eight specimens from seven samples.

Description. Test free, planispirally involute coiled, laterally compressed with 4½ triangular chambers in the last whorl. The last chamber is much larger than the previous ones. Sutures incise, rounded periphery. Wall coarsely agglutinated. Aperture interiomarginal.

Distribution. Originally described from the Paleogene of the Polish Carpathians, and ascribed to Maastrichtian–Eocene by Kaminski and Gradstein (2005), *H. horridus* has been recently reported from the Miocene of Congo Fan (Kender et al., 2009).

Haplophragmoides cf. horridus (Grzybowski, 1901)
Figure 18.23

cf. 1901 *Haplophragmiums horridum*; Grzybowski, p. 270, pl. 7, fig. 12.

Material. One single specimen from the sample PC060604.

Description. Similar to *H. horridus*, but very larger and with only 4 chambers in the last whorl.

Haplophragmoides cf. latissimisuturalis Smith,
1971
Figure 19.1-2

cf. 1901 *Haplophragmoides latissimisuturalis*; Smith, p. 25, pl. 1, fig. 6a-c, pl. 2, fig. 3a-b.

cf. 2004 *Haplophragmoides latissimisuturalis* Smith; Green, Kaminski, and Sikora, p. 124, pl. 2, fig. 1.

Material. 11 specimens from six samples.

Description. Test free, large, planispirally involute coiled, often compressed, subcircular and rounded periphery. Chambers large not well distinct, increasing gradually in size. Sutures limbate in the

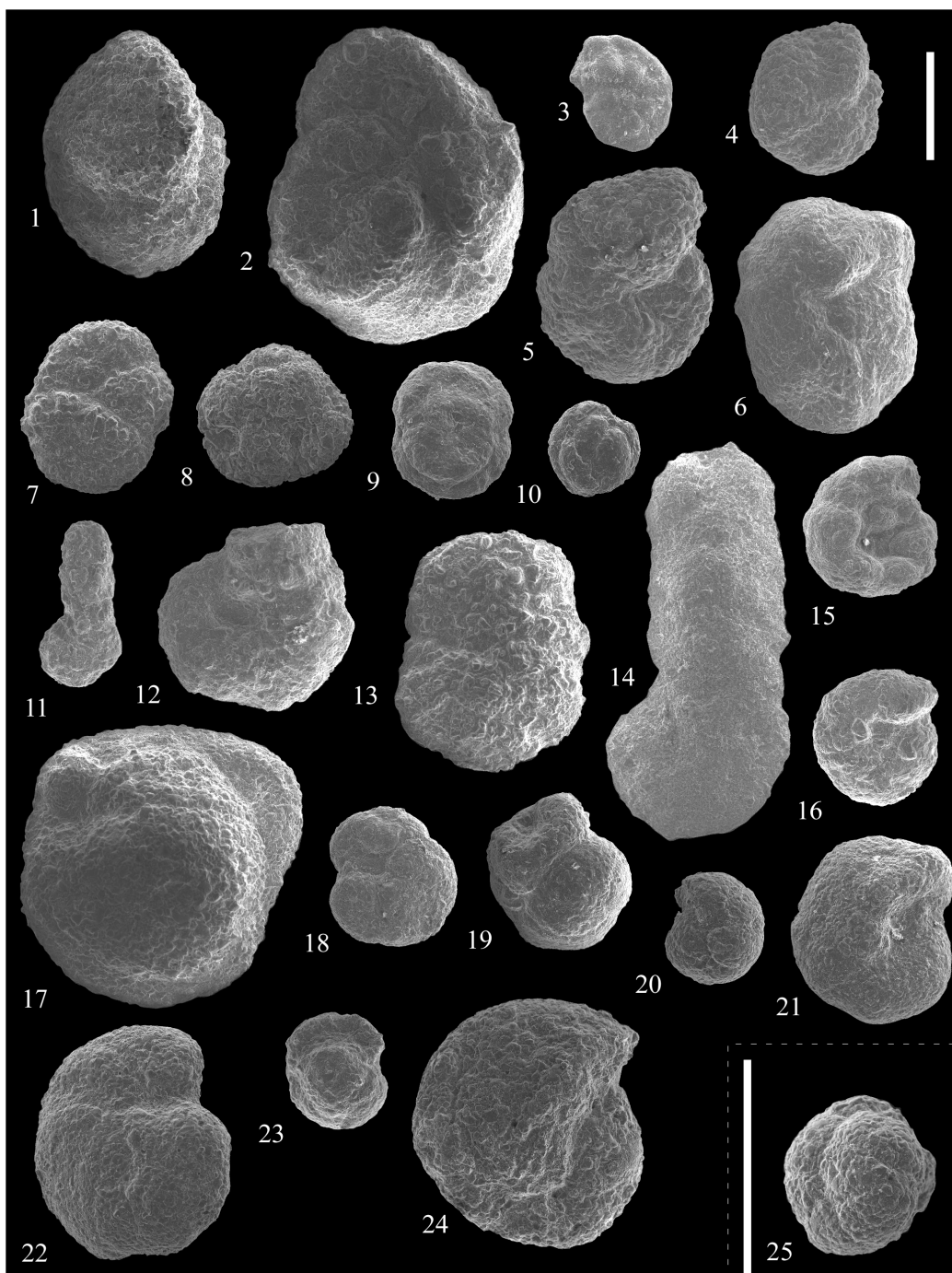


FIGURE 19. Scanning electron micrographs of Haplophragmoididae (1-6), Sphaeramminidae (7-10), Lituolidae (11-14), and Recurvoidea (15-25) from the Caltavuturo Formation cropping out at Portella Colla. 1-2, *Haplophragmoides* cf. *latissimus* Smith, 1971, PC3. 3, *Haplophragmoides* sp. 3, PC060615. 4, *Haplophragmoides* sp. 4, PC060601. 5, *Haplophragmoides* sp. 5, PC060615. 6, *Haplophragmoides* sp. 6, PC060621. 7-8, *Praesphaerammina subgaleata* (Vašiček, 1947), PC11 (7) and PC1 (8). 9-10, *Ammosphaeroidina pseudopauciloculata* (Mjatiuk, 1966), PC060604 (9) and PC060604 (10). 11, *Ammobaculites agglutinans* (d'Orbigny, 1846), PC060615. 12, *Ammobaculites* sp. 1, PC060607. 13, *Ammobaculites* sp. 3, PC15. 14, *Ammobaculites* sp. 2, PC060625. 15-16, *Budashevaella multicamerata* (Voloshinova and Budasheva, 1961), PC060604. 17, *Cribrostomoides subglobosus* (Cushman, 1910), PC060604. 18, *Recurvoidella lamella* (Grzybowski, 1898), PC060601. 19, *Recurvoides anormis* Mjatiuk, 1970, PC5. 20, *Recurvoides* sp. 1, PC060601. 21, *Recurvoides* sp. 2, PC060623. 22, *Recurvoides nucleolus* (Grzybowski, 1898), MM3. 23, *Recurvoides walteri* (Grzybowski, 1898), PC5. 24, *Trochammina bifaciata* Friedberg, 1901, PC060604. 25, *Thalmannammina subturbinata* (Grzybowski, 1898), MM14. Scale bar equals 0.5 mm.

latest chambers. Wall medium agglutinated. Aperture interiomarginal.

Distribution. *Haplophragmoides latissimisuturalis* was described from the Oligocene of California (Smith, 1971), and from the Miocene of the Gulf of Mexico (Green et al., 2004).

Haplophragmoides porrectus Maslakova, 1955
Figure 18.20

1955 *Haplophragmoides porrectus*; Maslakova, p. 47, pl. 3, figs. 5, 6.

2005 *Haplophragmoides porrectus* Maslakova; Kaminski and Gradstein, p. 353, pl. 354, figs. 1-6.

Material. Four specimens from three samples.

Description. Test free, rounded, planispirally involute coiled, composed of two whorls. The last one consists of 5–6 triangular chambers. Sutures depressed. Wall finely agglutinated.

Distribution. Paleocene–Eocene (Kaminski and Gradstein, 2005).

Haplophragmoides cf. porrectus Maslakova, 1955
Figure 18.24

cf. 1955 *Haplophragmoides porrectus*; Maslakova, p. 47, pl. 3, figs. 5, 6.

Material. One single specimen from the sample PC060615.

Description. Test free, small, compressed. Five chambers in the last whorl, sutures incise.

Haplophragmoides walteri (Grzybowski, 1898)
Figure 18.14-16

1898 *Trochammina walteri*; Grzybowski, pl. 11, fig. 31.

1960 *Haplophragmoides walteri* (Grzybowski); Geröch, p. 49, pl. 5, fig. 5.

2005 *Haplophragmoides walteri* (Grzybowski); Kender, Kaminski, and Cieszkowski, p. 266, fig. 13A.

2009 *Haplophragmoides walteri* (Grzybowski); Kender, Kaminski, and Jones, p. 500, pl. 5, fig. 9.

Material. 36 specimens from 16 samples.

Description. Test free, subcircular in outline, planispirally involute coiled, sutures incise. Chambers subtriangular, compressed near the periphery. Wall thin, finely agglutinated, surface smooth.

Distribution. Cosmopolitan species recorded from the Late Cretaceous to middle Miocene (Kender et al., 2009).

Remarks. In this taxon we include typical *H. walteri* morphotype, and the *H. walteri*-*H. carinatus* transitional forms common at the base of the Oligocene. At Portella Colla *H. walteri* is totally substituted by *H. carinatus* in the late Rupelian.

Haplophragmoides cf. walteri (Grzybowski, 1898)
Figure 18.21

1988 *Haplophragmoides* sp. cf. *walteri* (Grzybowski); Moullade, Kuhnt, and Thuro, p. 364, pl. 8, fig. 7.

1990 *Haplophragmoides cf. walteri* (Grzybowski); Kuhnt, p. 314, pl. 4, figs. 10-12.

Material. Four specimens from three samples.

Description. A small flattened *Haplophragmoides* with 4–5 chambers in the last whorl.

Remarks. Differs from *H. walteri* in having a smaller size, and a lower number of chambers in the last whorl.

Haplophragmoides sp. 1
Figure 18.25-26

Material. Six specimens from two samples.

Description. Test free, small, planispirally involute coiled with depressed umbilicus. Periphery circular and acute. 10–11 not well distinct chambers in the last whorl. Wall finely agglutinated.

Remarks. Differs from *H. excavatus* in having a smaller size, sutures less evident, and lower number of chambers.

Haplophragmoides sp. 2
Figure 18.27

Material. One specimen from the sample PC060603.

Description. Test free, small, planispirally involute coiled, with 6 globose chambers in the last whorl. Sutures incise, wall thick, coarsely agglutinated.

Haplophragmoides sp. 3
Figure 19.3

Material. One specimen from the sample PC060615.

Description. Test free, subcircular in outline, planispirally involute coil with 7 chambers in the ultimate whorl. Sutures few incise, and acute periphery. In umbilical position, one chamber of the penultimate whorl is visible.

Remarks. Differs from *H. walteri* by the smaller size, sutures not sigmoidal, and in having less chambers.

Haplophragmoides sp. 4
Figure 19.4

Material. One specimen from the sample PC060601.

Description. Planispiral involute coil with 4.5 triangular chambers increasing gradually in size in the last whorl. Sutures depressed.

Haplophragmoides sp. 5
Figure 19.5

Material. Two specimens from the sample PC060615.

Description. Planispiral involute coil, with 5–6 globose chambers increasing very rapidly in size in the last whorl. Sutures straight not incise.

Haplophragmoides sp. 6
Figure 19.6

Material. Two specimens from the sample PC060621.

Description. Planispiral involute coil, with five triangular chambers in the last whorl. Sutures few depressed, rounded periphery.

Haplophragmoides spp.

Material. Seven specimens from six samples.

Description. In this group are included all the compressed and incomplete specimens not determined at a specific rank.

Family SPHAERAMMINIDAE Cushman, 1933
Subfamily PRAESPHAERAMMININAE Kaminski
and Filipescu, 2000

Genus PRAESPHAERAMMINA Kaminski and
Filipescu, 2000

Praesphaerammina subgaleata (Vašiček, 1947)
Figure 19.7-8

1947 *Cystamina subgaleata*; Vašiček, p. 247, pl. 1, fig. 15, text fig. 3.

1981 *Sphaerammina subgaleata* Vašiček; Morgiel and Olszewska, p. 12, pl. 9, fig. 2.

2004 *Praesphaerammina subgaleata* (Vašiček); Green, Kaminski, and Sikora, p. 125, pl. 3, fig. 1.

2005 *Praesphaerammina subgaleata* (Vašiček); Kaminski and Gradstein, p. 369, pl. 85, figs. 1-6.

Material. Nine specimens from eight samples.

Description. Test free, flattened and subelliptic, the last chamber covers over 60% the previous chambers.

Distribution. Middle Eocene–late Miocene (Kaminski and Gradstein, 2005).

Family LITUOLIDAE de Blainville, 1827
Subfamily AMMOMARGINULINAE Podobina,
1978

Genus AMMOBACULITES Cushman, 1910
Ammobaculites agglutinans (d'Orbigny, 1846)
Figure 19.11

1846 *Spirolina agglutinans*; d'Orbigny, p. 137, pl. 7, figs. 10-12.

2005 *Ammobaculites agglutinans* (d'Orbigny); Kaminski and Gradstein, p. 324, pl. 70, figs. 1-8.

Material. Two specimens from two samples.

Description. Test free, robust, initially planispiral involute coil, becoming uniseriate in the last cham-

bers. The coiled portion consists of 4–5 chambers in the last whorl, separated by straight and depressed sutures. The uniseriate stage is rectilinear, composed of low, circular in section, chambers separated by indistinct sutures. Aperture terminal at the end of the ultimate chamber. Wall medium to coarse agglutinated.

Distribution. Late Cretaceous–Recent (Kaminski and Gradstein, 2005).

Ammobaculites sp. 1
Figure 19.12

Material. One incomplete specimen from the sample PC060607.

Description. Seven chambers visible in the last whorl of the planispiral coiled stage, separated by indistinct sutures. Umbilical region strongly depressed. The unique complete chamber of the uniseriate stage is very short and larger compared to previous chambers. Wall thick, coarsely agglutinated.

Remarks. Differs from *A. agglutinans* (d'Orbigny, 1846) in having more chambers in the planispiral portion increasing faster in size.

Ammobaculites sp. 2
Figure 19.14

Material. One specimen from the sample PC060625.

Description. Test free, flattened, with tapered periphery. Five chambers, triangular in section, in the planispiral involute portion, followed by 5 chambers uniseriately arranged with acute periphery. Sutures indistinct, wall finely agglutinated with sparse quartz grains.

Ammobaculites sp. 3
Figure 19.13

Material. One specimen from the sample PC15.

Description. Test free, large, initially planispirally involute coiled with 4 chambers divided by depressed sutures in the last whorl. The unique preserved chamber of the uniseriate stage is very large, and has a rectangular section. Wall thick, coarsely agglutinated.

Remarks. Differs from *A. agglutinans* (d'Orbigny, 1846) by the larger size, and by the shape of the ultimate preserved chamber. *Ammobaculites* sp. 1 has more chambers and sutures less depressed.

Superfamily RECURVOIDOIDEA Alekseychik-
Mitskevich, 1973

Family AMMOSPHAEROIDINIDAE Cushman,
1927

Subfamily AMMOSPHAEROIDININAE Cushman,
1927

Genus AMMOSPHAEROIDINA Cushman, 1910
Ammosphaeroidina pseudopauciloculata (Mjatluk, 1966)

Figure 19.9-10

- 1896 *Trochammina pauciloculata* Brady; Grzybowski, p. 23, pl. 8, figs. 51, 52.
1960 *Cystamina pauciloculata* (Brady); Geroch, p. 66, pl. 6, fig. 8.
1966 *Cystaminella pseudopauciloculata* Mjatluk; p. 264, pl. 1, figs. 5-7, pl. 2, fig. 6, pl. 3, fig. 3.
1990 *Ammosphaeroidina pseudopauciloculata* (Mjatluk); Kuhnt, p. 311, pl. 5, fig. 1.
2004 *Ammosphaeroidina pseudopauciloculata* (Mjatluk); Green, Kaminski, and Sikora, p. 125, pl. 5, fig. 3.

Material. 25 specimens from 10 samples.

Description. Test free, compressed, trochospirally coiled, trilobate in outline, elliptic and elongated in axial view or quadrilobate in ventral view, subelliptic in lateral view; 3-4 chambers in the last whorl increasing regularly in size covering the previous whorls. Chambers circular in outline, lenticular or subspheric with rounded periphery; sutures distinct, depressed. Aperture not distinguishable; wall smooth, finely agglutinated.

Distribution. Cosmopolitan species common from the Cretaceous to the Eocene (Kaminski and Gradstein, 2005), less frequent in the Oligocene, and signaled in the Miocene (Green et al., 2004; Kender et al., 2009).

Subfamily RECURVOIDINAE Alekseychik-Mitskevich, 1973

Genus BUDASHEVAELLA Loeblich and Tappan, 1964

Budashevaella multicamerata (Voloshinova and Budasheva, 1961)
Figure 19.15-16

- 1961 *Circus multicameratus*; Voloshinova and Budasheva, p. 201, pl. 7, fig. 6a-c, pl. 8, figs. 1a-c, 6a-c.
2005 *Budashevaella multicamerata* (Voloshinova); Kaminski and Gradstein, p. 386, pl. 90, figs. 1-6.
2006 *Budashevaella multicamerata* Voloshinova and Budasheva; Kaminski, Silye, and Kender, p. 384, pl. 4, fig. 6a-b.
2009 *Budashevaella multicamerata* Voloshinova and Budasheva; Kender, Kaminski, and Jones, p. 502, pl. 6, fig. 8.

Material. Two specimens from two samples.

Description. Test initially streptospirally coiled, later planispirally coiled, with 2 or 2½ whorls exteriorly visible. Chambers inflated, sutures depressed in the planispiral portion. The streptospiral coiled

portion is observable in the umbilical region. Wall thick with sparse agglutination.

Distribution. Middle Eocene-Miocene (Kaminski and Gradstein, 2005).

Genus CRIBROSTOMOIDES Cushman, 1910
Cribrostomoides subglobosus (Cushman, 1910)
Figure 19.17

- 1910 *Haplophragmoides subglobosum*; Cushman, p. 105, figs. 162-164.
2005 *Cribrostomoides subglobosus* (Cushman); Kaminski and Gradstein, p. 391, pl. 92, figs. 1-3.
2009 *Cribrostomoides subglobosus* (Cushman); Kender, Kaminski and Jones, p. 502, pl. 6, fig. 9.

Material. Six specimens from four samples.

Description. Test free, globose. Initially planispirally coiled, later planispiral involute, with 5-6 chambers in the last whorl increasing rapidly in size. Rounded periphery. Sutures depressed excepted for the last 2 chambers. Wall coarsely agglutinated.

Distribution. Late Cretaceous-Recent (Kaminski and Gradstein, 2005).

Cribrostomoides spp.

Material. 29 specimens from 14 samples.

Description. Broken and incomplete specimens with wall coarsely agglutinated, and initial streptospiral coil.

Genus RECURVOIDELLA Uchio, 1960
Recurvoidella lamella (Grzybowski, 1898)
Figure 19.18

- 1898 *Trochammina lamella*; Grzybowski, p. 290, pl. 11, fig. 25.
2005 *Recurvoidella lamella* Grzybowski; Kaminski and Gradstein, p. 399, pl. 94, figs. 1-3.

Material. Five specimens from five samples.

Description. Test free, initial streptospiral coil, later planispiral involute with 4-5 subglobose chambers in the last whorl, increasing rapidly in size. Periphery lobate, sutures depressed.

Distribution. Paleocene-Eocene (Kaminski and Gradstein, 2005).

Genus RECURVOIDES Earland, 1934
Recurvoides anormis Mjatluk, 1970
Figure 19.19

- 1970 *Recurvoides anormis*; Mjatluk, p. 84, pl. 18, fig. 4, pl. 19, figs. 1-4.
2005 *Recurvoides anormis* Mjatluk; Kaminski and Gradstein, p. 402, pl. 95, figs. 1-7.

Material. One specimen from the sample PC5.

Description. Test globose with large and rounded periphery. Involute streptospiral coil, the ultimate five chambers are planispirally enrolled. 6–7 chambers in the last whorl. Aperture at the base of the last chamber; wall thick with sparse agglutination.

Distribution. Campanian–Eocene (Kaminski and Gradstein, 2005).

Recurvoides nucleolus (Grzybowski, 1898)
Figure 19.22

- 1898 *Trochammina nucleolus*; Grzybowski, p. 291, pl. 11, figs. 28, 29.
1993 *Recurvoides nucleolus* (Grzybowski) emend Samuel, 1977; Kaminski and Geroch, p. 265, pl. 11, fig. 4a-d.
2005 *Recurvoides nucleolus* (Grzybowski) emend Samuel, 1977; Kaminski and Gradstein, p. 408, figs. 97-1, 97-2.

Material. Three specimens from three samples.

Description. Test free, rounded, and planoconvex. Initial streptospiral coil without changes in direction, followed by a short plano- or slowly trochospiral coil.

Distribution. Maastrichtian–Eocene (Kaminski and Gradstein, 2005).

Recurvoides walteri (Grzybowski, 1898)
Figure 19.23

- 1898 *Haplophragmium walteri*; Grzybowski, p. 280, pl. 10, fig. 24.
2005 *Recurvoides walteri* Grzybowski; Kaminski and Gradstein, p. 415, pl. 100, figs. 1-3.

Material. One specimen from the sample PC5.

Description. Test free, rounded, involute streptospiral coil with direction of coil changing during the ontogeny. Chambers increase slowly in size. Aperture at the base of the ultimate chamber. Test thick with sparse agglutination.

Distribution. Paleocene–Eocene (Kaminski and Gradstein, 2005).

Recurvoides sp. 1
Figure 19.20

Material. One specimen from the sample PC060601.

Description. Test subglobose, initial streptospirally coiled, followed by 3–4 chambers arranged planispirally. Chambers inflated increasing gradually in size, sutures depressed. Wall finely to medium agglutinated.

Recurvoides sp. 2
Figure 19.21

Material. One specimen from the sample PC060623.

Description. Test free, initial streptospiral coil, the ultimate whorl is planispirally involute coiled. The last chambers increase abruptly in size. Sutures are depressed and evident in the umbilical region.

Recurvoides spp.

Material. 29 specimens from 14 samples.

Description. Broken or incomplete specimens not recognizable at specific rank.

Genus THALMANNAMMINA Pokorny, 1951
Thalmanammina subturbinata (Grzybowski, 1898)
Figure 19.25

- 1898 *Haplophragmium subturbinatum*; Grzybowski, p. 280, pl. 10, fig. 23.
1993 *Thalmanammina subturbinata* (Grzybowski) emend. Pokorny, 1951; Kaminski and Geroch, p. 252, pl. 4, fig. 5a-d.
2005 *Thalmanammina subturbinata* (Grzybowski) emend. Pokorny, 1951; Kaminski and Gradstein, p. 419, pl. 101a-b.

Material. One specimen from the sample PC060604.

Description. Test globular with 10–12 chambers visible in the outer whorl. Streptospiral thalmanammina-type coil with axis of coil changing abruptly of 90°, followed by a second opposite refolding. Wall finely agglutinated, a little aperture at the base of the last chamber.

Distribution. Latest Cretaceous–Eocene (Kaminski and Gradstein, 2005).

Suborder TROCHAMMININA Saidova, 1981
Superfamily TROCHAMMINOIDEA Schwager, 1877

Family TROCHAMMINIDAE Schwager, 1877
Subfamily TROCHAMMININAE Schwager, 1877
Genus TROCHAMMINA Parker and Jones, 1859
Trochammina bifaciata Friedberg, 1901
Figure 19.24

- 1901 *Trochammina bifaciata*; Friedberg, p. 460, pl. 2, fig. 1a-b.

Material. One specimen from the sample PC060604.

Description. Test free, compressed, discoidal. Chambers not distinct on the dorsal side, whereas in the ventral side a well developed spire occur. Aperture interiomarginal, wall finely agglutinated with rough surface.

Trochammina sp. 1
Figure 20.1

Material. Five specimens from three samples.

Description. Test free, low-trochospiral coil with 4 chambers in the dorsal side and 3 in the ventral

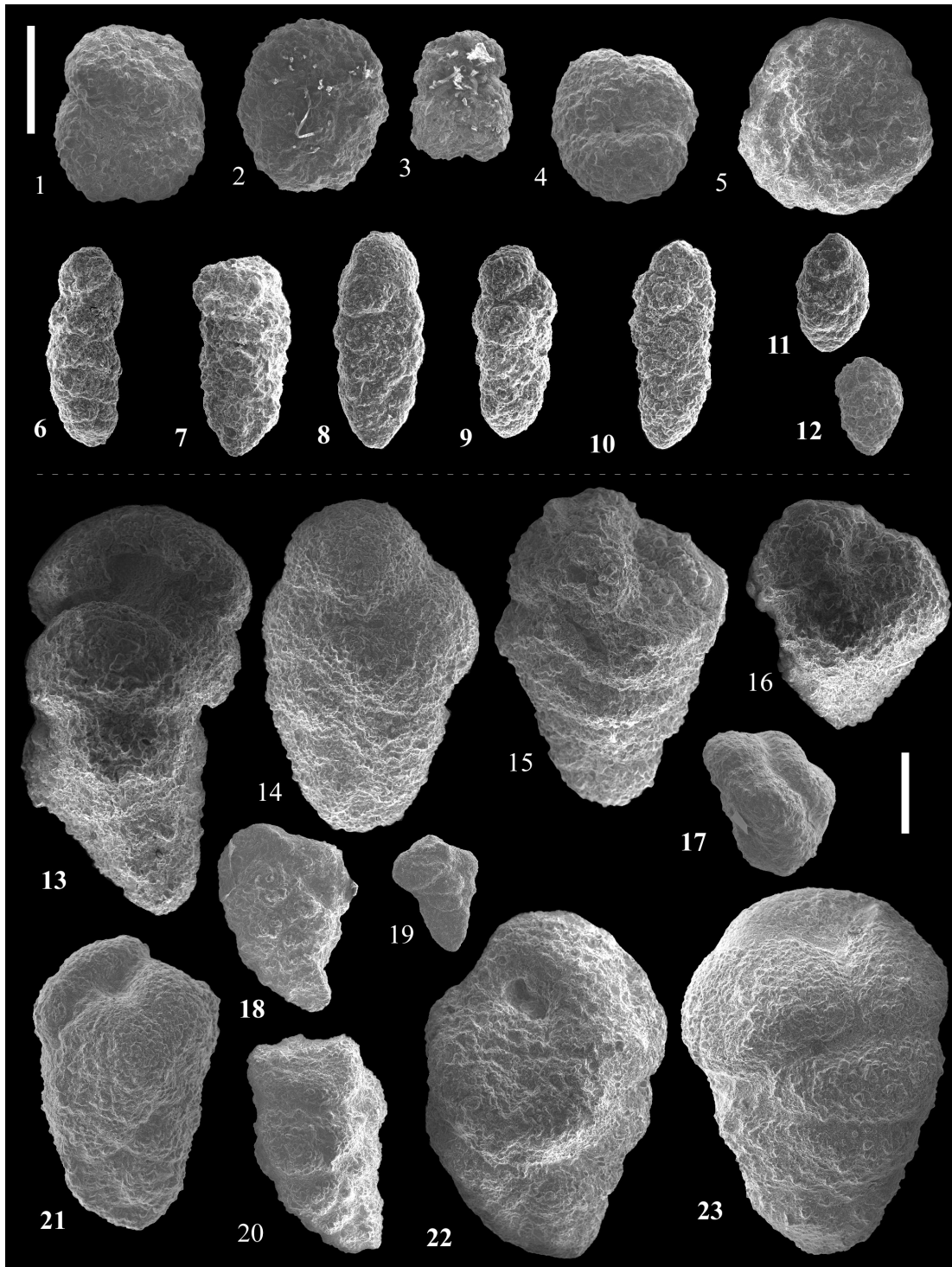


FIGURE 20. Scanning electron micrographs of Trochamminoidea (1-11, 13), Ataxophragmiidae (12, 17, 20-21), and Textulariina (14-16, 18-19, 22-23) from the Caltavuturo Formation cropping out at Portella Colla. 1, *Trochammina* sp. 1, PC060601. 2, *Trochammina* sp. 2, PC060601. 3, *Trochammina* sp. 3, PC060601. 4, *Trochammina* sp. 4, PC060604. 5, *Trochammina* sp. 5, PC060605. 6-10, *Karrerulina conversa* (Grzybowski, 1901), PC060615 (6), PC018 (7), PC11 (8), PC060615 (9) and PCs0 (10). 11, *Karrerulina horrida* (Mjatluk, 1970), PC060617. 12, *Remesella varians* (Glaessner, 1937), PC060601. 13, *Gaudryina* sp., PC1. 14, *Eggerella compressa* (Andreae, 1884), PC13. 15, *Eggerella* sp. 1, PC3. 16, *Eggerella* sp. 2, PC3. 17, *Arenobulimina* sp., PC060602. 18, *Siphotextularia* sp. 1, PC060621. 19, *Siphotextularia* sp. 2, PC060621. 20, *Tetraxiella subtilissima* PCs0. 21, *Gravellina* sp., PC060618. 22, *Valvulina flexilis* Cushman and Renz, 1941, PC060604. 23, *Valvulina* sp., PC060621. Scale bars equal 0.5 mm.

one. Chambers subcircular and flattened; sutures depressed. Aperture interiomarginal, wall coarsely agglutinated.

Trochammina sp. 2
Figure 20.2

Material. Four specimens from three samples.

Description. Test free, with 4–5 chambers in the dorsal side, and 3–4 in the ventral one increasing rapidly in size. Wall thick with very coarse agglutination obliterating the sutures.

Trochammina sp. 3
Figure 20.3

Material. One specimen from the sample PC060601.

Description. Test free, small, trochospiral globigerina-type coil. A spire visible on the dorsal side, three globose chambers visible in the ventral side; sutures depressed. Aperture interiomarginal, wall thick coarsely agglutinated.

Trochammina sp. 4
Figure 20.4

Material. Three specimens from the samples PC060604 and PC060605.

Description. Test free, low trochospiral coil; three subcircular and flattened chambers in the ventral side separated by sutures depressed. Periphery lobate.

Trochammina sp. 5
Figure 20.5

Material. One specimen from sample PC060605.

Description. Test free, globorotalia-type coil. Chambers flattened and discoidal, periphery lobate. Aperture interiomarginal, wall coarsely agglutinated.

Trochammina spp.

Material. 22 specimens from five samples.

Description. Broken specimens referred to the genus *Trochammina*.

Suborder VERNEUILININA Mikhalevich and Kaminski, 2004 in Mikhalevich, 2004
Superfamily VERNEULINOIDEA Cushman, 1911
Family PROLIXOPLECTIDAE Loeblich and Tappan, 1985
Genus KARRERULINA Finlay, 1940
Karrerulina conversa (Grzybowski, 1901)
Figure 20.6-10

1901 *Gaudryina conversa*; Grzybowski, p. 285, pl. 7, figs. 15, 16.

1977 *Plectina conversa* (Grzybowski); Krasheninikov and Pflaumann, p. 569, pl. 3, fig. 4a-b.

1992 *Karrerulina conversa* (Grzybowski); Morlotti and Kuhnt, p. 222, pl. 4, fig. 15.

2005 *Karrerulina conversa* (Grzybowski); Kaminski and Gradstein, p. 469, pl. 116, figs. 1-11.

Material. 26 specimens from 10 samples.

Description. Test free, elongated, initial trochospiral coil, followed by a triseriate stage, and finally a biseriate adult stage. Aperture terminal and circular.

Distribution. Paleocene–Oligocene (Kaminski and Gradstein, 2005).

Karrerulina horrida (Mjatluk, 1970)
Figure 20.11

1970 *Karrieriella horrida*; Mjatluk, p. 114-115, pl. 5, fig. 9, pl. 33, figs. 15-16c.

1996 *Karrerulina horrida* (Mjatluk); Kaminski, Kuhnt, and Radley, p. 12, pl. 2, fig. 16.

2005 *Karrerulina horrida* (Mjatluk); Kaminski and Gradstein, p. 473, pl. 117, figs. 1-11.

Material. 32 specimens from 15 samples.

Description. Test free elongated, rounded in trasversal section, composed of an initial trochospiral coil with 4–6 chambers per whorl, followed by a large-sized triseriate stage, and a final biseriate stage consisting of 1–2 whorls. Wall medium to finely agglutinated.

Distribution. Maastrichtian–Miocene (Kaminski and Gradstein, 2005).

Family REOPHACELLIDAE Mikhalevich and Kaminski, 2004 in Mikhalevich, 2004

Subfamily VERNEUILININAE Cushman, 1911

Genus GAUDRYINA d'Orbigny, 1839

Gaudryina sp.

Figure 20.13

Material. One single specimen from the sample PC1.

Description. Test conical, triangular in section, initially triseriate, latest biseriate with rounded section. Aperture an arc in the inner margin of the ultimate chamber.

Order LOFTUSIIDA Kaminski and Mikhalevich, 2004 in Mikhalevich, 2004

Superfamily Loftusiacea Brady, 1884

Suborder LOFTUSIINA Kaminski and Mikhalevich, 2004 in Mikhalevich, 2004

Superfamily HAPLOPHRAGMIOIDEA Eimer and Fickert, 1899

Family CYCLAMMINIDAE Marie, 1941

Subfamily ALVEOLOPHRAGMIINAE Saidova, 1981

Genus RETICULOPHRAGMIUM Maync, 1955
Reticulophragmium acutidorsatum (Hantken,

1868)
Figure 21.1-3

- 1868 *Haplophragmium acutidorsatum*; Hantken, p. 82, pl.1, fig. 1.
2004 *Cyclammia acutidorsata* (von Hantken); Green, Kaminski and Sikora, p. 127, pl. 4, fig. 1.
2006 *Reticulophragmium acutidorsatum* (Hantken); Kaminski, Silye, and Kender, p. 390, pl. 6, fig. 3.
2009 *Reticulophragmium acutidorsatum* (Hantken); Kender, Kaminski, and Jones, p. 504, pl. 8, fig. 9.

Material. 101 specimens from 20 samples.

Description. Test free, biconvex with acute periphery; planispiral involute coil with 12–14 chambers in the last whorl increasing gradually in size. Sutures few incise, aperture an arc at the base of the ultimate chamber; wall alveolar and finely agglutinated.

Distribution. Late Eocene-Miocene.

Reticulophragmium amplexens (Grzybowski,
1898)
Figure 21.4-7

- 1898 *Cyclammia amplexens*; Grzybowski, p. 292, pl. 12, figs. 1-3.
1954 *Cyclammia amplexens* Grzybowski; Geroch and Gradzinski, p. 39-40, tab. IV, figs. 10-13, tab. V, fig. 10a-d.
1992 *Reticulophragmium amplexens* (Grzybowski); Morlotti and Kuhnt, p. 223, pl. 4, figs. 9-11.
2005 *Reticulophragmium amplexens* (Grzybowski); Kaminski and Gradstein, p. 491, pl. 123, figs. 1-6.

Material. 18 specimens from four samples.

Description. Test free, biconvex, planispiral involute coil, with acute periphery and depressed umbilicus. Initial chambers are triangular and without alveoles which appear in the adult stage, simple and not branched.

Distribution. Eocene–Oligocene of the Thethys (Kaminski and Gradstein, 2005); signaled from the Miocene of the Greenland Sea (Osterman and Spiegler, 1996).

Reticulophragmium rotundidorsatum (Hantken,
1875)
Figure 21.8-10

- 1875 *Haplophragmium rotundidorsatum*; Hantken, p. 12-13, pl. 1, fig. 2.
1994 *Reticulophragmium rotundidorsatus* (von Hantken); Schröder-Adams and McNeil, p. 41, pl. 8, figs. 5-7.

2005 *Reticulophragmium rotundidorsatum* (Hantken); Kaminski and Gradstein, p. 503, pl. 126, figs. 1-7.

2009 *Reticulophragmium rotundidorsatum* (Hantken); Kender, Kaminski, and Jones, p. 505, pl. 9, fig. 3.

Material. 139 specimens from eight samples.

Description. Test free, subspheric, small to medium size, planispiral involute coil with rounded and thick periphery. Chambers increasing rapidly in size in the ultimate whorl, the last chamber, very large in size, tends to obliterate the umbilical region. Sutures straight and depressed; aperture multiples at the base of the last chamber. Wall alveolar and finely agglutinated.

Distribution. Middle Eocene–late Miocene (Kaminski and Gradstein, 2005).

Reticulophragmium projectum Schröder-Adams
and McNeil, 1994
Figure 21.13-14

1994 *Reticulophragmium projectus*; Schröder-Adams and McNeil, p. 41, pl. 8, figs. 1-4.

Material. 100 specimens from four samples.

Description. Test free, subglobose, planispiral involute coil, with rounded periphery. Sutures straight or weakly sigmoidal starting tangentially from the umbilicus in radial direction.

Distribution. Oligocene–Miocene of Beaufort-Mackenzie basin (Schröder-Adams and McNeil, 1994).

Remarks. Differs from *R. rotundidorsatum* by the form and direction of the sutures, and in having a less inflated chambers.

Subfamily CYCLAMMININAE Marie, 1941
Genus CYCLAMMINA Brady, 1879
Cyclammia cancellata Brady, 1879
Figure 21.11-12

1879 *Cyclammia cancellata*; Brady, p. 62, pl. 37, figs. 8-16.

2005 *Cyclammia cancellata* Brady; Kaminski and Gradstein, p. 476, pl. 118a-b.

Material. Six specimens from three samples.

Description. Test free, planispiral coil with rounded periphery, umbilicus depressed. Eleven chambers in the last whorl, sutures depressed. Wall thick and finely agglutinated with sparse quartz grains.

Distribution. Late Eocene to Recent (Kaminski and Gradstein, 2005).

Cyclammia placenta (Reuss, 1851)
Figure 21.15

1851 *Nonionina placenta*; Reuss, p. 72, pl. 5, fig. 33.

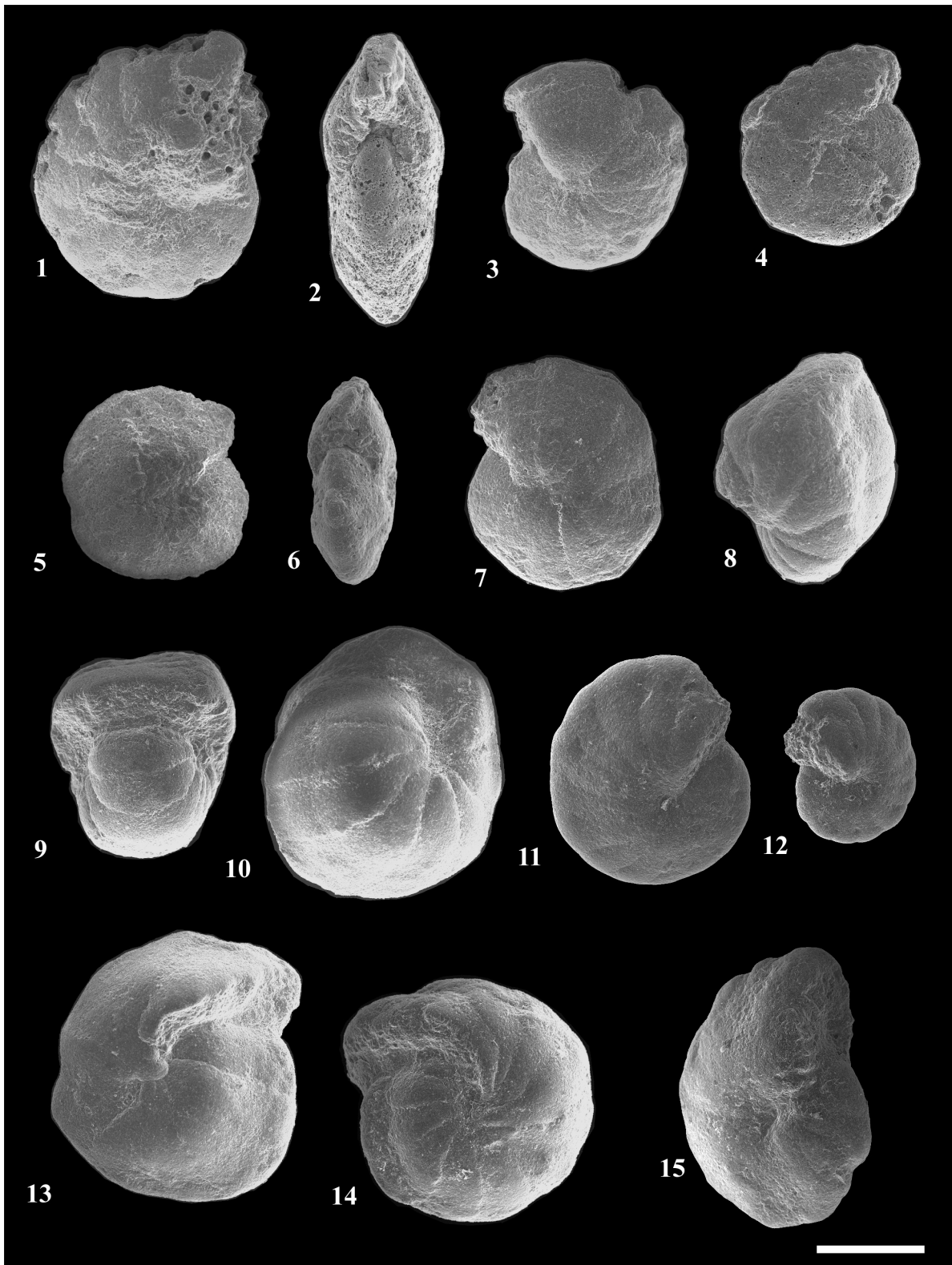


FIGURE 21. Scanning electron micrographs of Cyclamminidae from the Caltavuturo Formation cropping out at Portella Colla. **1-3**, *Reticulophragmium acutidorsatum* (Hantken, 1868), PC3. **4-7**, *Reticulophragmium amplexens* (Grzybowski, 1898), PC3. **8-10**, *Reticulophragmium rotundidorsatum* (Hantken, 1875), PC060624. **11-12**, *Cyclammina cancellata* Brady, 1879, PC22. **13-14**, *Reticulophragmium projectum* Schröder-Adams and McNeil, 1994, PC060624. **15**, *Cyclammina placenta* (Reuss, 1851), PC11. Scale bar equals 0.5 mm.

1981 *Cyclammina placenta* Reuss; Gradstein and Berggren, p. 254, pl. 7, figs. 4-8.

1989 *Reticulophragmium placenta* (Reuss); Kaminski, Gradstein, and Berggren, pl. 5, fig. 3a-b.

2005 *Cyclammina placenta* (Reuss); Kaminski and Gradstein, p. 480, pl. 119, figs. 1-6.

Material. Eight specimens from four samples.

Description. Test free, flattened and narrow, planispiral coil with acute periphery. The number of chambers in the last whorl is variable and dependent to the dimension of the test. Sutures sigmoidal.

Distribution. Eocene–Miocene (Kaminski and Gradstein, 2005).

Cyclammina spp.

Material. 18 specimens from eight samples.

Description. In this group are included all the post mortem compressed or broken specimens not recognizable at specific rank.

Suborder ATAXOPHRAGMIINA Fursenko, 1958
Superfamily ATAXOPHRAGMIOIDEA Schwager, 1877

Family ATAXOPHRAGMIIDAE Schwager, 1877
Subfamily ATAXOPHRAGMIINAE Schwager, 1877
Genus ARENOBULIMINA Cushman, 1927

Arenobulimina sp.
Figure 20.17

Material. Two specimens from the samples PC060602 and PC22.

Family GLOBOTEXTULARIIDAE Cushman, 1927
Subfamily GLOBOTEXTULARIINAE Cushman, 1927

Genus GRAVELLINA Brönnimann, 1953
Gravellina sp.
Figure 20.21

Material. One single specimen from the sample PC060618.

Genus TETRAXIELLA Seiglie, 1964
Tetraxiella subtilissima Cetean and Kaminski, 2011
Figure 20.20

2011 *Tetraxiella subtilissima*; Cetean and Kaminski, p. 258, pl. 1, figs 16, 17; pl. 2, figs 1-4, 21, 22.

Material. One specimen from the sample PCs0.

Description. Test elongated, conical, trochospiral. The chambers increase rapidly in size and tend to be subcircular and flattened. Aperture indistinct due to the collapsed wall.

Distribution. Originally described for the Chattian of Angola (Cetean and Kaminski, 2011).

Subfamily LIEBUSELLINAE Saidova, 1981

Genus REMESELLA Vasicek, 1947
Remesella varians (Glaessner, 1937)
Figure 20.12

1937 *Textulariella? varians*; Glaessner, p. 366, pl. 2, fig. 15.

Material. One specimen from the sample PC060601.

Remesella sp.

Material. One broken specimen from the sample PC060601.

Order TEXTULARIIDA Delage and Hérouard, 1896
Suborder TEXTULARIINA Delage and Hérouard, 1896

Superfamily EGGERELLOIDEA Cushman, 1937
Family EGGERELLIDAE Cushman, 1937
Subfamily EGGERELLINAE Cushman, 1937
Genus EGGERELLA Cushman, 1937
Eggerella compressa (Andreae, 1884)
Figure 20.14

1884 *Verneulina compressa*; Andreae, p. 107, pl. 8, figs. 2, 3.

1937 *Eggerella compressa* (Andreae); Cushman, p. 47, pl. 5, fig. 7, 8 (cum syn.).

Material. One specimen from the sample PC13.

Description. Test free, large, initially 4–5 chambers per whorl, whereas the adult stage becomes triseriate. Wall coarsely agglutinated.

Distribution. Oligocene (Andreae, 1884)

Remarks. The specimens figured by Andreae are smaller (at least 1.3 mm) in respect to the collected specimen measuring 2.5 mm.

Eggerella sp. 1
Figure 20.15

Material. One single specimen from the sample PC3.

Description. Test subconical, initially planispirally coiled, chambers decreasing in number with the ontogeny. The last chamber of the collected specimen is broken; wall coarsely agglutinated.

Eggerella sp. 2
Figure 20.16

Material. One single specimen from the sample PC3.

Description. Test subconical, trochospiral coil, 3 chambers in the last whorl. Chambers are inflated and increase rapidly in size. Aperture at the end of the last chamber hemmed by a lip.

Family VALVULINIDAE Berthelin, 1880
Subfamily VALVULININAE Berthelin, 1880
Genus VALVULINA d'Orbigny, 1826

Valvulina flexilis Cushman and Renz, 1941
Figure 20.22

1941 *Valvulina flexilis*; Cushman and Renz, p. 7, pl. 1, figs. 16, 17.

Material. One single specimen from the sample PC060604.

Description. Test free, triseriate, extending rapidly from a subacute apex. Periphery lobate, chambers rounded and inflated increasing rapidly in size; sutures incise. Aperture at the base of the last chamber; wall thick and coarsely agglutinated.

Distribution. Late Oligocene of the Agua Salada Formation (Cushman and Renz, 1941).

Valvulina sp.
Figure 20.23

Material. One single specimen from the sample PC060621.

Description. Triseriate coiled test not attributed to any known species.

Superfamily TEXTULARIOIDEA Ehrenberg, 1838
Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily SIPHOTEXTULARIINAE Loeblich and Tappan, 1985
Genus SIPHOTEXTULARIA Finlay, 1939

Siphotextularia sp. 1
Figure 20.18

Material. One specimen from the sample PC060621.

Description. Large and flattened test; the early stage is triseriate, and measures 1/3 of the total length, later the chambers are biseriate arranged with a quadrangular section.

Siphotextularia sp. 2
Figure 20.19

Material. One specimen from the sample PC060621.

Description. Small test with a short triseriate stage. The chambers increase rapidly in size.

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APPENDIX

Taxonomic list and results of the counts of the foraminiferal tests. Presented online as PDF file at palaeo-electronica.org/content/2017/1746-e-o-dwaf-from-sicily.

Sample	<i>Ammobaculites agglutinans</i>	<i>Ammobaculites</i> sp. 1	<i>Ammobaculites</i> sp. 2	<i>Ammobaculites</i> sp. 3	<i>Ammodiscus cretaceus</i>	<i>Ammodiscus incertus</i>	<i>Ammodiscus</i> cf. <i>latus</i>	<i>Ammodiscus latus</i>	<i>Ammodiscus peruvianus</i>	<i>Ammodiscus</i> sp. 1	<i>Ammodiscus</i> sp. 2	<i>Ammodiscus</i> sp. 3	<i>Ammodiscus</i> spp.	<i>Ammodiscus tenuissimus</i>	<i>Ammolagena clavata</i>	<i>Ammosphaeroidina pseudopauciloculata</i>	<i>Annectina biedai</i>	<i>Annectina</i> cf. <i>grzybowski</i>	<i>Arenobulimina d'orbigny</i>	<i>Arenobulimina</i> sp.
PC060601					1									3	1					
PC060602						1														1
PC060603						1						1								
PC060604															3	6				
PC060605					1									1	4	1				
PC1					1			3							5	1				
PC060607		1													3	4				
PC3															1					
PC060608														2		1				
PC060609														1						
PC5															3					
PC060611																				
PC060612															1					
PC060614															2	1				
PC11					1		4	14		1				6	11	2				
PC060615	1							2					1	7	19	6				
PC13						1		1							4					
PC060617								13	4					2	5	2		3		
PC15				1	1			3		1	1				2					
PC060618					4			4					5	7			2			
PCs0								1							3					
PC18														1	4					
PC060619																				
PC060621											1				3					
PC22					1									5	3				1	
PC060623																				
PC060624	1				1										1					
PC0606F																				
PC060625			1					1												

Appendix (continued).

Sample	<i>Arthrodrion grandis</i>	<i>Arthrodrion subnodosiformis</i>	<i>Bathysiphon</i> spp.	<i>Budashavella muticamerata</i>	<i>Caudamina gutta</i>	<i>Conglophragmium deforme</i>	<i>Conglophragmium irregulare</i>	<i>Cribrostomoides subglobosus</i>	<i>Cribrostomoides</i> spp.	<i>Cyclammina cancellata</i>	<i>Cyclammina placenta</i>	<i>Cyclammina</i> spp.	<i>Eggerella compressa</i>	<i>Eggerella</i> sp. 1	<i>Eggerella</i> sp. 2	<i>Gaudryna</i> sp.	<i>Glomospira extendens</i>	<i>Glomospira gordialis</i>	<i>Glomospira irregularis</i>	<i>Glomospira serpens</i>
PC060601					1							2								
PC060602																			1	
PC060603																				
PC060604				1	1			1	1			2						3		
PC060605									1											
PC1																1			1	1
PC060607									2		1									
PC3							2	2	2	1	4	1		1	1			1		
PC060608																				
PC060609																		1		
PC5				1			1											1		
PC060611							1	2												2
PC060612	2	1										3								
PC060614							2													
PC11	6	2							2		2						1			8
PC060615	21	3			1		4	4	4									3	3	
PC13		2							4			2	1							
PC060617	6				4		1	1	1										1	3
PC15	1										1									
PC060618			1		2				1										2	5
PCs0	1				2		5	1	1		1									
PC18	1				3		1											1		
PC060619	1				24				5										2	
PC060621	2				61		3	2	3	2								5		2
PC22	8								1	3										
PC060623						1														
PC060624	3		2				1					3						1		
PC0606F	2							1												
PC060625	2								1			4								

Appendix (continued).

Sample	<i>Glomospira</i> sp. 1	<i>Glomospira</i> sp. 2	<i>Glomospira</i> sp. 3	<i>Glomospira</i> spp.	<i>Gravellina</i> spp.	<i>Haplophragmoides</i> carinatus	<i>Haplophragmoides</i> cf. <i>kirki</i>	<i>Haplophragmoides</i> cf. <i>horridus</i>	<i>Haplophragmoides</i> <i>eggeri</i>	<i>Haplophragmoides</i> <i>excavatus</i>	<i>Haplophragmoides</i> <i>horridus</i>	<i>Haplophragmoides</i> cf. <i>latissimisuturalis</i>	<i>Haplophragmoides</i> <i>porrectus</i>	<i>Haplophragmoides</i> cf. <i>porrectus</i>	<i>Haplophragmoides</i> <i>walteri</i>	<i>Haplophragmoides</i> cf. <i>walteri</i>	<i>Haplophragmoides</i> sp. 1	<i>Haplophragmoides</i> sp. 2	<i>Haplophragmoides</i> sp. 3	<i>Haplophragmoides</i> sp. 4
PC060601										1	2				2					1
PC060602							1								1		5			
PC060603															1			1		
PC060604								1	2									1		
PC060605										2					2					
PC1											1				1					
PC060607																				
PC3												3	1							
PC060608																				
PC060609																				
PC5															7					
PC060611							1	1				2								
PC060612												1								
PC060614									1											
PC11	1								1			1			4					
PC060615														1	2	2			1	
PC13			1												1					
PC060617				1											7					
PC15	1																			
PC060618					1							2								
PCs0											1		2		1					
PC18						1									2					
PC060619						1					1				1					
PC060621						3					1		1		2	1				
PC22															1					
PC060623						2				1										
PC060624						1	1					2			1	1				
PC0606F						4					1									
PC060625						9					1									

Appendix (continued).

Sample	<i>Haplophragmoides</i> sp. 5	<i>Haplophragmoides</i> sp. 6	<i>Haplophragmoides</i> spp.	<i>Hormosina trinitatis</i>	<i>Hormosina velascoensis</i>	<i>Hormosina</i> sp. 1	<i>Hormosina</i> sp. 2	<i>Hyperammina</i> spp.	<i>Kalamopsis grzybowski</i>	<i>Karrerulina conversa</i>	<i>Karrerulina horrida</i>	<i>Lituotuba lituiformis</i>	<i>Nothia</i> cf. <i>latissima</i>	<i>Nothia excelsa</i>	<i>Nothia robusta</i>	<i>Nothia</i> spp.	<i>Paratrochamminoides acervulatus</i>	<i>Paratrochamminoides deflexiformis</i>	<i>Paratrochamminoides draco</i>	<i>Paratrochamminoides</i> aff. <i>gorayskii</i>
PC060601										1				1	1					
PC060602			1								2					2				
PC060603				1										1	1					
PC060604					1						1			1	1		1			
PC060605									1					1	1					
PC1														3	2		1			
PC060607					2						2			2	2					
PC3			2											6	8					
PC060608														1						
PC060609			1																	
PC5			1																	
PC060611											1			3				1		
PC060612			1								1									
PC060614											1			2						
PC11				4	3			1	6	3	1				1			1	1	
PC060615	2			1	2		1	1	3	4	9	1						1		2
PC13					1				3					1			1			
PC060617					2			1		2	2			3	1		1			
PC15					1				1	2									1	
PC060618					2			1	4	1	1			1	1		3			
PCs0									1	5	1			2	1					
PC18									5	2					4		2			
PC060619			1								2			3						
PC060621		2			1			1	17	4	3			5	32					
PC22				1					3	2				1	2					
PC060623								1	2					1		3				
PC060624				2		2							3	12	26					
PC0606F											3			1						
PC060625								2	1	1				6	9	3				

Appendix (continued).

Sample	<i>Paratrochamminoides heteromorphus</i>	<i>Paratrochamminoides mitratus</i>	<i>Paratrochamminoides olszewskii</i>	<i>Paratrochamminoides aff. olszewskii</i>	<i>Paratrochamminoides cf. olszewski</i>	<i>Paratrochamminoides sp. 1</i>	<i>Paratrochamminoides spp.</i>	<i>Placentamina placenta</i>	<i>Praespheramina subgaleata</i>	<i>Psammimopelta sp.</i>	<i>Psammisiphonella cylindrica</i>	<i>Psammisiphonella linearis</i>	<i>Psammospaera irregularis</i>	<i>Psammospaera cf. laevigata</i>	<i>Psammospaera sp. 1</i>	<i>Psammospaera sp. 2</i>	<i>Pseudonodosinella nodulosa</i>	<i>Pseudonodosinella elongata</i>	<i>Recurvoidella lamella</i>	<i>Recurvoides anormis</i>
PC060601						1	1			3	1						1	7	1	
PC060602							1													
PC060603									1			5								1
PC060604							5							1			1	2		
PC060605	1						5	1			2								4	
PC1							9		2		2	4	1				1			
PC060607			1										1							1
PC3							2				1							1		
PC060608							1		1											
PC060609																			1	1
PC5											2	1					1	5		1
PC060611					1		2					7							7	
PC060612					1						1	1							2	
PC060614	1						3				2	2					1	8		
PC11	1		1				18	2	1		7	19	1		1		4	17		
PC060615	5	1		1			19		1	1	39	4	5			1	4			1
PC13			1						1		1	2	5	1	3		1	7		
PC060617							12				11		4				4	7		
PC15			1				4	1			7	2	1		1			1		
PC060618	1	1			1		8	1			17	11					2	23		
PCs0		1					2	3			24		1	2			1	15		
PC18	1	1					1	1			5	2							7	
PC060619	6						3		1		1	3	1				2	12		
PC060621	1						3	1	1		41	7	3						15	
PC22	1						6				3	5	3						6	
PC060623			1				4					2							2	
PC060624							1				58	1							4	
PC0606F							2				1	1								
PC060625							1				1		1							

Appendix (continued).

Sample	<i>Recurvoides nucleolus</i>	<i>Recurvoides walteri</i>	<i>Recurvoides</i> sp. 1	<i>Recurvoides</i> sp. 2	<i>Recurvoides</i> spp.	<i>Remesella</i> aff. <i>varians</i>	<i>Remesella</i> sp.	<i>Reophax duplex</i>	<i>Reophax pilulifer</i>	<i>Reophax</i> sp. 1	<i>Repmanina charoides</i>	<i>Reticulophragmium acutidorsatum</i>	<i>Reticulophragmium amplectens</i>	<i>Reticulophragmium projectum</i>	<i>Reticulophragmium rotundidorsatum</i>	<i>Rhabdammina discreta</i>	<i>Rhabdammina eocenica</i>	<i>Rhabdammina</i> spp.	<i>Rhizammina indivisa</i>	<i>Rhizammina</i> spp.
PC060601			1		1		1	1			6	5					4		3	
PC060602											2							2		
PC060603											7					1	1		3	
PC060604	1				1						9	9			1	1			1	
PC060605	1				2	1						2	1						1	
PC1					1						4	2			1					
PC060607									1		1	1				8			1	
PC3											4	39	11			1	1	1	1	2
PC060608											1	1								
PC060609					4						3	3				1	2			
PC5		1			1						2					8	1	1		
PC060611					5						7	1							2	
PC060612					3						8					9	2		1	
PC060614												1					1			
PC11									1		8	4	2			5	2	1	13	
PC060615					2			1	3	1	4	1				4	2		4	3
PC13									1			12	4			4			3	
PC060617								1			8	7			1	1			1	
PC15	1				1			1			1					11			2	
PC060618					2						1	3				31		1	4	2
PCs0					4				1		12	2				2			3	1
PC18								1	1		8	2				4			1	
PC060619								1	1		7	2		1	4	6	1		1	
PC060621					1			2	2		18	1				11		2	8	
PC22												3		1	4	1				
PC060623			1		1				2		4					4		3	2	
PC060624								9	1		5			95	122	15	1	1		
PC0606F								2			1			3	3	3	3	1		
PC060625								1							3	3		4		1

Appendix (continued).

Sample	<i>Saccamina grzybowskii</i>	<i>Siphotextularia</i> sp. 1	<i>Siphotextularia</i> sp. 2	<i>Tetraxiella subtilissima</i>	<i>Subreophax</i> cf. <i>gutifera</i>	<i>Subreophax scalaris</i>	<i>Subreophax</i> cf. <i>pseudoscalaris</i>	<i>Subreophax splendidus</i>	<i>Thalmannammina subtrubinata</i>	<i>Trochammina bifaciata</i>	<i>Trochammina</i> sp. 1	<i>Trochammina</i> sp. 2	<i>Trochammina</i> sp. 3	<i>Trochammina</i> sp. 4	<i>Trochammina</i> sp. 5	<i>Trochammina</i> spp.	<i>Trochamminoides coronatus</i>	<i>Trochamminoides dubius</i>	<i>Trochamminoides grzybowskii</i>	<i>Trochamminoides intermedius</i>
PC060601											3	1	1							
PC060602																				
PC060603																				
PC060604							1	1	1	1	1	2		2						
PC060605							1							1	1					
PC1								1												
PC060607																				
PC3					1	1														
PC060608																				
PC060609																				1
PC5																				
PC060611																		1	1	
PC060612																	1			
PC060614																1				
PC11						1		3										2		
PC060615						1	1	1								1	6	2	1	
PC13																	1			
PC060617																5	1			
PC15					1						1	1							1	
PC060618						1										2		3		
PCs0				1			1													1
PC18																	1	1		
PC060619						1	1										1			
PC060621	2	1	1													4	3			2
PC22																				
PC060623																				
PC060624								2												1
PC0606F																				
PC060625						1														

Appendix (continued).

Sample	<i>Trochamminoides proteus</i>	<i>Trochamminoides cf. proteus</i>	<i>Trochamminoides septatus</i>	<i>Trochamminoides subcoronatus</i>	<i>Trochamminoides variolarius</i>	<i>Trochamminoides velascoensis</i>	<i>Trochamminoides sp. 1</i>	<i>Trochamminoides sp. 2</i>	<i>Trochamminoides sp. 3</i>	<i>Trochamminoides sp. 4</i>	<i>Trochamminoides spp.</i>	<i>Valvulina flexilis</i>	<i>Valvulina sp.</i>
PC060601	1				1						1		
PC060602	1												
PC060603				1			1				1		
PC060604			1		2			1				1	
PC060605													
PC1													
PC060607													
PC3				2							2		
PC060608											1		
PC060609											1		
PC5													
PC060611											1		
PC060612													
PC060614													
PC11				1	2	1							
PC060615				1		1					2		
PC13											2		
PC060617					1								
PC15				3							1		
PC060618								2			5		
PCs0				4						1			
PC18				2						1			
PC060619				1							2		
PC060621	2			1		1					3		1
PC22	1												
PC060623													
PC060624	1	1											
PC0606F													
PC060625													