

Late Cretaceous–Paleogene foraminiferal morphogroups as palaeoenvironmental tracers of the rifted Labrador margin, northern proto-Atlantic

EIICHI SETOYAMA^{1,2}, MICHAEL A. KAMINSKI^{3,4} and JAROSŁAW TYSZKA¹

1. Institute of Geological Sciences, Polish Academy of Sciences, ul. Senacka 1, 30-002 Kraków, Poland.
2. Energy & Geoscience Institute, University of Utah, 423 Wakara Way, Suite 300, Salt Lake City, Utah 84108, USA; email: esetoyama@egi.utah.edu
3. GeoSciences Department, King Fahd University of Petroleum & Minerals, Dhahran, 31261, Saudi Arabia; email: kaminski@kfupm.edu.sa
4. AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, al. Mickiewicza 30, 30-059 Kraków, Poland

Abstract

Upper Cretaceous and Cenozoic foraminiferal assemblages from the Hopedale Basin in the Labrador Sea have been investigated with an interest in biostratigraphy, palaeobiogeography and palaeoenvironmental changes, which were largely controlled by Cretaceous rifting events and the latest Cretaceous–Eocene sea-floor spreading along the Labrador Margin. In the previous studies the quantitative data of the assemblages were not published due to their large data sets. This study investigates samples from the Upper Cretaceous–Paleogene recovered by the Indian Harbour M-52 well in the Hopedale Basin with the main objective of a palaeoenvironmental analysis of the foraminiferal assemblages using morphogroup analysis.

The Upper Cretaceous and Paleogene assemblages are highly diversified and dominated by deep-water agglutinated foraminifera (DWAF). A biostratigraphy of the investigated interval generally agree with previously published biozonation schemes for the Labrador Shelf and surrounding areas including the *Caudammina gigantea* Zone and the *Caudammina gigantea-Uvigerinammina jankoi* Concurrent Zone. The interval between 10,750 and 10,690 feet reported as the Valanginian–Albian volcanic Alexis Formation may belong to younger formations because the assemblages are highly diversified with Late Cretaceous DWAF.

The presence of all the morphogroups and the consistent dominance of tubular forms in the Upper Cretaceous and Paleogene suggest mesotrophic, relatively oxygenated environments with bottom currents. With regard to palaeobathymetry, the high diversity and the dominance of DWAF with abundant tubular forms indicate a bathyal setting for the Alexis and Markland formations. The assemblages of the Selandian to Ypresian Cartright Formation that exhibit similarity to the Eocene outer neritic–upper bathyal assemblages in the Barents Sea suggest regional shallowing which could be related to the Selandian–earliest Thanetian regression in the Labrador Sea region.

INTRODUCTION

The Labrador Sea was an arm of a seaway connecting the proto-North Atlantic and Arctic, possibly from Campanian–Maastrichtian time (Gradstein & Srivastava, 1980), with the Norwegian–Greenland Sea being the other one. The Upper Cretaceous–Cenozoic foraminifera and biostratigraphy of the Labrador Sea have been investigated by a series of studies (e.g., Berggren & Aubert, 1976; Gradstein & Berggren, 1981; Kaminski *et al.*, 1989; Gradstein *et al.*, 1994). These studies described important taxa for a regional biostratigraphy, their stratigraphic ranges, taxonomic composition of assemblages, and their significance as indicators for palaeoenvironmental changes, which were largely controlled by the Cretaceous rifting and the latest Cretaceous–Eocene sea-floor spreading along the Labrador margin. The region is also one of the “type localities” of well-known deep-water

agglutinated (DWAF) assemblages, such as the “flysch type” fauna (Gradstein & Berggren, 1981) and the high latitude slope DWAF biofacies (Kuhnt *et al.*, 1989). These previous biostratigraphic and taxonomic studies were, however, mostly focused on the Cenozoic foraminiferal assemblages, and a full taxonomic study of the Upper Cretaceous assemblages has not been published.

A detailed taxonomic and palaeoenvironmental analysis of the Upper Cretaceous–Paleogene foraminiferal assemblages of the Labrador Sea would improve our current understanding of the distribution of foraminifera as well as the geological and palaeoceanographic development of the western North Atlantic. In this light, this study describes Upper Cretaceous–Paleogene foraminiferal assemblages from the Indi-

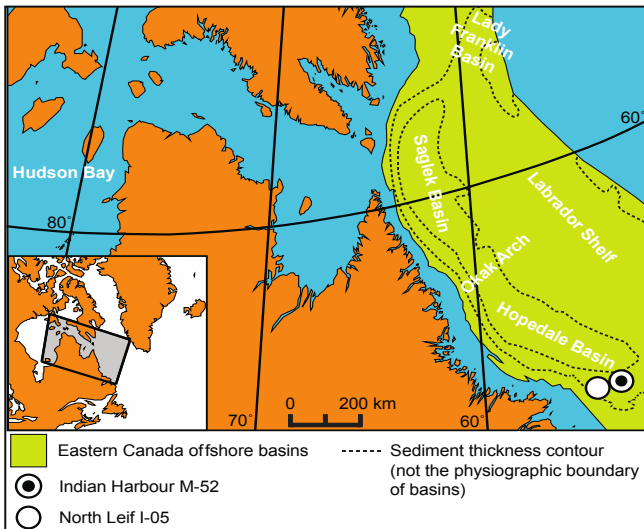


Figure 1. Schematic map with the location of the Indian Harbour M-52 well and North Leif I-05 well (modified after Mossop *et al.*, 2004).

an Harbour M-52 well with updated taxonomy and discusses their biostratigraphic distribution and palaeoenvironmental implications in the Hopedale Basin on Labrador Shelf.

Background Geology

The Hopedale Basin is the southernmost rift basin on the Labrador Shelf located to the south of the Saglek Basin, which is the other major basin on the shelf (Fig. 1). The Hopedale Basin includes three sub-basins, namely the Nain, Harrison, and Hamilton from the north to the south, and is bounded by the Okak Arch and an implied transfer zone to the north and by the Cartwright Transfer Fault Zone to the south (Enachescu, 2006a). The Precambrian and Paleozoic basement of the basin is overlain by the syn-rift volcanic Alexis Formation of Valanginian age (Dickie *et al.*, 2011) (Fig. 2). Rifting along the Labrador Margin started in the Early Cretaceous, possibly the earliest Valanginian (Dickie *et al.*, 2011), and continued until the onset of the sea-floor spreading, probably in Chron 33 of Campanian age (Roest & Srivastava, 1989; Srivastava & Roest, 1999) or Chron 31 (Chian *et al.*, 1995a), but not later than Chron 27 of Maastriichtian age (Danian) (Chalmers & Laursen, 1995; Chian *et al.*, 1995b; Chalmer & Pulvertaft, 2001), but not later than Chron 27 of Danian age (Chalmers & Laursen, 1995; Chian

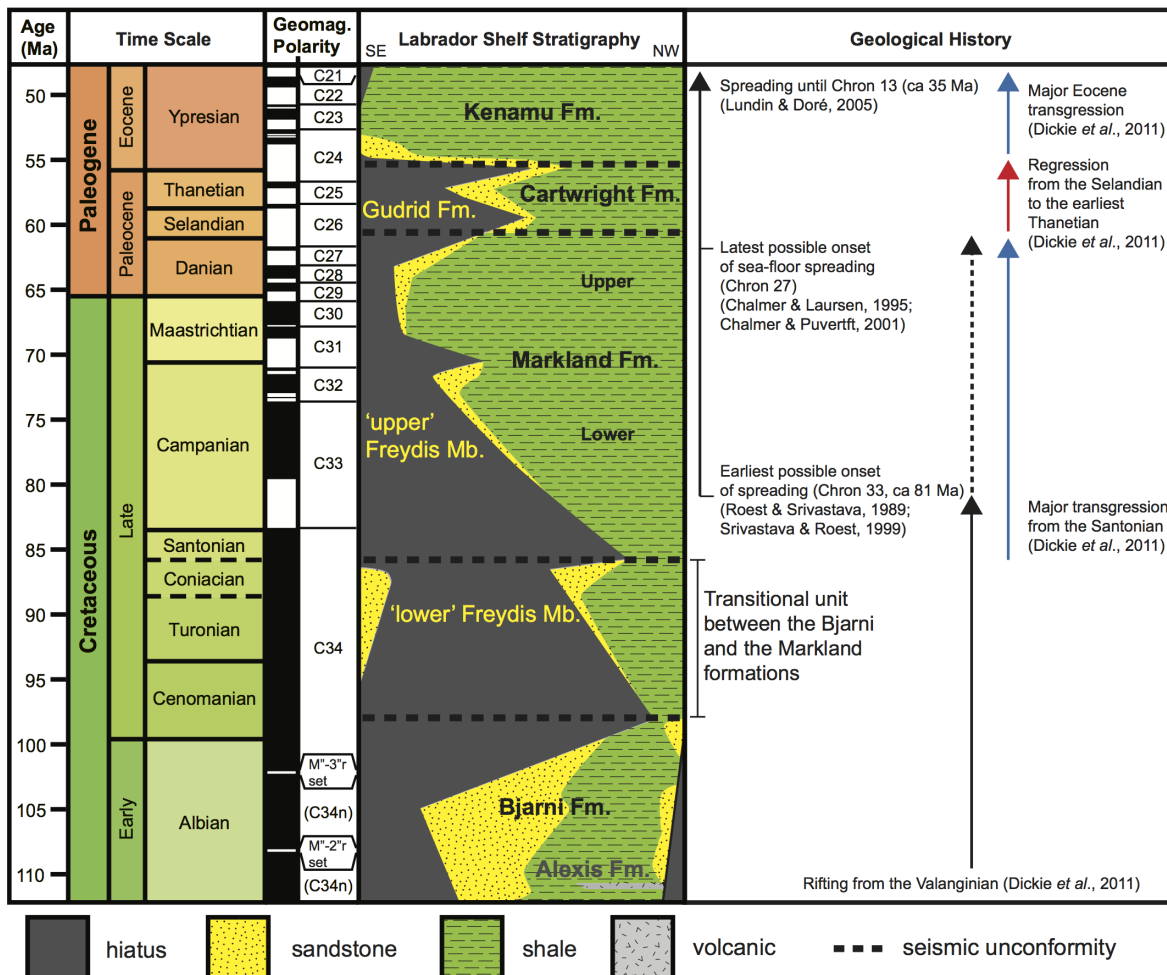


Figure 2. Lithostratigraphy of the Hopedale Basin and major geological and palaeoceanographic events (modified after Dickie *et al.*, 2011). The time scale is produced with TSCreator (<http://www.tscreator.org>).

et al., 1995b; Chalmer & Pulvertaft, 2001). The interval from the Early Cretaceous to the Campanian was a time of slower subsidence (Gradstein & Berggren, 1981; Dickie *et al.*, 2011), and the depositional setting of the Lower Cretaceous syn-rift clastic sediment, the Bjarni Formation, changes from nonmarine at its base to marginal marine to lagoonal, and becomes marine by the Albian (Dickie *et al.*, 2011). A first major transgression in the Labrador Sea started in the Santonian, and more rapid subsidence started in the Hopedale Basin in Campanian–Maastrichtian time. This was accompanied by rapid sedimentation of the Markland Formation in the basin, which represents deeper water environments (Gradstein & Berggren, 1981; Dickie *et al.*, 2011). These authors attributed the increased subsidence rate to the onset of the sea-floor spreading along the southern Labrador Sea. There is also a general trend in the Labrador Sea from the latest Cretaceous to the Eocene (Gradstein & Berggren, 1981) with a possible uplift in the Selandian caused by the Proto-Icelandic plume in the Davis Strait and a major regression beginning in the Selandian followed by another major transgression from the Ypresian (Dickie *et al.*, 2011).

Lithostratigraphy

The following description of the lithostratigraphy of the Labrador Shelf is summarised mainly after DeSilva (1999), Chalmers & Pulvertaft (2001) and Dickie *et al.* (2011). The basement of the Hopedale Basin is comprised of the Precambrian crystalline rocks and Paleozoic carbonates and clastics, a remnant of a Paleozoic shelf. The basement is overlain by the Valanginian–Albian Alexis Formation, which consists of altered basalts (Fig. 3). The synrift Bjarni Formation, comprised of sandstones and shales, ranges from the Hauterivian (Dickie *et al.*, 2011), or is possibly as old as the Upper Jurassic in undrilled deepest grabens (Enachescu, 2006b). The depositional environments of this formation were non-marine for the beginning and then marginal marine to lagoonal and finally became marine by the Albian (Dickie *et al.*, 2011). Chalmer & Pulvertaft (2001) suggested that the Upper Bjarni Member is predominantly nonmarine siltstones and shales with intercalated sandy beds of a deltaic to shallow marine environment. According to Dickie *et al.* (2011), there is a discontinuous and transitional unit between the Bjarni and Markland formations from the Cenomanian to the Coniacian. Sandstones of this interval are informally named the lower Freydis member and assigned to the Bjarni Formation. The beginning of the Markland Formation is related to the transgression on the Labrador shelf starting in the Santonian. This formation is dominated by marine shales, and deposited in thermally subsiding basins (Chalmers & Pulvertaft, 2001) or in a sag basin

environment on the proximal margin (Dickie *et al.*, 2011). The top of the Markland Formation is of Selandian age (middle Paleocene) in general, and is overlain by the Cartwright and Gudrid formations. The Selandian to Ypresian Cartwright Formation is dominated by shales (Chalmers & Pulvertaft, 2001; Dickie *et al.*, 2011) or comprised of marine clays and siltstones (DeSilva, 1999). The Gudrid Formation, contemporaneous with the Cartwright Formation, consists of sandstones. The Eocene shaly and silty Kanamu Formation overlies these two formations, and its deposition is related to the onset of a major transgression in the Ypresian (Dickie *et al.*, 2011).

The lithological data of Indian Harbour M-52 well are from Canada-Newfoundland and Labrador Offshore Petroleum Board (2008) and Wielens & Williams (2009) in this study (Fig. 3). Geochemical data for the Indian Harbour M-52 well are not available, and thus the total organic carbon (TOC) data for the formations considered in this study refer to the data from the North Leif I-05 well (Wielens & Williams, 2009), located about 55 km away from the Indian Harbour M-52 well to the west (Fig. 1). The TOC of the Mesozoic and Paleocene–Eocene sediment in the Hopedale Basin is relatively high, and generally ranges from 1% to over 5% in the Bjarni Formation, 1–3% in the Markland Formation, 2–4% in the Cartwright Formation, and 1–5% in the Kenamu Formation.

Previous Studies on Foraminifera

The foraminiferal assemblages from the Indian Harbour M-52 well were previously analysed by Gradstein & Berggren (1989), Miller *et al.* (1982), Kaminski (1987), and Gradstein *et al.* (1994), and the data have been integrated into other studies (e.g., Kaminski *et al.*, 1988; Kuhnt *et al.*, 1989). The highly diversified Maastrichtian–Paleocene agglutinated assemblages from this well is one of the “type” assemblages for the flysch-type fauna described by Gradstein & Berggren (1981), and Kuhnt *et al.* (1989) classified the Upper Cretaceous–Paleocene assemblages from M-52 well as the high latitude slope DWAF biofacies. Gradstein *et al.* (1994) estimated the palaeobathymetry to be upper bathyal (200–500 m) for the Maastrichtian–middle Eocene, whereas Miller *et al.* (1982) estimated to be upper bathyal (200–1000 m) in the Maastrichtian, deep neritic (100–200 m) in the Paleocene and upper bathyal in the early–middle Eocene. A regional biostratigraphy of the Paleocene–Pliocene was established by Gradstein *et al.* (1994) using quantitative biostratigraphic methods, recognising 11 LGR (Labrador-Grand Banks) zones.

MATERIALS AND METHODS

Materials

Foraminifera were examined in 25 picked faunal slides from the Indian Harbour M-52 well housed in the Former British Petroleum Microfossil Collection at the Natural History Museum, London, U.K. This set of samples is different from the one studied by Gradstein & Berggren (1981), Miller *et al.* (1982), Kaminski (1987), and Gradstein *et al.* (1994). Preparation methods and the size of sieve used are unexplained. Two length units, foot and meter, are used in this study because foraminiferal samples are labeled in feet, and the lithology has been reported in meters. From 10,300 feet, we have two samples, one is a ditch cutting and the other a side-wall core. These two samples are treated separately for analysis, but for a biostratigraphy, only the data from the side-wall core sample is included.

Illustration of Specimens

Photographs of specimens were taken with a Canon EOS500D digital camera mounted on a Nikon-1500 stereomicroscope at BioGeoLab, Cracow Reserch Centre, Institute of Geological Sciences, Polish Academy of Sciences, and stacked by a software CombineZP. SEM images of specimens were made using JEOL JSM-648OLV SEM at University College London, and JEOL JSM-5900 SEM at King Fahd University of Petroleum & Minerals in Dhahran, Saudi Arabia. Additionaly, for recurvoids and thalmanaminids, “rollograms” (see Bubík, 2000) were drawn to exhibit coiling modes of species following the methodology developed by Geroch (1962) and Bubík (1995, 2000).

Biodiversity Indices

Fisher alpha index (Fisher, 1943) was calculated as a measure of species diversity as well as species richness (the total number of species). Fisher alpha index is suggested to be less sensitive to variations in assemblage size (Magurran, 2004). The value of Fisher alpha index was computed with the PAST software (ver. 2.14) (Hammer *et al.*, 2001; Hammer & Harper, 2006).

Foraminiferal Morphogroup Analysis

The basic idea of morphogroup analysis is that species with different test shapes have different preferred habitats, which could be associated with their preferred feeding strategies, and thus preferred environments and that changes in the relative abundance of groups of similar test morphology would reflect environmental changes through time (Corliss,

1985; Jones & Charnock, 1985; Kaminski *et al.*, 1995; Murray *et al.*, 2011).

The morphogroup scheme for agglutinated foraminifera devised by Charnock & Jones (1985) has been modified and developed by subsequent authors (e.g., Båk *et al.*, 1997; Peryt *et al.*, 1997, 2004; van den Akker *et al.*, 2000; Murray *et al.*, 2011). A morphogroup scheme used in this study for agglutinated foraminifera follows Cetean *et al.* (2011a) that was modified for their study of Upper Cretaceous deep-water agglutinated foraminiferal assemblages.

As with agglutinated foraminifera, morphogroup schemes for calcareous benthic foraminifera were devised based on the distribution of modern taxa by Jones & Charnock (1985), and developed by others (e.g., Bernhard, 1986; Corliss & Chen, 1988; Alperin *et al.*, 2011). A morphogroup scheme for calcareous benthic foraminifera used in this study is after Frenzel (2000) which is an integration of previously published schemes including one by Koutsoukos & Hart (1990) that was developed after their detailed analysis of distribution patterns of Cretaceous foraminifera in the Sergipe Basin, Brasil.

Measurement of Tubular Forms

For the morphogroup analysis of agglutinated foraminifera, each fragment of tubular taxa is counted as one specimen after previous studies (e.g. Nagy *et al.*, 1995; Cetean *et al.*, 2011a). The cumulative length of tubular taxa is calculated for each sample in this study in an effort to quantify fragmented specimens following Kaminski & Kuhnt (1995) and to test wheather comparison of the relative abundance of M1 (tubular forms) between samples is reasonable. The cumulative length is standardised in sample size (100 specimens of all agglutinated foraminifera per sample) to allow comparison of assemblages of variable sizes (see Setoyama *et al.*, 2011b, 2013).

TAXONOMY

The taxonomy of benthic foraminifera is mainly based on the study of the Labrador Shelf fauna by Gradstein & Berggren (1981) and Gradstein *et al.* (1994), Britain and the North Sea fauna by Hart *et al.* (1989), King *et al.* (1989), and Charnock & Jones (1990), the North Atlantic fauna by Moullade *et al.* (1988), northern Mexican fauna by Alegret & Thomas (2001), Trinidad fauna by Cushman & Jarvis (1932), Kaminski *et al.* (1988), and Bolli *et al.* (1994), and the Tethyan fauna by Hanzlíková (1972), Geroch & Nowak (1984), Gawor-Biedowa (1992), and Bubík (1995). Additionally, the Ellis and Messina Catalog of Foraminifera (Ellis and Messina, 1940 +supplements) was also consulted.

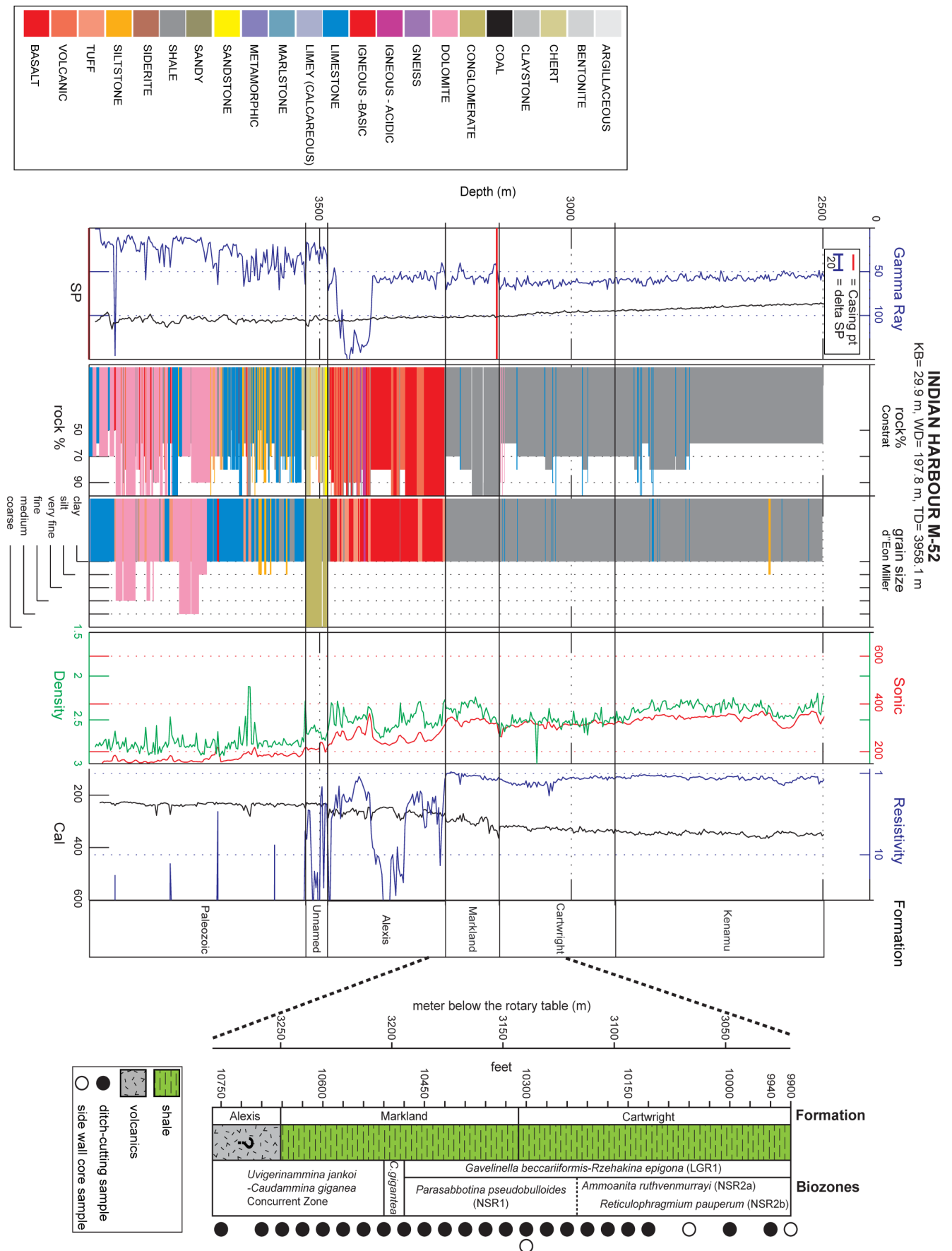


Figure 3. Lithology and geophysical data of Indian Harbour M-52 well with sample position (modified after Wielens & Williams, 2009).

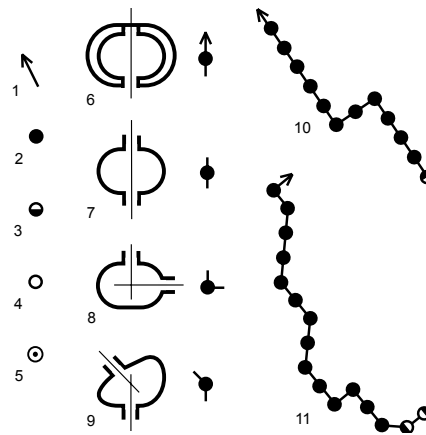


Figure 4. Symbols used in rollograms. 1: The direction of the aperture relative to the previous one. 2: Chamber fully visible on the test surface. 3: Chamber partially covered by later chambers. 4: Chamber visible, but covered by later chambers. 5: Proloculus. 6: The position and direction of aperture. 7: Straight coiling direction. 8: Change in coiling direction close to 90°. 9: Change in coiling direction between 90° and 180°. Coiling modes 10: Recurviform with abrupt changes of coiling direction after straight segments. 11: Thalmannammini-form with meandering coiling direction (after Bubík, 1995, 2000).

Ammoanita ruthvenmurrayi (Cushman & Renz, 1946)

Plate 4, fig. 2a–c

Trochammina ruthvenmurrayi Cushman & Renz, 1946, p. 24, pl. 3, fig. 13a–c.

Trochammina (Ammoanita) ruthvenmurrayi Cushman & Renz. – Charnock & Jones, 1990, p. 186, pl. 10, figs 4–9; pl. 22, fig. 2 (with synonymy).

Ammoanita ruthvenmurrayi (Cushman & Renz). – Kaminski & Gradstein, 2005, p. 455, pl. 111, figs 1–4.

Description. Test trochospiral, with convex spiral side and only slightly convex umbilical side, periphery acute to subacute, with seven to eight chambers in the last whorl, umbilicus closed. Chambers increasing slowly in size. Sutures curved backwards on the spiral side, more distinct, depressed, straight on the umbilical side. Wall finely agglutinated, smoothly finished. Aperture small interiomarginal, extraumbilical, often indistinct.

Remarks. Differs from *Ammoanita ingerlisae* Gradstein & Kaminski by its more convex spiral side, less convex umbilical side, more whorls and less acute periphery.

Ammoanita spp.

Remarks. Highly deformed, medium to large specimens which are trochospirally coiled with more than several chambers per whorl. Specimens of *Ammoanita ruthvenmurrayi* may well be included.

Ammobaculites spp.

Plate 2, fig. 4

Description. More than a few different forms of *Ammobaculites* are observed.

Ammodiscus cretaceus (Reuss, 1845)

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

Ammodiscus cretaceus (Reuss). – Kaminski & Gradstein, 2005, p. 145, pl. 14, figs 1a–10 (with synonymy).

Ammodiscus glabratus Cushman & Jarvis, 1928

Ammodiscus glabratus Cushman & Jarvis, 1928, p. 87, pl. 12, fig. 6a, b. – Kaminski & Gradstein, 2005, p. 148, pl. 15, figs 1a–6.

Ammodiscus latus Grzybowski, 1898

Ammodiscus latus Grzybowski, 1898, p. 282, pl. 10, figs 27, 28. – Kaminski & Gradstein, 2005, p. 150, pl. 16a, figs 1a–8; pl. 16b, figs 1–6.

Ammodiscus peruvianus Berry, 1928

Ammodiscus peruvianus Berry, 1928, p. 392, fig. 27. – Kaminski & Gradstein, 2005, p. 157, pl. 18, figs 1–6.

Ammodiscus cf. *planorbis* Höglund, 1947

Ammodiscus planorbis Höglund, 1947, p. 125, pl. 8, figs 4, 9; pl. 28, figs 13–16; textfigs 91, 92, 109.

Ammodiscus cf. *planorbis* Höglund. – Setoyama *et al.*, 2011a, p. 266, pl. 3, fig. 8.

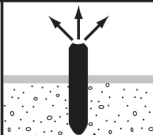
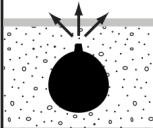
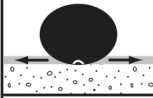

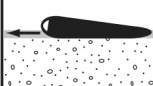



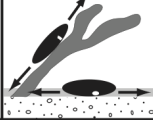
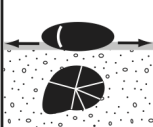
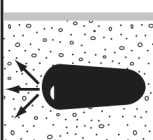
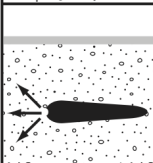
Morpho-group	Morpho-type	Test Form	Life position	Feeding habit	Environment	Main genera
M1		Tubular	Erect epifauna	Suspension feeding	Tranquil bathyal and abyssal with low organic flux	<i>Bathysiphon</i> <i>Kalamopsis</i> <i>Nothia</i> <i>Psammosiphonella</i> <i>Rhizammina</i>
M2	M2a 	Globular	Shallow infauna	Suspension feeding and/or Passive deposit feeding	Common in bathyal and abyssal	<i>Caudammina</i> <i>Hyperammina</i> <i>Placentammina</i> <i>Psammospaera</i> <i>Saccammina</i>
	M2b  	Rounded trochospiral and streptospiral	Surficial epifauna	Active deposit feeding	Shelf to deep marine	<i>Cribrostomoides</i> <i>Recurvoides</i> <i>Thalmanammina</i>
		Planoconvex trochospiral				
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	<i>Ammonoanita</i>
		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	<i>Ammolagena</i>
M3c 	Flattened streptospiral	Surficial epifauna	Active and passive deposit feeding	Upper bathyal to abyssal	<i>Ammosphaeroidina</i> <i>Praecystammina</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>Evolutinella</i> <i>Haplophragmoides</i> <i>Popovia</i> <i>Reticulophragmoides</i>
	M4b  	Elongate subcylindrical	Deep infauna	Active deposit feeding	Inner shelf to upper bathyal with increased organic matter flux	<i>Gerochammina</i> <i>Hormosina</i> <i>Karrerulina</i> <i>Praedorothia</i> <i>Protomarssonella</i> <i>Verneuilinoides</i>
Elongate tapered		<i>Ammobaculites</i> <i>Bicazammina</i> <i>Eobigenerina</i> <i>Rashnovammina</i> <i>Reophax</i> <i>Subreophax</i>				

Figure 5. Agglutinated foraminiferal morphogroups and morphotypes (modified after Cetean *et al.*, 2011a).













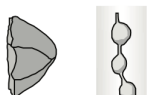
Morpho-group	Morphotype		Test form	Life position	Feeding habit	Main genera
A	1		conical, trochospiral periphery broadly rounded	epifauna	active deposit feeding	<i>Globorotalites</i> , <i>Gyroidinoides</i> , <i>Quadriformina</i>
	2		planoconvex, trochospiral periphery slightly angular to rounded one side maybe coarsely perforate	epifauna (and grazing herbivore)	active deposit feeding	<i>Brotzenella</i> , <i>Cibicidoides</i> , <i>Gavelinella</i> , <i>Stensioeina</i>
	3		biconvex, lenticular trochospiral to planispiral one side maybe coarsely perforate	epifauna	active deposit feeding	<i>Angulogavelinella</i> <i>Lenticulina</i> <i>Saracenaria</i>
	4		planispiral flattened	epifauna	active deposit feeding	not recorded in this study (e.g. <i>Spirillina</i>)
	5		planispiral to uniserial flattened palmate to subtriangular	epifauna / shallow infauna	deposit feeding	<i>Astacolus</i>
B	1		elongate cylindrical	epifauna/ infauna	deposit feeding	<i>Nodosaria</i> <i>Pyramidulina</i> <i>Ramulina</i>
	2		planispiral to low trochospiral rounded coarsely perforate	infauna	active deposit feeding	<i>Anomalinoidea</i>
	3		spherical	infauna	active deposit feeding	<i>Lagena</i> <i>Oolina</i> <i>Pullenia</i>
	4		elongate pyramidal to conical	infauna	active deposit feeder	<i>Praeglobbulimina</i> <i>Reussella</i>
	5		wedge-shaped flattened	infauna	active deposit feeder	<i>Coryphostomella</i>
	6		ovoidal	infauna	active deposit feeder	<i>Allomorphina</i> <i>Guttulina</i>
	7		low trochospiral to almost planispiral flattened, almost lenticular periphery acute with/without keel bilaterally almost symmetrical	infauna	active deposit feeder	<i>Osangularia</i>
C	1-5			epifauna, sessile		not recorded in this study (e.g. <i>Cibicides</i> , <i>Bullopora</i>)

Figure 6. Calcareous benthic foraminiferal morphogroups and morphotypes (modified after Frenzel, 2000)

Remarks. The same form was observed in the Upper Cretaceous of the SW Barents Sea (Setoyama *et al.*, 2011a).

Ammodiscus sp. 4

Plate 3, fig. 2a, b

Ammodiscus sp. 4 Setoyama *et al.*, 2011a, p. 267, pl. pl. 2, fig. 15.

Remarks. This slightly irregularly planispiral form was also observed in the SW Barents Sea (Setoyama *et al.*, 2011a).

Ammodiscus sp. 5

Ammodiscus sp. 5 Setoyama *et al.*, 2011a, p. 267, pl. 2, fig. 16a, b.

Remarks. The same form was observed in the SW Barents Sea (Setoyama *et al.*, 2011a).

Ammodiscus spp.

Remarks. A large number of broken specimens are recorded. More than a few different forms are observed.

Ammogloborotalia sp. 1

Plate 4, fig. 3a–c

Description. Test of medium size, planoconvex with a slightly convex umbilical side, seven chambers per whorl, periphery rounded, umbilicus slightly depressed. Chambers increasing in size gradually. Sutures slightly depressed, appear thick in immersion, indistinct due to rough test surface, curved backwards on both spiral and umbilical sides. Wall medium coarsely agglutinated, roughly finished. Aperture basal, indistinct.

Remarks. Differs from the genus *Ammoanita* by its flat spiral side, and from the genus *Insculptarenula* by its rounded periphery rather than an angular keel-like periphery.

Ammolagena contorta Waters, 1927

Plate 1, fig. 2

Ammolagena contorta Waters, 1927, p. 132, pl. 22, fig. 4.

Ammolagena sp. 1 Setoyama *et al.*, 2011a, p. 268, pl. 3, fig. 4.

Remarks. Differs from *Ammolagena clavata* (Jones & Parker) by its smaller proloculus, which is barely wider than the tubular chamber. This species was recorded in the Upper Cretaceous of the SW Barents Sea (Setoyama *et al.*, 2011a) and the Vøring Basin, offshore Norway (ES personal observation).

Ammolagena spp.

Plate 1, fig. 1

Remarks. Attached tubular forms without a proloculus. They are most likely tubular chambers of *A. contorta* because *Ammolagena clavata* is not observed in this study.

Ammomarginulina aubertae Gradstein & Kaminski, 1989

Ammomarginulina aubertae Gradstein & Kaminski, 1989, p. 74, pl. 3, figs 1–8; pl. 4, figs 1–3; textfig. 2

Ammosphaeroidina pseudopauciloculata (Mjatluk, 1966)

Cystamminella pseudopauciloculata Mjatluk, 1966, p. 246, pl. 1, figs 5–7; pl. 2, fig. 6; pl. 3, fig. 3.

Ammosphaeroidina pseudopauciloculata (Mjatluk). – Kaminski *et al.*, 1988, p. 193, pl. 8, figs 3a–5. – Kaminski & Gradstein, 2005, p. 376, pl. 87a, figs 1a–5; pl. 87b, figs 1a–10 (with synonymy).

Arenobulimina dorbignyi (Reuss, 1845)

Plate 2, fig. 13a, b

Bulimina dorbignyi Reuss, 1845, p. 38, pl. 13, fig. 74.

Arenobulimina dorbignyi (Reuss). – Kaminski *et al.*, 1988, p. 194, pl. 8, fig. 9. – Kuhnt & Urquhart, 2001, p. 46, pl. 4, figs 13, 14.

Remarks. Peryt *et al.* (1997) reported it from the *Abathomphalus mayaroensis* Zone (upper Maastrichtian) to the *Parvuloglobigerina eugubina* Zone (Danian) in the Eastern Alps. Gradstein *et al.* (1994) reported its last occurrence in the *Subbotina pseudobulloides* (NSR 1) Zone (lower Paleocene) in the North Sea. Kuhnt & Urquhart (2001) reported it from the *Caudamina gigantea* Zone (Maastrichtian) in the Iberia abyssal plain.

Arenobulimina spp.

Remarks. Elongate specimens with intercameral sutures oblique to the axis of coiling. Many of them are partially broken.

Arthrodendron spp.

Remarks. All the specimens are found as a single-chamber fragment.

Bathysiphon nodosariaformis Subbotina, 1950

Plate 1, fig. 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 *et al.*, 2011a, p. 269, pl. 1, fig. 4.

Budashevaella multicamerata (Voloshinova & Budasheva, 1961)

Plate 2, fig. 6

Circus multicameratus Voloshinova & Budasheva, 1961, p. 201, pl. 7, figs 6a–c; pl. 8, figs 1a–c, 6a–c.

Budashevaella multicamerata (Voloshinova). – Kaminski & Gradstein, 2005, p. 386, pl. 90, figs 1–6.

Remarks. This form can be distinguished by its finely agglutinated, smooth wall and numerous chambers (> 10) in the final whorl. The wall of many specimens is very dark brown in colour.

Budashevaella trinitatensis (Cushman & Renz, 1946)

Haplophragmoides flagleri Cushman & Hedberg var. *trinitatensis* Cushman & Renz, 1946, p. 18, p. 2, figs 2, 3.

Budashevaella trinitatensis (Cushman & Renz). – Kaminski *et al.*, 1988, p. 188, pl. 5, fig. 2a–b; pl. 10, figs 2, 3. – Kaminski & Gradstein, 2005, p. 389, pl. 91, figs 1a–6b.

Remarks. Differs from *B. multicamerata* by its smaller dimensions, more involute coiling and fewer chambers in the final whorl (6.5–8.5 chambers rather than 10–18 chambers).

***Budashevaella* spp.**

Remarks. Broken specimens of the genus with a typical smooth wall which is dark brown in colour in the studied material.

***Bulbobaculites* sp. 1**

Plate 4, fig. 1a–c

Description. Test robust, large with a few initial streptospiral whorls and one large last chamber. Six chambers externally visible in the streptospiral part. Chambers inflated, increasing rapidly in size. Suture distinct, depressed. Wall thick, coarsely agglutinated, roughly finished. Aperture terminal, circular, surrounded by a rim.

***Buzasina pacifica* (Krasheninnikov, 1973)**

Labrospira pacifica Krasheninnikov, 1973, p. 209, pl. 2, figs 4, 5.

Buzasina pacifica (Krasheninnikov). – Kaminski & Gradstein, 2005, p. 336, pl. 73, figs 1–5.

***Buzasina* spp.**

Remarks. Small, planispirally coiled specimens with three to four chambers in the final whorl are included.

***Caudammina* cf. *excelsa* (Dylążanka, 1923)**

Caudammina excelsa (Dylążanka). – Nagy *et al.*, 1997, pl. 3, fig. 4. – Kaminski & Gradstein, 2005, p. 230, pl. 40, figs 6–8.

Caudammina cf. *excelsa* (Dylążanka). – Setoyama *et al.*, 2011a, p. 270, pl. 4, figs 9, 10.

Remarks. The same species was observed in the Upper Cretaceous of the SW Barents Sea (Setoyama *et al.*, 2011a) and the Vøring Basin, offshore Norway (ES personal observation).

***Caudammina gigantea* (Geroch, 1960)**

Plate 1, fig. 14

Hormosina ovulum (Grzybowski) var. *gigantea* Geroch, 1960, p. 43, pl. 2, figs 18, 19.

Hormosina gigantea Geroch. – Bubík, 1995, p. 82, pl. 9, fig. 2.

Caudammina gigantea (Geroch). – Bąk, 2004, p. 27, pl. 4, figs 1–3.

Remarks. A number of intermediate forms between *C. gigantea* and *C. ovula* were observed in our material. Those specimens are included in *C. ovula* in this study.

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

Plate 1, fig. 15

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

Hormosina ovulum ovulum (Grzybowski). – Kaminski *et al.*, 1988, p. 186, pl. 2, fig. 10 (with synonymy).

Caudammina ovula (Grzybowski). – Kaminski & Gradstein, 2005, p. 233, pl. 41, figs 1a–8 (with synonymy).

***Caudammina ovuloides* (Grzybowski, 1901)**

Plate 1, fig. 16

Reophax ovuloides Grzybowski, 1901, p. 233, pl. 8, fig. 3.

Caudammina ovuloides (Grzybowski). – Kaminski & Gradstein, 2005, p. 238, pl. 42, figs 1a–7 (with synonymy).

***Caudammina* spp.**

Remarks. Broken specimens of globular forms with a typical thick smooth wall.

***Conglophragmium irregularis* (White, 1928)**

Trochamminoides irregularis White, 1928, p. 307, pl. 42, fig. 1.

Conglophragmium irregularis (White). – Kaminski & Gradstein, 2005, p. 284, pl. 57, figs 1–6.

***Conotrochammina whangaia* Finlay, 1940**

Plate 4, fig. 5a, b

Conotrochammina whangaia Finlay, 1940, p. 448, pl. 62, figs 1, 2.

– Kaminski & Gradstein, 2005, p. 463, pl. 1–7.

Remarks. This species can be distinguished from other trochamminids by its high trochospire, coarsely agglutinated wall and areal aperture. Differs from *Recurvoides* by its trochospiral coiling mode without a sudden change in coiling direction.

***Cribrostomoides subglobosus* (Cushman, 1910)**

Plate 2, fig. 7a–c

Lituola subglobosa M. Sars, 1869 (nomen nudum)

Haplophragmoides subglobosum (Sars). – Cushman, 1910, p. 105, figs 162–164.

Cribrostomoides subglobosus (Cushman) forma *subglobosus*. – Jones *et al.*, 1993, pl. 1, figs 1–5; pl. 2, figs 6–8; pl. 3, figs 1–7. – Kaminski & Gradstein, 2005, p. 391, pl. 92, figs 1–3.

Remarks. Differs from ?*Cribrostomoides trinitatensis* Cushman & Jarvis by its larger dimensions, narrower test and a single interio-areal to areal aperture.

?*Cribrostomoides trinitatensis* Cushman & Jarvis, 1928

Plate 2, figs 8, 9

Crirostomoides trinitatensis Cushman & Jarvis, 1928, p. 91, pl. 12, fig. 12a–b. – Kaminski *et al.*, 1988, p. 188, pl. 6, figs 1a–2b (with synonymy).

“*Crirostomoides*” *trinitatensis* Cushman & Jarvis. – Kaminski & Gradstein, 2005, p. 396, pl. 93, figs 1a–7.

?*Crirostomoides trinitatensis* Cushman & Jarvis. – Setoyama *et al.*, 2011a, p. 270, pl. 11, fig. 5.

Remarks. Most of specimens found in the Indian Harbour M-52 well are much smaller than its typical specimens, and very well silicified as illustrated by Kaminski & Gradstein (2005; pl. 93, figs 6, 7). Although specimens are well-preserved, interiomarginal multiple apertures were not observed under SEM.

Crirostomoides spp.

Remarks. Broken specimens with the slightly irregular planispiral coiling mode with an interio-areal aperture.

Cyclammina spp.

Plate 5, fig. 4a, b

Description. Test large, planispiral, involute with numerous low chambers. Sutures radial, sinuous, slightly depressed. Wall thick, alveolar, finely agglutinated, surface somewhat rough. Aperture multiple, interiomarginal and areal.

Remarks. All the specimens are broken.

Cystammina spp.

Remarks. Specimens with slightly elongated chambers, but not as elongated as *Cystammina pauciloculata* (Brady).

?*Dorothia* sp.

Description. Test of medium size, trochospiral with three chambers per whorl with one last biserial whorl. Chambers inflated, increasing rapidly in size. Suture distinct, depressed. Wall thick, canaliculated. Aperture pore-like at the base of the last chamber.

Remarks. This specimen differs from *Clavulinoides* by possessing the biserial whorl. However, it does not fit to *Dorothia* which has more than four chambers per whorl in the initial trochospiral portion.

Eobigenenerina variabilis (Vašíček, 1947)

Eobigenenerina variabilis Vašíček, 1947, p. 246, pl. 1, figs 10–12.

Eobigenenerina variabilis (Vašíček). – Cetean *et al.*, 2011b, p. 22, pl. 1, figs 1–12 (with synonymy).

Eratidus gerochi Kaminski & Gradstein, 2005

Eratidus gerochi Kaminski & Gradstein, 2005, p. 339, pl. 74, figs 1–11.

Remarks. Kaminski & Gradstein (2005) reported it from the lower Eocene to the lower Oligocene in the Canadian Arctic, the Labrador Sea, the Polish Carpathians and Moravia. It differs from *Plectoeratidus subarcticus* Kaminski, Setoyama & Tyszka by lacking the biserial portion.

Evolutinella rotulata (Brady, 1881)

Plate 2, figs 1, 2

Lituola (Haplophragmium) rotulatum Brady, 1881, p. 50, pl. 34, figs 5, 6.

Evolutinella rotulata (Brady). – Charnock & Jones, 1990, p. 169, pl. 5, figs 8, 9.; pl. 16, fig. 5. – Kender *et al.*, 2008, p. 124, pl. 4, fig. 4a, b.

Description. Test of medium size, planispiral, evolute, periphery wide, not rounded, umbilici deep, with six to eight chambers in the final whorl. Chambers subrectangular, increasing gradually in size. Sutures straight, depressed, but sometimes indistinct due to its rough, coarsely agglutinated wall. Aperture basal.

Remarks. This recent species is reported from the lower-middle Eocene of the North Sea (Charnock & Jones, 1990), from the Oligocene of the Congo Fan offshore Angola (Kender *et al.*, 2008), and from the upper Oligocene–middle Eocene Mackenzie Basin sequence of the Beaufort-Mackenzie Basin (Schröder-Adams & McNeil, 1994) in the fossil record.

Gerochammina lenis (Grzybowski, 1896)

Plate 4, fig. 6

Spiroplecta lenis Grzybowski, 1896, p. 288, pl. 9, figs 24, 25.

Spiroplecta deflexa Grzybowski, 1896, p. 288, pl. 9, figs 26, 27.

Gerochammina lenis (Grzybowski). – Neagu, 1990, p. 260, pl. 2, figs 22–32, p. 254, pl. 4, figs 28–31. – Setoyama *et al.*, 2011a, p. 271, pl. 10, fig. 7; pl. 11, fig. 15a–c.

Remarks. This species differs from *Karrerulina conversa* (Grzybowski, 1901) by being more robust, possessing a longer trochospiral portion and an areal aperture without a prominent apertural neck.

Gerochammina obesa Neagu, 1990

Plectina grzybowskii Neagu, nom. nov., 1962, p. 64, pl. 2, figs 30–33.

Gerochammina obesa Neagu, 1990, p. 260, pl. 2, figs 1–21. – Setoyama *et al.*, 2011a, p. 272, pl. 10, fig. 5a, b; pl. 11, fig. 16a, b.

?*Gerochammina* sp. 1

Description. Test robust, elongate, with the first 5–6 whorls coiled quadriserally followed by a triserial portion with three to four whorls and a final biserial portion with one to three whorls. Chambers subrectangular to oval, increasing in size slowly in the initial quadriserial stage, but more rapidly in the later triseial and biserial stages; chambers in the triserial and biserial stages become more inflated. Sutures slightly depressed. Wall medium coarsely agglutinated, finish rough. Aperture an oval to circular opening, basal to areal.

Remarks. This form closely resembles *G. lenis*, but differs by possessing the initial quadriseial and triserial stages in which chambers are nicely aligned rather than the trochospiral stage with four to five chambers followed by a high trochospiral portion which gradually becomes biserial. Differs from *Karrerulina coniformis* (Grzybowski) by possessing a basal to areal aperture and a longer trochospiral portion. The genus *Gaudryina* differs from this form by its initial triserial portion which is triangular in cross section.

Gerochammina spp.

Remarks. Specimens with an initial trochospiral portion with more than four chambers per whorl and a basal to areal aperture are included.

Glomospira diffundens Cushman & Renz, 1946

Plate 1, fig. 9

Glomospira gordialis (Jones & Parker) var. *diffundens* Cushman & Renz, 1946, p. 15, pl. 1, fig. 30.

Glomospira gordialis diffundens Cushman & Renz. – Hemleben & Troester, 1984, p. 519, pl. 1, fig. 21. – Kaminski & Gradstein, 2005, p. 175, pl. 23, figs 1–9.

Glomospira gordialis (Jones & Parker, 1860)

Plate 1, fig. 10

Trochammina squamata (Jones & Parker) var. *gordialis* Jones & Parker, 1860, p. 292–307 (no type figure given).

Glomospira gordialis (Jones & Parker). – Berggren & Kaminski, 1990, p. 73, pl. 1, fig. 1. – Kaminski & Gradstein, 2005, p. 181, pl. 25, figs 1–8.

Glomospira irregularis (Grzybowski, 1898)

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

Glomospira? irregularis (Grzybowski). – Hemleben & Troester, 1984, p. 519, pl. 1, fig. 22.

Glomospira irregularis (Grzybowski). – Kaminski & Geroch, 1993, p. 256, pl. 6, figs 6–8b.

“*Glomospira*” *irregularis* (Grzybowski). – Kaminski & Gradstein, 2005, p. 185, pl. 26, figs 1a–7 (with synonymy).

Glomospira spp.

Remarks. Broken streptospirally coiled tubular specimens are included.

Haplophragmoides eggeri Cushman, 1926

Haplophragmoides eggeri Cushman, 1926, p. 583, pl. 15, fig. 1a, b. – Kaminski & Gradstein, 2005, p. 342, pl. 75, figs 1–6.

Remarks. According to Kaminski & Gradstein (2005), it differs from *H. stomatus* (Grzybowski) by its coarser agglutination and depressed umbilical area and possessing a low apertural face.

Haplophragmoides herbichi Neagu, 1968

Haplophragmoides herbichi Neagu 1968, p. 238, pl. 1, figs 9–12. – Bubík, 1995, p. 104, pl. 3, figs 6a, b, p. 113, pl. 12, figs 6–8.

Haplophragmoides horridus (Grzybowski, 1901)

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

Haplophragmoides horridus (Grzybowski). – Kaminski & Gradstein, 2005, p. 347, pl. 77, figs 1–6.

Remarks. Differs from the other species of *Haplophragmoides* by its last large triangular chambers.

Haplophragmoides kirki Wickenden, 1932

Plate 2, fig. 3

Haplophragmoides kirki Wickenden, 1932, p. 85, pl. 1, fig. 1. – Kaminski & Gradstein, 2005, p. 351, pl. 78, figs 1a–6b.

Haplophragmoides nauticus Kender, Kaminski & Jones, 2006

Haplophragmoides nauticus Kender, Kaminski & Jones, 2006, p. 468, pl. 2, figs 1, 2.

Remarks. Only broken large specimens of the species with typical trapezoidal chambers and an acute, keel-like periphery were observed.

Haplophragmoides porrectus Maslakova, 1955

Haplophragmoides porrectus Maslakova, 1955, p. 47, pl. 3, figs 5, 6. – Kaminski *et al.*, 1988, p. 189, pl. 5, figs 7, 8. – Kaminski & Gradstein, 2005, p. 353, pl. 79, figs 1a–6.

Haplophragmoides stomatus (Grzybowski, 1899)

Trochammina stomata Grzybowski, 1898, p. 290, pl. 11, figs 26–27.

Haplophragmoides stomatus (Grzybowski). – Kaminski & Geroch, 1993, p. 311, pl. 11, figs 1–2. – Kaminski & Gradstein, 2005, p. 357, pl. 80, figs 1–6.

Remarks. Differs from *Haplophragmoides glabratus* Cushman & Waters by its finely agglutinated wall and rounded periphery, from *Haplophragmoides walteri* (Grzybowski) by its thicker and rounded periphery.

Haplophragmoides suborbicularis (Grzybowski, 1896)
emend. Kaminski & Gradstein, 2005

Cyclammina suborbicularis Grzybowski, 1896, p. 284, pl. 9, figs 5, 6.

Haplophragmoides suborbicularis (Grzybowski). – Kaminski & Gradstein, 2005, p. 358, pl. 81, figs 1–4.

Remarks. It differs from *H. eggeri* by having thicker periphery. It may resemble species of *Cribostrimoides* by having thick periphery and a smooth tazzo wall surface, especially when it is deformed, but differs by its basal aperture.

Haplophragmoides walteri (Grzybowski, 1898)

Trochammina walteri Grzybowski, 1898, p. 290, pl. 11, fig. 31.

Haplophragmoides walteri (Grzybowski). – Kaminski & Gradstein, 2005, p. 363, pl. 83, figs 1–6.

Remarks. This species can be readily distinguished by its acute “keeled” periphery and sutures which are often sigmoidal.

Haplophragmoides cf. walteri (Grzybowski, 1898)
Plate 3, fig. 3a–c

Haplophragmoides cf. walteri (Grzybowski). – Hemleben & Troester, 1984, p. 519, pl. 3, fig. 6. – Cetean *et al.*, 2011a, p. 91, pl. 4, figs 13, 14 (with synonymy).

Description. Test compressed, circular in outline, planispiral, involute, with six to seven triangular chambers in the final whorl. Chambers increasing gradually in size. Sutures straight, depressed. Wall finely agglutinated with much cement, smoothly finished. Aperture a basal slit.

Remarks. This form has been reported in several studies on Upper Cretaceous DWAF in the Atlantic and the Western Tethys.

Haplophragmoides sp. 4

Haplophragmoides sp. 4 Setoyama *et al.*, 2011a, p. 275, pl. 7, fig. 18a, b.

Haplophragmoides sp. 5

Haplophragmoides sp. 5 Setoyama *et al.*, 2011a, p. 275, pl. 8, fig. 3a–c.

Haplophragmoides spp.

Remarks. Planispiral, multi-chambered specimens with the basal aperture are included. Most of them are flattened and/or partially broken.

Hormosina velascoensis (Cushman, 1926)

Nodosinella velascoensis Cushman, 1926, p. 586, pl. 20, fig. 9.

Hormosina velascoensis (Cushman). – Kaminski & Gradstein, 2005, p. 243, pl. 44, figs 1–8.

Remarks. Only specimens with a few chambers are found in our material.

Hyperammina dilatata Grzybowski, 1896

Plate 1, fig. 8

Hyperammina dilatata Grzybowski, 1896, p. 274, pl. 8, fig. 17a–b. – Liszka & Liszkowa, 1981, p. 162, pl. 1, fig. 8.

“*Hyperammina dilatata*” Grzybowski. – Kaminski & Gradstein, 2005, p. 140, pl. 12, figs 1–5 (with synonymy).

Remarks. In the Indian Harbour M-52 well, only specimens with a smooth, finely agglutinated wall are found.

Kalamopsis grzybowskii (Dyląganka, 1923)

Plate 1, fig. 18

Hyperammina grzybowskii Dyląganka, 1923, p. 65.

Kalamopsis grzybowskii (Dyląganka). – Kaminski & Gradstein, 2005, p. 252, pl. 47, figs 1–12 (with synonymy).

Remarks. Specimens with a thick, smooth wall (pl. 1, fig. 18) are included. They are more common than typical thin-walled specimens in the studied material.

Karrerulina coniformis (Grzybowski, 1898)

Gaudryina coniformis Grzybowski, 1898, p. 295, pl. 12, fig. 7.

Karrerulina coniformis (Grzybowski). – Kaminski & Geroch, 1993, p. 269, pl. 13, figs 1–4. – Kaminski & Gradstein, 2005, p. 465, pl. 115, figs 1a–9 (with synonymy).

Karrerulina conversa (Grzybowski, 1901)

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

Karrerulina conversa (Grzybowski). – Kaminski & Gradstein, 2005, p. 468, pl. 116, figs 1a–11b (with synonymy).

Karrerulina horrida (Mjatliuk, 1970)

Karrerulina horrida Mjatliuk, 1970, p. 114, pl. 5, fig. 9; pl. 33, figs 15, 16. Kaminski & Gradstein, 2005, p. 473, pl. 117, figs 1a–

11.

***Karrerulina* spp.**

Remarks. Specimens with the initial trochospiral portion with chambers aligned as in quadriserial coiling manner are included. The position of an aperture is variable from basal to terminal.

***Nothia latissima* (Grzybowski, 1898)**

Dendrophrya latissima Grzybowski, 1898, p. 272, pl. 10, fig. 8.

Nothia latissima (Grzybowski). – Kaminski & Gradstein, 2005, p. 111, pl. 3, figs 1–4b.

Remarks. It can be distinguished from other tubular taxa by its very wide, compressed test and very thin wall in proportion to the test size.

***Nothia robusta* (Grzybowski, 1898)**

Plate 1, fig. 4

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

Nothia robusta (Grzybowski). – Kaminski & Gradstein, 2005, p. 114, pl. 4, figs 1–8.

***Nothia* spp.**

Description. Flattened tubular specimens with rough surface. *Nothia excelsa* (Grzybowski) may well be included. However, no branching specimens are recorded.

***Paratrochamminoides acervulatus* (Grzybowski, 1896)**

Plate 1, fig. 23a, b

Trochammina acervulatus Grzybowski, 1896, p. 274, pl. 9, fig. 4

Paratrochamminoides acervulatus (Grzybowski). – Kaminski & Gradstein, 2005, p. 290, pl. 59, figs 1–7.

***Paratrochamminoides deflexiformis* (Noth, 1912) emend.
Kaminski & Gradstein (2005)**

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

Paratrochamminoides deflexiformis (Noth). – Kaminski & Gradstein, 2005, p. 293, pl. 60, figs 1a–4b.

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

Plate 1, fig. 24

Ammodiscus gorayskii Grzybowski, 1898, p. 283, pl. 11, fig. 5.

Paratrochamminoides gorayskii (Grzybowski). – Kaminski & Geroch, 1993, p. 255, pl. 5, fig. 8a–d. – Kaminski & Kuhnt, 2004, p. 281 (no figure given). – Kaminski & Gradstein, 2005, p. 297, pl. 61, figs 1–5.

***Paratrochamminoides heteromorphus* (Grzybowski, 1898)**

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

Paratrochamminoides heteromorphus (Grzybowski). – Kaminski & Geroch, 1993, p. 258, pl. 7, fig. 3a, b. – Kaminski & Kuhnt, 2004, p. 281 (no figure given). – Kaminski & Gradstein, 2005, p. 298, pl. 62, figs 1–10 (with synonyms).

***Paratrochamminoides mitratus* (Grzybowski, 1901)**

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

Paratrochamminoides mitratus (Grzybowski). – Kaminski & Geroch, 1993, p. 278, pl. 16, fig. 4a,b. – Kaminski & Kuhnt, 2004, p. 282 (no figure given). – Kaminski & Gradstein, 2005, p. 302, pl. 63, figs 1a–7.

***Paratrochamminoides cf. mitratus* (Grzybowski, 1901)**

Plate 1, fig. 25

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

Remarks. Differs from typical specimens of *P. mitratus* by possessing elongated chambers rather than globular ones.

***Paratrochamminoides olszewskii* (Grzybowski, 1898)**

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

Paratrochamminoides olszewskii (Grzybowski). – Kaminski & Geroch, 1993, p. 257, pl. 7, figs 1, 2. – Kaminski & Kuhnt, 2004, p. 282 (no figure given). – Kaminski & Gradstein, 2005, p. 305, pl. 64, figs 1a–7.

***Placentammina placenta* (Grzybowski, 1898)**

Plate 1, fig. 7

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

Placentammina placenta (Grzybowski). – Kaminski & Gradstein, 2005, p. 136, pl. 11, figs 1–6.

***Plectoeratidus subarcticus* Kaminski, Setoyama & Tyszka,
2009**

Eratidus foliaceus (Brady). – Charnock & Jones, 1990, p. 181, pl. 9, fig. 10, pl. 20, fig. 9a, b.

Plectoeratidus subarcticus Kaminski, Setoyama & Tyszka, 2009, p. 143, fig. 2 A1–E3.

***Popovia elegans* (Kaminski, 1987)**

Phenacophragma elegans Kaminski in: Kaminski & Geroch, 1987, p. 186, textfigs 5–8, pl. 1, figs 8–14b. – Kaminski *et al.*, 1988, p. 190, pl. 4, fig. 10; pl. 10, figs 10–13.

Popovia elegans (Kaminski). – Kaminski & Gradstein, 2005, p. 486, pl. 121, figs 1a–8.

***Praecystammina globigerinaeformis* Krasheninnikov, 1973**

Plate 2, fig. 5

Praecystamina globigerinaeformis Krasheninnikov, 1973, p. 211, pl. 2, figs 1, 2. – Krasheninnikov, 1974, p. 641, pl. 6, figs 1–3. – Gradstein & Berggren, 1981, p. 258, pl. 9, figs 11–15. – Hemleben & Troester, 1984, p. 521, pl. 4, fig. 8. – Moullade *et al.*, 1989, p. 365, pl. 7, fig. 6.

Remarks. In the original description of this species, Krasheninnikov (1973) described the aperture as slit-like or oval, thus the form illustrated as *Praecystamina cf. globigerinaeformis* by Gradstein *et al.* (1994; pl. 3, figs 13–17) is treated as *P. globigerinaeformis* in this study.

Praedorothia sp. 1

Praedorothia sp. 1 Setoyama *et al.*, 2011a, p. 279, pl. 10, fig. 3a, b.

Remarks. The same form was observed in the Upper Cretaceous of the SW Barents Sea (Setoyama *et al.*, 2011a). This form superficially resembles *Dorothia* sp. 1 illustrated by Charnock & Jones (1990), but differs by possessing a noncanaliculate wall.

Praesphaerammina gerochi (Hanzlíková, 1972)

Sphaerammina gerochi Hanzlíková, 1972, p. 45, pl. 8, figs 4–7.

Praesphaerammina gerochi (Hanzlíková). – Kaminski & Gradstein, 2005, p. 367, pl. 84, figs 1a–4b.

Praesphaerammina spp.

Remarks. Flat planispiral forms with a last chamber which is unproportionately larger than the previous ones and covers the earlier whorl and with an areal aperture.

Psammosphaera fusca Schultze, 1875 emend. Heron-Allen & Earland, 1913

Psammosphaera fusca Schultze, 1975, p. 113, pl. 2, fig. 8a–f.

Psammosphaera fusca Schultze. – Charnock & Jones, 1990, p. 146, pl. 1, fig. 4. – Kaminski & Gradstein, 2005, p. 125, pl. 8, figs 1–9.

Psammosiphonella cylindrica (Glaessner, 1937)

Plate 1, fig. 5

Rhabdammina cylindrica Glaessner, 1937, p. 354, pl. 1, fig. 1.

Psammosiphonella cylindrica (Glaessner). – Kaminski & Gradstein, 2005, pl. 5/6, figs 9–13 (with synonymy).

Psammosiphonella discreta (Brady, 1881)

Rhabdammina discreta Brady, 1881, p. 48.

Psammosiphonella discreta (Brady). – Kaminski & Gradstein, 2005, p. 117, pl. 5/6, figs 1–8 (with synonymy).

Psammosiphonella spp.

Description. Tubular specimens with more or less uniform diameter and medium to coarsely agglutinated wall with equidimensional grains. Some specimens are slightly curved.

Pseudonodosinella nodulosa (Brady, 1879), emend.

Loeblich & Tappan, 1987

Plate 1, fig. 21

Reophax nodulosa Brady, 1879, p. 52, pl. 4, figs 7, 8

Pseudonodosinella nodulosa (Brady). – Kaminski & Gradstein, 2005, p. 259, pl. 49, figs 1–9 (with synonymy).

Pseudonodosinella parvula (Huss, 1966)

Plate 1, fig. 22

Reophax parvulus Huss, 1966, p. 21, pl. 1, figs 26–30.

Pseudonodosinella parvula (Huss). – Geroch & Kaminski, 1995, p. 118, pl. 2, figs 1–19 (with synonymy).

Recurvoidella sp. 1

Plate 3, fig. 4a–c

Description. Test small, laterally compressed, planispirally coiled with the coiling axis slightly changing, with five to six chambers in the final whorl. Chambers globular, increasing in size slowly. Sutures slightly depressed, appear thick in immersion. Wall medium coarsely agglutinated, roughly finished. Aperture a basal slit, not symmetrical. The apertural lip is not clear due to its rough test surface.

Recurvoidella spp.

Remarks. Specimens which are planispirally coiled with the slightly changing coiling axis are included. Most of them are deformed or partially broken.

Recurvoides anormis Mjatluk, 1970

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

Recurvoides nucleolus (Grzybowski, 1898)

Plate 5, fig. 5a–e

Trochammina nucleolus Grzybowski, 1898, p. 291, pl. 11, figs 28, 29.

Recurvoides nucleolus Grzybowski. – Kaminski & Geroch, 1993, p. 265, pl. 11, fig. 4a–d. – Bubik, 1995, p. 85, pl. 10, fig. 10a–c.

Recurvoides pentacameratus Krasheninnikov, 1974

Recurvoides pentacameratus Krasheninnikov, 1974, p. 638, pl. 3, fig. 3a–c.

Recurvoides cf. pseudononioninoides Neagu & Platon,
1994
Plate 3, fig. 6a–d

Recurvoides pseudononioninoides Neagu & Platon, 1994, p. 7, pl. 10, figs 4, 5.

Recurvoides pseudosymmetricus Neagu & Platon, 1994

Recurvoides pseudosymmetricus Neagu & Platon, 1994, p. 11, pl. 1, figs 1–12; pl. 2, figs 1–5, 7–9.

Recurvoides recurvoidiformis (Neagu & Tocarjescu, 1970)
Plate 3, fig. 7a–d

Thalmanamina recurvoidiformis Neagu & Tocarjescu, 1970, p. 38, pl. 4, figs 1–12; pl. 40, figs 10–15.

Recurvoides recurvoidiformis (Neagu & Tocarjescu). – Bubík, 1995, p. 85, pl. 4, figs 11, 12.

Recurvoides retroseptus (Grzybowski, 1896) emend.
Kaminski & Gradstein, 2005

Cyclammina retrosepta Grzybowski, 1896, p. 284, pl. 9, figs 7, 8.

Recurvoides retroseptus (Grzybowski). – Kaminski & Gradstein, 2005, p. 410, pl. 98, figs 1–3.

Recurvoides simuloplanus Neagu & Platon, 1994

Recurvoides simuloplanus Neagu & Platon, 1994, p. 12, pl. 6, figs 11, 12; pl. 7, figs 6, 7.

Recurvoides variabilis Hanzlíková, 1973

Recurvoides variabilis Hanzlíková, 1973, p. 148, pl. 4, figs 5–8; textfigs 3A–F. – Bubík, 1995, p. 85, pl. 4, fig. 13a–c.

Recurvoides walteri (Grzybowski, 1898) emend. Mjatluk,
1970
Plate 3, fig. 8a–c

Haplophragmoides walteri Grzybowski, 1898, p. 280, pl. 10, fig. 24.

Recurvoides walteri (Grzybowski). – Kaminski & Gradstein, 2005, p. 415, pl. 100, figs 1–3.

Recurvoides sp. 3
Plate 7, fig. 7a–d

Remarks: It resembles superficially *Recurvoides imperfectus* (Hanzlíková), but differs by possessing fewer changes in coiling direction and narrower chambers (see Bubík, 2000).

Recurvoides sp. 4
Plate 7, fig. 8a–d

Remarks: This small- to medium-sized form is similar to *Recurvoides variabilis* Hanzlíková, but different in possessing chambers which grow slowly (see Bubík, 2000). It is more common in the lower half of the studied interval.

Recurvoides sp. 5

Plate 3, fig. 9a–c; Plate 7, fig. 9a–d

Remarks: This form can be distinguished from *Recurvoides sp. 4* by its coiling direction which changes more often and laterally compressed test.

Recurvoides spp.

Remarks. Numerous specimens with the recurvoidiform coiling mode and an areal aperture are recorded in the material studied. Many of them are flattened or partially broken so that they could not be identified at the species level.

Reophax duplex Grzybowski, 1896
Plate 1, fig. 19

Reophax duplex var. α Grzybowski, 1896, p. 276, pl. 8, figs 23, 24.

Reophax duplex Grzybowski. – Kaminski & Gradstein, 2005, p. 266, pl. 51, figs 1–9.

Description. Test of medium size, comprised of two spherical chambers which are similar in size. Wall coarsely agglutinated, roughly finished. Aperture terminal, on a raised rim.

Reophax cf. pilulifer Brady, 1884

Reophax pilulifer Brady, 1884, p. 292, pl. 30, figs 18–20.

Description. Only specimens with a few chambers are found in our material.

Repmanina charoides (Jones & Parker, 1860)
Plate 1, figs 11, 12

Trochammina squamata var. *charoides* Jones & Parker, 1860, p. 304 (type figure not given).

Glomospira charoides (Jones & Parker). – Berggen & Kaminski, 1990, p. 60, pl. 1, fig. 2 (lectotype). – Kaminski & Gradstein, 2005, p. 168, pl. 22, figs 1–16 (with synonymy).

Repmanina charoides (Jones & Parker). – Alegret & Thomas, 2001, p. 201, pl. 10, fig. 11.

Reticulophragmium garcilassoi (Frizzel, 1943)
Plate 5, fig. 1a–c

Cyclammina garcilassoi Frizzel, 1943, p. 338, pl. 55, fig. 11a, b.

Reticulophragmium garcilassoi (Frizzel). – Kaminski & Gradstein, 2005, p. 496, pl. 124, figs 1–6.

Description. Test medium to large, planispiral, involute to slightly evolute, circular to slightly lobate in outline, umbilici depressed, with 10–16 chambers in the final whorl. Periphery subacute. Chambers increasing in size slowly. Sutures clear, sinuous, slightly depressed. Wall thick, alveolar, finely agglutinated with much originally organic cement, smoothly finished. Aperture a basal slit.

Reticulophragmium pauperum (Chapman, 1904) emend.
Ludbrook, 1977
Plate 4, fig. 11a–c

Cyclammina paupera Chapman, 1904, p. 229, pl. 22, fig. 6.

Reticulophragmium pauperum (Chapman, 1904) emend. Ludbrook, 1977. – Kaminski & Gradstein, 2005, p. 501, pl. 126, figs 1–7.

Description. Test medium sized, planispiral, involute, circular in outline, umbilici only slightly depressed, with eight to ten chambers in the final whorl. Periphery subacute. Chambers increasing slowly in size. Sutures clear, straight, slightly depressed. Wall thick, finely agglutinated with much originally organic cement, smoothly finished. Large alveoli concentrated along the sutures and periphery. Aperture a basal slit.

Remarks. This form can be distinguished by its large alveoli concentrated along the sutures and periphery.

Reticulophragmium “acute”
Plate 5, fig. 3a–c

Description. Test small to medium, planispiral, involute, with nine chambers in the final whorl. Periphery acute to subacute. Chambers triangular, increasing in size gradually. Sutures slightly curved backwards, slightly depressed. Wall alveolar, finely agglutinated with much originally organic cement, smoothly finished. Aperture a basal slit. Apertural face high.

Remarks. This form was previously reported from the Paleocene of Indian Harbour M-52 well by Kaminski (1987).

Reticulophragmium “robust”
Plate 5, fig. 2a–c

Description. Test small to medium, planispiral, involute, with nine chambers in the final whorl. Periphery rounded. Chambers triangular, increasing gradually in size. Sutures radial, straight to slightly curved backwards, slightly depressed. Wall alveolar, finely agglutinated with much originally organic cement, smoothly finished. Aperture a basal

aperture. Apertural face high.

Remarks. This form was reported from the Paleocene of Indian Harbour M-52 well and Gudrid H-55 well in the Labrador Sea by Kaminski (1987).

Reticulophragmoides jarvisi (Thalman, 1932) emend.
Gradstein & Kaminski, 1989
Plate 4, fig. 10a–c

Nonion cretacea Cushman & Jarvis, 1932, p. 41, pl. 12, fig. 12a, b.
Nonion jarvisi Thalman, 1932, p. 312.

Reticulophragmoides jarvisi (Thalman). – Kaminski & Gradstein, 2005, p. 508, pl. 128, figs 1–8.

Rhabdammina sp. 5
Plate 1, fig. 1

Remarks: Differs from other fragments of *Rhabdammina* and *Psammosiphonella* by much larger diameter with very thick wall.

Rhabdammina spp.

Description. Robust tubular specimens with thick, coarsely agglutinated wall.

Rhizammina spp.
Plate 1, fig. 6

Description. Test tubular, small, often curved, fragmented. Wall thin, finely to medium coarsely agglutinated, finish smooth to slightly rough. Aperture at the open ends of the tube.

Rzehakina epigona (Rzehak, 1895)
Plate 1, fig. 13

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

Rzehakina epigona (Rzehak). – Bubík & Kaminski, 2000, p. 75, pl. 1, figs 1a–4b. – Kaminski & Gradstein, 2005, p. 205, pl. 31, figs 1a–4b (with synonymy).

Rzehakina lata Cushman & Jarvis, 1928

Rzehakina epigona var. *lata* Cushman & Jarvis, 1928, p. 93, pl. 13, fig. 11a, b.

Rzehakina lata Cushman & Jarvis. – Kaminski & Gradstein, 2005, p. 212, pl. 34, figs 1–5.

Rzehakina minima Cushman & Renz, 1946

Rzehakina epigona (Rzehak) var. *minima* Cushman & Renz, 1946, p. 24, pl. 3, fig. 5.

Rzehakina epigona Cushman & Renz. – Kaminski & Gradstein, 2005, p. 215, pl. 35, figs 1a–10 (with synonymy).

Saccamina grzybowskii (Schubert, 1902)

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

Saccamina grzybowskii (Schubert). – Kaminski & Gradstein, 2005, p. 132, pl. 10, figs 1–9.

Saccamina sphaerica Brady, 1884

Saccamina sphaerica Sars, 1872, p. 250.

Saccamina sphaerica Sars. – Brady, 1871, p. 183. – Brady, 1884, p. 253, pl. 18, figs 11–15. – Hemleben & Troester, 1984, p. 522, pl. 1, fig. 15. – Charnock & Jones, 1990, p. 146, pl. 1, fig. 7; pl. 13, fig. 5.

Remarks. This species is attributed to Brady following Loeblich & Tappan (1961).

***Saccamina* spp.**

Remarks. Unilocular specimens with only one aperture are included.

Spiroplectammina* cf. *biformis (Parker & Jones, 1865)

Plate 2, fig. 10

Textularia agglutinans d'Orbigny var. *biformis* Parker & Jones, 1865, p. 370, pl. 15, figs 23, 24.

Spiroplectammina biformis (Parker & Jones). – Riveiros & Patterson, 2008, p. 12, fig. 5.6a–c.

Remarks. *Spiroplectammina biformis* is a recent species originally reported from the Davis Strait. It is often reported from the Arctic and fjord areas (e.g., Korsun & Hald, 2000; Lloyd, 2006; Riveiros & Patterson, 2008), but also reported from the Sulu Sea (Szarek *et al.*, 2004). The species is known to be tolerant to low saline and hypoxic conditions (Sen Gupta & Machain-Castillo, 1993; Lloyds, 2006; Murray & Alve, 2011) like a fossil species of the genus, *Spiroplectammina spectabilis* (Haig, 2003; Kaminski & Gradstein, 2005).

Spiroplectammina navarroana Cushman, 1932 emend.

Gradstein & Kaminski, 1989

Plate 2, fig. 12

Spiroplectammina navarroana Cushman, 1932, p. 96, pl. 11, fig. 14. – Gradstein & Kaminski, 1989, p. 83, pl. 9, figs 1a–12. – Kaminski & Gradstein, 2005, p. 426, pl. 103, figs 1–12 (with synonymy).

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

Plate 2, fig. 11

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 & Gradstein, 2005, p. 435, pl. 104, figs 1a–6b (with synonymy).

Spiroplectinella dentata (Alth, 1850)

Textularia dentata Alth, 1850, p. 262, pl. 13, fig. 13.

Spiroplectinella dentata (Alth). – Kaminski & Gradstein, 2005, p. 439, pl. 106, figs 1a–8.

Spirosigmoilinella compressa Matsunaga, 1955

Spirosigmoilinella compressa Matsunaga, 1955, p. 50, figs 1, 2. – Kaminski & Gradstein, 2005, p. 218, pl. 36, figs 1–7 (with synonymy).

Subreophax aduncus (Brady, 1882)

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

Subreophax aduncus (Brady). – Charnock & Jones, 1990, p. 165, pl. 4, fig. 20; pl. 15, fig. 18. – Ceteau *et al.*, 2011a, p. 87, pl. 2, figs 14–16.

Subreophax pseudoscalaris (Samuel, 1977)

Plate 1, fig. 17

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

Subreophax pseudoscalaris (Samuel). – Kaminski & Gradstein, 2005, p. 281, pl. 56, figs 1–6.

Subreophax scalaris (Grzybowski, 1896)

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

Subreophax scalaris (Grzybowski). – Kaminski & Gradstein, 2005, p. 278, pl. 55, figs 1–7. – Ceteau *et al.*, 2011a, p. 87, pl. 3, fig. 7.

***Subreophax* spp.**

Remarks. Specimens consisting of a few irregular pseudochambers are included.

Thalmannammina meandertornata Neagu & Todorjescu,
1970

Thalmannammina meandertornata Neagu & Todorjescu. – Neagu, 1970, p. 38, pl. 3, figs 9–15; pl. 40, figs 1–9. – Neagu & Platon, 1994, p. 20, pl. 10, figs 1, 2. – Bubík, 1995, p. 88, pl. 6, fig. 8a–c.

***Thalmannammina* sp. 1**

Plate 7, fig. 10a–e

Remarks. Its coiling mode is somewhat similar to *Thalmannammina simpla* Neagu & Platon and *Thalmannammina gerochi* Neagu & Platon, but differs by possessing more chambers externally visible.

***Thalmannammina* spp.**

Remarks. Numerous specimens with the thalmannammini-form coiling mode are recorded.

***Thurammina* spp.**

Plate 3, fig. 1

Description. Test of small to medium size, globular, compressed, with small protuberances. Wall medium coarsely agglutinated, slightly rough.

***Tritaxia* cf. *danica* Hofker, 1960**

Plate 4, fig. 7a–c

Tritaxia danica Hofker, 1960, p. 240, fig. 23a–c.

Description. Test large, triangular in section, tapered, triserial, then uniserial, periphery not carinate, sides not concave. Chambers increasing in size slowly, except when the chamber arrangement changes from triserial to uniserial. Sutures indistinct. Wall finely to medium coarsely agglutinated, slightly rough. Aperture terminal on a neck.

Remarks. *T. danica* was originally described from the lowermost Danian of Kjölby Gaard, Denmark. It differs from *Tritaxia dubia* (Reuss) and *Tritaxia pyramidata* (Reuss) by lacking carinate angles and concave sides of the test. Our specimens are less elongated than the specimens illustrated by Hofker (1960).

***Tritaxia* spp.**

Remarks. Pyramidal specimens with an initial triserial portion, angled edges, a thick, solid wall and a pore-like aperture near the base of the last chamber.

***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 & Gradstein, 2005, p. 314, pl. 67, figs 1–5.

***Trochamminoides subcoronatus* (Grzybowski, 1896)**

Plate 1, fig. 26

Trochammina subcoronata Grzybowski, 1896, p. 274, pl. 9, fig. 3a–c.

Trochamminoides subcoronatus (Grzybowski). – Kaminski & Gradstein, 2005, p. 318, pl. 68, figs 1–6.

Remarks. Differs from *T. proteus* by its large sac-shaped chambers and less evolute coiling.

***Trochammina* spp.**

Remarks. Various forms of *Trochammina* are observed. Most of specimens are partially broken and compressed. Other genera of Trochamminacea, such as *Conotrochammina* and *Trochamminopsis*, may be included as well.

***Trochamminopsis altiformis* (Cushman & Renz, 1946)**

Plate 4, fig. 4a–c

Trochammina globigeriniformis var. *altiformis* Cushman & Renz, 1946, p. 24, pl. 3, figs 7–11.

Trochammina altiformis (Cushman & Renz). – Moullade *et al.*, 1988, p. 366, pl. 8, figs 1–3.

Trochamminoipsis altiformis (Cushman & Renz). – Kaminski & Gradstein, 2005, p. 458, pl. 112, figs 1–3.

Description. Test medium to large, high trochospiral, often laterally compressed, with three and a half chambers per whorl. Chambers inflated, increasing rapidly in size. Sutures distinct, depressed. Wall finely agglutinated, smoothly finished in our material. Aperture umbilical.

***Turritellella* sp. 1**

Description. Test medium-sized, the proloculus followed by a tubular chamber which is tightly coiled in a high trochospiral manner. The tubular chamber increasing in diameter very slowly. Wall thick, finely agglutinated, finish somewhat rough. Aperture at the open end of the tube.

Remarks. This form can be a juvenile form of *Turritellella shoneana* (Siddall). Charnock & Jones (1990) reported *T. shoneana* in the Paleocene and Eocene of the North Sea.

***Uvigerinammina jankoi* (Majzon, 1943)**

Plate 4, figs 8, 9

Uvigerinammina jankoi Majzon, 1943, p. 158, pl. 2, fig. 15a, b. – Krashennikov, 1974, pl. 6, figs 9, 10. – Krashennikov & Pflaumann, 1977, pl. 3, figs 12, 13. – Moullade *et al.*, 1988, p. 367, pl. 10, figs 1–6. – Malata & Oszczytko, 1990, p. 519, pl. 3, figs 12, 13. – Neagu, 1990, p. 255, pl. 4, figs 7–15. – Bubik, 1995, p. 89, pl. 13, fig. 13.

Remarks. As Moullade *et al.* (1988) and Malata & Oszczytko (1990) pointed out, this species is morphological very variable. There are a “typical” form with a subcircular cross-section and small elongate chambers and without

clear, depressed sutures, and a more elongated form with three large elongated chambers in the final whorls with distinct, depressed sutures as reported by Moullade *et al.* (1990) (pl. 4, figs 8, 9). The size of an apertural neck also differs between the forms with the “typical” form often having a less prominent neck. In our material, the “typical” form is rare. Well-preserved specimens have more than three chambers per whorl in the initial whorl (pl. 4, fig. 8c).

Uvigerinammina cf. praejankoi Neagu, 1990

Plate 2, fig. 14

Uvigerinammina praejankoi Neagu, 1990, p. 255, pl. 3, figs 1–33.

Remarks. Specimens of *Uvigerinammina* with two large final chambers giving a tendency to become biserial are included in this form.

Uvigerinammina spp.

Remarks. Broken specimens of *Uvigerinammina*, often missing last chambers, are included. They can be distinguished from other triserial genera by its typical arrangement of chambers and stolens (see Geroch & Nowak, 1984, pl. 7, figs 11, 12).

Verneulinoides spp.

Remarks. Small triserial specimens with solid wall are included.

RESULTS

Foraminiferal assemblages

A total of 158 agglutinated and 87 calcareous benthic foraminiferal taxa, and 24 planktic taxa were identified from the Upper Cretaceous and Paleogene intervals in the Indian Harbor M-52 well. The foraminiferal assemblages are dominated by agglutinated foraminifera throughout the studied interval (Fig. 7). Agglutinated specimens are well-silicified, but often compressed and partially broken. Some of the specimens are very dark in colour, but many of them are transparent and filled often with pyrite or glauconite. Agglutinated foraminiferal assemblages are highly diversified with typical DWAF taxa, such as *Caudammina*, *Paratrochaminoides*, and *Uvigerinammina* in the lower part of the interval and *Budashevaella*, *Reticulophragmium*, and *Karrerulina* in the upper part. *Recurvoides* is abundant throughout the studied succession, and *Repmanina charoides* (Jones & Parker) shows a high relative abundance in the lower interval. Carbonate-cemented agglutinated foraminifera are almost absent, and rzehakinids are also very rare.

Calcareous benthic foraminifera are recorded in most of the samples, and their relative abundance reaches over 20% at 10,300 feet, although it usually does not exceed 10% (Fig. 7). The diversity of calcareous benthic foraminifera in the studied material is variable depending on the number of specimens and their preservation state. Planktic foraminifera, including *Globigerinelloides*, *Hedbergella*, *Heterohelix* and *Rugoglobigerina*, occur in many samples as a minor component of assemblages in the top of the Alexis Formation and the lower part of the Markland Formation (Fig. 7). The upper halves of the Markland Formation and the Cartwright Formation contain a few species of *Subbotina*. The preservation of calcareous foraminifera is very variable. All the specimens show signs of dissolution, which are often more noticeable with planktic foraminifera. Broken specimens are frequent for both calcareous benthic and planktic foraminifera.

Biostratigraphy

The top of the upper Maastrichtian in the well was placed at 10,480 feet in M-52 well by Gradstein & Berggren (1981), Kaminski (1987), and Gradstein *et al.* (1994). Gradstein & Berggren (1981) and Miller *et al.* (1982) established the *Abathomphalus mayaroensis* Zone between 10,660–10,480 feet. *A. mayaroensis* is not recorded in our material, nor typical Maastrichtian calcareous benthic species reported by Gradstein & Berggren (1981) such as *Bolivinoidea draco* (Marsson) and *Reussella szajnochae* (Grzybowski). The last occurrence (LO) of *Caudammina gigantea* (Geroch) is recorded at 10,480 feet, and above this level, no typical Upper Cretaceous species are identified (Fig. 8).

The LO of *Uvigerinammina jankoi* (Majzon) is recorded at 10,510 feet, just below the LO of *C. gigantea* in our material. The LO of *U. jankoi* is reported in the middle–upper Campanian *Globotruncana ventricosa* Zone in the Eastern Carpathians (Neagu *et al.*, 1992), and the *Uvigerinammina jankoi-Caudammina gigantea* Concurrent Zone is established for the lower Campanian in the Atlantic and Western Tethys by Moullade *et al.* (1988) and Kuhnt *et al.* (1992, 1998). Taxa known from the Campanian and Maastrichtian including some species of *Rugoglobigerina*, *Brotzenella monterelensis* (Marie), *Cibicidoides velascoensis* (Cushman), *Globorotalites michelianus* (d’Orbigny) and *Stensioeina pommerana* (Brotzen) (Hart *et al.*, 1989; Bolli *et al.*, 1994; Bailey *et al.*, 2009) are recorded below the LO of *U. jankoi*. Thus, the sample at 10,480 feet is assigned to the *Caudammina gigantea* Zone of Geroch & Nowak (1984), most probably of late Maastrichtian age based on the data of Gradstein & Berggren (1981). Samples from the interval between 10,750 and 10,510 feet are assigned to the

Uvigerinamina jankoi–*Caudamina gignatea* Concurrent Zone of early to middle Campanian age after Moullade *et al.* (1988) and Kuhnt *et al.* (1992, 1998). Most of this interval could be of Santonian–early Campanian age because the acme of *U. jankoi* is recorded in the Turonian–Santonian in the North Atlantic and Western Tethys (Kuhnt *et al.*, 1992; Kuhnt & Urquhart, 2001), and the known range of *Stensioeina exsculpta exsculpta* (Reuss) is from the Coniacian to the lowermost Campanian in the English Chalk and the North Sea (Hart *et al.*, 1989; Bailey *et al.*, 2009). There may be a hiatus spanning from the middle Campanian to the lower Maastrichtian, between 10,480 and 10,510 feet, based on our biostratigraphic interpretation, unless the middle Campanian–lower Maastrichtian interval was condensed and deposited between the unsampled 30-foot interval.

Above the *Caudamina gigantea* Zone, it is difficult to establish biozones. The top of the lower Paleocene (*Parasubbotina pseudobulloides* Zone) is set at 3,118 m (ca. 10,230 feet), and the top of the Paleocene at 3,030 m (ca. 9,940 feet) based on their qualitative interpretation or 2,970±70 m (9,744±230 feet) by quantitative correlation methods by Gradstein & Berggren (1981) and Gradstein *et al.* (1994). The *Gavelinella beccariiiformis*–*Rzehakina epigona* Zone (LGR1) spans from the Lower to Upper Paleocene in their zonal scheme. Although *G. beccariiiformis* (White) and *R. epigona* (Rzehak) disappear much lower in the investigated succession, typical Paleocene taxa such as *Ammoanita ruthvenmurrayi* (Cushman & Renz), *Reticulophragmoides garcilassoi* (Frizzel), *R. pauperum* (Cushman), and *Subbotina triloculinoides* (Plummer) are recorded in the Paleocene interval.

The peak of *Repmanina charoides* at 10,450 feet could be correlated to those recorded in the lower Danian in Agost, Spain (Alegret *et al.*, 2003) and in Gubbio, Italy (Coccioni *et al.*, 2010). However, these acmes of *R. charoides* are related to different environmental events and not yet a well-correlated bioevent like the peak of *R. charoides* just above the Paleocene/Eocene boundary (e.g., Gradstein *et al.*, 1994; Kuhnt & Urquhart, 2001; Galeotti *et al.*, 2004). Furthermore, this species is consistently recorded from the Upper Cretaceous in our material. Thus, although the abundant occurrence of *R. charoides* may well be useful to distinguish the Upper Cretaceous to Lower Paleocene interval in the Labrador Sea, the peak is not discrete enough to define the Danian in this study.

The side wall core sample at 9,900 feet might be of Eocene age as it contains *Eratidus gerochi* Kaminski & Gradstein, an Eocene species. The age, however, cannot be attributed

to this sample with certainty because we do not have samples from the younger succession. Two broken specimens of *Haplophragmoides nauticus* Kender, Kaminski & Jones at 10,000 feet, which is reported from the Upper Oligocene–Lower Miocene of the Congo Fan (Kender *et al.*, 2006) and the Lower Eocene of the Polish Carpathians (Waškowska, 2011), are probably caved from above.

Morphogroup Analysis

Quantification of tubular forms

There is a high correlation between the total cumulative length and the total number of tubular specimens ($R^2=0.96$ and 0.99) indicating a similar degree of fragmentation of tubular forms in all samples after taphonomic and washing processes (Fig. 9). Changes in the proportion of M1 (tubular forms) can also be traced to those in the standardised tubular length (Fig. 10). These results suggest that comparison of the number of fragments of tubular forms between samples in this study is more reasonable than between samples with different degrees of fragmentation of tubular specimens. *Psammosiphonella* is the major constituent of the standardised tube length throughout the succession. *Nothia* is a minor constituent in the Alexis and Markland formations, but contributes more to the cumulative length in the Cartwright Formation. Taxa included into “others” in Figure 10 are mainly fragments of *Kalamopsis* and *Bathysiphon*, and specimens of *Rhizammina* are relatively rare.

Agglutinated foraminifera

All the morphogroups are present in most of the samples. M1 (tubular form) is dominant in both the Upper Cretaceous and Paleocene intervals. The relative abundance of M1 increases until 10,600 feet, and decreases until 10,450 feet, just above the top of the *Caudamina gigantea* Zone. The proportion of M1 increases again until 10,210 feet, just above the lower to upper Paleocene transition, and falls until the top of the interval studied. The sudden decrease in M1 at 10,330 feet may well be related to its small sample size (68 agglutinated foraminiferal specimens) because the side-wall core sample at the same level contains 213 agglutinated specimens and shows a higher proportion of M1. M2 (mainly rounded epifauna) is common in all the samples. M2a (mostly *Caudamina* in this study), whose proportion remains low, peaks at 10,480 feet (ca. 9%). M2b (mostly recurvoids) shows a general increasing trend throughout the Upper Cretaceous and the Paleocene with some fluctuation. M2c (mostly *Spiroplectamina*) is a minor component of the assemblages, and its peak at 9,900 feet is due to the small sample size (16 agglutinated specimens). M3a (mostly

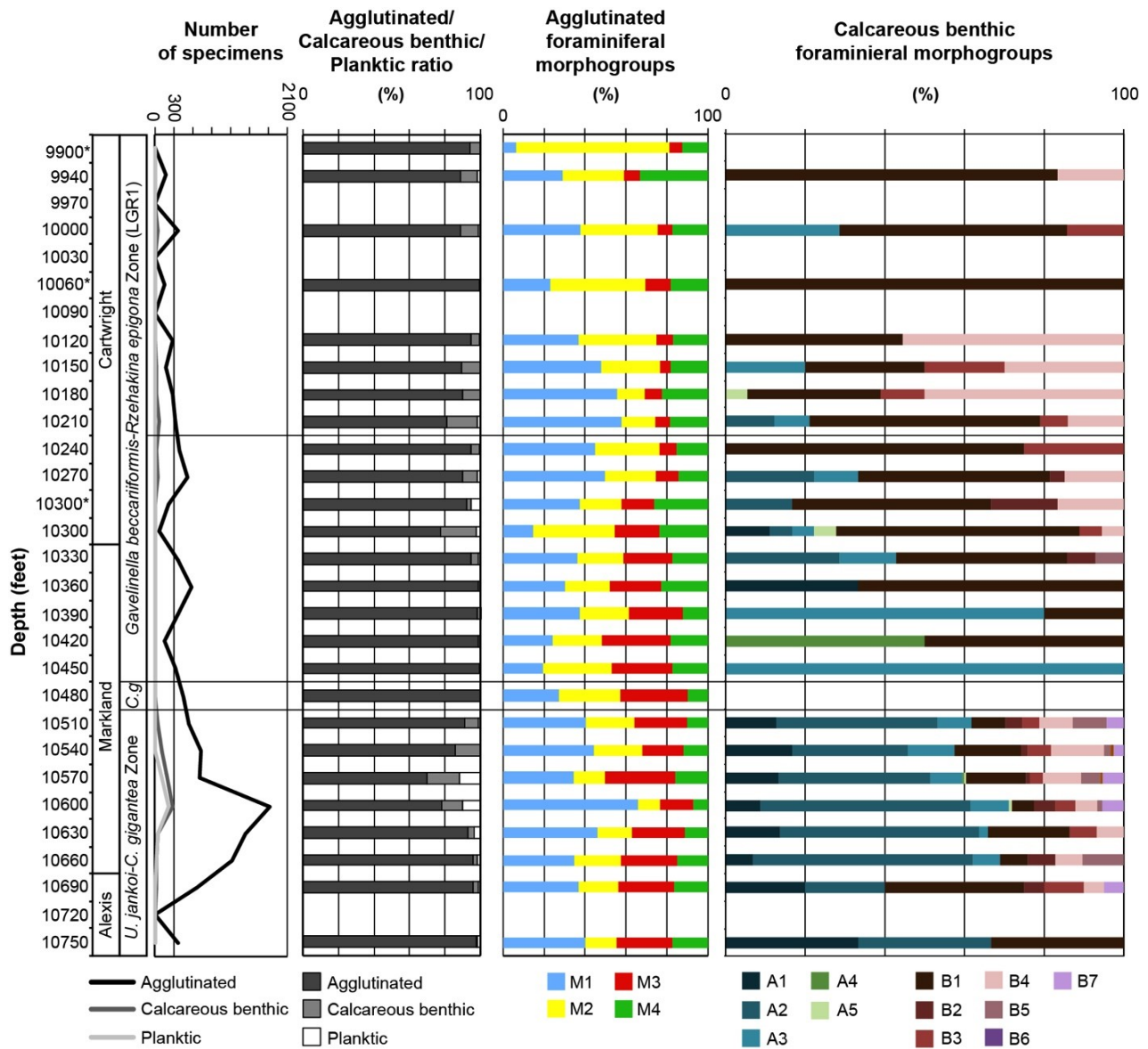


Figure 7. Number of specimens, agglutinated/calcareous benthic/planktic foraminifera ratio and morphogroups of agglutinated and calcareous benthic foraminifera. * = side wall core sample. *C. g.*: *Caudammina gigantea*

Repmaniana) shows a high relative abundance (12–31%) in the Alexis and Markland formations, but becomes a smaller component of the assemblages (<10%) in the Cartwright Formation. The abundance of M3b (*Ammolagena*) is small, and it is confined to the *Uvigerinammina jankoi-Caudammina gigantea* Zone. The proportion of M3c (flattened streptospiral forms) stays below 10%, except for 10,300 feet where the sample size is small. M4 (infauna) is consistently present (7–32%). The abundance of M4a (rounded planispiral forms) and M4b (elongate forms) seems to be inversely related. M4b is more common in the Alexis and Markland formations and become less in the Cartwright Formation, whereas M4a is more abundant in the Cartwright Formation. In general, the composition of agglutinated assemblages is similar in the Alexis and Markland

formations, and noticeable changes occur in the Cartwright Formation with a decreasing trend in M1 and an increasing trend in M2b and M4a upwards, and the lower relative abundance of M2a, M3a and M4b.

Calcareous foraminifera

The epifaunal groups (A1–5) are generally more common in the Alexis and Markland formations, and the infaunal groups (B1–7) become dominant in the Cartwright Formation (Fig. 7). The epifaunal sessile groups (C1–5) are absent in the material studied. The sample size of many calcareous benthic assemblages is too low to quantitatively analyse in detail, and only the samples at 10,600, 10,570 and 10,540 feet contain more than 100 specimens of calcareous benthic foraminifera.

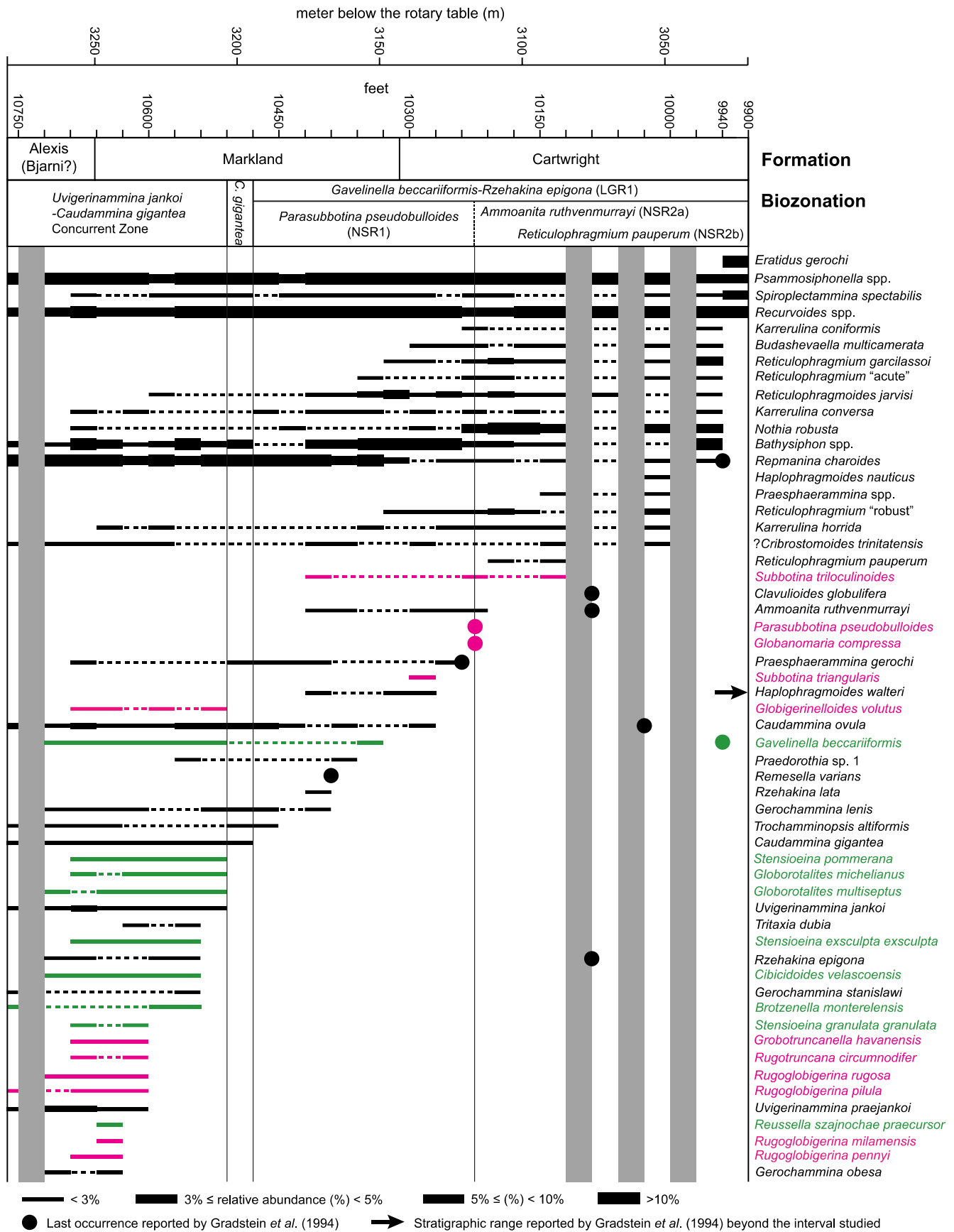


Figure 8. Stratigraphic ranges of selected foraminiferal taxa in Indian Harbour M-52 well.

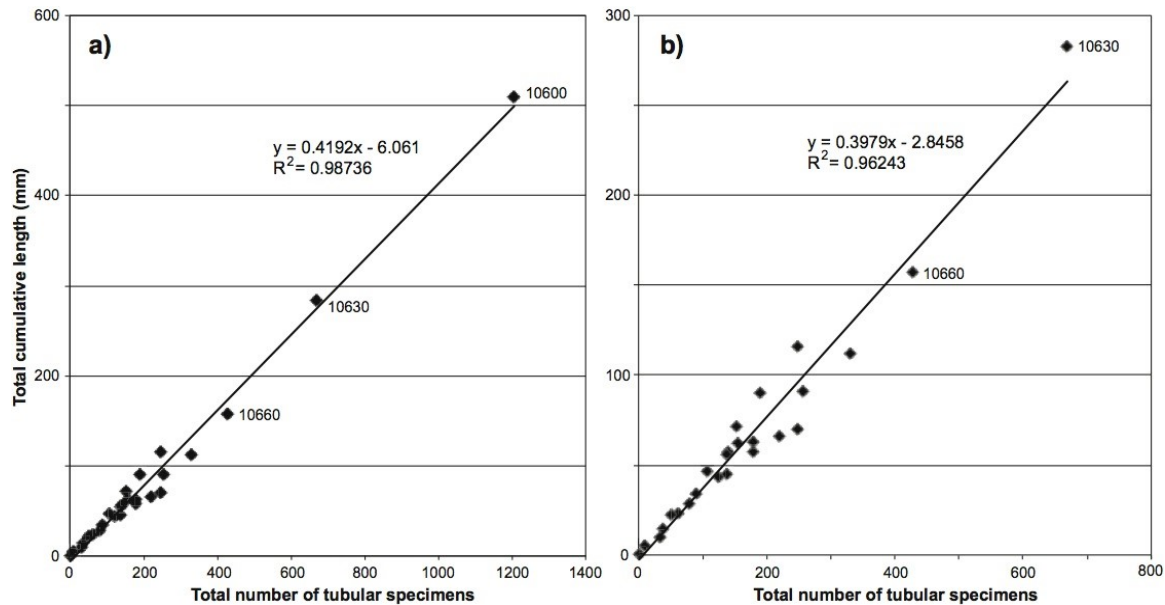


Figure 9. Comparison of total cumulative length and total number of tubular specimens. a) with all the samples; b) without sample at 10,600 feet.

At these depths, A2 (planoconvex trochospiral forms) dominates the assemblages, and the group is mainly composed of *Cibicidoides velascoensis*, *Gavelinella beccariiformis* and *Stensioeina pommerana*. The sample from 10,210 feet contains 57 specimens of calcareous benthic foraminifera including rectilinear uniserial forms, *Cibicidoides*, *Lenticulina*, and *Praeglobobulimina*.

DISCUSSION

Preservation of calcareous foraminifera

Calcareous benthic foraminifera regularly occur as minor components in both Upper Cretaceous and Paleocene foraminiferal assemblages of the Indian Harbour M-52 well. Specimens are etched to various degrees, and broken specimens are common especially among elongated uniserial forms. Taxa commonly recorded in our material include *Cibicidoides*, *Gavelinella*, and *Gyroidinoides* which have a thick wall, and some species of these genera are considered to be resistant to dissolution (Widmark & Malmgren, 1988). The assemblages also contain nodosariids, buliminiids, and *Pullenia* which are considered as taxa susceptible to dissolution by Widmark & Malmgren (1988). Planktic foraminifera are also present in our material. Specimens of planktic foraminifera are more etched, and fragmented specimens are more common than calcareous benthic foraminifera. The planktic assemblages are composed almost entirely of small taxa including *Globigerinelloides multispina* and *Rugoglobigerina rugosa* which are common among the planktic foraminifera in this study. These species are considered as

dissolution susceptible by Malmgren (1987). It is clear that calcareous assemblages are affected by dissolution based on the preservation state of calcareous specimens, but it is difficult to estimate how much of original assemblages have been lost. Nevertheless, calcareous benthic and planktic foraminifera were very likely small components in the original assemblages because small planktic foraminifera and supposedly dissolution susceptible calcareous benthic taxa are still present in our material, and if there has been very intensive dissolution, these taxa would be absent without leaving etched specimens. The small taxa-dominated planktic assemblages are also likely the original feature as only a single broken large specimen, which is probably *Globor-tuncana arca* (Cushman), is recorded in our material, and if larger keeled forms were originally present and abundant, fossil assemblages should also contain them because they are generally more resistant to dissolution (Malmgren, 1987; Nguyen *et al.*, 2009). The rather diminished calcareous benthic and planktic foraminiferal assemblages are probably related to the high-latitude position of the study area (Kuhnt *et al.*, 1989; Premoli Silva & Sliter, 1999; Hart, 2007).

Palaeoenvironment and Palaeobathymetry

The highly diversified, agglutinated-dominant foraminiferal assemblages of the Upper Cretaceous of Indian Harbour M-52 well indicate relatively well-oxygenated to slightly dysoxic, mesotrophic, possibly middle-to-lower bathyal environments. The significant domination of agglutinated foraminifera, the high abundance of tubular forms (M1), the

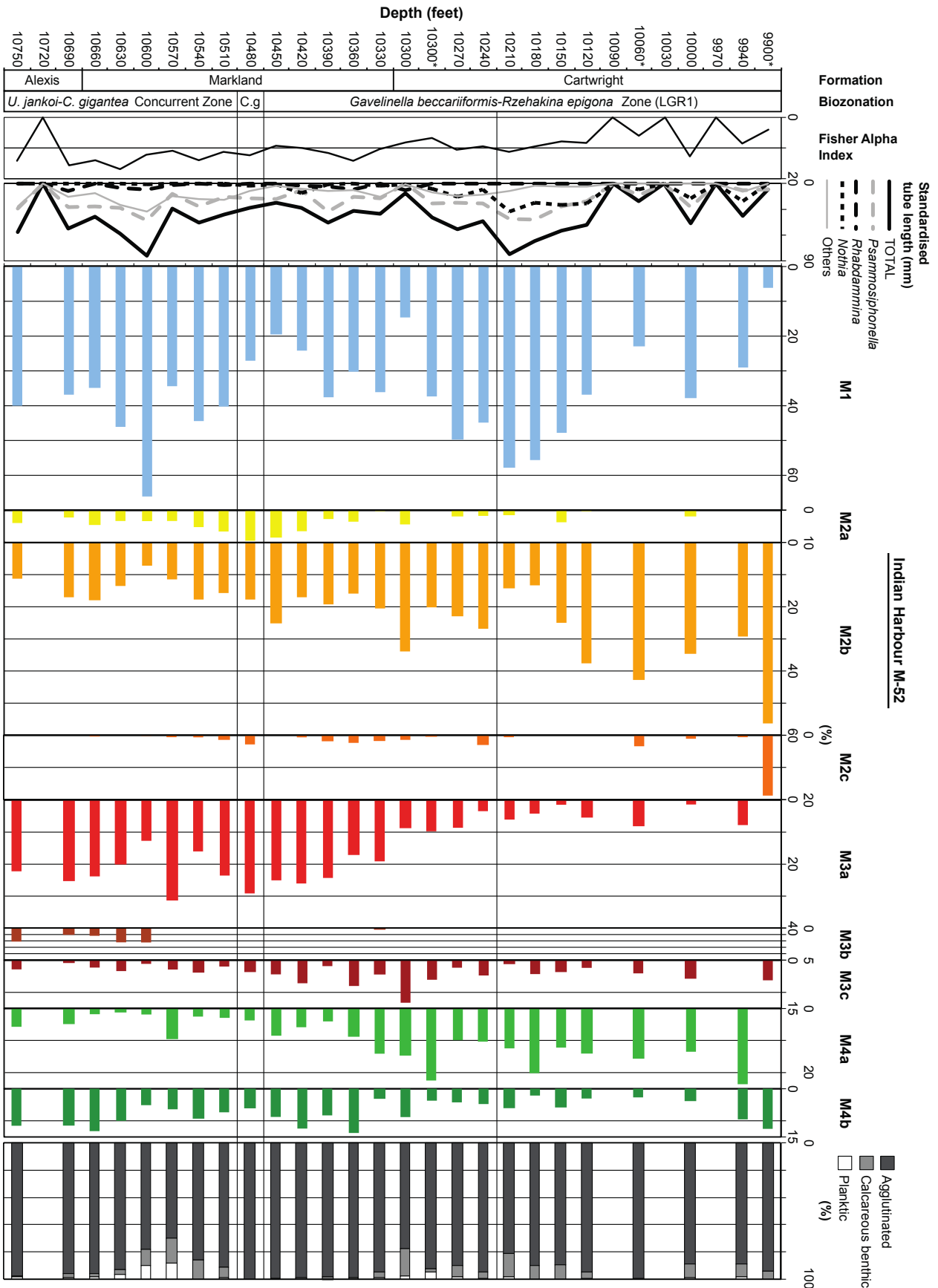


Figure 10. Species diversity of agglutinated foraminifera, standardised length of tubular forms and proportions of morphotypes. *: side-wall core. C. g.: *Caudammina gigantea*

high proportion of agglutinated and calcareous epifauna (M1, M2, M3, CH-A) in the Alexis and Markland formations qualify the assemblages as “Association F” of Koutsoukos & Hart (1990) which is characteristic of Late Cretaceous middle to lower slope environments. In addition, the high abundance of *Recurvoides* and *Thalmanammina* suggests that the fauna is also similar to “the *Recurvoides* Association” of Haig (1979), typical of Cretaceous deep-water environments. Abundant occurrences of tubular forms are usually confined to slope environments in recent and fossil records (e.g., Jones & Charnock, 1985; Schröder, 1986; Koutsoukos & Hart, 1990; Nagy *et al.*, 2000), and Murray *et al.* (2011) suggested that the mere presence of tubular forms is indicative enough of bathyal and deeper environments exposed to weak bottom currents. The diversity of benthic foraminiferal assemblages, in general, increases with greater water depth in oxygenated areas (e.g., Murray, 2006; Murray *et al.*, 2011). The high diversity of the Labrador Sea assemblages, which is equivalent to contemporary and modern bathyal assemblages, indicates deep-water environments.

The increased abundance of *Nothia robusta* (Grzybowski) in the upper Paleocene interval might indicate a shallowing bathymetry and/or more turbiditic environments as the basin was filled in with sediments (Kaminski & Gradstein, 2005). This is in accordance with the frequent occurrence of *Reticulophragmium* and *Budashevaella* and the increased abundance of streptospiral forms (M2b), which are characteristic of “Foraminiferal Biofacies 3” in the Eocene outer neritic–upper bathyal facies in the Barents Sea (Nagy *et al.*, 2000), and a decrease in the diversity and standardised tube length in the upper Paleocene. This change in the assemblages may be related to the regression from the Selandian to the earliest Thanetian (Dickie *et al.*, 2011).

The presence of all morphogroups together with the moderate relative abundance of infaunal forms (M4) indicates a mesotrophic, relatively well-oxygenated environment according to the TROX model (Jorissen *et al.*, 1995; Van der Zwaan *et al.*, 1999) (Fig. 11). Additionally, the high abundance of robust tubular forms, namely *Psammosiphonella*, throughout the studied interval indicates the presence of bottom water currents. The bottom-water environment in Late Cretaceous and Paleocene times was likely rather stable, and changes were gradual because there is no dramatic change in the relative abundance of morphogroups. Among the planktic assemblages, there is no flux of *Hedbergella* and *Heterohelix*, and *A. mayaroensis*, *Globigerinelloides*, *G. araca* and *Rugotruncana*, which were recorded in this study and Gradstein *et al.* (1994), are classified as mesotrophic

taxa by Premoli Silva & Sliter (1999). These suggest that the upper water column was probably mesotrophic, which is in accord with the benthic assemblages.

Another peculiar feature of the assemblages is the persistent occurrence of *Repmanina charoides* in the samples between 10,750 and 10,300 feet, mostly the Alexis and Markland formations. *Repmanina charoides* is known as a disaster opportunist and to be tolerant to stressed environments (see discussion in Kaminski & Gradstein, 2005 and subsequent studies, e.g., Cetean *et al.*, 2008; Waškowska, 2011) with epifaunal to deep infaunal life positions (see Phipps, 2011). In our material, *R. charoides*, however, does not dominate the assemblages. Therefore, although the species is a useful biological indicator for extreme environmental changes when dominating, its common occurrence in the Upper Cretaceous and Paleocene in M-52 well may simply correspond to a deep-water environment, and its reduced abundance in the Cartwright Formations is probably related to the Selandian–Thanetian regression and associated changes, such as a shallower bathymetry and more terrigenous input, as the recent *R. charoides* shows a ecological preference to more oligotrophic, deep-water environments in the Mediterranean Sea (De Rijk *et al.*, 2000).

Problem with the Alexis Formation

The interval between 3,484 m and 3,250 m is reported as the Alexis Formation, which is composed of tuff and basalt (Fig. 3) and ranges up to the Albian (Dickie *et al.*, 2011). Samples from this interval contain the diversified DWAF assemblages of the Santonian–Campanian age as discussed above, and the composition of assemblages are similar to ones in the Markland Formation. Although it depends on the thickness of volcanic ash layer, foraminiferal assemblages in volcanic ash are usually diminished and less diversified in comparison to those before and after volcanic events, and assemblages just above ash layers are dominated by early recolonisers (Hess *et al.*, 2001; Galeotti *et al.*, 2002; Waškowska, 2011). The samples with diversified foraminiferal assemblages could have been collected from shales deposited during non-volcanic periods between volcanic events in the Alexis Formation, if shales are present. Taxa in the assemblages from the interval are, however, not of the Lower Cretaceous, and thus the results of this study point to the necessity of revising the lithology and age of the interval between 10,750 and 10,690 feet which is labelled as the Alexis Formation. This interval may well belong to the Markland Formation or the upper part of the transitional interval between the Bjarni and Markland formations of Dickie *et al.* (2011).

CONCLUSIONS

A total of 245 taxa of benthic foraminifera and 24 taxa of planktic foraminifera are identified from the Upper Cretaceous and Paleocene formations of the Hopedale Basin, Labrador Sea. The assemblages are dominated by agglutinated foraminifera, but calcareous benthic and planktic foraminifera are recorded regularly throughout the interval (Fig. 7).

The *Uvigerinamina jankoi*–*Caudamina gigantea* Concurrent Zone (lower to middle Campanian) (10,750–10,660 feet), and the *Caudamina gigantea* Zone at 10,480 feet are recognised in the Upper Cretaceous (Fig. 8). The sample at 10,480 feet might be of late Maastrichtian age based on the published data from Gradstein *et al.* (1994). There seems to be a hiatus from the middle Campanian up to the lower Maastrichtian. The interval between 10,750 and 10,690 feet may not belong to the Valanginian–Albian Alexis Formation as reported by Canada–Newfoundland and Labrador Offshore Petroleum Board (2008). The interval could belong to the Markland Formation or the transitional unit between the Bjarni and the Markland formations described by Dickie *et al.* (2011).

The morphogroup analysis of benthic foraminiferal assemblages shows that the assemblage composition in the Alexis and Markland formations is similar to the middle–lower slope “Association F” of Koutsoukos & Hart (1990), and

the high proportion of *Recurvoides* also assigns the assemblages of M-52 well to the deep-water “*Recurvoides* Association” of Haig (1979). The high abundance of M1 (tubular forms), the presence of all morphogroups and the moderate proportion of M4 (infaunal) (Fig. 10) suggest relatively well-oxygenated, mesotrophic, bathyal environments with bottom water currents.

The composition of the agglutinated assemblages changes in the Cartwright Formation and becomes similar to the outer shelf–upper bathyal “Foraminiferal Biofacies 3” of Nagy *et al.* (2000). This change is likely related to the Selandian–earliest Thanetian regression.

ACKNOWLEDGEMENTS

We are grateful for the access to the Former British Petroleum Microfossil Collection at the Natural History Museum, London, U.K. We thank Mushabbab Assiri for technical support in the KFUPM SEM laboratory and Jim Davy in the SEM lab of the Earth Sciences department, UCL. We would also like to thank Felix Gradstein for his critical comments which improved this manuscript. ES was supported by grant to MAK from Total s.a. and from the W. Storrs Cole Memorial Research Award of the Geological Society of America. ES and JT acknowledge the support from the ING PAN internal “MIKRO” project. The ING PAN is supported by the 7th European Framework Programme, ATLAB Project no 285989.

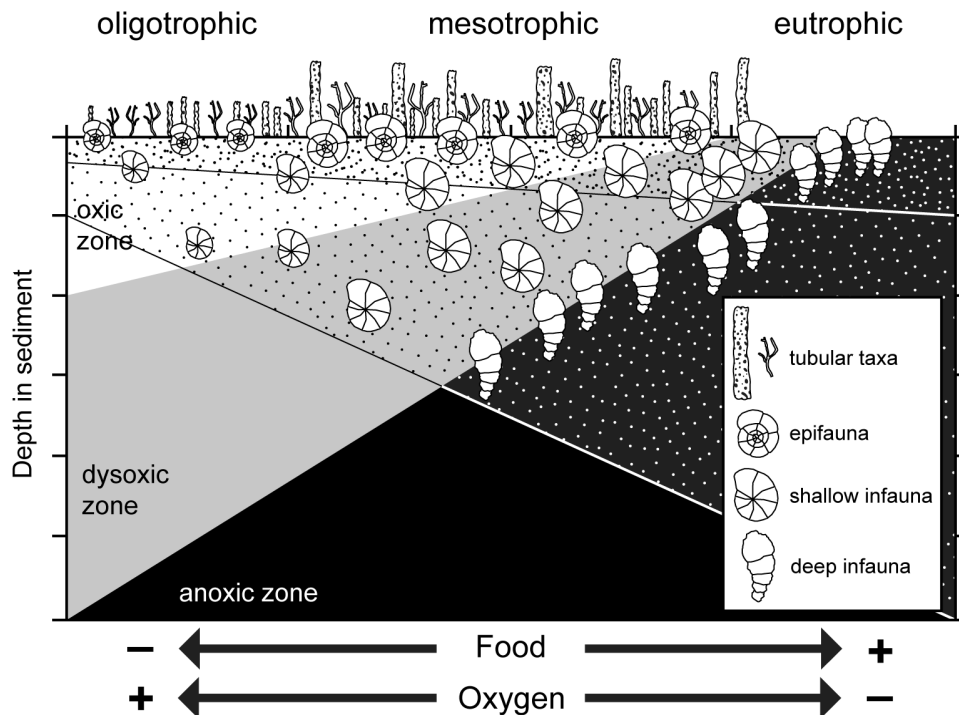


Figure 11. TROX model (modified after Jorissen *et al.*, 1995; Van der Zwaan *et al.*, 1999). Fine tubular forms are added to oligotrophic conditions representing the abyssal and Scaglia-type biofacies, and thicker, more robust ones to mesotrophic conditions representing the slope biofacies (see Kaminski & Kuhnt, 1995).

REFERENCES

- Alegret, L., Molina, E. & Thomas, E. 2003. Benthic foraminiferal turnover across the Cretaceous/ Paleogene boundary at Agost (southern Spain): paleoenvironmental inferences. *Marine Micropaleontology*, **48**, (3–4), 251–279.
- Alegret, L. & Thomas, E. 2001. Upper Cretaceous and lower Paleogene benthic foraminifera from northeastern Mexico. *Micropaleontology*, **47**, (4), 269–316.
- Alperin, M.I., Cusminsky, G.C. & Bernasconi, E. 2011. Benthic foraminiferal morphogroups on the Argentine continental shelf. *Journal of Foraminiferal Research*, **41**, (2), 155–166.
- Bailey, H.W., Hart, M.B. & Swiecicki, A. 2009. Evolutionary lineages of benthic foraminifera in the chalk seas of NW Europe and their application to problem solving. In: Demchuk, T.D. & Gary, A.C. (eds), *Geological Problem Solving with Microfossils: A Volume in Honor of Garry D. Jones*. SEPM Special Publication, **93**, 233–249.
- Bąk, K., Bąk, M., Geroch, S. & Manecki, M. 1997. Biostratigraphy and paleoenvironmental analysis of benthic Foraminifera and radiolarians in Paleogene variegated shales in the Skole Unit, Polish Flysch Carpathians. *Annales Societatis Geologorum Poloniae*, **67**, (2–3), 135–154.
- Berggren, W.A. & Aubert, J. 1976. Eocene benthonic foraminiferal biostratigraphy and paleobathymetry of Orphan Knoll (Labrador Sea). *Micropaleontology*, **22**, (3), 327–346.
- Bernhard, J.M. 1986. Characteristic assemblages and morphologies of benthic foraminifera from anoxic, organic-rich deposits: Jurassic through Holocene. *Journal of Foraminiferal Research*, **16**, (3), 207–215.
- Bolli, H.M., Beckmann, J.-P. & Saunders, J.B. 1994. *Benthic foraminiferal biostratigraphy of the south Caribbean region*. Cambridge University Press, Cambridge. 408 pp.
- Bubík, M. 1995. Cretaceous to Paleogene agglutinated foraminifera of the Bílé Karpaty unit (West Carpathians, Czech Republic). In: Kaminski, M.A., Geroch, S. & Gasiński, M.A. (eds), *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **3**, 71–116.
- Bubík, M. 2000. New observations on the type specimens of Recurvoidinae (Foraminifera) described by Hanzlíková (1966, 1972 and 1973). In: Hart, M.B., Kaminski, M.A. & Smart, C.W. (eds), *Proceedings of the Fifth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **7**, 59–70.
- Canada-Newfoundland and Labrador Offshore Petroleum Board, 2008. *Schedule of Wells: Newfoundland and Labrador Offshore Area. October 2008*.
- Cetean, C.G., Bălc, R., Kaminski, M.A. & Filipescu, S. 2008. Biostratigraphy of the Cenomanian–Turonian boundary in the Eastern Carpathians (Dâmbovița Valley): preliminary observations. *Studia Universitatis Babeş-Bolyai, Geologia*, **53**, (1), 11–13.
- Cetean, C.G., Bălc, R., Kaminski, M.A. & Filipescu, S. 2011a. Integrated biostratigraphy and palaeoenvironments of an upper Santonian – upper Campanian succession from the southern part of the Eastern Carpathians, Romania. *Cretaceous Research*, **32**, (5), 575–590.
- Cetean, C.G., Setoyama, E., Kaminski, M.A., Neagu, T., Bubík, M., Filipescu, S. & Tyszka, J. 2011b. *Eobigenerina*, a cosmopolitan deep-water agglutinated foraminifer, and remarks on late Paleozoic to Mesozoic species formerly assigned to *Pseudobolivina* and *Bigenerina*. In: Kaminski, M.A. & Filipescu, S. (eds), *Proceedings of the Eighth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **16**, 19–27.
- Chalmers, J. & Laursen, K. 1995. Labrador Sea: the extent of continental and oceanic crust and the timing of the onset of seafloor spreading. *Marine and Petroleum Geology*, **12**, (2), 205–217.
- Chalmers, J.A. & Pulvertaft, T.C.R. 2001. Development of the continental margins of the Labrador Sea—a review. In: Wilson, R.C.L., Whitmarsh, R.B., Taylor, B. & Froitzheim, N. (eds), *Non-Volcanic Rifting of Continental Margins: A Comparison of Evidence from Land and Sea*. Geological Society, London, Special Publication, **187**, 77–105.
- Charnock, M.A. & Jones, R.W. 1990. Agglutinated foraminifera from the Paleogene of the North Sea. In: Hemleben, C., Kaminski, M.A., Kuhnt, W. & Scott, D.B. (eds), *Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera*. NATO ASI Series C, **327**, 139–244. Kluwer Academic Publishers.
- Chian, D., Loudon, K.E. & Reid, I. 1995a. Crustal structure of the Labrador Sea conjugate margins and implications for the formation of nonvolcanic continental margins. *Journal of Geophysical Research*, **100**, (B-12), 24239–24253.
- Chian, D., Keen, C., Reid, I. & Loudon, K.E. 1995b. Evolution of nonvolcanic rifted margins: New results from the conjugate margins of the Labrador Sea. *Geology*, **23**, (7), 589–592.
- Coccioni, R., Frontalini, F., Bancalà, G., Fornaciari, E., Jovane, L. & Sprovieri, M. 2010. The Dan-C2 hyperthermal event at Gubbio (Italy): Global implications, environmental effects, and cause(s). *Earth and Planetary Science Letters*, **297**, (1–2), 298–305.
- Corliss, B.H. 1985. Microhabitats of benthic foraminifera within deep-sea sediments. *Nature*, **314**, (6010), 435–438.
- Corliss, B.H. & Chen, C., 1988. Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology*, **16**, (8), 716–719.
- Cushman, J.A. & Jarvis, P.W. 1932. Upper Cretaceous foraminifera from Trinidad. *Proceedings of the United States National Museum*, **80**, (2914), 1–60.
- De Rijk, S., Jorissen, F.J., Rohling, E.J. & Troelstra, S.R. 2000. Organic flux control on bathymetric zonation of Mediterranean benthic foraminifera. *Marine Micropaleontology*, **40**, (3), 151–166.
- DeSilva, N.R. 1999. Sedimentary basins and petroleum systems offshore Newfoundland and Labrador. In: Fleet, A.J. & Boldy, S.A.R. (eds), *Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference*, 501–515.
- Dickie, K., Keen, C.E., Williams, G.L. & Dehler, S.A. 2011. Tectonostratigraphic evolution of the Labrador margin, Atlantic Canada. *Marine and petroleum Geology*, **28**, (9), 1663–1675.
- Ellis, B.F. & Messina, A.R. 1940 *et seq.* *Catalog of Foraminifera*. American Museum of Natural History Special Publication. New York.
- Enachescu, M. 2006a. Hopedale Basin-1: Favorable geology, advanced technology may unlock Labrador's substantial resources. *Oil and Gas Journal*, **104**, (23), 29–34.
- Enachescu, M. 2006b. Hopedale Basin-2: Atlantic off Labrador poised for modern exploration round. *Oil and Gas Journal*, **104**, (24), 36–42.
- Fisher, R.A. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. Part 3. A theoretical distribution for the apparent abundance of different species. *Journal of Animal Ecology*, **12**, (1), 54–58.
- Frenzel, P. 2000. Die benthischen Foraminiferen der Rügener Schreibkreide (Unter-Maastricht, NE-Deutschland). *Neue Paläontologischen Abhandlungen*, **3**, 1–361.
- Galeotti, S., Bellagamba, M., Kaminski, M.A. & Montanari, A. 2002. Deep-sea benthic foraminiferal recolonisation following a volcanoclastic event in the lower Campanian of the Scaglia Rossa Formation (Umbria–Marche Basin, central Italy). *Marine Micropaleontology*, **44**, (1–2), 57–76.

- Galeotti, S., Kaminski, M.A., Coccioni, R. & Speijer, R.P. 2004. High-resolution Deep-Water Agglutinated Foraminiferal record across the Paleocene/Eocene transition in the Contessa Road Section (central Italy). In: Bubik, M. & Kaminski, M.A. (eds), *Proceedings of the Sixth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, 8, 83–103.
- Gawor-Biedowa, E. 1992. Campanian and Maastrichtian foraminifera from the Lublin Upland, Eastern Poland. *Palaeontologia Polonica*, 52, 1–187.
- Geroch, S. 1962. *Thalmannammina* and *Plectrocurvoides* (Foraminifera) in the Lower Cretaceous of the Flysch Carpathians. *Rocznik Polskiego Towarzystwa Geologicznego*, 32 (2), 281–300.
- Geroch, S. & Nowak, W. 1984. Proposal of zonation for the Late Tithonian–Late Eocene, based upon Arenaceous Foraminifera from the Outer Carpathians, Poland. In: Oertli, H.J. (Ed.), *Benthos '83, 2nd International Symposium on Benthic Foraminifera (Pau, April 1983) Elf Aquitaine, Esso Rep and Total CFP. Pau and Bourdeaux*, 225–239.
- Gradstein, F.M. & Berggren, W.A. 1981. Flysch-type agglutinated foraminifera and the Maastrichtian to Paleogene history of the Labrador and North Seas. *Marine Micropaleontology*, 6 (3), 211–268.
- Gradstein, F.M., Kaminski, M.A., Berggren, W.A., Krisiansen, I.L. & d'Iorio, M.A. 1994. Cenozoic biostratigraphy of the Central North Sea and Labrador Shelf. *Micropaleontology*, 40, 1–152. Supplement for 1994.
- Gradstein, F.M. & Srivastava, S.P. 1980. Aspects of Cenozoic stratigraphy and paleoceanography of the Labrador Sea and Baffin Bay. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 30, 261–295.
- Haig, D.W. 1979. Global distribution patterns for mid-Cretaceous foraminiferids. *Journal of Foraminiferal Research*, 9, (1), 29–40.
- Haig, D.W. 2003. Palaeobathymetric zonation of foraminifera from lower Permian shale deposits of a high-latitude southern interior sea. *Marine Micropaleontology*, 49, (4), 317–334.
- Hammer, Ø. & Harper, D.A.T. 2006. *Paleontological Data Analysis*. Blackwell Publishing, Oxford. 351 pp.
- Hammer, Ø., Harper, D.A.T. & Ryan, P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*, 4, (1) http://palaeo-electronica.org/2001_1/past/issue1_01.htm 9 pp.
- Hanzlíková, E. 1972. Carpathian Upper Cretaceous Foraminifera of Moravia (Turonian – Maastrichtian). *Ústřední Ústav Geologický*, 39, 160 pp.
- Hart, M.B. 2007. Late Cretaceous climates and foraminiferid distributions. In: Williams, M., Haywood, A.M., Gregory, F.J. & Schmidt, D.N. (eds), *Deep-Time Perspectives on Climate Change: Marrying the Signal from Computer Models and Biological Proxies*. The Micropaleontological Society Special Publications. The Geological Society, London, pp. 235–250.
- Hart, M.B., Bailey, H.W., Crittenden, S., Fletcher, B.N., Price, R.J. & Swiecicki, A. 1989. Cretaceous. In: Jenkins, D.G. & Murray, J.W. (eds), *Stratigraphical Atlas of Fossil Foraminifera*, 2nd edition. Ellis Horwood Ltd, Chichester, pp. 273–371.
- Hess, S., Kuhnt, W., Hill, S., Kaminski, M.A., Holbourn, A. & de Leon, M. 2001. Monitoring the recolonization of the Mt Pinatubo 1991 ash layer by benthic foraminifera. *Marine Micropaleontology*, 43, (1–2), 119–142.
- Hofker, J. 1960. The foraminifera of the lower boundary of the Danish Danian. *Bulletin of the Geological Society of Denmark*, 14, 212–242.
- Jones, R.W. & Charnock, M.A. 1985. “Morphogroups” of agglutinated foraminifera. Their life positions and feeding habits and potential applicability in (paleo)ecological studies. *Revue de Paléobiologie*, 4, (2), 311–320.
- Jorissen, F.J., de Stigter, H.C. & Widmark, J.G.V. 1995. A conceptual model explaining benthic foraminiferal microhabitats. *Marine Micropaleontology*, 26, (1–4), 3–15.
- Kaminski, M.A. 1987. *Cenozoic Deep-Water Agglutinated Foraminifera in the North Atlantic*. Unpublished PhD thesis, Woods Hole Oceanography Institution, Massachusetts Institute of Technology, Joint Program in Oceanography, WHOI-88-3, 262 pp.
- Kaminski, M.A., Gradstein, F.M. & Berggren, W.A. 1989. Paleogene benthic foraminifer biostratigraphy and paleoecology at Site 647, southern Labrador Sea. In: Srivastava, S.P., Arthur, M., Clement, B., et al. (eds), *Proceedings of the Ocean Drilling Program, Scientific Results*, 105, 705–730.
- Kaminski, M.A., Gradstein, F.M., Berggren, W.A., Geroch, S. & Beckmann, J.P. 1988. Flysch-type agglutinated foraminiferal assemblages from Trinidad: Taxonomy, Stratigraphy and Paleobathymetry. In: Rögl, F. & Gradstein, F.M. (eds), *Proceedings of the Second Workshop on Agglutinated Foraminifera, Vienna 1986. Abhandlungen der Geologischen Bundesanstalt*, 41, 155–228.
- Kaminski, M.A. & Kuhnt, W. 1995. Tubular agglutinated foraminifera as indicators of organic carbon flux. In: Kaminski, M.A., Geroch, S. & Gasiński, M.A. (eds), *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, 3, 141–144.
- Kaminski, M.A., Boersma, A., Tyszka, J. & Holbourn, A.E.L., 1995. Response of deep-water agglutinated foraminifera to dysoxic conditions in the California borderland basins. In: Kaminski, M.A., Geroch, S. & Gasiński, M.A. (eds), *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation, Special Publication, 3, 131–140.
- Kender, S., Kaminski, M.A. & Jones, R.W. 2006. Four new species of deep water agglutinated foraminifera from the Oligocene–Miocene of the Congo Fan (offshore Angola). *Micropaleontology*, 52, (5), 465–470.
- Kender, S., Kaminski, M.A. & Jones, R.W. 2008. Oligocene Deep-Water Agglutinated Foraminifera from the Congo Fan, Offshore Angola: Palaeoenvironments and Assemblages Distributions. In: Kaminski, M.A. & Coccioni, R. (eds), *Proceedings of the Seventh International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, 13, 107–156.
- King, C., Bailey, H.W., Burton, C.A. & King, A.D. 1989. Cretaceous of the North Sea. In: Jenkins, D.G. & Murray, J.W. (eds), *Stratigraphical Atlas of Fossil Foraminifera*, 2nd edition. Ellis Horwood Ltd, Chichester, 372–417.
- Korsun, S. & Hald, M. 2000. Seasonal dynamics of benthic foraminifera in a glacially fed fjord of Svalbard, European Arctic. *Journal of Foraminiferal Research*, 30, (4), 251–271.
- Kuhnt, W., Geroch, S., Kaminski, M.A., Moullade, M. & Neagu, T. 1992. Upper Cretaceous abyssal claystones in the North Atlantic and Western Tethys: Current status of biostratigraphical correlation using agglutinated foraminifera and palaeoceanographic events. *Cretaceous Research*, 13, (5–6), 467–478.
- Koutsoukos, E.A.M. & Hart, M.B. 1990. Cretaceous foraminiferal morphogroup distribution patterns, palaeocommunities and trophic structures: a case study from the Sergipe Basin, Brazil. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 81, (3), 221–246.
- Kuhnt, W., Kaminski, M.A. & Moullade, M. 1989. Late Creta-

- ceous deep-water agglutinated foraminiferal assemblages from the North Atlantic and its marginal seas. *Geologische Rundschau*, **78**, (3), 1121–1140.
- Kuhnt, W., Moullade, M. & Kaminski, M. 1998. Upper Cretaceous, K/T boundary, and Paleocene agglutinated foraminifera from Hole 959D (Côte D'Ivoire-Ghana Transform Margin). In: Lohmann, M.J. & Moullade, M. (eds), *Proceedings of the Ocean Drilling Program, Scientific Results*, 159, 389–411.
- Kuhnt, W. & Urquhart, E. 2001. Tethyan flysch-type benthic foraminiferal assemblages in the North Atlantic: Cretaceous to Palaeogene deep water agglutinated foraminifera from the Iberia abyssal plain (ODP Leg 173). *Revue de Micropaléontologie*, **44**, (1), 27–59.
- Lloyds, J.M. 2006. Modern distribution of benthic foraminifera from Disko Bugt, West Greenland. *Journal of Foraminiferal Research*, **36**, (4), 315–331.
- Lundin, E.R. & Doré, A.G. 2005. The fixity of the Iceland “hotspot” on the Mid-Atlantic Ridge: Observational evidence, mechanisms, and implications for Atlantic volcanic margins. In: Foulger, G.R., Natland, J.H., Presnall, D.C. & Anderson, D.L. (eds), *Plates, plumes, and paradigms*. Geological Society of America Special Paper, **388**, 627–651.
- Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Science Ltd., Oxford. 256 pp.
- Malata, E. & Oszczytko, N. 1990. Deep water agglutinated foraminiferal assemblages from Upper Cretaceous red shales of the Magura Nappe / Polish Outer Carpathians. In: Hemleben, C., Kaminski, M.A., Kuhnt, W. & Scott, D.B. (eds), *Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera*. NATO ASI Series C, **327**, pp. 507–524. Kluwer Academic Publishers.
- Malmgren, B.A. 1987. Differential dissolution of Upper Cretaceous planktonic foraminifera from a temperate region of the South Atlantic Ocean. *Marine Micropaleontology*, **11**, (4), 251–271.
- Miller, K.G., Gradstein, F.M. & Berggren, W.W. 1982. Late Cretaceous to Early Tertiary agglutinated benthic foraminifera in the Labrador Sea. *Micropaleontology*, **28**, (1), 1–30.
- Mossop, G.D., Wallace-Dudley, K.E., Smith, G.G. & Harrison, J.C. 2004. *Sedimentary Basins of Canada*. Geological Survey of Canada Open File Map 4673.
- Moullade, M., Kuhnt, W. & Thurrow, J. 1988. Agglutinated benthic foraminifera from Upper Cretaceous variegated clays of the North Atlantic Ocean (DSDP Leg 93 and DSDP Leg 103). In: Boillot, G., Winterer, E.L., et al. (eds), *Proceedings of the Ocean Drilling Program, Scientific Results*, **103**, 349–377.
- Murray, J.W. 2006. *Ecology and Applications of Benthic Foraminifera*. Cambridge University Press, Cambridge. 426 pp.
- Murray, J.W. & Alve, E. 2011. The distribution of agglutinated foraminifera in NW European seas: Baseline data for the interpretation of fossil assemblages. *Palaeontologica Electronica*, **14**, (2), 14A: 41p; palaeo-electronica.org/2011_2/248/index.html
- Murray, J.W., Alve, E. & Jones, B.W. 2011. A new look at modern agglutinated benthic foraminiferal morphogroups: their value in palaeoecological interpretation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **309**, (3–4), 229–241.
- Nagy, J., Gradstein, F.M., Kaminski, M.A. & Holbourn, A.E. 1995. Foraminiferal morphogroups, palaeoenvironments and new taxa from Jurassic to Cretaceous strata of Thakkhola, Nepal. In: Kaminski, M.A., Geroch, S. & Gasiński, M.A. (eds), *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **3**, 181–209.
- Nagy, J., Kaminski, M.A., Kuhnt, W. & Bremer, M.A. 2000. Agglutinated foraminifera from neritic to bathyal facies in the Palaeogene of Spitsbergen and the Barents Sea. In: Hart, M.B. & Kaminski, M.A. (eds), *Proceedings of the Fifth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **7**, 333–361.
- Neagu, T., Platon, E., Dumitrescu, G. & Selea, L. 1992. The biostratigraphical significance of agglutinated foraminifera in the Eastern Carpathians (Upper Cretaceous). *Analele Universitatii Bucuresti*, 15–16, 45–49.
- Nguyen, T.M.P., Petrizzo, M.R. & Speijer, R.P. 2009. Experimental dissolution of a fossil foraminiferal assemblage (Paleocene–Eocene Thermal Maximum, Dababiya, Egypt): implications for paleoenvironmental reconstructions. *Marine Micropaleontology*, **73**, (3–4), 241–258.
- Peryt, D., Lahodinsky, R. & Durakiewicz, T. 1997. Deep-water agglutinated foraminiferal changes and stable isotope profiles across the Cretaceous–Paleogene boundary in the Rotwandgraben section, Eastern Alps (Austria). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **132**, (1–4), 287–307.
- Peryt, D., Alegret, L. & Molina, E. 2004. Agglutinated foraminifera and their response to the Cretaceous/Paleogene (K/P) boundary event at Ain Settara, Tunisia. In: Bubík, M. & Kaminski, M.A. (eds), *Proceedings of the Sixth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **8**, 393–412.
- Phipps, M. 2011. The infaunal habitat of *Repmantina charoides*: Data from the Portuguese Margin. In: Kaminski, M.A. & Filipescu, S. (eds), *Proceedings of the Eighth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **16**, 359.
- Premoli Silva, I. & Sliter, W.V. 1999. Cretaceous paleoceanography: evidence from planktonic foraminiferal evolution. In: Barrera, E. & Johnson, C.C. (eds), *Evolution of the Cretaceous Ocean–Climate System*. Geological Society of America Special Paper, **332**, 301–328.
- Riveiros, N.V. & Patterson, R.T. 2008. An illustrated guide to fjord foraminifera from the Seymour-Belize Inlet Complex, Northern British Columbia, Canada. *Palaeontologia Electronica*, **11**, (1), 2A, 45 pp. http://palaeo-electronica.org/2008_1/145/index.html
- Roest, W.R. & Srivastava, S.P. 1989. Sea-floor spreading in the Labrador Sea: A new reconstruction. *Geology*, **17**, (11), 1000–1003.
- Schröder, C.J. 1986. Deep-water arenaceous foraminifera in the Northwest Atlantic Ocean. *Canadian Technical Report Hydrography Ocean Sciences*, **71**, 191 pp + vii.
- Schröder-Adams, C.J., & McNeil, D.H. 1994. New paleoenvironmentally important species of agglutinated foraminifera from the Oligocene and Miocene of the Beaufort Sea, Arctic Canada. *Journal of Foraminiferal Research*, **24**, (3), 178–190.
- Sen Gupta, B.K. & Machain-Castillo, M.L. 1993. Benthic foraminifera in oxygen-poor habitats. *Marine Micropaleontology*, **20**, (3–4), 183–201.
- Setoyama, E., Kaminski, M.A. & Tyszka, J. 2011a. Late Cretaceous Agglutinated Foraminifera and Implications for the Biostratigraphy and Palaeobiogeography of the southwestern Barents Sea. In: Kaminski, M.A. & Filipescu, S. (eds), *Proceedings of the Eighth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, **16**, 251–309.
- Setoyama, E., Kaminski, M.A. & Tyszka, J. 2011b. The Late Cretaceous–Early Paleocene palaeobathymetric trends in the southwestern Barents Sea – Palaeoenvironmental implications of benthic foraminiferal assemblage analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **307**, (1–4), 44–58.
- Setoyama, E., Radmacher, W., Kaminski, M.A. & Tyszka, J. 2013. Foraminiferal and palynological biostratigraphy and biofacies from a Santonian–Campanian submarine fan system

- in the Vøring Basin (offshore Norway). *Marine and Petroleum Geology*, **43**, 396–408.
- Srivastava, S.P. & Roest, W.R. 1999. Extent of oceanic crust in the Labrador Sea. *Marine and Petroleum Geology*, **16**, (1), 65–84.
- Szarek, R., Kitazato, H., Nomaki, H. & Shimanaga, M. 2004. Deep-sea benthic foraminiferal assemblages from the dysoxic Sulu Sea: Modern analogue for the mid-Cretaceous Warm Dysoxic Ocean – preliminary results. *Frontier Research on Earth Evolution*, **2**, 1–5.
- van den Akker, T.J.H.A., Kaminski, M.A., Gradstein, F.M. & Wood, J. 2000. Campanian to Palaeocene biostratigraphy and palaeoenvironments in the Foula Sub-basin, west of the Shetland Islands, UK. *Journal of Micropalaeontology*, **19**, (1), 23–43.
- Van der Zwaan, G.J., Duijnste, I.A.P., den Dulk, M., Ernst, S.R., Jannink, N.T. & Kouwenhoven, T.J. 1999. Benthic foraminifers: proxies or problems? A review of paleocological concepts. *Earth-Science Reviews*, **46**, (1–4), 213–236.
- Waškowska, A. 2011. Response of Early Eocene deep-water benthic foraminifera to volcanic ash falls in the Polish Outer Carpathians: Palaeocological implications. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **305**, (1–4), 50–64.
- Widmark, J.G.V. & Malmgren, B.A. 1988. Differential dissolution of Upper Cretaceous deep-sea benthonic foraminifers from the Angola Basin, South Atlantic Ocean. *Marine Micropaleontology*, **13**, (1), 47–78.
- Wielens, H.J.B.W. & Williams, G.L. 2009. *Stratigraphic cross section Gudrid-Freydis, Hopedale Basin South, in the Labrador Sea, on the east coast of Canada, from North to South*. Geological Survey of Canada, Open File 5905.

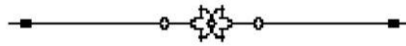


Plate 1

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Ammolagena* sp. on *Rhabdammina* sp. 5, 10,690 feet.
2. *Ammolagena contorta* on *Bathysiphon nodosariaformis*, 10,690 feet.
3. *Bathysiphon* sp., 10,690 feet.
4. *Nothia robusta*, 10,000 feet.
5. *Psammosiphonella cylindrica*, 10,630 feet.
6. *Rhizammina* sp., 10,660 feet.
7. *Placentammina placenta*, 10,000feet.
8. *Hyperammina dilatata*, 10,510 feet.
9. *Glomospira diffundens*, 10,750 feet.
10. *Glomospira gordialis*, 10,660 feet.
11. *Repmanina charoides*, 10,690 feet.
12. *Repmanina charoides*, 10,660 feet.
13. *Rzehakina epigona*, 10,540 feet.
14. *Caudammina gigantea*, 10,690 feet.
15. *Caudammina ovula*, 10,690 feet.
16. *Caudammina ovuloides*, 10,660 feet.
17. *Subreophax pseudoscalaris*, 10,600 feet.
18. *Kalamopsis grzybowskii*, 10,690 feet.
19. *Reophax duplex*, 10,540 feet.
20. *Reophax* sp., 10,660 feet.
21. *Pseudonodosinella nodulosa*, 10,630 feet.
22. *Pseudonodosinella parvula*, 10,480 feet.
23. *Paratrochamminoides acervulatus*, 10,630 feet, a) spiral side view, b) edge view.
24. *Paratrochamminoides gorayskii*, 10,690 feet.
25. *Paratrochamminoides* cf. *mitratus*, 10,630 feet.
26. *Trochamminoides subcoronatus*, 10,630 feet.

Plate 1

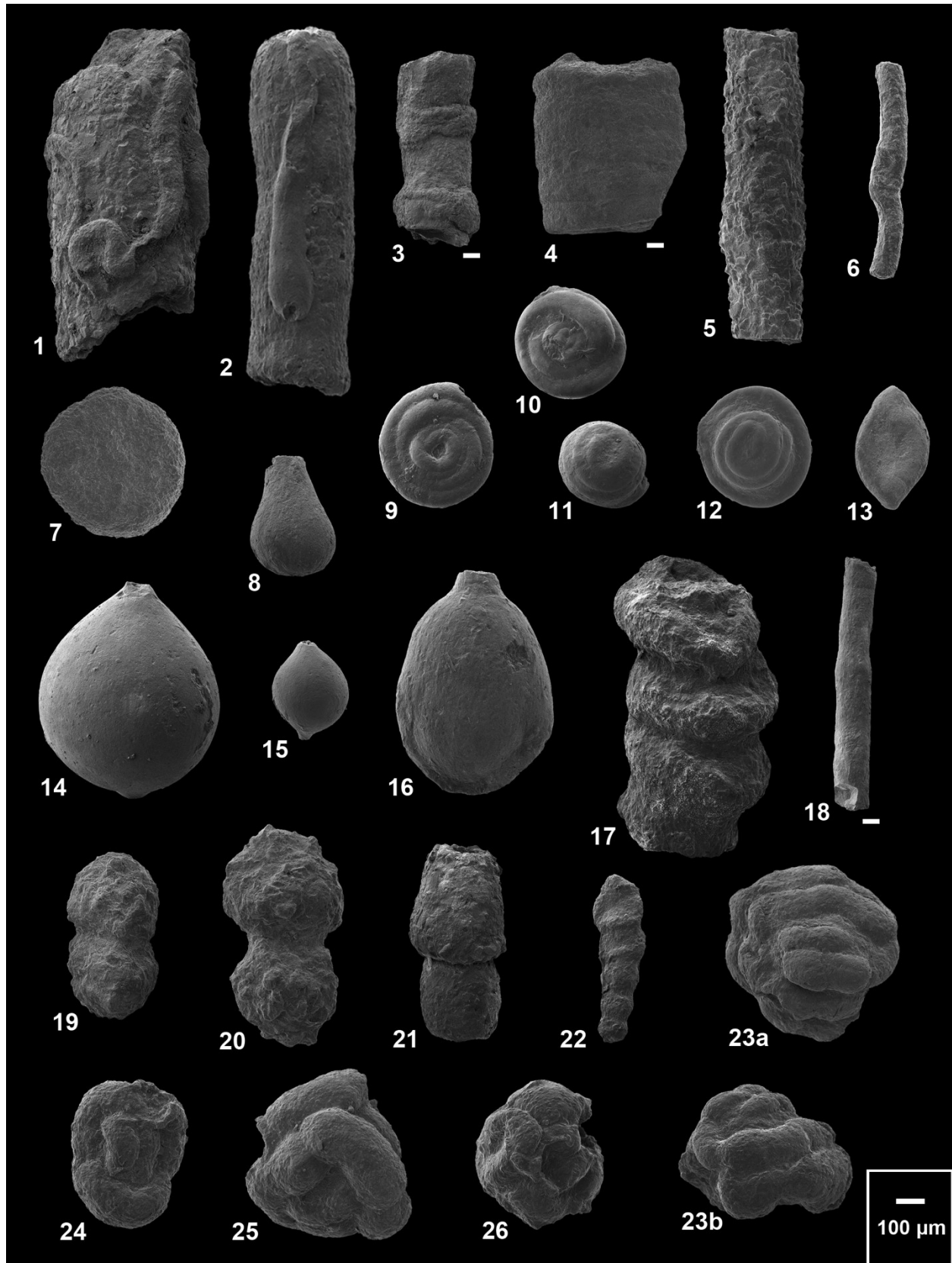


Plate 2

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Evolutinella rotulata*, 10,690 feet.
2. *Evolutinella rotulata*, 10,660 feet.
3. *Haplophragmoides kirki*, 10,570 feet.
4. *Ammobaculites* sp., 10,690 feet.
5. *Praecystamina globigerinaeformis*, 10,660 feet.
6. *Budashevaella multicamerata*, 10,150 feet.
7. *Cribrostomoides subglobosus*, 10,690 feet, a) apertural view, b) LL, c) the close-up view of the aperture.
8. ?*Cribrostomoides trinitatensis*, 10,690 feet, a) apertural view, b) the close-up view of the aperture.
9. ?*Cribrostomoides trinitatensis*, 10,690 feet., a) LL, b) apertural view.
10. *Spiroplectamina* cf. *biformis*, 10,000 feet.
11. *Spiroplectamina spectabilis*, 10,480 feet.
12. *Spiroplectamina navarroana*, 10,690 feet.
13. *Arenobulimina dorbignyi*, 10,690 feet.
14. *Uvigerinamina* cf. *praejankoi*, 10,630 feet.

Plate 3

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Thuramina* sp., 10,420 feet.
2. *Ammodiscus* sp. 4, 10,690 feet, a) spiral side, b) edge view.
3. *Haplophragmoides* cf. *walteri*, 10,600ft.
4. *Recurvoidella* sp. 1, 10,630 feet, a) apertural view, dry, b) LR, in immersion, c) LL, in immersion.
5. *Recurvoides nucleolus*, 10,630 feet, a) apertural view, in immersion, b) LR, in immersion, c) LL, immersion, d) posterior view, in immersion, e) rologram.
6. *Recurvoides* cf. *pseudononioninoides*, 10,600 feet, a) apertural view, in immersion, b) LR, in immersion, c) LL, in immersion, d) rologram.
7. *Recurvoides recurvoidiformis*, 10,600 feet, a) apertural view, in immersion, b) LR, in immersion, c) LL, in immersion, d) rologram.
8. *Recurvoides walteri*, 10,600 feet, a) LL, in immersion, b) apertural view, dry, c) LR, in immersion.
9. *Recurvoides* sp. 5, 10,630 feet, a) apertural view, in immersion, b) LR, in immersion, c) LL, in immersion.

Plate 2

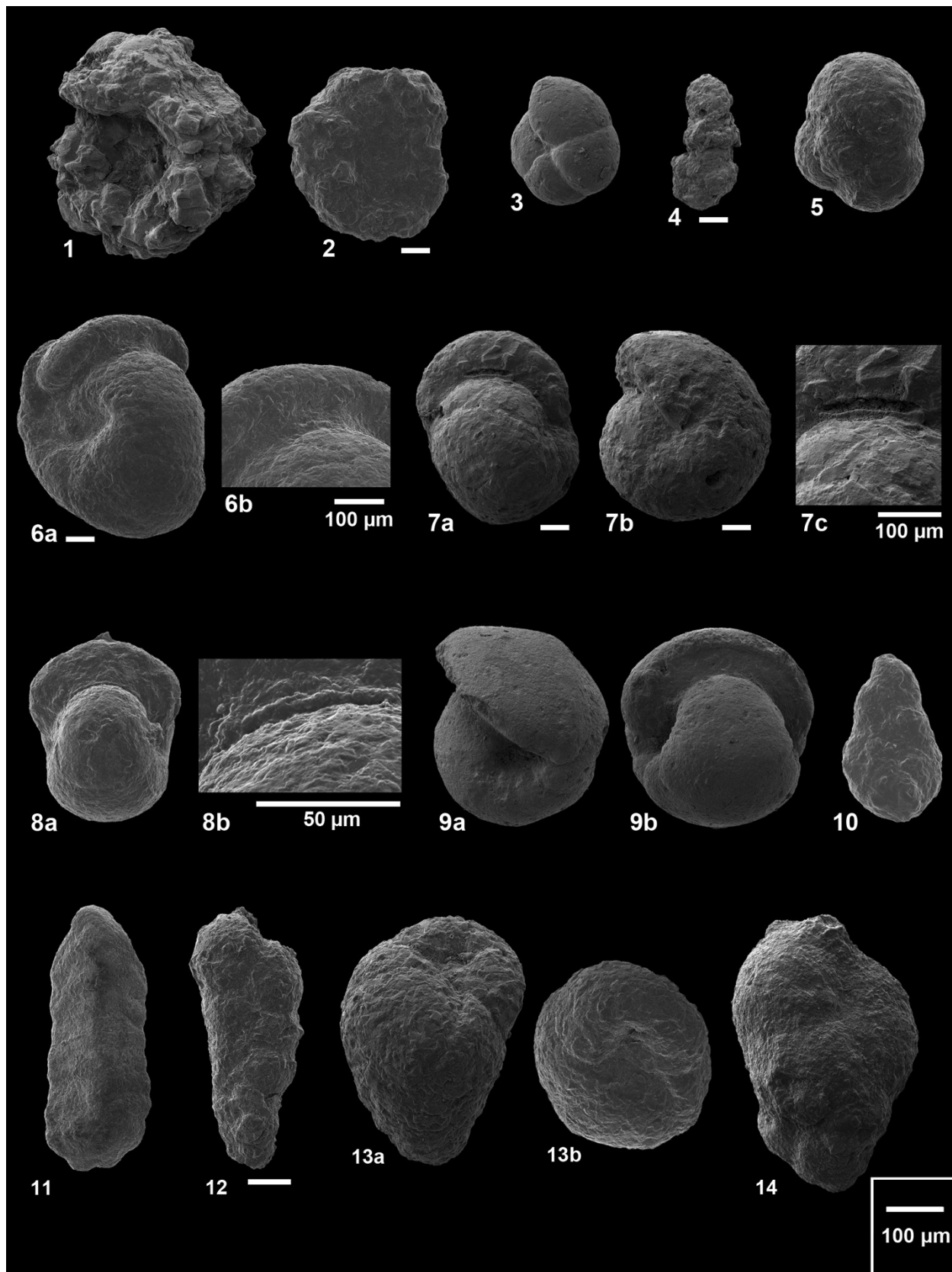


Plate 3

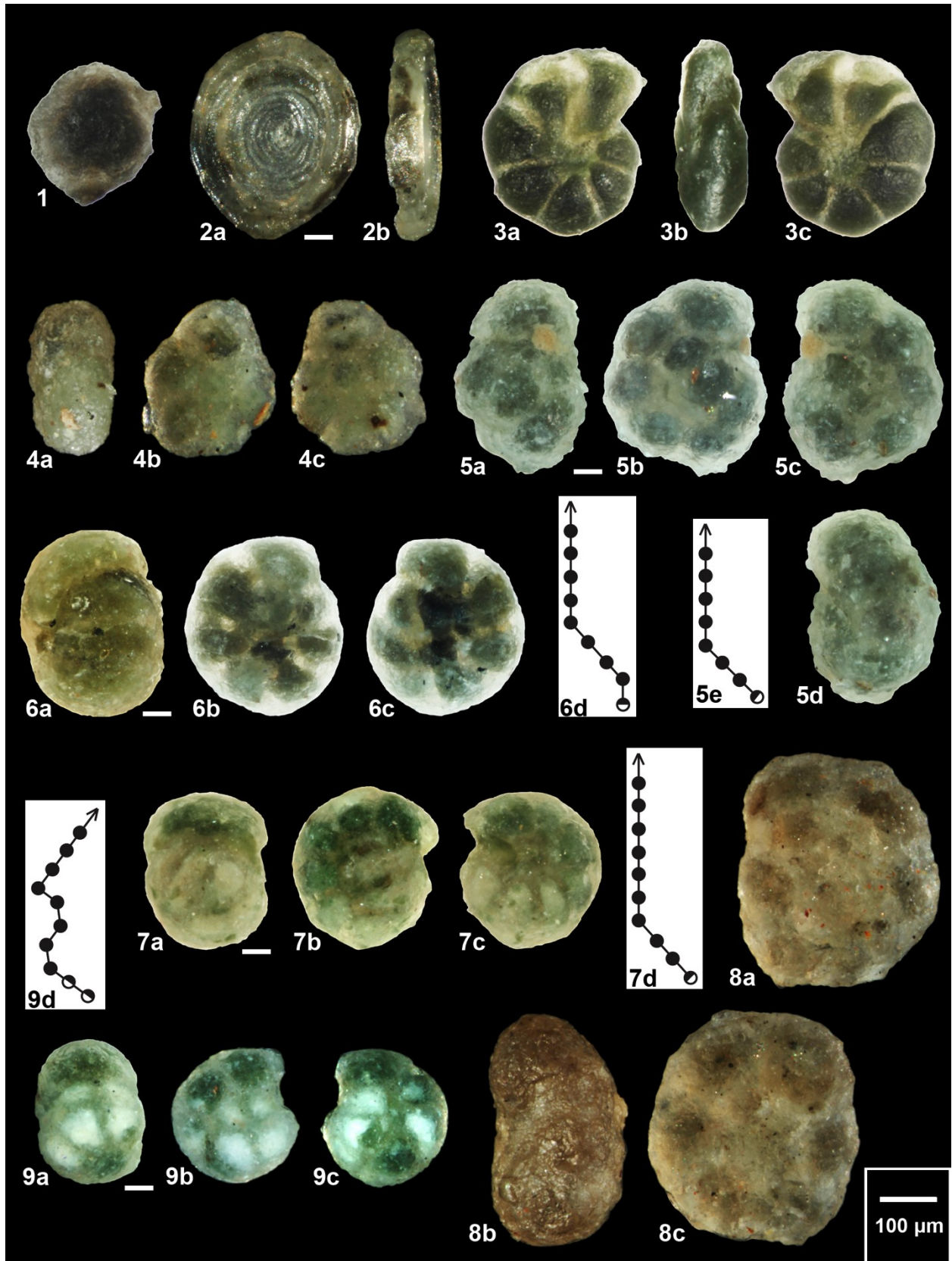


Plate 4

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Bulbobaculites* sp. 1, 10,690 feet, a) LR, in immersion, b) LL, in immersion, c) edge view, in immersion.
2. *Ammoanita ruthvenmurrayi*, 10,360 feet, a) dorsal side, in immersion, b) ventral side, in immersion, c) edge view, dry.
3. *Ammogloborotalites* sp. 1, 10,660 feet, a) dorsal side, in immersion, b) ventral side, in immersion, c) edge view, dry.
4. *Trochamminopsis altiformis*, 10,660 feet, a) dorsal side, immersion, b) ventral side, dry, c) edge view, in immersion.
5. *Conotrochammina whangaia*, 10,630 feet, a) edge view, dry, b) dorsal side, in immersion.
6. *Gerochammina lenis*, 10,690 feet, in immersion.
7. *Tritaxia* cf. *danica*, 10,600 feet, a) dry, b) in immersion, c) apertural view, dry.
8. *Uvigerinammina jankoi*, 10,630 feet, a), b) and c) in immersion.
9. *Uvigerinammina jankoi*, 10,630 feet, a) and b) in immersion.
10. *Reticulophragmoides jarvisi*, 10,300 feet, a) and b) in immersion, c) edge view, dry.
11. *Reticulophragmium pauperum*, 10,180 feet, a) LR, dry, b) edge view, dry, c) LL, in immersion.

Plate 5

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Reticulophragmium garcilassoii*, 10,270 feet, a) LL, dry, b) LL, in immersion with transmitted light, c) edge view, dry.
2. *Reticulophragmium* “robust”, 10,510 feet, a) edge view, in immersion with transmitted light, b) LR, dry, c) LL, in immersion with transmitted light.
3. *Reticulophragmium* “acute”, 10,270 feet, a) LR, dry, b) edge view, dry, c) LL, in immersion with transmitted light.
4. *Cyclamina* sp., 10,210 feet, a) LL, in immersion, b) edge view, dry.
5. *Lenticulina* sp. 1, 10,660 feet, a) LR, in immersion, b) edge view, dry, c) LL, dry.
6. *Lenticulina* sp. 2, 10,600 feet, a) LR, in immersion, b) edge view, dry, c) LL, dry.
7. *Lenticulina* sp. 3, 10,600 feet, a) LR, in immersion, b) edge view, dry, c) LL, dry.
8. *Ramulina* sp., 10,630 feet.
9. *Praebulimina arkadelphiana*, 10,630 feet.
10. *Praebulimina reussi*, 10,600 feet.
11. *Reussella szajnochae praecursor*, 10,600 feet.
12. *Pullenia quternaria*, 10,600 feet, a) LL, b) apertural view.
13. *Pullenia marssoni*, 10,600 feet, a) LL, b) apertural view.

Plate 4

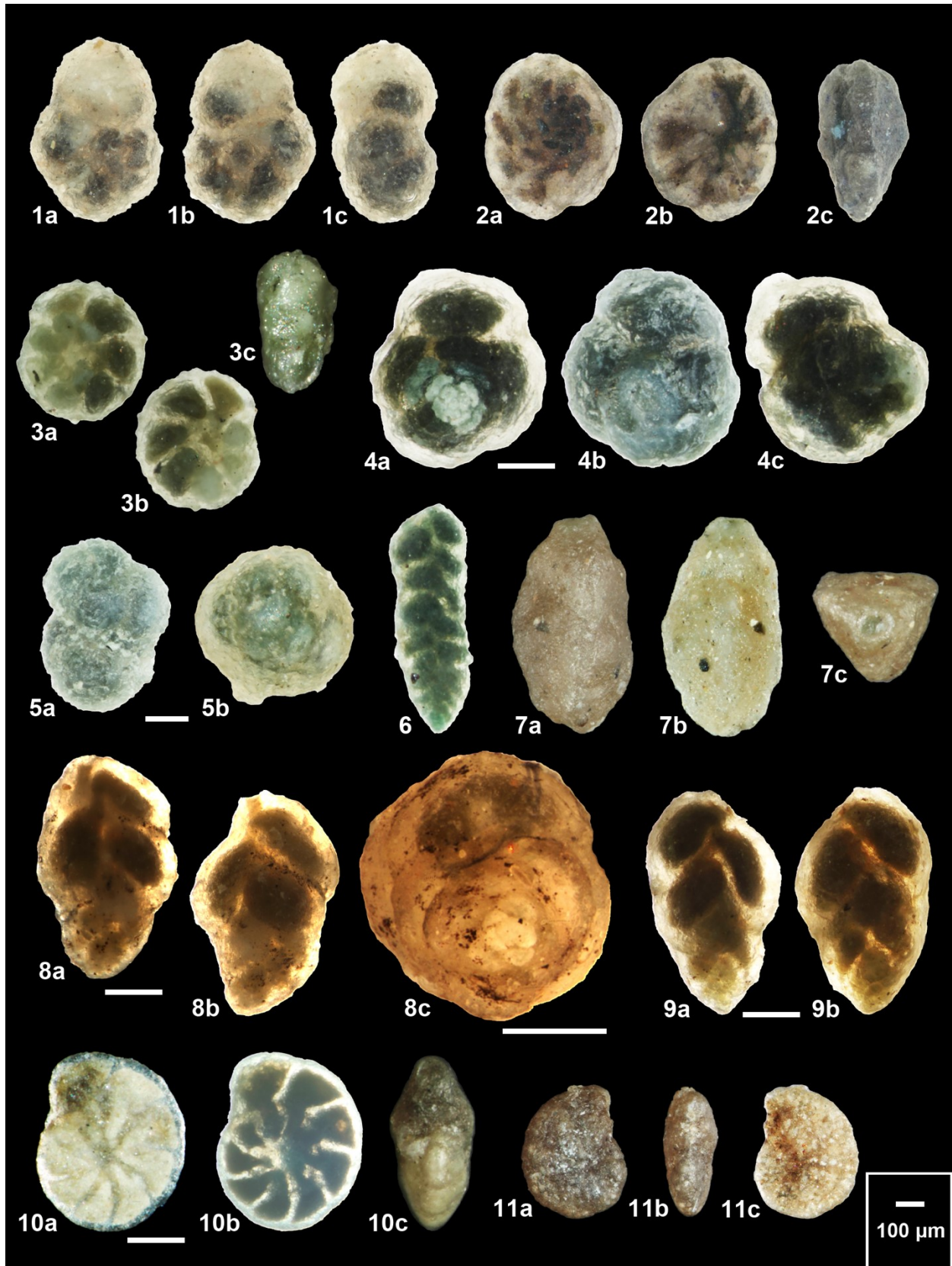


Plate 5

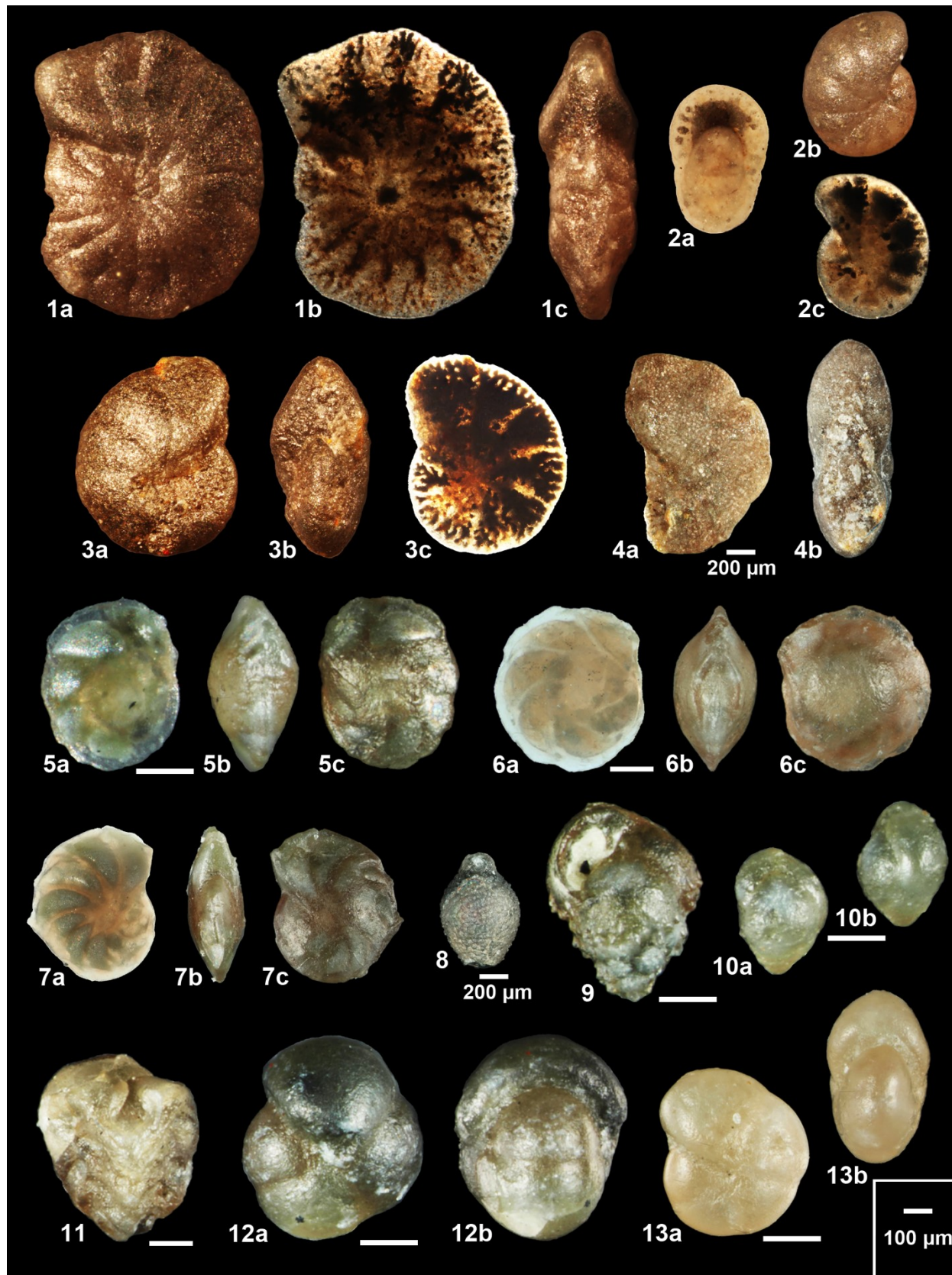


Plate 6

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Quadrimorphina allomorphinoidea*, 10,600 feet, a) dorsal side, b) edge view, c) ventral side.
2. *Quadrimorphina minuta*, 10,630 feet, a) dorsal side, b) edge view, c) ventral side.
3. *Anomalina* sp. 1, 10,690 feet, a) ventral side, dry, b) ventral side, in immersion, c) edge view, dry, d) dorsal side, dry, e) dorsal side, in immersion.
4. *Anomalinoidea* sp. 1, 10,600 feet, a) ventral side, dry, b) edge view, dry, c) dorsal side, dry.
5. *Cibicidoides velascoensis*, 10,600 feet, a) dorsal side, b) edge view, c) ventral side.
6. *Cibicidoides velascoensis*, 10,600 feet, a) ventral side, b) edge view, c) dorsal side.
7. *Cibicidoides voltzianus*, 10,630 feet, a) dorsal side, b) edge view, c) ventral side.
8. *Brotzenella monterelensis*, 10,690 feet, a) dorsal side, dry, b) dorsal side, in immersion, c) edge view, d) ventral side, dry, e) ventral side, in immersion.

Plate 7

Upper Cretaceous–Paleogene foraminifera from Indian Harbor M-52 well:

1. *Stensioeina exsculpta exsculpta*, 10,630 feet, a) ventral side, b) edge view, c) dorsal side.
2. *Stensioeina granulata granulata*, 10,660 feet, a) ventral side, b) edge view, c) dorsal side.
3. *Stensioeina pommerana*, 10,600 feet, a) ventral side, b) edge view, c) dorsal side.
4. *Berthelina* sp. 1, 10,600 feet, a) dorsal side, b) edge view, c) ventral side.
5. *Berthelina incerta*, 10,570 feet, a) dorsal side, in immersion, b) edge view, dry, c) ventral side, dry, d) ventral side, in immersion.
6. “*Gavelinella*” *beccariiiformis*, 10,630 feet, a) ventral side, b) edge view, c) dorsal side.
7. *Recurvoides* sp. 3, 10,600 feet, a) apertural view, b) LR, c) LL, d) rologram.
8. *Recurvoides* sp. 4, 10,600 feet, a) apertural view, b) LL, c) LR, d) rologram.
9. *Recurvoides* sp. 5, 10,630 feet, a) apertural view, b) LR, c) LL, d) rologram.
10. *Thalmanamina* sp. 1, 10,690 feet, a) apertural view, b) bottom view, c) LR, d) posterior view, e) rologram.

Plate 6

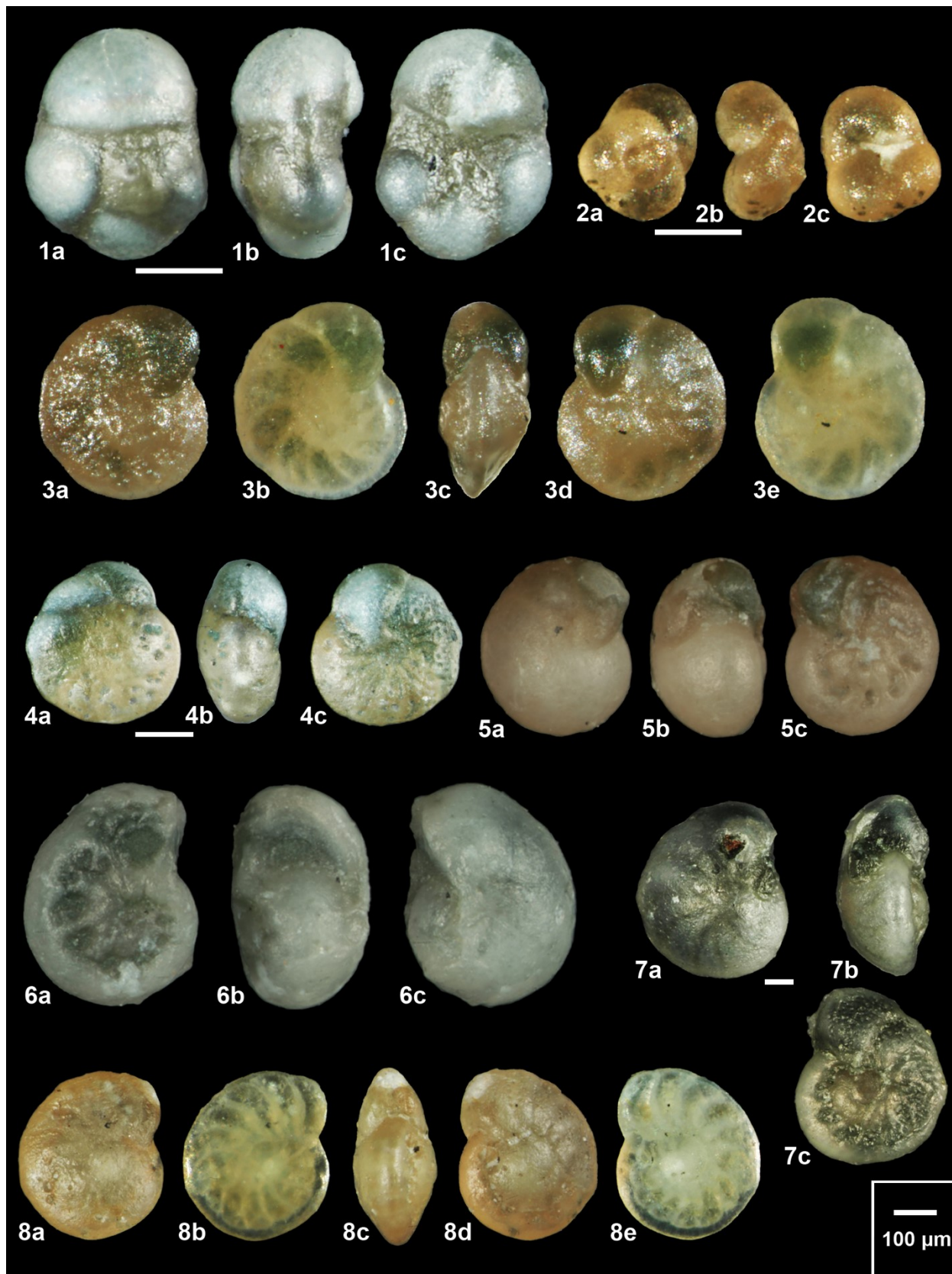


Plate 7

