

# Upper Cretaceous agglutinated foraminifera from a red sediment interval in the southern Norwegian Sea

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**ABSTRACT:** Foraminiferal assemblages from a red sediment interval of the uppermost Santonian–middle Campanian Nise Formation, offshore Norway were examined for taxonomy and their paleoenvironmental implications using morphogroup analysis. The relatively highly diversified assemblages are composed only of deep-water agglutinated forms, and in total 61 taxa were identified. The taxonomic and morphogroup composition of the assemblages resemble both the slope flysch-type biofacies in containing robust tubular forms and rzehakinids, and assemblages described from Cretaceous Oceanic Red Beds (CORBs) in the North Atlantic and the Carpathians in the high abundance of infaunal forms in supposedly environments with low flux of organic matter. The intermediate nature of the assemblages in the red sediment interval is probably related to the shallower bathyal depositional settings and higher flux of organic matter due to the proximity to land in a narrow seaway inferred from morphogroup analysis than abyssal settings of other CORBs. The foraminifera from the red sediment may be regarded as the background deep-water assemblage which reflects well-oxygenated and low-nutrient environments only with small terrigenous input in the Norwegian Sea which was tectonically active during the Cretaceous.

## INTRODUCTION

The Cretaceous Oceanic Red Beds (CORBs) (Wang et al. 2004; Hu et al. 2005), which represent deposition in well-oxygenated, oligotrophic environments at a relatively low sedimentation rate, are geographically widespread (see Wang et al. 2011; Hu et al. 2012), and foraminiferal assemblages from Upper Cretaceous red sediments have been documented in the Atlantic (Moullade et al. 1988; Kuhnt and Moullade 1991; Scott 2009), the Pacific (Krasheninnikov 1973, 1974) and the Tethys (e. g. Kuhnt 1990; Bubík 1995; Bak 2000; Cetean et al. 2011; Bindu et al. 2013). Upper Cretaceous red/pink chalk or limestone intervals, such as parts of the Hod and Hydra formations, are also known in the North Sea and the Norwegian Sea (see Deegan and Scull 1977; Isaksen and Tonstad 1989; Hampton et al. 2010), though they are not so extensively studied as CORBs from the North Atlantic or the Carpathians (see Wang et al. 2011; Hu et al. 2012). Similarly, although foraminiferal assemblages of the *Tritaxia dubia* Zone with red planktic foraminifera from reddish sediments in the Norwegian Sea were concisely described by Gradstein et al. (1999), so far there has been no detailed documentation of foraminiferal assemblages from oceanic red beds in the Norwegian Sea. Therefore, the main objectives of this study is to report the taxonomy of foraminifera from the Upper Cretaceous oceanic red sediment recovered from well 6306/5-1 on the eastern border of the Møre Basin in the southern Norwegian Sea and investigate the morphogroup composition of the assemblages and its paleoenvironmental implications in relationship to previously described CORB foraminiferal assemblages.

## BACKGROUND GEOLOGY

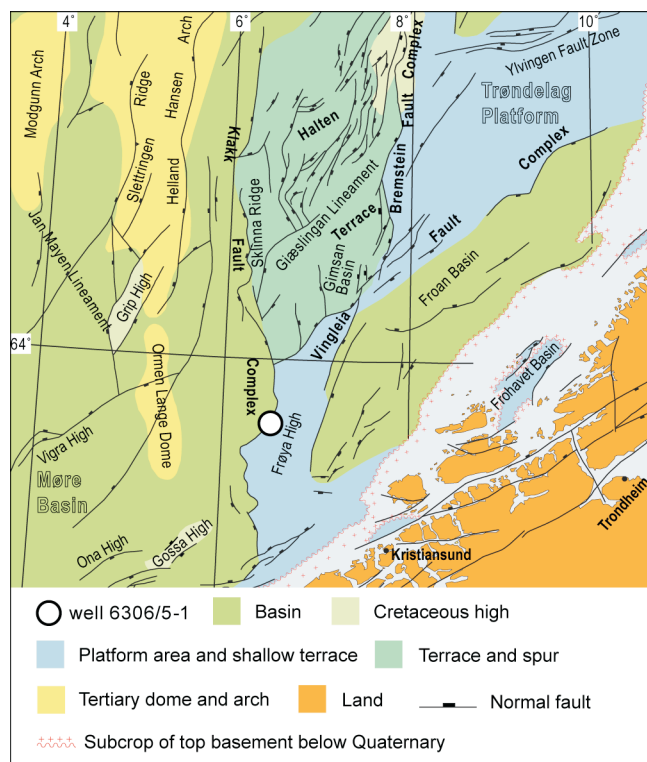
Well 6306/5-1 was drilled on the Klakk Fault Complex which was formed during the late Middle Jurassic–Early Cretaceous

rifting episode (Blystad et al. 1995) and defines the border between the Frøya High and the Møre Basin (text-figure 1). The studied interval, 1762m–1757.3m, contains the uppermost Santonian–middle Campanian Nise Formation and the Danian–Lower Selandian Egga Member of the Tang Formation (text-figure 2), according to the Norwegian Petroleum Directorate (NPD)’s factpages (2013). The lithological description below follows the Norwegian Interactive Offshore Stratigraphic Lexicon (<http://www.nhm2.uio.no/norlex/>). The Nise Formation is light to medium grey in color and composed mainly of mudstones with siltstones, sandstones and carbonate stringers. The color of sediments from 1760m–1761.82m is, however, reddish brown in the core photo provided by the NPD’s factpages (2013), but the description of this reddish sediment is unfortunately not available. The overlying Egga Member is greenish, medium to coarse grained, sand-dominated turbidites (see Sømme et al. 2009). The values of total organic carbon content (TOC) are given at depth of 1757m (0.13%) and 1757.5m (0.8%) for the Egga Member by the NPD’s factpages (2013), but not available for the Nise Formation in this well.

## MATERIALS AND METHODS

Foraminifera were examined in twelve picked faunal slides provided by F. M. Gradstein. Two of them are from the Egga Member and the other ten from the Nise Formation, which includes the red sediment interval, in well 6306/5-1. All the samples were core samples, and prepared following standard industrial techniques. The abundance of each species is given in Appendix 1. Photographs of foraminiferal specimens were taken with different focused areas using a Nikon digital camera Digital Sight DS-Fi1 mounted on a Nikon-1500 stereomicroscope at the Earth Sciences Department, King Fahd University of Petroleum & Minerals, Saudi Arabia, and they were stacked using a software CombineZP.

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TEXT-FIGURE 1  
Map of the study area in the southern Norwegian Sea (modified after Blystad et al. 1995).

Morphogroup analysis of assemblages was performed to investigate paleoenvironmental conditions semiquantitatively and to facilitate comparison with assemblages from other CORBs. The method was devised in an effort to analyze paleoenvironmental and paleobathymetric conditions reflected by foraminiferal assemblages (Corliss 1985; Jones and Charnock 1985; Corliss and Chen 1988), and has been developed by subsequent studies (e.g. Koutsoukos and Hart 1990; Nagy et al. 1995, 2009; Murray et al. 2011). The morphogroup scheme of Cetaan et al. (2011) that was modified for the analysis of Upper Cretaceous deep-water agglutinated foraminifera was employed in this study (text-figure 3). Species richness (the total number of species) and Fisher alpha index (Fisher 1943) were calculated as a measure of species diversity using the PAST software (version 3.0) (Hammer et al. 2001; Hammer and Harper 2006) to supplement paleoenvironmental interpretation.

## RESULTS

### Foraminiferal assemblages

Foraminiferal assemblages from both the Nise Formation and the Egga Member are comprised only of agglutinated species without calcareous benthic and planktic taxa, and only one calcareous-cemented agglutinated species, *Spiroplectinella dentata* (Alth 1850), was recorded. Casts of calcareous forms were also not found in the slides. The preservation of specimens from the grey intervals of the Nise Formation and the Egga Member is very variable, whereas specimens are less silicified, but generally preserved better in the red sediment interval. In total 61 agglutinated foraminiferal taxa are recorded, and most component taxa of the assemblages in this study are known as

cosmopolitan deep-water agglutinated foraminifera that are commonly recorded in the Upper Cretaceous and Paleogene of the North Atlantic and the Western Tethys (see Kaminski and Gradstein 2005). On the other hand the assemblages do not contain characteristic small abyssal species of the Krashennikov fauna (sensu Kaminski et al. 1999), and large coarsely agglutinated taxa, such as *Arthrodendron*, are absent or rare. The assemblages from the grey interval of the Nise Formation above the red interval and the Egga Member contain very low numbers of specimens, and the diversity is also generally very low. They contain mostly very well-silicified *Psammosiphonella* and *Recurvoides* (text-figure 4). In contrast, foraminiferal assemblages are more abundant and diversified in the red interval of the Nise Formation. *Cystammina sveni* Gradstein and Kaminski 1997, *Gerochammina stanislavi* Neagu 1990 and *Haplophragmoides eggeri* Cushman 1926 are common along with various tubular forms in this interval, whereas *Spiroplectammina navarroana* Cushman 1932 and *S. spectabilis* (Grzybowski 1898) are rare in the red sediment.

The results of morphogroup analysis show that the morphogroup composition of the assemblages is variable, while the relative abundance of the tubular morphogroup (M1) is high in all the samples (text-figure 5). In the Egga Member and the grey interval of the Nise Formation above the red sediment, the increased relative abundance of M1 (tubular forms) and M2b (rounded trochospiral and streptospiral and planoconvex trochospiral forms) is recorded, although the assemblages are impoverished. The relative abundance of infaunal morphogroup (M4) is generally higher in the lower half of the studied interval, including the red sediment, and M4 is absent in the top three samples. Flattened streptospiral forms (M3c), which are supposed to be surficial epifauna, are almost confined to the red sediment, and their relative abundance shows a similar trend to that of M4. No sessile forms (M3b) are recorded in the studied material, and M2c, including *Spiroplectammina* and *Spiroplectinella*, are rare in the red interval.

### Age

In this study, no specifically age diagnostic species used in the biostratigraphic scheme of Gradstein et al. (1999) for the Norwegian Sea were identified in the assemblages from both the Nise Formation and the Egga Member. Index species, such as *Caudammina gigantea* (Geroch 1960) and *Uvigerinammina jankoi* (Majzon 1943), that have been commonly reported from the CORBs in the North Atlantic (Moullade et al. 1988; Kuhnt et al. 1992), were also absent. The assemblages from the red sediment interval of the Nise Formation are somewhat similar to those from the Campanian of the Vøring Basin described by Setoyama et al. (2013) by lacking calcareous components and containing *Gerochammina stanislavi* whose known stratigraphic range is up to the Campanian. The red sediment interval also contains *Rzehakina epigona* (Rzehak 1895) whose first occurrence is reported mostly from the Campanian, rarely from the Turonian and Santonian (Kaminski and Gradstein 2005), and last occurrence generally in the lower Campanian *Fenestrella belli* Zone offshore Norway (Gradstein et al. 1999). The assemblages of the middle-upper Campanian *Tritaxia dubia* Zone of Gradstein et al. (1999) in the Norwegian Sea contain red planktic foraminifera recovered from red sediments, and these assemblages also contain various calcareous-cemented agglutinated taxa which are absent in this study. Nevertheless, we infer that the foraminiferal assemblages in the red sediment in this study are probably of Campanian age based on the pres-

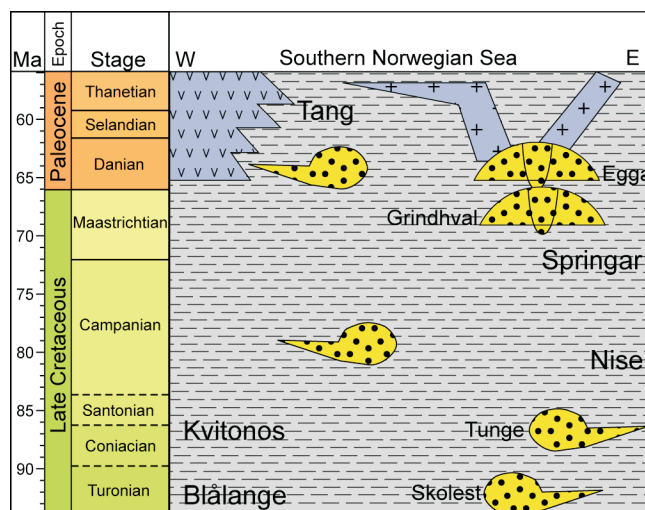
ence of *G. stanislawi*, whose last occurrence is in the Campanian, and *Rz. epigona*, which first appears generally in the Campanian (text-figure 4). This is also in accordance with the latest Santonian–Campanian age of the Nise Formation.

## DISCUSSION

### Paleoenvironmental implications

The relatively high diversity of foraminiferal assemblages in the red interval of the Nise Formation and the grey interval below and the results of the morphogroup analysis which show that microhabitats were fully occupied suggest relatively oxygenated environments with flux of organic matter which was high enough to support both epifauna and infauna on the sea floor (Jorissen et al. 1995; Kaminski et al. 1995; Kuhnt et al. 1996). The high abundance of infaunal forms in assemblages with tubular forms is a common feature among recent abyssal (Kuhnt et al. 2000) and Upper Cretaceous oceanic red bed fauna (e. g. Kuhnt et al. 1996; Kaminski et al. 1999; Båk 2000; Lemańska 2005). The infaunal forms found in the red bed in this study, mostly *Gerochammina*, are considered as *K*-strategists adapted to low trophic environments and were important components of assemblages in the red intervals during the Turonian–Santonian (Kuhnt et al. 1996). The elongated and slender species of *Gerochammina* may have occupied a very shallow position within sediments or may have been epifaunal in oligotrophic environments as similarly elongated species of *Spiroplectinata* that have been suggested to be epibenthic suspension and/or deposit feeders (Tyszka and Thies 2001). The preservation potential of infaunal forms might also be facilitated by their infaunal life habitat compared to epifauna, whereas epifaunal forms were imposed with lower preservation potential in highly oxic conditions on the sediment surface when sedimentation rates are low, which may accelerate decomposition of agglutinated tests and could consequently lead to the elevated abundance of infaunal forms in fossil assemblages of CORBs (Kuhnt et al. 1996; Kaminski et al. 1999).

There are no marked differences between the assemblages from the red and the grey interval below. Both assemblages are composed of species of the “Flysch-type” biofacies (Gradstein and Berggren 1981), and their morphogroup compositions are similar except for more abundant tubular forms and fewer infaunal forms in the grey interval (text-figure 5). As discussed above, the increased abundance of infaunal forms (M4) could be related to more oligotrophic and oxic environments of the red sediment. We cannot say with certainty what caused the changes in the oxygen level of bottom waters, but because the assemblages of the red interval do not remarkably differ from those from the grey interval below, a sudden decrease in organic flux and/or deepening of the seafloor is not likely. Thus, the color change from grey to red is probably caused by the introduction of oxygenated bottom currents to the area with low terrigenous input as with the case of the Nierental Formation in the northern calcareous Alps (Wagreich and Krenmayr 2005). The change from red to grey was possibly caused by either the termination of oxygenated bottom currents and/or an increase of terrigenous input. The assemblages of the Egga Member and the upper grey interval of the Nise Formation contain only small numbers of specimens which resulted in very variable morphogroup composition, and the species diversity is much lower than those in the red sediment. These features are similar to the assemblages from the Campanian sandstones of the inner to middle fan subenvironment in the Vøring Basin



TEXT-FIGURE 2



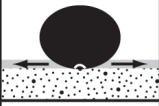






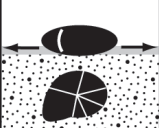
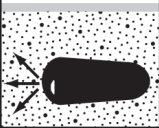
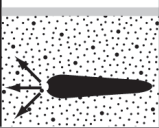
Lithostratigraphy for the Upper Cretaceous and Paleocene of the southern Norwegian Sea (modified after NORLEX 2011).

(Setoyama et al. 2013), where turbiditic conditions are expected.

### Paleobathymetry

Although we do not know the carbonate contents of the reddish sediment, the virtual absence of calcareous benthic, planktic and calcareous-cemented foraminifera suggests that the carbonate content of the sediment is very low (see Kuhnt and Moullade 1991). Upper Cretaceous foraminiferal assemblages without calcareous components similar to the assemblages in this study are known from the Upper Cretaceous Plantagenet Formation in the North Atlantic (Kuhnt and Moullade 1991; Scott 2009), and sedimentation of the Upper Cretaceous red claystones and carbonate-free red shales in the North Atlantic is associated with areas below the calcium carbonate compensation depth (CCD), usually in the abyssal zone (Scott 2009; Hu et al. 2012). The regional CCD might have been shallower in the Norwegian Sea than in the North Atlantic, as expected at the higher latitude (Berger and Winterer 1974), and thus the deposition of carbonate-free red sediment could have taken place in the bathyal zone. The assemblages of the red interval in this study do not contain characteristic species of the abyssal Krasheninnikov fauna, such as the small species of *Haplophragmoides* described by Krasheninnikov (1973, 1974), and they are not as highly diversified as assemblages from Upper Cretaceous abyssal red clays, for example, the *Trochammina gyroidinaeformis* biofacies (Kuhnt and Moullade 1991). The abundant occurrence of various tubular forms (M1), which suggests slope environments with gentle bottom currents (Jones and Charnock 1985; Murray et al. 2011), and the presence of DWA taxa common in slope environments in the assemblages indicate a bathyal depositional setting for the Nise Formation. In any case, in the Norwegian Sea where the final break-up of the lithospheric crust took place in the Paleocene–Eocene transition (Faleide et al. 2008), the existence of abyssal depths is not very likely during the Late Cretaceous. Therefore we conclude that the paleobathymetry of the study area in the Late Cretaceous was not deeper than the bathyal zone.



Morpho-group		Morpho-type	Test form	Life position	Feeding habit	Environment	Main genera
M1			Tubular	Erect epifauna	Suspension feeding	Tranquil bathyal and abyssal with low organic flux	<i>Kalamopsis</i> , <i>Nothia</i> <i>Psammosiphonella</i> <i>Rhabdammina</i> <i>Rhizammina</i> <i>Tolypammina</i>
M2	M2a		Globular	Shallow infauna	Suspension feeding and/or Passive deposit feeding	Common in bathyal and abyssal	<i>Caudammina</i> <i>Hyperammina</i> <i>Psammosphaera</i>
	M2b		Rounded trochospiral and streptospiral	Surficial epifauna	Active deposit feeding	Shelf to deep marine	<i>Recurvoides</i> <i>Thalmanammina</i>
			Planoconvex trochospiral				<i>Trochammina</i>
	M2c		Elongate keeled	Surficial epifauna	Active deposit feeding	Shelf to marginal marine	<i>Plectoeratidus</i> <i>Spiroplectammina</i> <i>Spiroplectinella</i>
M3	M3a		Flattened trochospiral	Surficial epifauna	Active and passive deposit feeding	Lagoonal to abyssal	not in this study
			Flattened planispiral and streptospiral				<i>Ammodiscus</i> <i>Annectina</i> <i>Glomospira</i> <i>Repmanina</i> <i>Rzehakina</i>
	M3b		Flattened irregular	Surficial epifauna	Suspension feeding	Upper bathyal to abyssal	not in this study
	M3c		Flattened streptospiral	Surficial epifauna	Active and passive deposit feeding	Upper bathyal to abyssal	<i>Ammosphaeroidina</i> <i>Cystammina</i> <i>Paratrochamminoides</i> <i>Trochamminoides</i>
M4	M4a		Rounded planispiral	Surficial epifauna and/or shallow infauna	Active deposit feeding	Inner shelf to upper bathyal	<i>Buzasina</i> <i>Haplophragmoides</i>
	M4b		Elongate subcylindrical	Deep infauna	Active deposit feeding	Inner shelf to upper bathyal with increased organic matter flux	<i>Gerochammina</i> <i>Verneuilinoides</i>
			Elongate tapered				<i>Hormosina</i> <i>Pseudonodosinella</i> <i>Reophax</i> <i>Subreophax</i>

TEXT-FIGURE 3  
Morphogroup scheme for agglutinated foraminifera (modified after Cetaan et al. 2011).

### Relationship to other CORB assemblages

The assemblages of the red interval in this study exhibit some similarity to both the flysch-type biofacies with robust tubular forms and rzehakinids, typical in slope settings, and assemblages of CORBs, such as the abyssal flysch-type biofacies (Bubík 1995) in the North Atlantic and the Carpathians. The assemblages, for example, contain rather high abundance of infaunal forms in oxic environments with low nutrient levels inferred from the red sediment, and *Recurvoides* and *Cystammina*, which are also abundant in the abyssal assemblages, are also common in the red interval of the Nise Formation. The assemblages, however, differ from the abyssal DWAF biofacies (sensu Kuhnt et al. 1989) by the absence of fragile tubular forms and typical small abyssal species of the Krasheninnikov fauna. Additionally, rzehakinids, which are often related to high trophic environments and are absent or very rare in the abyssal biofacies and Scaglia-type biofacies (Kuhnt et al. 1989; Bubík 1990; Kaminski et al. 2011a), are recorded in the red interval of this study. These features of the assemblages of the red interval are similar to the *Uvigerinammina jankoi* assemblage described from the Upper Cretaceous red shales of the Magura nappe by Malata and Oszczytko (1990) which shows intermediate characters of the flysch-type and abyssal foraminiferal biofacies. The *Uvigerinammina jankoi* assemblage also includes very common *Recurvoides* and *Gerochammina* (originally reported as *Karrerriella lenis*) as well as some rzehakinids and *Praecystammina globigerinaeformis*, which is morphologically similar to *Cystammina*. The absence of the Krasheninnikov fauna and the presence of rzehakinids in the assemblages could be related to slightly higher organic flux to the sea floor in the studied area which was probably in the bathyal zone and located close to land in a narrow seaway during the Late Cretaceous, compared with conditions represented by the abyssal assemblages. The assemblages of the red interval of this study may represent a background deep-sea assemblage of the Norwegian Sea during the Late Cretaceous, as sedimentation of CORB can be regarded as the primary type of background pelagic and hemipelagic sedimentation in deep-sea conditions (Wagreich and Krenmayr 2005). Any changes in environmental parameters to relatively oxic environments with low nutrient levels and clastic input represented by the red interval, for example, would lead to different biofacies described in a Campanian submarine fan system (Setoyama et al. 2013).

### CONCLUSIONS

The foraminiferal assemblages from the red sediment interval of the Nise Formation in the southern Norwegian Sea are here described for the first time. In total, 61 foraminiferal taxa are reported from the Egga Member and the Nise Formation including the red interval. The assemblages are composed of cosmopolitan DWAF taxa, and typical small species of the abyssal Krasheninnikov fauna are absent as well as the fragile tubular forms that are common in CORBs. There was only one calcareous-cemented agglutinated species, *Spiroplectinella dentata*, recorded in this study, suggesting deposition of the studied interval near the regional CCD. No age-diagnostic foraminiferal species, such as *Caudammina gigantea* and *Uvigerinammina jankoi*, are present in the assemblages. Morphogroup analysis shows a high abundance of infaunal forms in the red interval which is a common feature of fossil assemblages of CORBs. The environment inferred from the taxonomic and morphogroup composition of the assemblages is relatively oxygenated, in the bathyal zone, with a higher flux of organic mat-

ter than in truly oligotrophic abyssal conditions, which is reflected by the intermediate character between the slope flysch-type biofacies and abyssal DWAF biofaeces.

### TAXONOMY

The classification of agglutinated foraminifera by Kaminski (2014) was used for the taxa listed below.

Class FORAMINIFERA d'Orbigny 1826

Subclass MONOTHALAMANA Pawłowski, Holzmann and Tyszkiewicz 2013

Order ASTORRHIZIDA Lankester 1885

Suborder ASTORRHIZINA Lankester 1885

Family RHABDAMMINIDAE Brady 1884

Subfamily RHABDAMMININAE Brady 1884

Genus *Rhabdammina* M. Sars in Carpenter 1869

#### *Rhabdammina* sp. A

Plate 1, figure 1

**Description.** Test tubular, robust. Wall thick, coarsely agglutinated with large grains, very roughly finished.

**Remarks.** Specimens are fragmented and flattened. The test consists of grains of various sizes.

#### *Rhabdammina* spp.

**Remarks.** Robust tubular specimens with a test composed of grains of various sizes are included.

Subfamily BATHYSIPHONINAE Avnimelech 1952

Genus *Bathysiphon* Sars 1872

*Bathysiphon nodosariaformis* Subbotina 1950

Plate 1, figure 2

*Bathysiphon nodosariaformis* SUBBOTINA 1950, p. 67, pl. 4, figs 1–7. – BULATOVA in SUBBOTINA 1964, p. 87, pl. 3, figs 1–8 (non figs 9–11). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 269, pl. 1, fig. 4.

*Bathysiphon* sp. 1 NAGY, KAMINSKI, KUHN and BREMER 2000, pl. 4, figs 7–10.

**Remarks.** This species is superficially similar to *Psammosiphonella discreta* (Brady 1881) with a robust test with distinctive constrictions, but differs in possessing a much smoother test composed of finer and well-sorted grains with much cement.

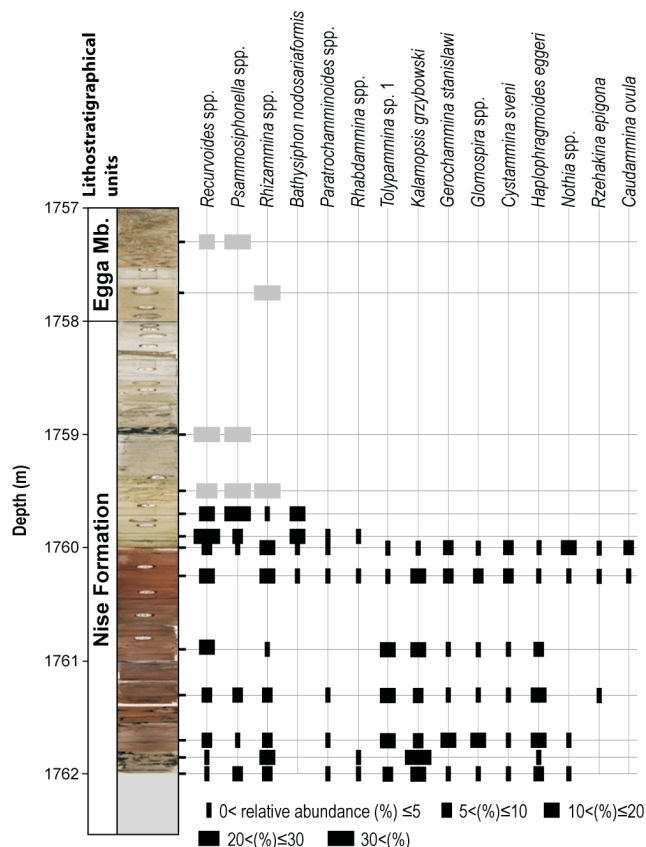
Genus *Nothia* Pflaumann 1964

#### *Nothia* sp. A

Plate 1, figures 3, 4

**Description.** Test large, tubular, free. Wall relatively thin, medium coarsely agglutinated with grains of various sizes.

**Remarks.** Although the bilamellar structure of the test wall and bifurcation are not observed, this form included in *Nothia*. Differs from other large species of the genus, such as *Nothia latissima* (Grzybowski 1898) and *Nothia robusta* (Grzybowski 1898), by its medium coarsely agglutinated wall with large agglutinated grains.



TEXT-FIGURE 4

Stratigraphic ranges and relative abundance of selected taxa. The photograph of the cores from the Norwegian Petroleum Directorate (NPD)'s factpages (2013). Grey lines indicate samples which contain less than 40 specimens.

#### *Nothia* spp.

**Remarks.** Flattened tubular specimens with somewhat rough wall surface are included.

Genus *Psammosiphonella* Avnimelech 1952

#### *Psammosiphonella cylindrica* (Glaessner 1937)

Plate 1, figure 5a,b

*Rhabdammina cylindrica* GLAESSNER 1937, p. 354, pl. 1, fig. 1.

*Psammosiphonella cylindrica* (Glaessner). – KAMINSKI and GRADSTEIN 2005, pl. 5/6, figs 9–13 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 280, pl. 2, fig. 6a, b.

#### *Psammosiphonella discreta* (Brady 1881)

Plate 1, figure 6

*Rhabdammina discreta* BRADY 1881, p. 48.

*Psammosiphonella discreta* (Brady). – KAMINSKI and GRADSTEIN 2005, p. 117, pl. 5/6, figs 1–8 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 280, pl. 1, fig. 6; pl. 2, fig. 7a, b.

Family RHIZAMMINIDAE Wieser 1931

Genus *Rhizammina* Brady 1879

#### *Rhizammina* sp. A

Plate 1, figure 7

**Remarks.** This form may resemble *Hyperammina rugosa* Verdenius and Van Hinte 1983 with large grains included in the test, but differs in possessing a thinner test that is more loosely cemented and incorporates smaller grains.

#### *Rhizammina* spp.

Plate 1, figure 8

**Remarks.** Thin-walled, curved tubular specimens are included. Many of them are also flattened due to its thin wall.

Suborder SACCAMMININA Lankester 1885

Superfamily PSAMMOSPHAEROIDEA Haeckel 1894

Family PSAMMOSPHAERIDAE Haeckel 1894

Subfamily PSAMMOSPHAERINAE Haeckel 1894

Genus *Psammosphaera* Schulze 1875

*Psammosphaera fusca* Schultze 1875 emend. Heron-Allen and Earland 1913

Plate 1, figures 10, 11

*Psammosphaera fusca* SCHULTZE 1875, p. 113, pl. 2, fig. 8a–f. – CHARNOCK and JONES 1990, p. 146, pl. 1, fig. 4. – KAMINSKI and GRADSTEIN 2005, p. 125, pl. 8, figs 1–9. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 280, pl. 1, figs 16, 17.

**Remarks.** The two specimens found in the red interval are smaller than the ones found in the grey interval of the Nise Formation.

Subclass TUBOTHALAMANA Pawłowski, Holzmann and Tyszk 2013

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

#### *Hyperammina rugosa* Verdenius and Van Hinte 1983

Plate 1, figure 9

*Hyperammina rugosa* VERDENIUS and VAN HINTE 1983, p. 187, fig. 16, pl. 1, figs 12–14. – KAMINSKI and GRADSTEIN 2005, p. 143, pl. 13, figs 1–4. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 277, pl. 2, fig. 10; pl. 3, figs 1, 2.

**Remarks.** This species is common in the Paleogene of the western Barents Sea (Nagy et al. 1997, 2000), and it is also reported from the Upper Cretaceous of the SW Barents Sea (Setoyama et al. 2011a) and of the Vøring Basin, offshore Norway (Setoyama et al. 2013).

Superfamily HORMOSINELLOIDEA Rauser and Reitlinger 1986

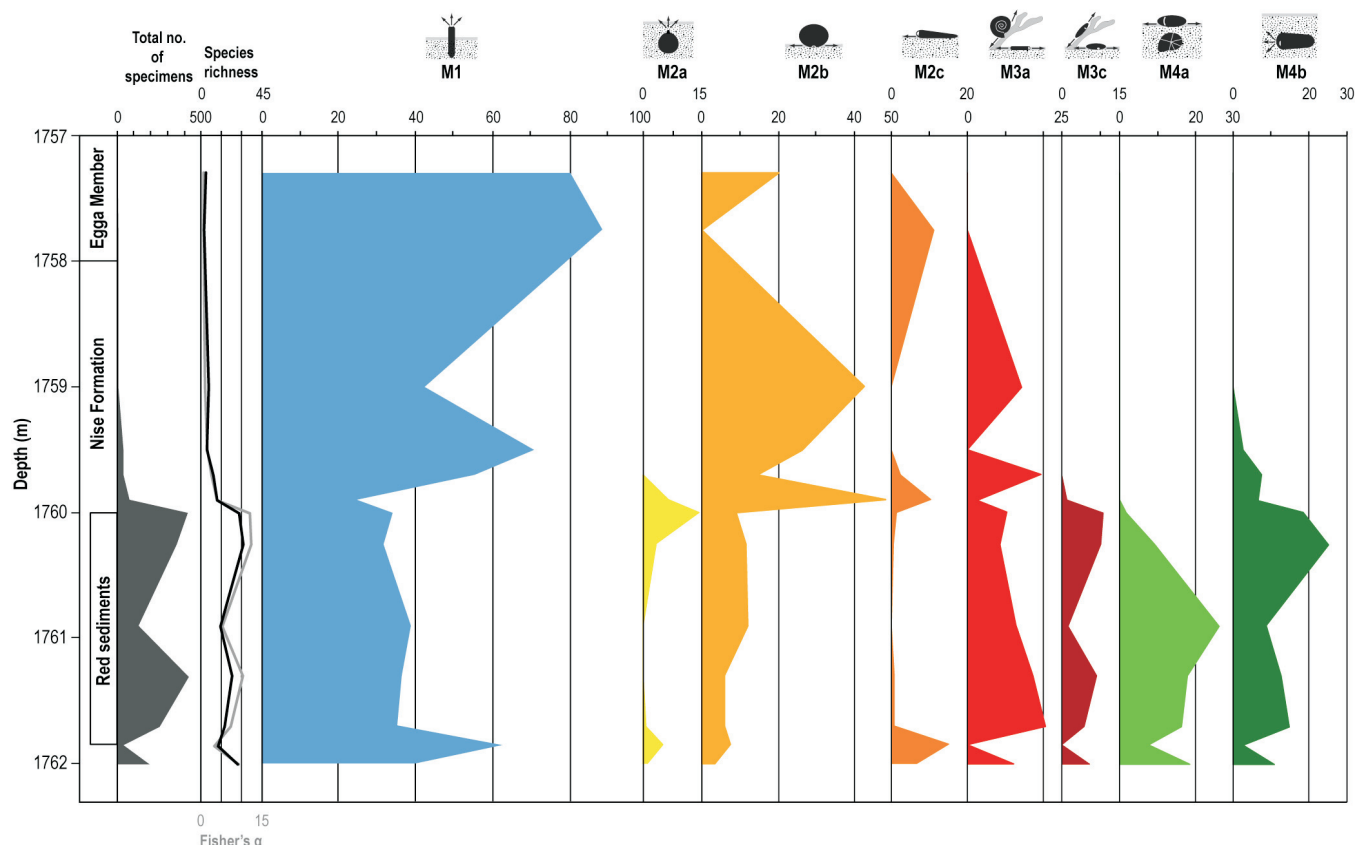
Family HORMOSINELLIDAE Rauser and Reitlinger 1986

Genus *Caudammina* Montanaro-Gallitelli 1955

#### *Caudammina ovula* (Grzybowski 1896) emend. Geroch 1960

Plate 1, figures 12, 13

*Reophax ovulum* GRZYBOWSKI 1896, p. 276, pl. 8, figs 19–21.



TEXT-FIGURE 5  
Diversity measures and relative abundance of morphogroups.

*Hormosina ovulum ovulum* (Grzybowski). – KAMINSKI, GRADSTEIN, BERGGREN, GEROCH and BECKMANN 1988, p. 186, pl. 2, fig. 10.

*Caudammina ovula* (Grzybowski). – KAMINSKI and GRADSTEIN 2005, p. 233, pl. 41, figs 1–8 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 270, pl. 4, figs 5–7.

**Remarks.** A few specimens that can be regarded as intermediate forms between *C. ovula* and *C. gigantea* were included.

*Caudammina ovuloides* (Grzybowski 1901)

Plate 1, figures 14, 15

*Reophax ovuloides* GRZYBOWSKI 1901, p. 233, pl. 8, fig. 3.

*Hormosina ovuloides* (Grzybowski). – KAMINSKI, GRADSTEIN, BERGGREN, GEROCH and BECKMANN 1988, p. 186, pl. 2, figs 3, 4.

*Caudammina ovuloides* (Grzybowski). – KAMINSKI and GRADSTEIN 2005, p. 238, pl. 42, figs 1–7 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 270, pl. 4, fig. 8.

**Remarks.** The specimens in this study do not possess a long stolon, and the chambers overlap with different degrees. The size of chambers does not change much as added.

Genus *Subreophax* Saidova 1975

*Subreophax aduncus* (Brady 1882)

Plate 1, figure 16

*Reophax aduncus* BRADY 1882, p. 715 (type figure not given).

*Subreophax aduncus* (Brady). – CHARNOCK and JONES 1990, p. 165, pl. 4, fig. 20; pl. 15, fig. 18. – KAMINSKI, CETEAN, BĂLC and COCCIONI 2011, p. 87, pl. 2, figs 14–16.

*Subreophax longicameratus* Kaminski, Cetea, Bălc and Coccioni 2011

Plate 1, figure 17

*Subreophax* sp. 1 KUHNT 1990, p. 326, pl. 3, fig. 14.

*Subreophax* sp. 1 Kuhnt. – COCCIONI et al. 1995, p. 150, pl. 2, fig. 11.

*Subreophax longicameratus* KAMINSKI, CETEAN, BĂLC and COCCIONI 2011, p. 87, pl. 2, figs 17–21; pl. 3, figs 1–5. – SETOYAMA, KAMINSKI and TYSZKA 2013, fig. 5. 15.

**Remarks.** The chambers of specimens observed in this study are not as elongated as the specimens illustrated by Kaminski et al. (2011) and Setoyama et al. (2013). Specimens with both rectangular and more oval pseudochambers are included. The specimens are different from *Subreophax splendidus* (Grzybowski 1898) by its more elongated chambers.

*Subreophax scalaris* (Grzybowski 1896)

Plate 1, figure 18

*Reophax guttifera* (Brady) var. *scalaria* GRZYBOWSKI, 1896, p. 277, pl. 8, fig. 26a, b.

*Subreophax scalaris* (Grzybowski). – KAMINSKI and GRADSTEIN, 2005, p. 278, pl. 55, figs 1–7. – KAMINSKI, CETEAN, BĂLC and



COCCIONI 2011, p. 87, pl. 3, fig. 7. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 286, pl. 4, fig. 15.

***Subreophax* spp.**

**Remarks.** Broken specimens with a few flattened pseudo-chambers are included.

Suborder AMMODISCINA Mikhalevich 1980  
Superfamily AMMODISCOIDEA Reuss 1862  
Family AMMODISCIDAE Reuss 1862  
Subfamily AMMODISCINAE Reuss 1962  
Genus *Ammodiscus* Reuss 1962

***Ammodiscus cretaceus* (Reuss 1845)**  
Plate 2, figure 1

*Operculina cretacea* REUSS 1845, p. 35, pl. 13, figs 64, 65.  
*Ammodiscus cretaceus* (Reuss). – CUSHMAN 1934, p. 45. – KUHN 1990, p. 310, pl. a, figs 2, 3 – KAMINSKI and GRADSTEIN 2005, p. 145, pl. 14, figs 1a–10 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 266, pl. 3, fig. 5.

**Remarks.** Differs from *Ammodiscus glabratus* Cushman and Jarvis 1928 by its more evolute, less biconcave test. Some specimens show clear striations.

***Ammodiscus glabratus* Cushman and Jarvis 1928**

*Ammodiscus glabratus* CUSHMAN and JARVIS 1928, p. 87, pl. 12, fig. 6a, b. – KAMINSKI and GRADSTEIN 2005, p. 148, pl. 15, figs 1a–6. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 266, pl. 2, fig. 11a, b.

**Remarks.** Large biconcave planispiral specimens with more involute coiling mode and sometimes with very slight striations.

***Ammodiscus* sp. A**  
Plate 2, figure 2

**Description.** Test of medium size, planispiral, slightly involute, relatively thick. Wall finely agglutinated with much cement, smoothly finished. The periphery rounded. Aperture at the open end of the tube.

**Remarks.** This form differs from *Ammodiscus tenuissimus* Grzybowski 1898 by its rounded periphery and more involute coiling mode.

***Ammodiscus* sp. B**  
Plate 2, figure 3

**Description.** Test of medium size, planispiral, completely evolute, thin, flat. The initial portion often coiled in a slightly irregular way. The tubular portion increases in diameter slowly, especially in the last few whorls. Wall finely agglutinated with much cement, smoothly finished. The periphery rounded. Aperture at the open end of the tube.

**Remarks.** The form might resemble *Annectina biedai* Gradstein and Kaminski 1997 or *Glomospirella* sp 1 in the SW Barents Sea described by Setoyama et al. (2011a) by possessing the early portion coiled in a slightly irregular planispiral mode and being coiled evolute. The initial portion is, however, not coiled in various planes or streptospirally.

***Ammodiscus* spp.**

**Remarks.** Broken planispiral tubular specimens and small specimens that cannot be identified at the species level are included.

Subfamily TOLYPAMMININAE Cushman 1928  
Genus *Tolypammina* Rhumbler 1895

***“Tolypammina”* sp. A**  
Plate 1, figures 19, 20

*Tolypammina* sp. 1 SETOYAMA, KAMINSKI and TYSZKA 2013, p. 401, fig. 5. 11, 12.

**Description.** Test tubular, often curved and flattened. Wall thin, somewhat coarsely agglutinated with much cement, sometimes including grains of disproportionately large size, finish smooth to rough.

**Remarks.** Although the possession of slightly rough wall does not agree with the description of the genus given by Loeblich and Tappan (1987), both forms with a smooth and rough wall surface are included as they co-occur. This form may be the same as Campanian–Maastrichtian specimens from the western Central Atlantic described as *Tolypammina* sp. 1 and *Tolypammina* sp. 2 by Hemleben and Troester (1984, pl. 2, figs 1, 2). Kuhn (1990) also described coarsely agglutinated tubular forms that are not attached as *Tolypammina* sp. 1 and *Tolypammina* sp. 2 from the Upper Cretaceous Scaglia Rossa and Capas Rojas facies.

Subfamily USBEKISTANIINAE Vialov 1968  
Genus *Glomospira* Rzehak 1885

***Glomospira diffundens* Cushman and Renz 1946**  
Plate 2, figures 4, 5

*Glomospira gordialis* (Jones and Parker) var. *diffundens* CUSHMAN and RENZ 1946, p. 15, pl. 1, fig. 30.  
*Glomospira gordialis diffundens* Cushman and Renz. – HEMLEBEN and TROESTER 1984, p. 519, pl. 1, fig. 21. – KAMINSKI and GRADSTEIN 2005, p. 175, pl. 23, figs 1–9. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 272, pl. 2, fig. 19; pl. 3, figs 17, 18.

**Remarks.** In the studied material, specimens with the initial portion coiled like *Repmanina charoides* (Jones and Parker 1860), which can be identified as *Glomospira gordialis* (Jones and Parker 1860), were not observed.

***“Glomospira” irregularis* (Grzybowski 1898)**  
Plate 2, figures 6, 7

*Ammodiscus irregularis* GRZYBOWSKI 1898, p. 285, pl. 11, figs 2, 3.  
*Glomospira? irregularis* (Grzybowski). – HEMLEBEN and TROESTER 1984, p. 519, pl. 1, fig. 22.  
*Glomospira* (*Tolypammina*?) *irregularis* (Grzybowski). – KUHN 1990, p. 311, pl. 1, fig. 12.  
*Glomospira irregularis* (Grzybowski). – KAMINSKI and GEROCH 1993, p. 256, pl. 6, figs 6–8b. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 272, pl. 3, fig. 20; pl. 7, fig. 1.  
*“Glomospira” irregularis* (Grzybowski). – KAMINSKI and GRADSTEIN 2005, p. 185, pl. 26, figs 1a–7 (with synonymy). – KAMINSKI, CETEAN, BĂLC and COCCIONI 2011, p. 85, pl. 1, fig. 15.

**Remarks.** It can be distinguished from other species of *Glomospira* by its large size and rough test surface.



**Glomospira spp.**

**Remarks.** Broken tubular specimens which are glomospirally coiled.

Genus *Repmanina* Suleymanov, in Arapova and Suleymanov 1966

**Repmanina charoides** (Jones and Parker 1860)

*Trochammina squamata* var. *charoides* JONES and PARKER 1860, p. 304 (type figure not given).

*Glomospira charoides* (Jones and Parker). – BERGGEN and KAMINSKI 1990, p. 60, pl. 1, fig. 2 (lectotype). – KUHNT 1990, p. 311, pl. 1, figs 9, 10. – KAMINSKI and GRADSTEIN 2005, p. 168, pl. 22, figs 1–16 (with synonymy).

*Repmanina charoides* (Jones and Parker). – ALEGRET and THOMAS, 2001, p. 201, pl. 10, fig. 11. – KAMINSKI, CETEAN, BĂLC and COCCIONI 2011, p. 86, pl. 1, fig. 17a, b. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 283, pl. 3, figs 22, 23.

Superfamily LITUOTUBOIDEA Loeblich and Tappan 1984

Family LITUOTUBIDAE Loeblich and Tappan 1984

Genus *Lituotuba* Rhumbler 1895

**Lituotuba lituiformis** (Brady 1879)

Plate 2, figure 8

*Trochammina lituiformis* BRADY 1879, p. 59, pl. 5, fig. 16.

*Lituotuba lituiformis* (Brady). – KUHNT 1990, p. 318, pl. 1, figs 17, 18. – KAMINSKI and GRADSTEIN 2005, p. 287, pl. 58, figs. 1–8.

**Remarks.** Only one specimen was recorded at 1761.3m in this study. This species can be readily distinguished from species of *Paratrochamminoides* and *Trochamminoides* by its rudimentary chambers and uncoiling portion.

Genus *Paratrochamminoides* Soliman 1972

**Paratrochamminoides gorayskii** (Grzybowski 1898), emend. Kaminski and Geroch 1993

Plate 2, figure 9

*Ammodiscus gorayskii* GRZYBOWSKI 1898, p. 283, pl. 11, fig. 5.

*Paratrochamminoides gorayskii* (Grzybowski). – KAMINSKI and GEROCH 1993, p. 255, pl. 5, fig. 8a–d. – KAMINSKI and KUHNT 2004, p. 281 (no figure given). – KAMINSKI and GRADSTEIN 2005, p. 297, pl. 61, figs 1a–5. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 278, pl. 5, figs 9, 10.

**Paratrochamminoides heteromorphus** (Grzybowski 1898)

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

*Paratrochamminoides heteromorphus* (Grzybowski). – KUHNT 1990, p. 320, pl. 5, fig. 18. – KAMINSKI and GEROCH 1993, p. 258, pl. 7, fig. 3a, b. – KAMINSKI and KUHNT 2004, p. 281 (no figure given). – KAMINSKI and GRADSTEIN 2005, p. 298, pl. 62, figs 1–10 (with synonyms). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 278, pl. 5, fig. 11a–c.

**Paratrochamminoides spp.**

**Remarks.** Broken and/or flattened specimens of the genus are included. Such specimens of *Trochamminoides* might be included.

Family TROCHAMMINOIDEA Haynes and Nwabufu-Ene 1998

Genus *Trochamminoides* Cushman 1910

**Trochamminoides proteus** (Karrer 1866) emend. Rögl 1995

*Trochammina proteus* KARRER 1866, p. 494, pl. 1, fig. 8 (not figs 1–7). *Trochamminoides proteus* (Karrer). – RÖGL 1995, p. 255, textfigs 7–9; pl. 2, figs 1–6. – KAMINSKI and GRADSTEIN 2005, p. 314, pl. 67, figs 1–5.

Order SCHLUMBERGERINIDA Mikhalevich 1980

Suborder SCHLUMBERGERININA Mikhalevich 1980

Superfamily RZEHAKINOIDEA Cushman 1933

Family RZEHAKINIDAE Cushman 1933

Subfamily RZEHAKININAE Cushman 1933

Genus *Rzehakina* Cushman 1927

**Rzehakina epigona** (Rzehak 1895)

Plate 2, figures 10a,b

*Silicina epigona* RZEHAK 1895, p. 214, pl. 6, fig. 1a–c.

*Rzehakina epigona* (Rzehak). – BUBÍK and KAMINSKI 2000, p. 75, pl. 1, figs 1a–4b. – KAMINSKI and GRADSTEIN 2005, p. 205, pl. 31, figs 1a–4b (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 284, pl. 3, figs 25, 26; pl. 7, fig. 3a, b.

**Remarks.** As noted by Bubík and Kaminski (2000), this species is morphologically variable. Some specimens are more evolute and flattened, but not to the extent of *Rzehakina fissistomata* (Grzybowski 1901), and their coil sutures are often not so clear in the studied material.

**Rzehakina minima** Cushman and Renz 1946

Plate 2, figures 11a,b

*Rzehakina epigona* (Rzehak) var. *minima* CUSHMAN and RENZ 1946, p. 24, pl. 3, fig. 5.

*Rzehakina epigona* Cushman and Renz. – KAMINSKI and GRADSTEIN 2005, p. 215, pl. 35, figs 1a–10 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 284, pl. 4, fig. 1; pl. 7, fig. 5a, b. – WAŚKOWSKA 2011, fig. 5. 26, 27.

**Remarks.** This species can be distinguished from the other species of *Rzehakina* by its more slender test with evolute coiling mode and chambers which increase in thickness only slowly as added.

Subclass GLOBOTHALAMANA Pawłowski, Holzmann and Tyszk 2013

Order LITUOLIDA Lankester 1885

Suborder HORMOSININA Mikhalevich 1980

Superfamily HORMOSINOIDEA Haeckel 1894

Family ASCHEMOCELLIDAE Vialov 1966

Genus *Kalamopsis* de Folin 1883

**Kalamopsis grzybowskii** (Dyląganka 1923)

Plate 2, figure 12

*Hyperammina grzybowskii* DYLAŻANKA 1923, p. 65.

*Kalamopsis grzybowskii* (Dyląganka). – KAMINSKI and GRADSTEIN 2005, p. 252, pl. 47, figs 1–12 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 277, pl. 4, figs 18, 19.

**Remarks.** Specimens without constrictions are also included.

**Kalamopsis cf. grzybowskii** (Dyląganka 1923)

Plate 2, figure 13

*Kalamopsis grzybowskii* (Dyląganka). – CHARNOCK and JONES 1990, p. 151, pl. 1, fig. 22.

**Remarks.** This form is more robust than the typical form of the species and possesses a very thick, smooth wall. Additionally, septa are not clearly visible.

Family REOPHACIDAE Cushman, 1927  
Genus *Reophax* de Montfort 1808  
Family HORMOSINIDAE Haeckel 1894  
Subfamily HORMOSININAE Haeckel 1894  
Genus *Hormosina* Brady 1879

***Hormosina velascoensis*** (Cushman 1926)

*Nodosinella velascoensis* CUSHMAN 1926, p. 586, pl. 20, fig. 9.  
*Hormosina velascoensis* (Cushman). – KAMINSKI and GRADSTEIN 2005, p. 243, pl. 44, figs 1–8. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 276, pl. 5, fig. 1.

Genus *Pseudonodosinella* Saidova 1970

***Pseudonodosinella* spp.**

**Remarks.** Broken uniserial specimens with a terminal aperture on a short neck without the earlier portion are included. Many of them are also flattened due to their thin wall.

Suborder LITUOLINA Lankester 1885  
Superfamily LITUOLOIDEA de Blainville 1827  
Family HAPLOPHRAGMOIDIDAE Maync 1952  
Genus *Buzasina* Loeblich and Tappan 1985

***Buzasina* sp.**

**Remarks.** Only one small specimen with three visible chambers is recorded.

Genus *Haplophragmoides* Cushman 1910

***Haplophragmoides eggeri*** Cushman 1926  
Plate 2, figure 14

*Haplophragmoides eggeri* CUSHMAN 1926, p. 583, pl. 15, fig. 1a, b. – KAMINSKI and GRADSTEIN 2005, p. 342, pl. 75, figs 1–6.

**Description.** Test small, planispiral, tightly coiled, involute with seven to eight chambers in the final whorl and circular outline. Chambers increase in size slowly as added. Periphery rounded. Umbilici depressed. Wall finely agglutinated with much cement, finish somewhat rough. Sutures radial, very slightly curved, flush or slightly depressed, appear as thick bands. Aperture an interiomarginal slit.

**Remarks.** Differs from *Haplophragmoides herbichi* Neagu 1968 by its more rounded periphery and somewhat rough wall.

***Haplophragmoides porrectus*** Maslakova 1955  
Plate 3, figure 1

*Haplophragmoides porrectus* MASLAKOVA 1955, p. 47, pl. 3, figs 5–6. – KAMINSKI, GRADSTEIN, BERGGREN, GEROCH and BECKMANN 1988, p. 189, pl. 5, figs 7, 8. – KAMINSKI and GRADSTEIN 2005, p. 353, pl. 79, figs 1a–6. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 275, pl. 8, fig. 1a, b.

**Remarks.** This species is distinguished from the other species by its elliptical outline, inflated chambers and incised, radial sutures.

***Haplophragmoides stomatus*** (Grzybowski 1898)  
Plate 2, figure 15

*Trochammina stomata* GRZYBOWSKI 1898, p. 290, pl. 11, figs 26, 27.  
*Haplophragmoides stomatus* (Grzybowski). – KAMINSKI and GEROCH, 1993, p. 311, pl. 11, figs 1, 2. – KAMINSKI and GRADSTEIN, 2005, p. 357, pl. 80, figs 1a–6b.

**Description:** Test medium to large, planispirally coiled, involute with about eight chambers in the final whorl. Periphery rounded. Chambers triangular, increase in size rapidly as added. Sutures flush, thick. Wall finely agglutinated, smoothly finished. Aperture slit-like, interiomarginal.

**Remarks.** Specimens vary in size. Sutures in some specimens are slightly curved backwards.

***Haplophragmoides walteri*** (Grzybowski 1898)  
Plate 3, figure 2

*Trochammina walteri* GRZYBOWSKI 1898, p. 290, pl. 11, fig. 31.  
*Haplophragmoides walteri* (Grzybowski). – KAMINSKI and GRADSTEIN 2005, p. 363, pl. 83, figs 1–6. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 275, pl. 6, figs 8, 9.

**Remarks.** The specimens found in this study are smaller than typical specimens of the species as in the Upper Cretaceous of the SW Barents Sea (Setoyama et al. 2011a).

***Haplophragmoides cf. walteri*** (Grzybowski 1898)  
Plate 2, figure 16

*Trochammina walteri* GRZYBOWSKI 1898, p. 290, pl. 11, fig. 31.  
*Haplophragmoides walteri* (Grzybowski). – KAMINSKI and GRADSTEIN 2005, p. 363, pl. 83, figs 1–6.

**Description.** Test of medium size, planispiral, slightly evolute, flattened with acute periphery probably due to postmortem compaction. Chambers triangular, increasing in size slowly as added, about nine in the final whorl. Sutures slightly depressed, straight or curved backwards. Wall finely agglutinated, fine to slightly rough. Aperture an interiomarginal slit.

**Remarks.** This form differs from *Haplophragmoides walteri* by being slightly evolute and lacking the keel-like periphery, and also from *Haplophragmoides cf. walteri* previously described from the other CORBs, for example, by Moullade et al. (1988), Kuhnt (1990) and Kaminski et al. (2011a) by possessing more chambers in the final whorl. Some specimens show an apertural-lip-like structure. It also resembles *Haplophragmoides nauticus* Kender, Kaminski and Jones 2006 with slightly evolute coiling and small open umbilici, but the latter possess a distinctly evolute coiling mode, widely open umbilici and trapezoidal chambers as remarked by Kender et al. (2006).

***Haplophragmoides* spp.**

**Remarks.** Broken and/or flattened specimens of the genus are included.

Superfamily RECURVOIDOIDEA Alekseychik-Mitskevich 1973  
Family AMMOSPHAERIODINIDAE Cushman 1927  
Subfamily AMMOSPHAERIODININAE Cushman 1927  
Genus *Ammosphaeroidina* Cushman 1910

***Ammosphaeroidina pseudopauciloculata*** (Mjatliuk 1966)  
Plate 3, figure 4

*Cystamminella pseudopauciloculata* MJATLIUK, 1966, p. 246, pl. 1, figs 5–7; pl. 2, fig. 6; pl. 3, fig. 3.  
*Ammosphaeroidina pseudopauciloculata* (Mjatluk). – KAMINSKI, GRADSTEIN, BERGGREN, GEROCH and BECKMANN 1988, p. 193, pl. 8, figs 3a–5. – KAMINSKI and GRADSTEIN 2005, p. 376, pl. 87a, figs 1a–5; pl. 87b, figs 1a–10 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, pl. 268, pl. 11, figs 2, 3.

Genus *Cystammina* Neumayr 1889

*Cystammina sveni* Gradstein and Kaminski 1997

Plate 3, figures 5, 6

*Cystammina sveni* GRADSTEIN and KAMINSKI 1997, p. 225, figs 11, 12 (1–6). – HOLBOURN, HENDERSON and MACLEOD 2013, p. 228, figs 1–3.

**Remarks.** The extent of the areal, slit-like aperture differs among the specimens. Specimens without a clear lip are also included. The species has also been reported from the Carpathian turbidites (Waśkowska 2011), but the Eocene specimens from the Carpathians differ in possessing a more rounded aperture.

Subfamily RECURVOIDINAE Alekseychik-Mitskevich 1973  
 Genus *Recurvoidella* Uchio 1960

*Recurvoidella* sp.

Plate 3, figure 3a,b

**Description.** Test of medium size, circular in outline, planispirally coiled with the coiling axis slightly wobbling, with about six chambers in the final whorl. Periphery broadly rounded. Sutures slightly depressed, thick. Wall finely agglutinated with much cement. Aperture a basal slit. An apertural lip is not observed.

Genus *Recurvoides* Earland 1934

*Recurvoides pseudononioninoides* Neagu and Platon 1994

*Recurvoides pseudononioninoides* NEAGU and PLATON 1994, p. 7, pl. 10, figs 4, 5. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 281, pl. 9, fig. 2a–c; pl. 12, fig. 4a–d.

**Remarks.** This species is also reported from the Upper Cretaceous of the SW Barents Sea (Setoyama et al. 2011a).

*Recurvoides* spp.

**Remarks.** Many specimens of the genus have a very coarse surface due to silicification, and could not be identified at the species level. Specimens of *Thalmannammina* might also be included.

Genus *Thalmannammina* Pokorný 1951

*Thalmannammina* spp.

**Remarks.** Specimens that show the thalmannamminiform coiling mode (see Bubík 1995) are included.

Suborder SPIROPLECTAMMININA Mikhalevich 1992  
 Superfamily SPIROPLECTAMMINOIDEA Cushman 1927  
 Family SPIROPLECTAMMINIDAE Cushman 1927  
 Subfamily SPIROPLECTAMMININAE Cushman 1927  
 Genus *Plectoeratidus* Kaminski, Setoyama and Tyszká 2009

*Plectoeratidus subarcticus* Kaminski, Setoyama and Tyszká 2009

*Eratidus foliaceus* (Brady). – CHARNOCK and JONES 1990, p. 181, pl. 9, fig. 10; pl. 20, fig. 9a, b.

*Plectoeratidus subarcticus* KAMINSKI, SETOYAMA and TYSZKA 2009, p. 143, fig. 2 A1–E3.

**Remarks.** This form can be distinguished from the species of *Eratidus* and *Spiroplectammina* by its thin elongated test with the biserial to uniserial rectilinear part. This species is reported from the Upper Cretaceous of the SW Barents Sea (Kaminski et al. 2009), the Vøring Basin, offshore Norway (Setoyama et al. 2013) and in the Labrador Sea (Setoyama, personal observation).

Genus *Spiroplectammina* Cushman 1927

*Spiroplectammina navarroana* Cushman 1932 emend. Gradstein and Kaminski 1989

Plate 3, figure 7

*Spiroplectammina navarroana* CUSHMAN 1932, p. 96, pl. 11, fig. 14. – GRADSTEIN and KAMINSKI 1989, p. 83, pl. 9, figs 1a–12. – KAMINSKI and GRADSTEIN 2005, p. 426, pl. 103, figs 1–12 (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 285, pl. 11, figs 6, 7.

*Spiroplectammina spectabilis* (Grzybowski 1898) emend. Kaminski 1984

*Spiroplecta spectabilis* GRZYBOWSKI 1898, p. 293, pl. 12, fig. 12. *Spiroplectammina spectabilis* (Grzybowski). – KAMINSKI 1984, p. 31, pl. 12, figs 1–9; pl. 13, figs 1–8. – KAMINSKI and GRADSTEIN 2005, p. 435, pl. 104, figs 1a–6b (with synonymy). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 285, pl. 11, figs 8, 9.

Genus *Spiroplectinella* Kisel'man 1972

*Spiroplectinella dentata* (Alth, 1850)

Plate 3, figure 8

*Textularia dentata* ALTH 1850, p. 262, pl. 13, fig. 13. *Spiroplectinella dentata* (Alth). – KAMINSKI and GRADSTEIN 2005, p. 439, pl. 106, figs 1a–8. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 286, pl. 11, figs 10, 11.

**Remarks.** This species is the only species with calcareous cement recorded in this study.

Family TEXTULARIOPSIDAE Loeblich and Tappan 1982

Genus *Rashnovammina* Neagu and Neagu 1995

*Rashnovammina munda* (Krashennikov 1974)

*Pseudobolivina munda* KRASHENINNIKOV 1974, p. 210, pl. 2, figs 10, 11.

*Pseudobolivina* sp. cf. *munda* (Krashennikov). – KUHNT 1990, p. 324, pl. 6, figs 1, 2.

*Rashnovammina munda* (Krasheninnikov). – KAMINSKI, CETEAN, BÄLC and COCCIONI 2011, p. 93, pl. 5, fig. 16. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 281, pl. 13, fig. 8.

**Remarks.** Differs from *Parvigenerina* sp. 3 (Kuhnt, 1990) by its tightly coiled biserial portion only with the tendency to become lax uniserial (sensu Kaminski et al. 2011b).

Family PSEUDOBOLIVINIDAE Wiesner 1931

Genus *Parvigenerina* Vella 1957

***Parvigenerina* sp. 3** (Kuhnt 1990)

Plate 3, figure 9

*Pseudobolivina* sp. 3 KUHNT 1990, p. 324, pl. 6, fig. 5.

*Parvigenerina* sp. 3 (Kuhnt). – CETEAN, SETOYAMA, KAMINSKI, NEAGU, BUBÍK, FILIPESCU and TYSZKA 2011, p. 23, pl. 1, figs 20, 21. – KAMINSKI, CETEAN, BÄLC and COCCIONI 2011, p. 93, pl. 5, figs 13, 14.

**Remarks.** This form is distinctive with its coiling mode changing from biserial to loosely biserial to lax uniserial (sensu KAMINSKI et al. 2011b).

Suborder TROCHAMMININA Saidova 1981

Superfamily TROCHAMMINOIDEA Schwager 1877

Family TROCHAMMINIDAE Schwager 1877

Subfamily TROCHAMMININAE Schwager 1877

Genus *Trochammina* Parker and Jones 1859

***Trochammina* spp.**

**Remarks.** Small, flattened specimens of the genus are included.

Suborder VERNEUILININA Mikhalevich and Kaminski 2004

Superfamily VERNEUILINOIDEA Cushman 1911

Family PROLIXOPLECTIDAE Loeblich and Tappan 1985

Genus *Gerochammina* Neagu, 1990

***Gerochammina stanislawi*** Neagu 1990

Plate 3, figures 12, 13

*Gerochammina stanislawi* NEAGU 1990, p. 253, pl. 1, figs 1–26. – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 272, pl. 10, fig. 6.

**Remarks.** This species is distinguishable from other Upper Cretaceous elongate forms by its long biserial portion, short trochospiral portion and areal aperture. The position of the areal aperture is variable, and in some specimens it is almost terminal, but without a clear apertural neck as in *Karrerulina conversa* (Grzybowski).

***Gerochammina* spp.**

**Remarks.** Most of them are probably juveniles of *G. stanislawi* with a short biserial portion.

Family VERNEUILINIDAE Cushman 1911

Subfamily VERNEUILINOIDINAE Suleymanov 1973

Genus *Verneuilinoides* Loeblich and Tappan 1949

***Verneuilinoides* sp. aff. *perplexus*** (Loeblich 1946)

Plate 3, figure 10

*Verneuilina perplexa* LOEBLICH 1946, p. 138, pl. 22, figs 14–16.

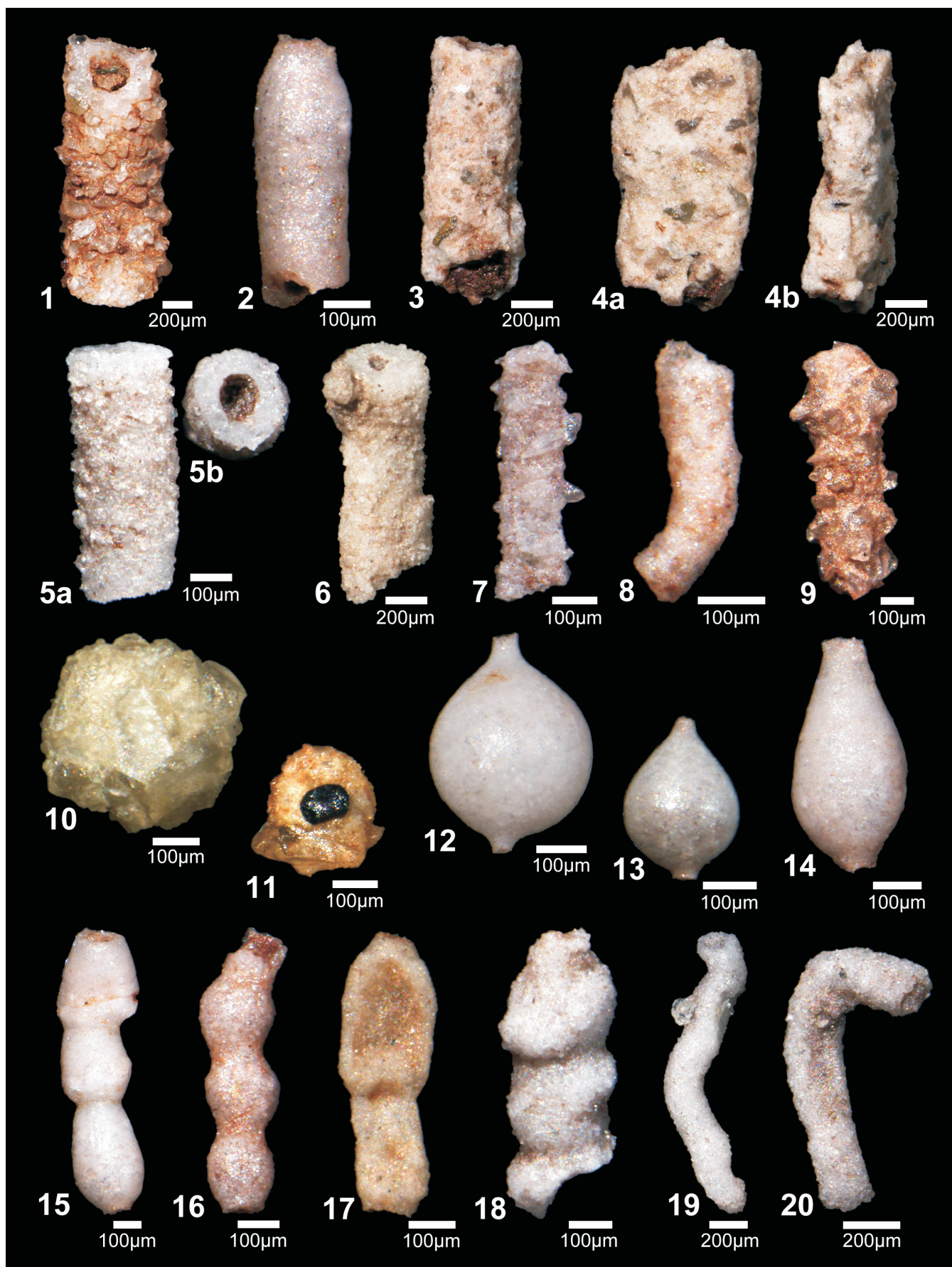
*Verneuilinoides perplexus* (Loeblich). – LOEBLICH and TAPPAN 1949, p. 91.

*Verneuilinoides* sp. aff. *perplexus* (Loeblich). – SETOYAMA, KAMINSKI and TYSZKA 2011a, p. 289, pl. 10, fig. 12; pl. 13, fig. 9a, b.

## PLATE 1

- |  |  |
|--|--|
| 1 <i>Rhabdammina</i> sp. A, 1760.25m.  | 11 <i>Psammosphaera fusca</i> , 1760.25m.    |
| 2 <i>Bathysiphon nodosariaformis</i> , 1760m.  | 12 <i>Caudammina ovula</i> , 1760m.          |
| 3 <i>Nothia</i> sp. A, 1760m. A specimen not flattened.                                      | 13 <i>Caudammina ovula</i> , 1760m.          |
| 4 <i>Nothia</i> sp. A, 1760m. A flattened specimen.  | 14 <i>Caudammina ovuloides</i> , 1760m.      |
| 5 <i>Psammosiphonella cylindrica</i> , 1761.7m. a) Lateral side view, b) Cross-section view. | 15 <i>Caudammina ovuloides</i> , 1760m.      |
| 6 <i>Psammosiphonella discreta</i> , 1761.3m.  | 16 <i>Subreophax aduncus</i> , 1760m.        |
| 7 <i>Rhizammina</i> sp. A, 1761.3m.  | 17 <i>Subreophax longicameratus</i> , 1760m. |
| 8 <i>Rhizammina</i> sp., 1762m.  | 18 <i>Subreophax scalaris</i> , 1761.33m.    |
| 9 <i>Hyperammina rugosa</i> , 1760m.   | 19 “ <i>Tolypammina</i> ” sp. A, 1761.7m.    |
| 10 <i>Psammosphaera fusca</i> , 1759.9m.   | 20 “ <i>Tolypammina</i> ” sp. A, 1761.7m.    |





**Description.** Test of small to medium size, tapered, triserial. Chambers increasing in size very rapidly. Sutures distinct, depressed. Wall finely agglutinated, smoothly finished. Aperture an interiomarginal high arch.

**Remarks.** This form was recorded in the Upper Cretaceous of the SW Barents Sea (Setoyama et al. 2011a).

***Verneuilinoides* sp. A**

**Description.** Test elongate, of small to medium size, triserial throughout, twisted. Chambers increasing in size rapidly as added. Sutures depressed. Wall finely agglutinated with much cement, smoothly finished. Aperture a basal, low arch.

**Remarks.** Differs from *Verneuilinoides* sp. aff. *perplexus* by its chambers that increase more rapidly in size and more tapered outline.

Order LOFTUSIIDA Kaminski and Mikhalevich 2004  
Suborder LOFTUSIINA Kaminski and Mikhalevich 2004  
Family CYCLAMMINIDAE Marie 1941  
Subfamily ALVEOLOPHRAGMIINAE Saidova 1981  
Genus *Popovia* Suleymanov 1965

***Popovia* spp.**

Plate 3, figures 14, 15

**Remarks.** Small planispiral specimens with an alveolar wall. They could be juveniles of *Popovia beckmanni* (Kaminski and Geroch 1987). A broken specimen illustrated (pl. 3, fig. 14) might be *P. beckmanni*.

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**PLATE 2**

- 1 *Ammodiscus cretaceus*, 1760m.
- 2 *Ammodiscus* sp. A, 1761.3m. a) Spiral view, dry, b) Spiral view, in immersion, c) edge view.
- 3 *Ammodiscus* sp. B, 1761.3m, in immersion.
- 4 *Glomospira diffundens*, 1760.25m.
- 5 *Glomospira diffundens*, 1760.25m.
- 6 *Glomospira irregularis*, 1760.25m.
- 7 *Glomospira irregularis*, 1760m.
- 8 *Lituotuba lituiformis*, 1761.3m.
- 9 *Paratrochaminoides gorayskii*, 1760m.
- 10 *Rzehakina epigona*, 1760m. a) Dry, b) in immersion.
- 11 *Rzehakina minima*, 1760m. a) Dry, b) in immersion.
- 12 *Kalamopsis grzybowskii*, 1760.25m.
- 13 *Kalamopsis* cf. *grzybowskii*, 1761.3m.
- 14 *Haplophragmoides eggeri*, 1762m. a) Lateral right view, b) Apertural view.
- 15 *Haplophragmoides stomatus*, 1760.25m. a) Lateral left view, b) Apertural view.
- 16 *Haplophragmoides* cf. *walteri*, 1762m. a) Lateral left view, b) Lateral right view in immersion, c) Apertural view.



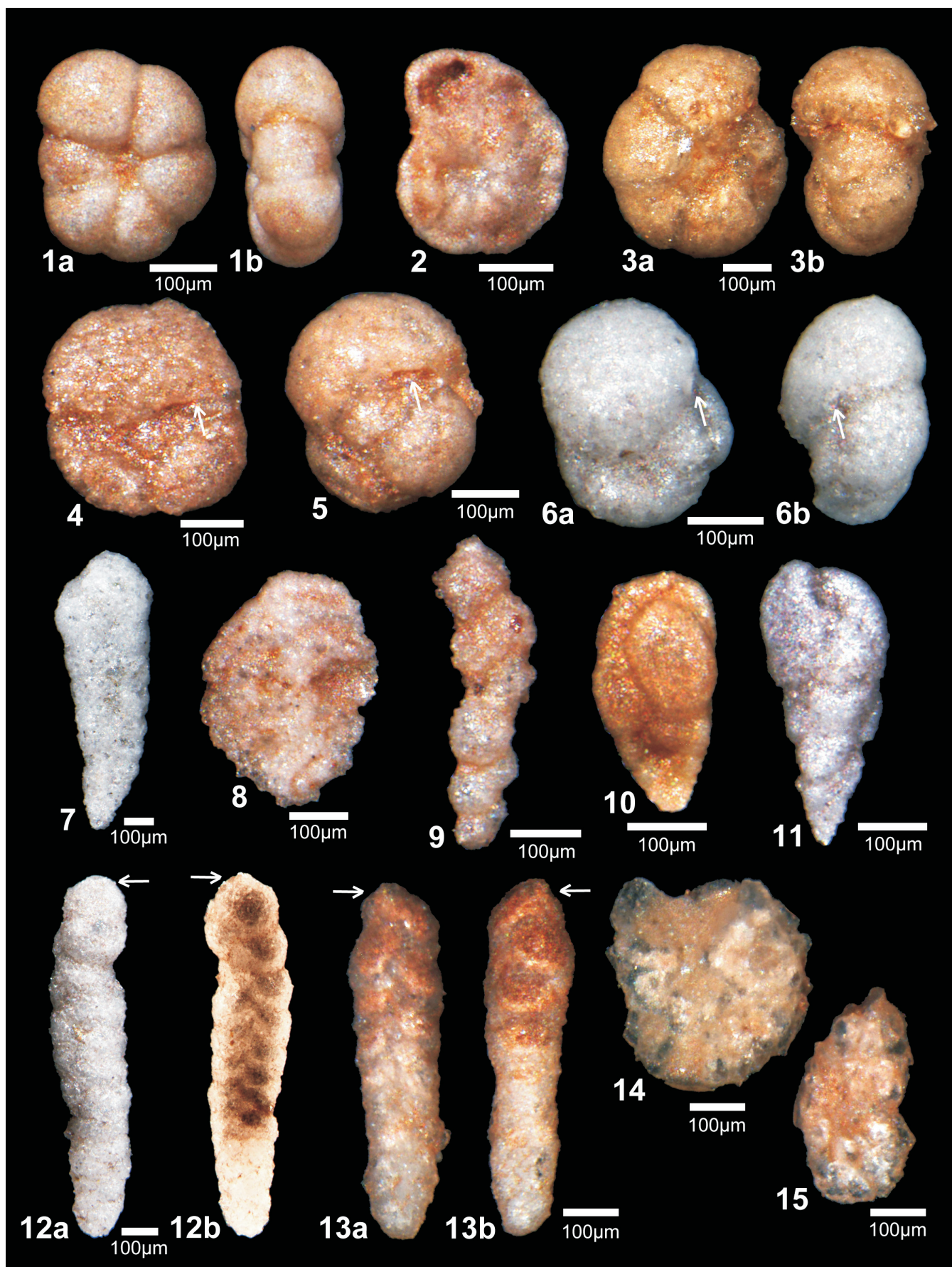


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### PLATE 3

- 1 *Haplophragmoides porrectus*, 1760.25m. a) Lateral left view, b) Apertural view.
- 2 *Haplophragmoides walteri*, 1760.25m.
- 3 *Recurvoidella* sp., 1760.25m. a) Lateral right view, b) Apertural view.
- 4 *Ammosphaeroidina pseudopauciloculata*, 1760.25m. Arrow indicates the aperture.
- 5 *Cystammina sveni*, 1760.25m. Arrow indicates the aperture.
- 6 *Cystammina sveni*, 1761.7m. Arrow indicates the aperture.
- 7 *Spiroplectammina navarroana*, 1761.8m.
- 8 *Spiroplectinella dentata*, 1760m.
- 9 *Parvigenerina* sp. 3, 1760m.
- 10 *Verneuilinoides* sp. aff. *perplexus*, 1760.25m.
- 11 *Verneuilinoides* sp. A, 1761.7m.
- 12 *Gerochammina stanislawi* 1761.7m. a) Dry, b) In immersion.
- 13 *Gerochammina stanislawi* 1760m. a) In immersion, b) In immersion.
- 14 *Popovia* sp., 1760m. In immersion.
- 15 *Popovia* sp., 1760m. In immersion.





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APPENDIX 1

Foraminiferal specimen counts for Well 6306/5-1.

	1762	1761.85	1761.7	1761.3	1760.9	1760.25	1760	1759.9	1759.7	1759.5	1759	1757.75	1757.3
<i>Ammodiscus cretaceus</i>	1	0	0	0	0	0	11	0	0	0	0	0	0
<i>Ammodiscus glabratus</i>	9	0	12	0	0	0	0	0	0	0	0	0	0
<i>Ammodiscus</i> sp. A	0	0	0	2	0	8	2	0	1	0	0	0	0
<i>Ammodiscus</i> sp. B	1	0	6	30	9	0	0	0	0	0	0	0	0
<i>Ammodiscus</i> spp.	5	0	3	11	1	1	0	2	4	0	1	0	0
<i>Ammosphaeroidina pseudopauciloculata</i>	0	0	0	8	0	3	3	0	0	0	0	0	0
<i>Bathysiphon nodosariaformis</i>	0	0	0	0	0	12	8	11	7	0	0	0	0
<i>Buzasina</i> sp.	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Caudammina ovula</i>	0	0	0	0	0	3	29	0	0	0	0	0	0
<i>Caudammina ovuloides</i>	0	0	0	0	0	0	10	0	0	0	0	0	0
<i>Cystammina sveni</i>	7	0	7	17	2	31	33	0	0	0	0	0	0
<i>Gerochammina stanislavi</i>	3	0	26	13	4	24	24	0	0	0	0	0	0
<i>Gerochammina</i> spp.	13	1	0	17	4	37	9	0	0	1	0	0	0
<i>Glomospira diffundens</i>	0	0	0	0	0	7	2	0	0	0	0	0	0
<i>Glomospira irregularis</i>	0	0	0	8	0	8	7	0	0	0	0	0	0
<i>Glomospira</i> spp.	5	0	30	11	5	5	0	0	0	0	0	0	0
<i>Haplophragmoides eggeri</i>	18	1	36	54	7	15	3	0	0	0	0	0	0
<i>Haplophragmoides porrectus</i>	4	0	0	5	0	8	0	0	0	0	0	0	0
<i>Haplophragmoides stomatus</i>	0	0	0	0	0	6	0	0	0	0	0	0	0
<i>Haplophragmoides walteri</i>	0	0	0	0	0	3	0	0	0	0	0	0	0
<i>Haplophragmoides</i> cf. <i>walteri</i>	4	0	3	0	0	0	0	0	0	0	0	0	0
<i>Haplophragmoides</i> spp.	9	2	3	15	25	0	1	0	0	0	0	0	0
<i>Hyperammina rugosa</i>	2	2	2	0	0	7	21	0	0	0	0	0	0
<i>Kalamopsis grzybowskii</i>	27	16	24	35	19	42	8	0	0	0	0	0	0
<i>Kalamopsis</i> cf. <i>grzybowskii</i>	0	0	0	7	0	0	0	0	0	0	0	0	0
<i>Lituotuba lituiformis</i>	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Nothia</i> sp. A	0	0	0	0	0	0	45	0	0	0	0	0	0
<i>Nothia</i> spp.	4	0	6	0	0	3	7	0	0	0	0	0	0
<i>Paratrochamminoides gorayskii</i>	2	0	0	2	0	3	5	1	0	0	0	0	0
<i>Paratrochamminoides heteromorphus</i>	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Paratrochamminoides</i> spp.	4	0	8	11	0	1	4	0	0	0	0	0	0
<i>Parvigenerina</i> sp. 3 (Kuhnt)	0	0	0	0	0	0	3	0	0	0	0	0	0
<i>Plectoeratidus subarcticus</i>	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Popovia</i> spp.	1	0	0	3	1	0	3	0	0	0	0	0	0
<i>Psammosiphonella cylindrica</i>	0	0	2	6	0	0	0	0	14	9	0	0	0
<i>Psammosiphonella discreta</i>	17	0	0	20	0	0	1	6	0	3	3	0	4
<i>Psammosphaera fusca</i>	0	0	0	0	0	2	0	5	0	0	0	0	0
<i>Pseudonodosinella</i> spp.	0	0	0	4	0	3	0	1	0	0	0	0	0
<i>Rashnovammina munda</i>	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Recurvoidella</i> sp.	0	0	0	0	0	2	0	0	0	0	0	0	0
<i>Recurvoides pseudononioninoides</i>	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Recurvoides</i> spp.	7	2	14	26	15	36	37	37	6	10	3	0	1
<i>Repmanina charoides</i>	3	0	2	11	1	0	6	0	3	0	0	0	0
<i>Rhabdammina</i> sp. A	1	2	0	0	0	3	0	0	0	0	0	0	0
<i>Rhabdammina</i> spp.	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>Rhizammina</i> sp. A	0	0	0	0	0	7	3	0	0	0	0	8	0
<i>Rhizammina</i> spp.	14	7	15	31	6	38	62	0	2	15	0	0	0
<i>Rzehakina epigona</i>	0	0	0	2	0	2	11	0	0	0	0	0	0
<i>Rzehakina minima</i>	0	0	0	0	0	0	5	0	0	0	0	0	0
<i>Spiroplectammina navarroana</i>	13	6	2	0	0	0	0	7	1	0	0	1	0
<i>Spiroplectammina specitabilis</i>	0	0	0	2	0	0	0	1	0	0	0	0	0
<i>Spiroplectinella dentata</i>	0	0	0	1	0	2	4	0	0	0	0	0	0
<i>Subreophax aduncus</i>	0	0	0	0	0	0	19	0	0	0	0	0	0
<i>Subreophax longicameratus</i>	0	0	0	6	1	1	11	0	0	0	0	0	0
<i>Subreophax scalaris</i>	0	0	1	5	0	2	0	1	0	0	0	0	0
<i>Subreophax</i> spp.	0	0	0	0	2	16	5	2	0	0	0	0	0
<i>Thalmanammina</i> spp.	0	0	1	0	0	3	0	0	0	0	0	0	0
<i>Tolypammina</i> sp. A	15	0	42	56	24	6	11	0	0	0	0	0	0
<i>Trochamminoides proteus</i>	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Verneuilinoides</i> cf. <i>perplexus</i>	1	0	0	3	0	3	1	0	0	0	0	0	0
<i>Verneuilinoides</i> sp. A	1	0	2	0	0	0	0	0	0	0	0	0	0
unidentified elongate forms	3	0	9	6	0	3	4	1	3	0	0	0	0
TOTAL	195	40	256	429	126	358	421	77	41	38	7	9	5