Foraminifera of the Australo-Antarctic Gulf: The Upper Cretaceous of IODP Site U1512

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ABSTRACT: We present a detailed taxonomic assessment of Late Cretaceous (Turonian–Santonian) agglutinated and calcareous benthic, and planktonic foraminifera from IODP Site U1512 in the Great Australian Bight, also known as the "Australo-Antarctic Gulf" (AAG). This study expands upon the dataset of Wolfgring et al. (2021, 2023) with 25 additional samples and a systematic revision of key taxa.

Agglutinated foraminifera (*Kalamopsis grzybowskii*, *Haplophragmoides*) dominate the assemblages, reflecting the persistent low-carbonate setting. Dysoxic conditions in the semi-restricted AAG were influenced by high terrestrial input from the Ceduna River system. The marginal marine seaway documents limited oceanic exchange. Calcareous benthic (e.g., *Notoplanulina*, *Gyroidinoides*) and planktonic foraminifera (e.g., *Whiteinella baltica*) occur only sporadically, marking short-lived phases of improved marine connectivity, possibly tied to tectonic subsidence and eustatic highs during the Turonian–Coniacian.

The Coniacian–Santonian strata record an increase in calcareous taxa and the appearance of *Uvigerinammina jankoi*, together with the consistent presence of *Bulbobaculites problematicus*, offering a link to the Tethyan agglutinated foraminiferal biozonation of Geroch and Nowak (1984). By integrating new taxonomic data with existing geochemical and biostratigraphic records, this work refines paleoenvironmental reconstructions of the AAG, highlighting the interplay of tectonics, freshwater runoff, and ocean circulation patterns during the stages of the opening of the AAG and the breakup of eastern Gondwana.

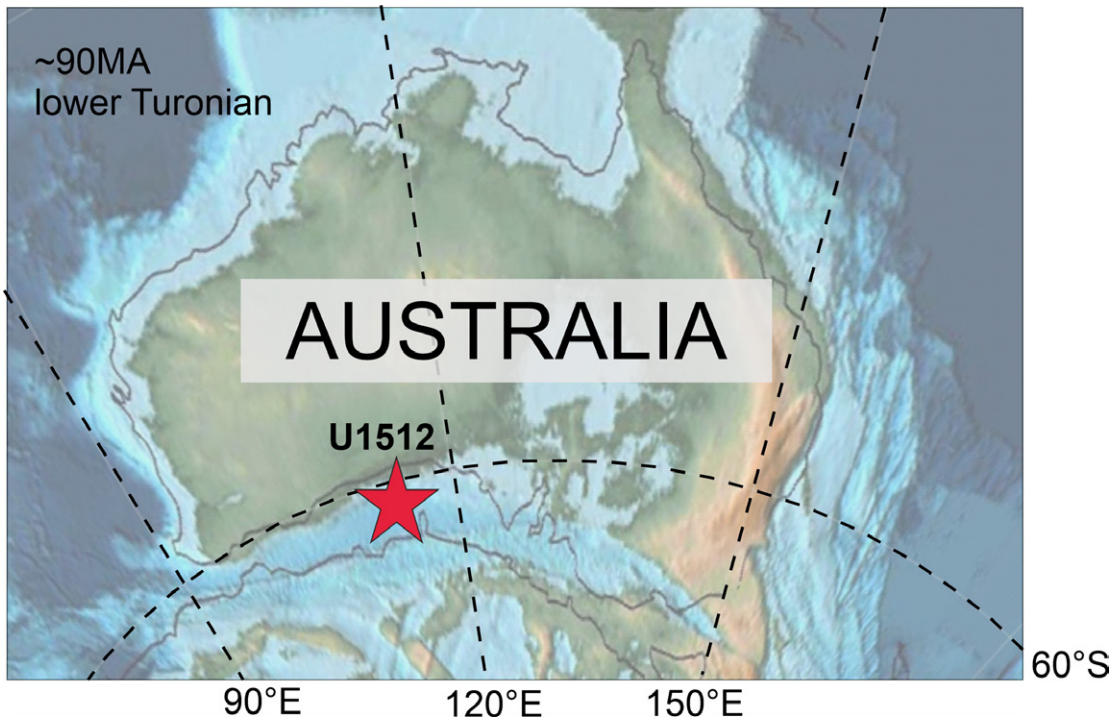
Keywords: Late Cretaceous, Agglutinated Foraminifera, Australia, Gondwana.

INTRODUCTION

The International Ocean Discovery Programme (IODP) Expedition 369 Site U1512, located in the Ceduna Sub-basin of the Great Australian Bight (GAB), provides a high-latitude record spanning the Upper Cretaceous (early Turonian to the early Campanian, ~94–84 Ma) (Huber et al. 2019; MacLeod et al. 2020; Wainman et al. 2020; Wolfgring et al. 2021). The sediments recovered at Site U1512 primarily consist of a 690 m thick sequence of black silty clay and claystone, deposited within an ~E–W oriented, elongated rift system that developed during the gradual separation of Australia and Antarctica and the eventual breakup of East Gondwana (Totterdell et al. 2000; Direen et al. 2011). These deposits offer a continuous archive of paleoenvironmental and paleoclimatic conditions in the AAG. The AAG was characterized as a marginal marine setting that was strongly influenced by continental runoff from the Ceduna River system to the north, thus displaying the interplay between marine and estuarine depositional settings (MacDonald et al. 2013; Lloyd et al. 2016; Huber et al. 2019) (text-fig. 1).

The microfossil assemblage at Site U1512 is composed primarily of benthic foraminifera, with subordinate planktonic foraminifera, and abundant radiolaria in specific intervals. Agglutinated benthic foraminiferal taxa dominate the foraminiferal assemblages and represent most of the benthic foraminifera recovered from these deposits. Tubular and planispiral forms, including *Kalamopsis*, *Ammodiscus*, and *Haplophragmoides*, are particularly abundant, while calcareous benthic and planktonic foraminifera appear intermittently throughout the succession, marking changes in the depositional setting. The taxonomic composition of these assemblages reflects a dynamic palaeoenvironment characterized by fluctuating marine-terrestrial interactions and variations in oceanic circulation and suggests a benthic ecosystem that was periodically influenced by high terrestrial input, variable degrees of restricted marine conditions, and variable nutrient availability (Huber et al. 2019; MacLeod et al. 2020; Wainman et al. 2020; Kaminski et al. 2020; Wolfgring et al. 2021; 2024).

This study provides the documentation of foraminiferal taxa recovered at Site U1512 and an overview of palaeoenvironmental change in the Late Cretaceous AAG. By integrating micropalaeontological data with existing stratigraphic and geochemical records from previous studies on the Cretaceous of Site U1512 (Huber et al. 2019; MacLeod et al. 2020; Watkins and Guerra 2020; Wolfgring et al. 2021, 2024), this work aims at a comprehensive documentation of benthic foraminiferal taxa to enhance our understanding of how benthic foraminiferal communities responded to climatic and palaeoceanographic change during the Late Cretaceous in a high-latitude continentally influenced Cretaceous basin.



TEXT-FIGURE 1
Palaeomap of Australia at ~90 Ma in the lower Turonian. Site 1512 is marked by a star. Map after Scotese (2016).

GEOLOGICAL AND PALAEONTOLOGICAL SETTING

IODP Site U1512 is situated in the Ceduna Sub-basin of the Great Australian Bight (GAB), a region that preserves an Upper Cretaceous sedimentary succession documenting palaeoenvironments during the separation of Australia and Antarctica (MacLeod et al. 2020). This section, positioned at a palaeolatitude of approximately 60°S during the Late Cretaceous, records deposition in an epicontinental marine basin that evolved as part of the Australo-Antarctic Gulf (AAG) (Wainman et al. 2020; Wolfgring et al. 2021) (text-figs 1, 2). The rifting of Gondwana and the formation of the AAG began in the Jurassic (Oxfordian) (Totterdell et al. 2000). The seaway between Australia and Antarctica connected to the Indian Ocean in the west and was presumably restricted to the east by the South Tasman Rise (Direen et al. 2011). The complete separation of Antarctica and Australia is reconstructed to have taken place diachronously (from west to east) no earlier than the Santonian (MacLeod et al. 2020; Wainman et al. 2020; Wolfgring et al. 2021).

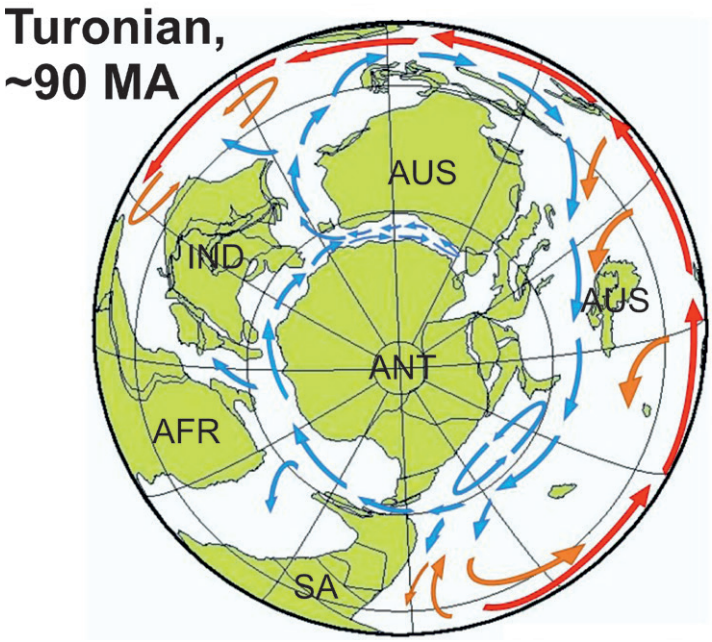
MATERIAL AND METHODS

The study material was collected from the western part of the Ceduna Sub-basin of the Bight Basin, IODP Expedition 369 Hole U1512A drilled at a water depth of 3,070.87 m (Latitude 34°01.6406′S, Longitude 127°57.7605′E; Huber et al. 2019). Core-catcher samples were initially examined shipboard for biostratigraphic analysis and were subsequently re-evaluated together with additional core samples from onshore localities as described in several studies, including those by Kaminski et al. (2020); Watkins and Guerra (2020); MacLeod et al. (2020) and Wolfgring et al. (2021), which provide a biostratigraphic framework for this study.

The present study focuses on the analysis of foraminiferal assemblages in 96 samples from Hole U1512A and presents a systematic account of the recovered benthic and planktonic foraminifera. The analysed samples were selected through the depth interval 20 to 692 metres below sea floor (mbsf) at an average sample spacing of 7.07 m (text-fig. 3). Sample positions and depths are given in meters below seafloor (mbsf), if not stated otherwise.

Samples (with a sample size of ~30 cc each) were disaggregated by boiling in soap solution and sieved through >125 μm and >45 μm sieves. Agglutinated and calcareous benthic, as well as planktonic foraminifera were picked from the >125 μm fraction at the AGH University of Science and Technology (Kraków, Poland) and the King Fahd University of Petroleum and Mines (Dhahran, Saudi Arabia). Benthic foraminifera were counted, and single fragments were considered representing one specimen. Samples and microslides are stored in the European Micropalaeontological Reference Centre (Micropress Europe, AGH University of Kraków). The number of individuals is reported as foraminifera/sample ratio (30 cc). Some benthic foraminifera recovered in the small size fraction (38–125 μm) were not identified at the genus/species level because taxonomically important features could not be confidently observed.

Taxonomic identification follows the classifications established by Premoli Silva and Verga (2004) for planktonic taxa, and by Loeblich and Tappan (1987) for calcareous benthic foraminifera. Agglutinated forms are classified according to Kaminski and Gradstein (2005), Setoyama et al. (2011, 2017), Kaminski (2014), and Waśkowska et al. (2020). Where applicable, we integrate subsequent refinements to higher-level taxonomy, particularly the revised family-level framework proposed by Revets (1996) for rotaliine taxa, including e.g., the recognition of Cancrisidae. Fragments of tubular foraminiferal forms were counted as a single individual. Morphotypes of agglutinated and



TEXT-FIGURE 2
Paleogeographic map of the southern hemisphere in the Turonian (~90MA). Arrows indicate paleocurrents and circulation patterns. Reconstruction from https://www.odsn.de/. The paleocurrents and circulation patterns are modified after Baumgartner et al. (2023).

calcareous benthic foraminifera were pooled to avoid inter-operator bias in taxonomic identification (Table 1, text-fig. 4).

Foraminiferal content and systematic taxonomy

For this study, 96 samples from Hole U1512A, covering a depth interval from 20.30 to 691.98 mbsf composite depth drilled during Expedition 369 were examined for foraminiferal content. This study is based on the same sample material previously presented in Wolfgring et al. (2021) (71 samples) and incorporates an additional 25 samples to enhance the biostratigraphic and taxonomic resolution at Site U1512.

This study expands upon the dataset of Al-Hilali (2023), which includes an assessment of benthic and planktonic foraminiferal content in selected samples; full counts and taxonomic documentation are available in the Supplementary Files (ST.1, ST.2). While the study of Wolfgring et al. (2021) placed the emphasis on biostratigraphy and geochemical proxies, here we present an extended evaluation of the foraminiferal taxa, with a focus on taxonomy, systematics, and assemblage composition.

The biostratigraphic framework predominantly relies on the nannofossil zonations by Watkins and Guerra (2020). The absolute ages are assigned (text-fig. 3) according to UC, CC and NC boundary datums as given in Anthonissen and Ogg (2012). Benthic and planktonic foraminiferal zonations are according to Wolfgring et al. (2021).

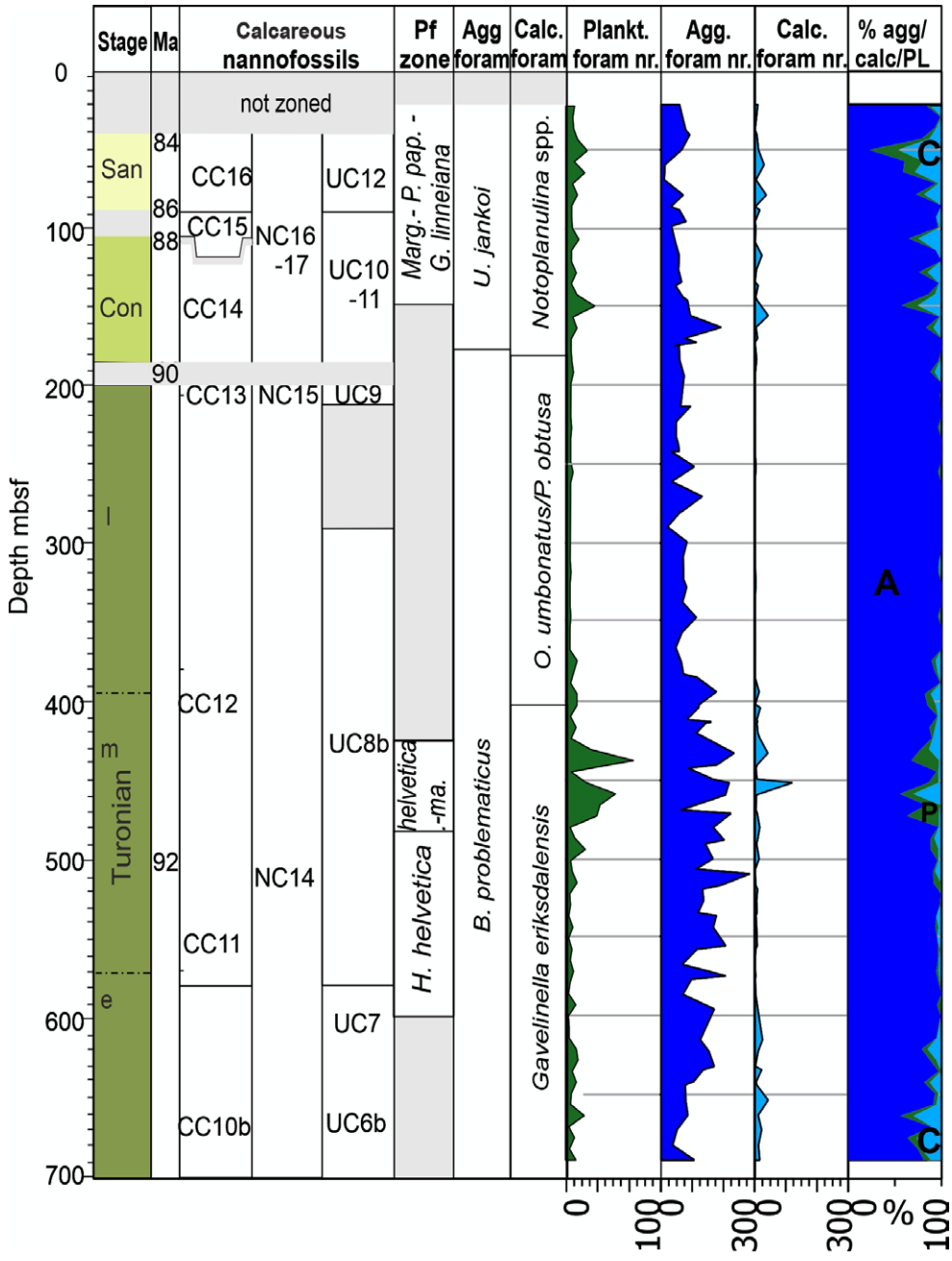
Statistical analysis

Quantitative data from Site U1512 were processed using a streamlined dataset based on foraminiferal morphotypes to highlight the palaeoecology of the benthic assemblage, to minimize biases between taxonomic analysis in the two sample sets by Wolfgring et al. (2021) and Al-Hilali (2023). We prepared the benthic foraminiferal dataset for statistical analyses, using statistics packages in the language R (R development Core Team, 2017) and PAST (Hammer et al. 2001). For all quantitative analyses, we removed trends in abundance data of agglutinated and calcareous benthic foraminiferal morphotypes and row-normalized the dataset.

A hierarchical cluster analysis after Ward (1963) using Euclidean distance measures was first applied to the normalized abundance data of 23 agglutinated and calcareous benthic foraminiferal morphotypes (M1a to CHB-4) to identify recurring assemblage types. Cluster membership was subsequently compared with the DCA distribution to identify consistent patterns between assemblage groups and ordination structure (text-fig. 5).

A Detrended Correspondence Analysis (DCA) was then carried out to explore the composition of benthic foraminiferal morphotypes along the studied interval. Information from planktonic forms was not added to this analysis. A DCA is an ordination technique that arranges samples and taxa along axes according to their compositional similarity. The species composition and assemblage characteristics help to interpret underlying ecological and environmental gradients. The analysis was based on normalized abundance data of 23 agglutinated and calcareous benthic foraminiferal morphotypes (M1a to CHB-4). The ordination was performed on the variance/covariance matrix of the normalized data, using detrending by segments to remove arch effects. For each morphotype, axis scores, total relative abundance, distance from the DCA origin, and weighted importance (calculated as abundance × distance) were computed to assess their influence on the overall distribution pattern (table 2). The resulting sample scores along the first two axes were used to visualise major gradients in assemblage composition.

To evaluate the contribution of individual morphotypes to the DCA structure, total abundance, total importance (i.e., the total axis loadings per morphotype), and weighted importance (product of relative abundance and axis score) were calculated for



TEXT-FIGURE 3
Stratigraphic framework of Site U1512. Stage age in million years (Ma), calcareous nannofossil stratigraphy after Watkins and Guerra (2020), planktonic and benthic foraminiferal zonation after Wolfgring et al. (2021), unzoned intervals are shaded in gray. Planktonic, agglutinated and calcareous benthic foraminiferal frequency (Plankt., Agg., Calc. foram nr.) and calcareous to agglutinated benthic foraminifera ratio (%BF agg/calc) are also shown. Marg. = *Marginotruncana*, P. pap. = *Planoheterohelix papula*, *G. linneiana* = *Globotruncana linneiana*, *H. helvetica* = *Helvetoglobotruncana helvetica*, *B. problematicus* = *Bulbobaculites problematicus*, *U. jankoi* = *Uvigerinammina jankoi*, *O. umbonatus* = *Oridorsalis umbonatus*, *P. obtusa* = *Pleurostomella obtusa*, A= Agglutinated foraminifera, C= Calcareous foraminifera, P=Planktonic foraminifera. Note different scale between planktonic and benthic foraminiferal abundance.

each morphotype across three DCA axes. The resulting values represent the overall influence ("most important"), which indicates the relative contribution of each morphogroup in the dataset. These calculations allow a comparison between taxa with high numerical abundance and those with strong compositional weight within the DCA ordination space.

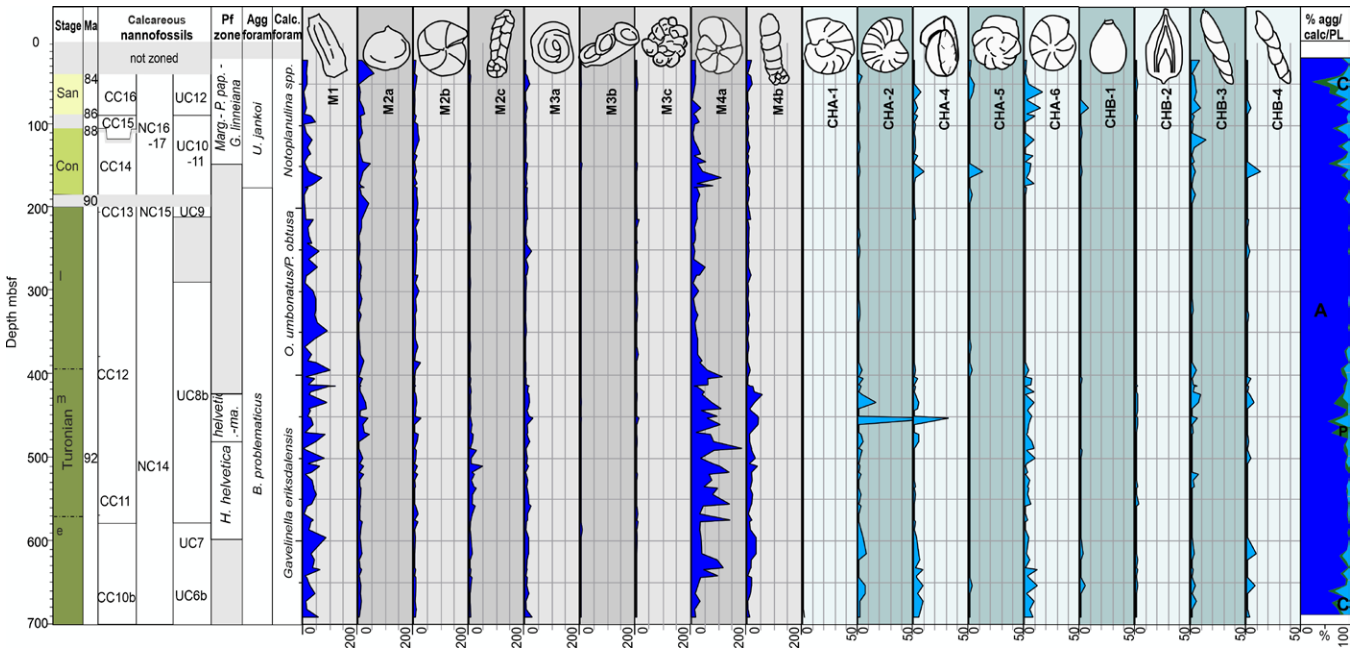
RESULTS

Foraminiferal fauna at Site U1512

The foraminiferal assemblage at IODP Site U1512 documents a diverse and consistent faunal record of benthic foraminifera across the investigated interval from 20.30 to 691.98 mbsf. The section is overwhelmingly dominated by agglutinated forms

TABLE 1
Morphotype categories of agglutinated and calcareous benthic foraminifera according to morphology and habitat preference, complemented by results of Koutsoukos and Hart (1990) for calcareous forms and from Setoyama et al. (2017) for agglutinated forms. CH = calcareous hyaline; CP = calcareous porcelaneous; M = agglutinated morphotype. "Grayed-out" categories were not documented at Site U1512.

	Type	Morphology	Preferred habitat	Examples in U1512
M1	M1a	Tubular, uniserial, circular aperture	Errect epifaunal	*Psammosiphonella*
M2	M2a	Tubular, uniserial straight and dendritic, flattened	Sessile epifaunal-shallow infaunal creeping forms	*Bathysiphon, Hyperammina, Rhizammina*
epi-/infaunal	M2b	Tubular, branching, flattened network forming	Sessile epifaunal-shallow infaunal creeping forms	*Nothia*
	M2c	Uniserial, flattened	Sessile epifaunal-shallow infaunal creeping forms	*Aschemocella, Arthrodendron, Kalamopsis, Pseudonodosinella, Subreophax*
M3	M3a	Unilocular, rounded, flattened	Mobile epifaunal	*Placentammina, Saccammina, Thurammina*
epifaunal	M3b	Unilocular, flattened, planispiral/streptosiral, irregularly coiled	Mobile epifaunal	*Ammodiscus, Glomospira, Glomospirella*
	M3c	Multichamberd, flattened, planispiral/streptospiral, irregularly coiled	Mobile epifaunal	*Paratrochamminoides, Trochamminoides, Lituotuba*
	M3d	Biconvex , rounded, trochospiral	Mobile epifaunal	*Trochammina*
M4	M4a	Unilocular, globular, rounded, elongated	Infaunal	*Psammosphaera, Technitella*
globular infaunal	M4b	Multichambered, globular, trochospiral/steptospiral, planconvex trochospiral	Infaunal	*Cribrostomoides, Recurvoides*
M5	M5a	Flattened, keeled,	Infaunal	*Haplophragmium, Ammomarginulina*
discoidal		planispiral and streptospiral		*Haplophragmoides, Buzasina, Labrospira*
M6	M6a	Elongate uniserial (straight or straight with coiled initial part)	Infaunal	*Reophax, Hormosinella, Caudammina, Ammobaculites, Bulbobaculites, Sculptobaculites*
elongate (continuation is lower)	M6b	Elongate bi- and multiserial	Infaunal	*Dorothia, Praedorothia, Pseudobolivina, Gerochammina, Rectogerochammina Uvigerinammina*
	M6c	Elongate bi- and multiserial, keeled	Mobile shallow-deep infuanal	*Textularia, Textulariopsis, Spiroplectammina, Eobigenerina, Gaudryina, Gaudryinopsis, Verneuilinoides*
CH-A	CHA-1	Plano-convex, low/high trohospire	Epifaunal	*Gavelinella intermedia*
predominantly epifaunal	CHA-2	Concavo-convex, low trochospiral, broad	Epifaunal	*Cibicidoides, Quadrimoprphina, Gavelinella*
	CHA-3	Leticular, low trochospiral periphery subacute/carinate	Epifaunal	*Notoplanulina, Protosangularia*
	CHA-4	Conical, low trochospiral	Epifaunal/infaunal	*Epistomina, Cibicides, Gyroidinoides*
	CHA-5	Lenticular, planispiral periphery subacute/carinate	Epifaunal/infaunal	*Lenticulina, Saracenaria, Astacolus, Marginulina, Marginulinopsis*
	CHA-6	Inflated biconvex, periphery broadly rounded	Epifaunal/infaunal	-
	CHA-7	Conical, low/high trochospiral	Epifaunal	-
	CHA-8	Discoidal-flattened	Bilocular	-
CH-B	CHB-1	Globular/ovate to elongate/fusiform	Epifaunal/infaunal	*Oolina, Ellipsoidella/Ellipsoglandulina*
predominantly shallow to deep infaunal	CHB-2	Broad to palmate, compressed planispiral to uncoiled uniserial	Epifaunal/infaunal	*Frondicularia*
	CHB-3	Elongate, straigt to arcuate uniserial or planispiral-uniserial	Epifaunal/infaunal	*Dentalina, Laevidentalina, Pyramidulina*
	CHB-4	Tapered rounded elongate triserial biserial uniserial	Infaunal	*Pleurostomella, Colomia, Praebulimina, Tritaxia*
	CHB-5	Tapered flattened-elongate biserial	Infaunal	-
	CP	Porcelaneous walled	Epifaunal/ shallow infaunal	-



TEXT-FIGURE 4
Distribution of benthic foraminifera in the Turonian to Santonian of IODP Hole U1512A. The biostratigraphic framework is based on calcareous nannofossils, planktonic foraminifera (Pf) and calcareous benthic foraminifera (Calc. foram) (for annotations for the biostratigraphic framework, refer to text-fig. 3), frequency of agglutinated benthic foraminifera is shaded in gray, for calcareous in green, the relative abundance of agglutinated (A) and calcareous benthic foraminifera (C), as well as planktonic taxa (P) is given on the right margin.

(text-fig. 3), presenting on average more than 90% of the overall benthic taxa. Calcareous forms are rare and restricted to isolated patches.

Planktonic foraminifera are rare and mostly present in the lower to middle Turonian (from ~600–450 mbsf) and in the uppermost Coniacian to Santonian parts of Site U1512 (~20–150 mbsf), allowing the interpretation of planktonic foraminiferal biostratigraphic information in these intervals. Their occurrence most likely depends on environmental as well as preservation factors. The abundance data of planktonic, benthic, as well as the agglutinated foraminifera and benthic foraminiferal morphotypes are illustrated in text-figs 3 and 4, and documented in the supplementary materials (St. 1, St. 2).

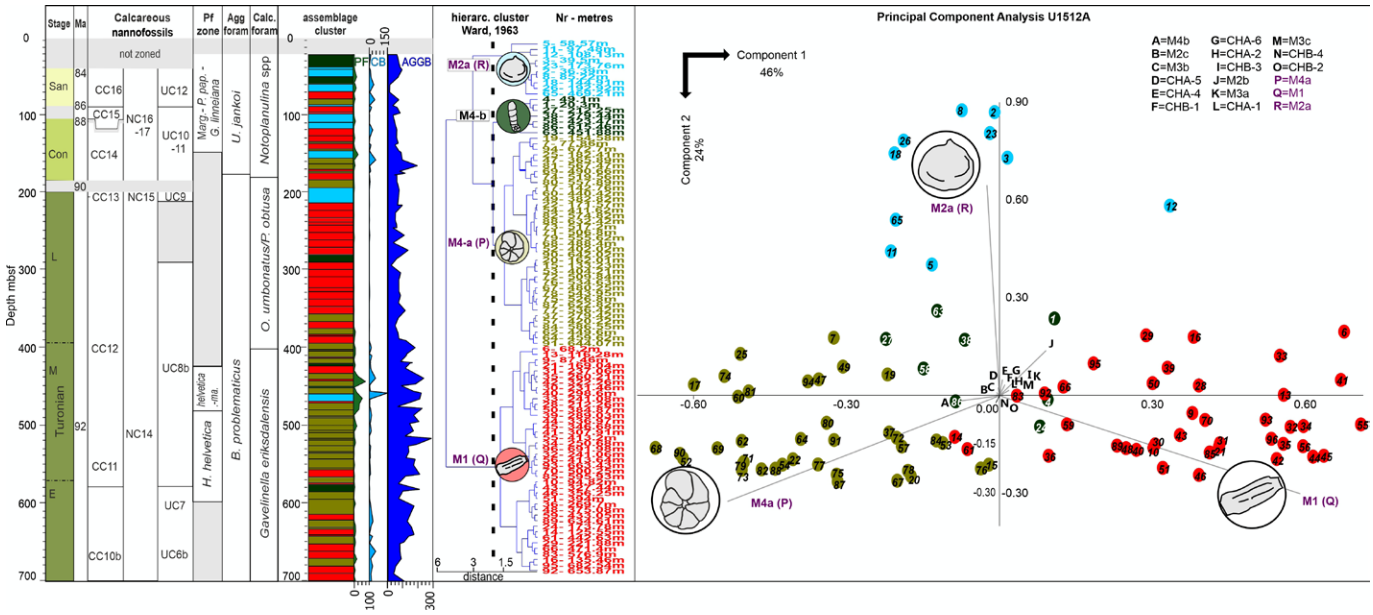
Planktonic foraminifera

Planktonic foraminifera at IODP Site U1512 are generally poorly to moderately preserved, the state of preservation improves significantly in Cores 52R–50R. Planktonic foraminifera occur in three distinct intervals from the Turonian to Santonian: in the lower Turonian (between ~700 and 600 mbsf: 0–14% of the total foraminiferal assemblage), in the middle Turonian (between ~500 and 400 mbsf: 0.5–30% of the total content), and in the Coniacian to Santonian interval where the highest abundance was recorded (between 40 and 180 mbsf: up to 40% of total foraminiferal content) (text-fig. 3).

Despite limited diversity and lack of key biostratigraphic markers, the presence of characteristic taxa allows for tentative correlation to Tethyan biozones. To complement the biostratigraphic framework of Wolfgring et al. (2021), the assessment of selected samples (in Al-Hilali 2023) for planktonic foraminifera resulted in *Whiteinella baltica* as the most frequent planktonic form, followed by the rare occurrence of *Muricohedbergella delrioensis* and *Planoheterohelix globulosa* with occasional juvenile forms of *Globigerinelloides* and *Muricohedbergella*. These data align well with the planktonic foraminiferal and calcareous nannofossil biostratigraphic results of Huber et al. (2019), Watkins and Guerra (2020) and Wolfgring et al. (2021) and corroborate the planktonic foraminiferal zonation of Site U1512. Huber et al. (2019) and Wolfgring et al. (2021) identified the *Helvetoglobotruncana helvetica* zone from 489.58–603.85 mbsf, the *Helvetoglobotruncana helvetica-Falsotruncana maslakovae* Zone from 476.79–428.98 mbsf and the *Dicarinella concavata-Dicarinella asymetrica* Zone 153.73–28.57 mbsf, text-fig. 3).

Benthic foraminifera

Across all samples, the most abundant agglutinated taxa are uniserial and planispiral forms: *Kalamopsis grzybowskii* and *Haplophragmoides* (*H. concavus*, *H. walteri*, *H. antarcticus*, *H. tenellulus* and *Haplophragmoides* spp.). Other common agglutinated taxa include *Gerochammina* (*G. lenis*, *Gerochammina* spp.), and *Bulbobaculites problematicus* and *Bulbobaculites* sp., which dominate in selected intervals. Among calcareous benthic foraminifera, the overall abundance is significantly lower. The most frequent forms include Gyroidinoides (*G. quadratus*, *G. subconicus*, *G. globosus*), *Lenticulina*, *Dentalina* and *Laevidentalina*, as well as the occasional occurrence of gavelinellids, although individually these taxa by far do not reach the prominence of their agglutinated counterparts (text-fig. 3). The overwhelming majority of benthic foraminiferal taxa are agglutinated, while forms with calcareous tests only amount to 6.8% in average over the whole section with a notable higher than average occurrence between ~700 and 600 mbsf, ~500 and 400 mbsf, and ~170 mbsf and the top of the section. Between ~380 and 190 mbsf, Hole U1512A is virtually barren of calcareous benthic forms.



TEXT-FIGURE 5
Hierarchical clustering of the benthic foraminiferal stock of Site U1512. The biostratigraphic framework is based on calcareous nannofossils, planktonic foraminifera (Pf) and calcareous benthic foraminifera (Calc. foram) (for annotations for the biostratigraphic framework, refer to text-fig. 3). Samples clustered by foraminiferal assemblages clustered in the hierarchical cluster analysis (using Ward 1963 as a similarity measure), absolute abundance of planktonic foraminifer (PF), calcareous benthic foraminifera (CB) and agglutinated foraminifera (AGGB), clusters are color-coded according to the dominant genera (*Kalamopsis* dominating morphotype M2c; in red, *Haplophragmoides*, M5a; in blue, *Bulbobaculites*, *Gavelinella* and *Kalamopsis*, M6a, CHA-2, M2c; and in grey *Placentammina* and *Rhizammina*, M2a, M3a.

Test preservation is generally moderate, with agglutinated forms showing minimal fragmentation. Extensive folding and diagenetic alteration are occasionally observed (prominently displayed in *Haplophragmoides*) (Wolfgring et al. 2021; 2023). Some calcareous tests appear poorly preserved, suggesting the influence of corrosion or dissolution on the preservation of calcareous material during some intervals (Wolfgring et al. 2021).

Illustrated by hierarchical clustering, four intervals, with at times vague boundaries regarding their species composition, representing different palaeoecology were identified (text-figs 5). Visualized by hierarchical clustering and the detrended correspondence analysis, three agglutinated morphotypes represented by three dominating morphotypes account for most of the variation in the dataset: M5a (including e.g., *Haplophragmoides* and *Buzasina* as dominant elements), M2c (e.g., *Kalamopsis*) and M2a (e.g., *Bathysiphon*, *Rhizammina*) contribute to ~67% of variation at Site U1512 (10 most important morphotypes contribute to over ~90%), while other agglutinated forms are underrepresented, and calcareous benthic forms are scarce throughout most of the section (text-figs 5, 6, table 2).

In the lower Turonian (700–600 mbsf), we identify dominant agglutinated foraminifera, characterized by the consistent presence of *Bulbobaculites problematicus*, alongside common *Haplophragmoides* and *Kalamopsis*. The calcareous benthic foraminifera are present in moderate abundance and are marked by abundant *Gavelinella eriksdalensis*, establishing this species as a key indicator for the calcareous benthic fauna during the early Turonian interval. Common distribution of *Pleurostomella obtusa*, *Pleurostomella acuta* and *Gyroidinoides* and *Lenticulina* are also noted. Agglutinated benthic foraminiferal data identified an alternating dominance of uniserial *Kalamopsis grzybowskii* and *Haplophragmoides* in this interval (represented by morphology groups M2c, M5a, M6a and CHA-2, text-fig. 5).

In the mid Turonian (600–400 mbsf), agglutinated benthics peak in abundance in this interval with *Haplophragmoides* spp., *Kalamopsis grzybowskii*, and *Bulbobaculites problematicus* as dominant elements and most samples representing dominant morphotype M5a (text-figs 4, 5). Similar to the underlying interval, the mid Turonian documents an increase elongate keeled forms like *Spiroplectammina* and globular agglutinated forms like *Placentammina*, as well as flattened planospiral forms like *Glomospira*. In this interval, calcareous benthic foraminifera show comparatively high abundance with highly frequent gavelinellids, *Gyroidinoides* and *Lenticulina* together with the appearance of planktonic taxa (text-fig. 3). We document the first questionably identified occurrence of isolated specimens of the epifaunal calcareous benthic form *Notoplanulina* (probably *N. compressa*). The combined occurrence of *B. problematicus* and *G. eriksdalensis* defines a well-developed mid-Turonian benthic community between 460 and 430 mbsf, tolerant of moderate dysoxia but able to support calcareous faunas (Wolfgring et al. 2021).

In the upper Turonian (400–200 mbsf), agglutinated forms continue to dominate, although with slightly lower diversity and abundance than in underlying strata. The assemblage is dominated by the *Kalamopsis grzybowskii* (M2c) and records diminishing numbers of *Haplophragmoides*, as well as *Spiroplectammina* and *Bulbobaculites* (text-figs 4, 5). This interval sees the virtual disappearance of calcareous benthic foraminifera that sharply decline from an average abundance of ~7% of benthic foraminifera between 700 to 400 mbsf to an average of less than only 1% between 400 and 200 mbsf (text-figs 3, 5). Sporadic occurrences of *Pleurostomella obtusa*, *Cibicidoides* (?) and *Dentalina* represent the curtailed calcareous assemblage. The assemblage probably reflects increasing bottom-water stress, likely related

TABLE 2
Detrended Correspondence Analysis (DCA) output table listing morphotype scores on the first three axes, total relative abundance (%), distance from the DCA origin, weighted importance (abundance × distance), and each morphotype's share of the total weighted importance. The ten most influential morphotypes are shaded in grey.

Morphotype	Axis 1	Axis 2	Axis 3	Tot. abund (%)	Distance	W-imp.	Rel. contr. (%)
				Total relative abundance	distance from DCA origin	Weighted importance (abund × dist.)	Share of total weighted importance
M5a	333	144	83	37,21	372,17	13848,44	42,60
M2c	0	175	175	20,87	247,49	5164,36	15,89
M2a	258	31	330	6,82	420,03	2864,74	8,81
M6a	217	243	74	4,51	334,09	1505,38	4,63
M3b	182	247	57	4,50	312,06	1403,18	4,32
M6c	265	227	-85	2,99	359,14	1072,05	3,30
M6b	222	85	0	4,35	237,72	1035,21	3,18
CHA-6	116	323	264	2,19	432,99	948,93	2,92
M1a	473	147	177	1,50	525,99	790,03	2,43
CHA-2	149	298	268	1,53	427,59	654,34	2,01
M3a	111	-34	101	4,09	153,88	629,40	1,94
CHA-4	128	321	288	1,30	449,85	586,43	1,80
M4b	95	-2	120	3,54	153,07	542,22	1,67
CHB-3	164	223	267	1,01	384,60	388,74	1,20
M4a	538	88	220	0,52	587,87	305,43	0,94
M3c	110	118	168	1,02	232,91	237,62	0,73
CHB-4	145	300	124	0,51	355,53	181,36	0,56
M3d	111	81	66	0,95	152,44	145,44	0,45
CHA-5	158	307	55	0,26	349,63	89,17	0,27
CHB-1	152	299	135	0,16	361,57	58,06	0,18
CHB-2	190	290	119	0,14	366,55	51,94	0,16
CHA-1	28	331	116	0,01	351,85	3,32	0,01
M2b	46	-7	37	0,02	59,45	1,12	0,00

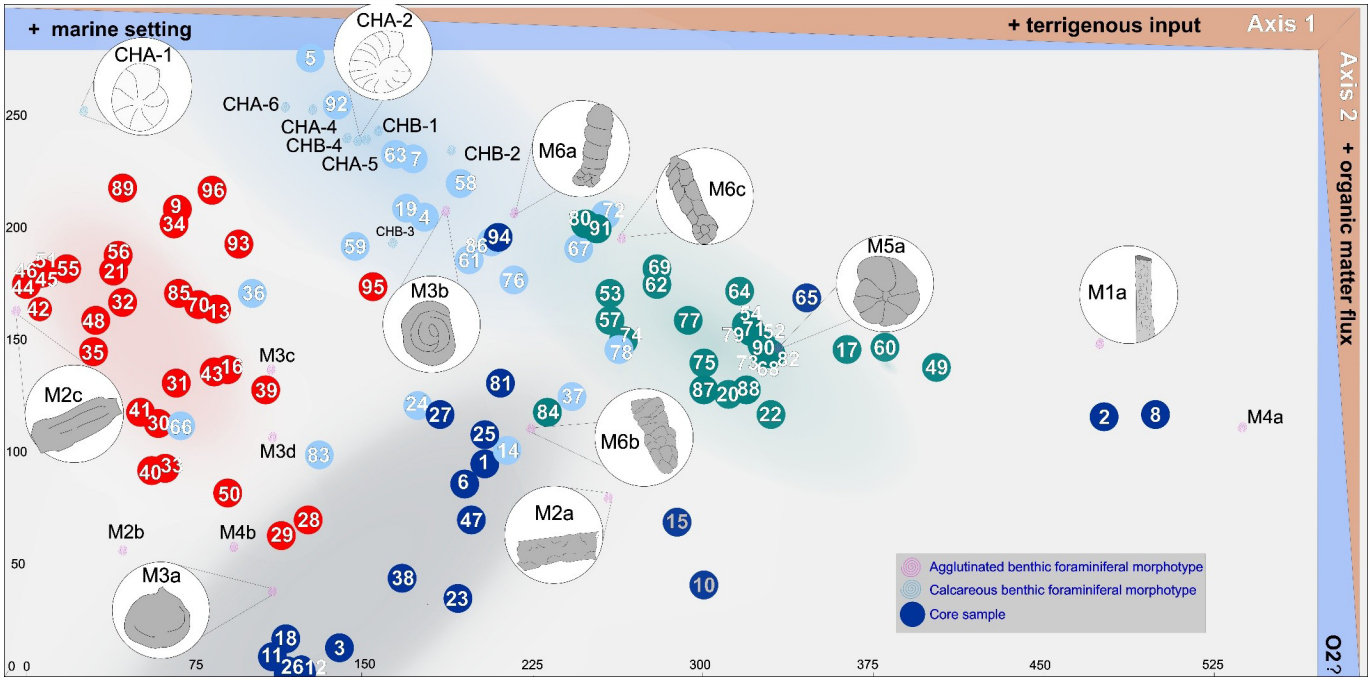
to changes in ocean chemistry accompanied by a shift in marine connections, trophic connections and reduced carbonate availability (Wolfgring et al. 2021).

In the Coniacian to Santonian (200–20 mbsf) interval, agglutinated benthic foraminifera remain dominant, but the faunal composition changes. *Uvigerinammina jankoi* appears, defining the onset of the *U. jankoi* zone. This form is associated with a lower-diversity agglutinated fauna dominated by *Kalamopsis* and *Haplophragmoides* with a high share of *Bathysiphon* and *Rhizammina* (M2a) globular agglutinated forms, such as *Thurammina* or *Placentammina* (M3a). The number of calcareous benthic foraminifera is higher relative to the previous interval (from less than 1% to ~10% of benthic foraminifera). We record the presence of *Notoplanulina*, including the zonal marker *N. rakauroana*, as well as *N. australis* and *Notoplanulina* sp. 1, the *Notoplanulina* zone (Malumian 1990) for the Coniacian to Santonian of Site U1512 (text-figs 4, 5). The species composition of calcareous and agglutinated benthic foraminifera in this interval advocates for a higher carbonate saturation, probably linked to the increasingly opening of the AAG in during the Late Cretaceous (Wolfgring et al. 2021).

DISCUSSION

Depositional water depths, environments and dominant benthic species:

The benthic foraminiferal assemblages at Site U1512 offer insights into the development and the oceanographic dynamics of a marginal marine Cretaceous basin in the southern high latitudes. The dominance of agglutinated benthic taxa and the subordinate calcareous benthic, and rare occurrence of planktonic forms suggest a restricted basin with limited connections to the proto–Indian Ocean during the early Turonian (700–600 mbsf, Wolfgring et al. 2021; 2023). Between 700 and 600 mbsf, as well as between 600 and 500 mbsf, a largely dysoxic to only moderately oxygenated palaeoenvironment that is characterised by the high abundance of *Haplophragmoides* (representing the dominant element in morphotype M5a) can be reconstructed. Planktonic taxa were documented in the lowermost strata of Site U1512 and disappear towards the mid Turonian.



TEXT-FIGURE 6
Detrended Correspondence Analysis (DCA) biplot of benthic foraminiferal morphotypes from the studied interval. Samples (numbered circles) and morphotypes (M1a–CHB-4) are arranged according to compositional similarity. Axis 1 (0–550) represents a gradient from oxygenated, carbonate-rich conditions at lower axis values to terrigenous-dominated, oxygen-depleted environments at higher axis values. Axis 2 (0–300) likely reflects a subtle gradient in oxygenation, low organic matter flux conditions at lower values to oxygen-depleted, high organic matter flux environments at higher values. Calcareous morphotypes are shown in light blue, agglutinated morphotypes in grey, and core samples in blue. Enlarged sketches illustrate representative morphotypes occupying distinct positions along these environmental gradients. See table 2 for morphotype scores and significance.

The brackish-water tolerance of the latter (Kuhnt et al. 1996; Murray 2006), combined with probable runoff from the Ceduna river system into the AAG, supports a scenario of fluctuating dominance between estuarine or marginal marine conditions and phases of a well-connected marine basin between Australia and Antarctica (see Wolfgring et al. 2021; 2023). These conditions must have supported some niches for calcareous benthic foraminifera that appear sporadically in the older intervals of Site U1512 (text-figs 4, 5).

This interval between 500 and 400 mbsf is marked by both an increase in calcareous benthic taxa, e.g., *Gavelinella eriksdalensis*, *Gyroidinoides*, and *Lenticulina* (CHA-2, CHA-5) as well as a sustained appearance of planktonic foraminifera, as noted in Wolfgring et al. (2021), this implies a temporary improvement of basin connectivity and oxygenation, possibly due to an increase in water masses originating in the proto-Indian Ocean, or reduced terrestrial sediment influx. Agglutinated forms still dominate, and the co-occurrence of *Bulbobaculites problematicus* (M6, becoming a common element between 413 and 509 mbsf) and *Kalamopsis* (M2c) suggests a dysoxic, neritic to upper bathyal environment with some evidence for carbonate dissolution as well. But likely still influenced rather by a marginal marine than an estuarine regime.

The upper Turonian of Site U1512 illustrates the dominance of *Kalamopsis grzybowskii* (M2c), especially between ~400 and 200 mbsf, where the absence of calcareous benthic as well as planktonic foraminifera, alongside this group, supports deposition in fine-grained, possibly organic-rich muds in an isolated basin that was characterised by reduced oxygenation (but probably not strictly anoxic conditions), carbonate undersaturation, and minimal ventilation (see also Wolfgring et al. 2021). At the margins of the interval dominated by *Kalamopsis* (M2c), calcareous benthic as well as planktonic foraminifera can be documented, suggesting marine conditions that turned unfavourable for calcareous foraminifera. The two morphologies on the respective other ends of the DCA (text-fig. 6), M5a (e.g., *Haplophragmoides*) and M2c (i.e., *Kalamopsis*), are likely to represent fundamentally different palaeoenvironments along a salinity and probably palaeodepth gradient, illustrating the different stages between a marginal marine, restricted setting, and an estuarine-influenced basin. Another paleoecological gradient that could be considered is the difference in substrate provenance: *Kalamopsis* can point to finer-grained sediment, poor oxygenation, paired with limited circulation in a restricted basin, favouring the presence of agglutinated taxa at the expense of calcareous taxa by dissolution in a possibly corrosive palaeoenvironment. Wolfgring et al. (2021) documented an initial sharp increase in the abundance of radiolaria at Site U1512 from ~400 mbsf onwards, raising the possibility that surface as well as bottom waters were undersaturated in $CaCO_3$.

Except for this interval, the elements of the foraminiferal assemblage throughout include both shallow-water and deep(er)-water species (including agglutinated benthic, calcareous benthic and planktonic foraminiferal taxa), which could indicate a mixed depositional signal. That indicates downslope transport of shallow-water taxa or the observed assemblage may reflect synsedimentary mixing processes which could both have contributed to the superposition of different palaeoecological indicators from different bathymetric settings (such as brackish-tolerant *Hap-*

lophragmoides and planktonic foraminifera, see Kuhnt et al. 1996; Murray 2006). Thus, the original characteristics of the shallow-water deposits could have been partially overprinted by a deeper-water fauna, complicating the interpretation of the depositional environment.

The interpretation of palaeodepth throughout Hole U1512A faces some challenges, particularly in the upper Turonian. While fauna dominated by agglutinated long forms are often considered indicative of relatively deep, "quiet" basins, sometimes affected by carbonate corrosion linked to water depth and associated with submarine fans and slopes (e.g., Morlotti 1988; Galeotti et al. 2004; Murray et al. 2011), depth remains only one of several proxies. Similar assemblages can be explained by aforementioned palaeoenvironmental traits in much shallower shelf settings (<100 m), irrespective of water depth related changes in ocean chemistry (Murray and Alve 2011). Waśkowska et al. (2018) speculate that dominance of primitive creeping epifauna in the Eocene Outer Carpathians did primarily reflect oxygen deficiency and organic-rich deposition rather than changes in palaeodepth conditions.

In light of the interplay of estuarine input, basin subsidence, and episodic oceanic connectivity, we deliberately avoid a definitive palaeodepth interpretation for the upper Turonian interval documented at Site U1512.

The Coniacian–Santonian assemblages document a turning point in the palaeoenvironmental evolution of Site U1512. The reappearance of planktonic foraminifera and the increase in calcareous benthic taxa, including *Notoplanulina rakauroana*, a zonal marker in southern high-latitude basins (Malumian 1990), illustrates an increase in marine connectivity. These changes coincide with the progressive opening of the Australo-Antarctic Gulf to the Indian Ocean and document the transition from a restricted AAG and an isolated basin a more open, mid to outer neritic, to a bathyal system by the Santonian.

CONCLUSIONS

Based on the analysis of benthic foraminiferal assemblages, four palaeoenvironmental intervals or settings were identified, although some of these intervals exhibit slow transitions and compositional overlaps, as reflected in the DCA results (text-fig. 6, see also Wolfgring et al. 2021). These intervals include: (1) a restricted Turonian interval characterized by a moderately connected setting with planktonic foraminifera present between 700 and 600 mbsf, which transitions into a setting with distinguished freshwater influence; (2) a more open marine during the mid-Turonian phase with increased calcareous taxa and planktonics; (3) a late Turonian phase marked by declining faunal diversity and carbonate saturation; and (4) a Coniacian–Santonian transition to more open, outer neritic to upper bathyal conditions.

The high abundance of radiolarians in Site U1512, particularly in the upper Turonian, supports the interpretation of a stressed environment for benthic foraminifera, coinciding with the phase of declining calcareous taxa and foraminiferal diversity between 400 and 200 mbsf. This shift is likely related to a regional decline in carbonate saturation, potentially driven by changes in productivity, freshwater runoff, or circulation patterns.

SYSTEMATIC PALAEONTOLOGY

The following section provides a systematic listing of the most significant foraminiferal taxa recovered at Site U1512, with emphasis on key morphological features, stratigraphic occurrence, and palaeoecological implications. The classification of the agglutinated foraminifera follows Kaminski (2014), while the calcareous foraminifera are listed according to Loeblich and Tappan (1987).

Agglutinated benthic foraminifera:

Family RHABDAMMINIDAE Brady 1884
Subfamily BATHYSIPHONINAE Avnimelech 1952
Genus ***Bathysiphon*** Sars 1872

Bathysiphon sp.
Plate 1, figure 1a, b

Diagnosis: Straight to slightly curved; large test; monothalamous; unbranched long thin tubes, however, they could have transverse constrictions or interior divisions, wall agglutinated, composed of fine-grained sand or silt grains.

Remarks: *Bathysiphon* is a widespread constituent of the present deep-ocean benthic biota, exhibiting notable abundance in areas that receive sediments and nutrients from nearby continents (Gooday et al. 1997; Miller 2005). The biological aspects of this species have been thoroughly investigated by several scientists (Miller 2005).

Distribution: Cosmopolitan, Mesozoic–Cenozoic.

Genus ***Psammosiphonella*** Avnimelech 1952

Psammosiphonella sp. 1
Plate 1, figure 2a, b

Diagnosis: Tubular agglutinated coarse-grained monothalamous test: cross-sectional shape is either circular or slightly elliptical, test straight to slightly curved, without any obvious expansion in any part of the tube and having a diameter that is either steady or slightly decreasing in one direction; the inside of the tube is uniformly wide, without any constriction, and it has apertures at both ends.

Distribution: Cosmopolitan, Ordovician, Silurian, Cretaceous, Cenozoic, Recent (Avnimelech 1952).

Psammosiphonella discreta (Brady 1881)
Plate 1, figure 3a, b

Rhabdammina discreta BRADY 1881, p. 48, pl. 22, figs 7-10. – CHARNOCK and JONES 1990, p. 152, pl. 1, fig. 25, pl. 13, fig. 23.
Psammosiphonella discreta (Brady). – KAMINSKI and GRADSTEIN 2005, p. 117-119, fig. 5, pl. 5/6.

Diagnosis: Angular coarse-grained agglutinated test, cylindrical shape, with openings at both ends; tubular straight to slightly curved, subdivided into segments by irregular gaps, characterized by minor constrictions. Wall coarse on the exterior, smooth on the inside.

Distribution: Cosmopolitan long ranging taxa (Kaminski and Gradstein 2005).

Family RHIZAMMINIDAE Wiesner 1931
Genus ***Rhizammina*** Brady 1879

Rhizammina sp.1
Plate 1, figure 4a, b

Diagnosis: Tubular test; unbranched; agglutinated, consisting of fine to somewhat coarse grains; slightly compressed.

Rhizammina sp. 2
Plate 1, figure 5a, b

Diagnosis: Meandering test; agglutinated, composed of fine to slightly coarse grains with rare fragments of sponge spicules; unbranched; strongly compressed.

Rhizammina sp. 3
Plate 1, figure 6a, b

Diagnosis: Slightly curved tubular test; agglutinated composed of coarse grains with fragments of sponge spicules; unbranched; round in cross-section.

Family ASCHEMOCELLIDAE Vyalov 1966
Genus ***Kalamopsis*** de Folin 1882

Kalamopsis grzybowskii (Dylążanka 1923)
Plate 1, figure 7

Hyperammina grzybowskii DYLĄŻANKA 1923, p. 65, pl. 1.
Bathysiphon nodosariaformis (Dylążanka). – SUBBOTINA 1950 p. 67, pl. 1, fig. 4.
Silicotuba grzybowskii (Dylążanka). – GEROCH 1966, p. 438, fig. 6.
Grzybowskiammina grzybowskii (Dylążanka). – NEAGU 2012, p.67, pl. 1, fig. 32-33.
Kalamopsis grzybowskii (Dylążanka). – KAMINSKI and GRADSTEIN 2005, p. 252, pl. 47, figs 1–12.– WOLFGRING et al., 2021, p. 5, fig. 4, nr. 2. – KAMINSKI et al. 2021, p. 349, pl. 4, fig. 6. – HIKMAHTIAR et al. 2022, p. 734, pl. 3, fig. 10. – FLORES et al. 2026, p. 345, pl. 3, fig. 2a,b.

Diagnosis: Uniserial test; flattened; comprised of elongated very fine-agglutinated chambers; smooth surface.

Distribution: Cosmopolitan, Late Cretaceous and Palaeocene.

Family HORMOSINELLIDAE Rauzer-Chernousova and Reitlinger 1986
Genus ***Subreophax*** Saidova 1975

Subreophax sp.
Plate 1, figure 8

Diagnosis: Test meandering, with an irregular shape; comprised of somewhat elongated chambers; coarse grained wall; it has apertures at both ends.

Remarks: Differs from the Palaeogene species *Subreophax scalaris* (Grzybowski) in possessing more elongated chambers. The specimens in our study exhibit deformities, however they nonetheless exhibit the characteristic traits often associated with the genus.

Family PSAMMOSPHAERIDAE Haeckel 1894
Genus ***Psammosphaera*** Schulze 1875

Psammosphaera sp. 1
Plate 1, figure 9a, b

Diagnosis: fine to medium-grained agglutinated test; unilocular; elliptical outline; rounded periphery; flat or slightly compressed in the centre.

Psammosphaera sp. 2
Plate 1, figure 10a, b

Diagnosis: unilocular; spherical form; flat; subrounded, coarse-grained test, the presence of sponge spicules and radiolaria in the test is characteristic.

Family SACCAMINIDAE Brady 1884
Subfamily SACCAMINIDAE Brady 1884
Genus ***Placentammina*** Thalmann 1947

Placentammina placenta (Grzybowski 1898)
Plate 1, figure 11a, b

Reophax placenta GRZYBOWSKI 1898, p. 276, pl. 10, figs 9- 10.
Saccammina placenta (Grzybowski). – KAMINSKI et al. 1988, p. 183, pl. 2, fig. 9.
Placentammina placenta (Grzybowski). – KAMINSKI and GRADSTEIN 2005, p. 136, pl. 11, figs 1-6.– KAMINSKI et al. 2021, p. 344, pl. 1, fig. 10. – FLORES et al. 2026, p. 341, pl. 1, fig. 9a,b.

Diagnosis: Fine-grained agglutinated test; single chamber; oval to circular in shape compressed from the side view; simple aperture on a small neck.

Remarks: Similar to other finely agglutinated forms recovered at Site U1512, specimens of *Placentammina placenta* appear compressed, deflated and sometimes deformed.

Distribution: Cosmopolitan, Cretaceous to Neogene.

Family HYPERAMMINIDAE Eimer and Fickert 1899
Subfamily HYPERAMMININAE Eimer and Fickert 1899
Genus ***Hyperammina*** Brady 1878

Hyperammina elongata Brady 1878
Plate 1, figure 12a, b

Hyperammina elongata BRADY 1878, p. 433, pl. 20, fig. 2a-b.
Hyperammina bradyi SHCHEDRINA 1946, pp. 139-148.

Diagnosis: Coarse-grained agglutinated test, long straight to slightly curved test, beginning has a rounded shape, compressed from the side view. The open narrow end that creates the overall aperture. Periphery irregular, inside smooth.

Remarks: The specimens from Site U1512 show similarity to the type species description.

Distribution: Cosmopolitan, Early Ordovician – Holocene.

Family AMMODISCIDAE Reuss 1862
Subfamily AMMODISCINAE Reuss 1862

Genus ***Ammodiscus*** Reuss 1862

Ammodiscus cretaceus (Reuss 1845)
Plate 1, figure 13a-c

Operculina cretacea REUSS 1845, p. 35, pl. 13, fig. 64-65.
Cornuspira cretacea (Reuss). – WHITE 1928, p. 185, pl. 27, fig. 9.
Ammodiscus cretaceus (Reuss). – TAPPAN 1962, p. 130, pl. 30, figs 1, 2. – KRASHENINNIKOV and PFLAUMANN 1978, p. 569, pl. 2, fig. 7. – KAMINSKI and GRADSTEIN 2005, p. 145, pl. 14, figs 1-10. – BENEDETTI 2017, pp. 24-25 fig. 13/5. – KAMINSKI et al. 2021, p. 347, pl. 2, fig. 14. – FLORES et al. 2026, p. 342, pl. 1, fig. 19.

Diagnosis: Planispiral large test; circular-elliptical in shape; tubular chamber flat on both sides, deepening toward the central portion; around 7-8 whorls; evolute coiling; significant coil suture; last three to four whorls asymmetrical and wider than the previous whorls; semicircular aperture; wall finely agglutinated, with a smooth surface.

Remarks: Despite the description of the type species provided by Reuss in 1845, which mentioned a rough surface, the wall surfaces of our specimens are smooth. Our species is similar to the junior synonym of *A. cretaceus* which was described as *Cornuspira hoernesi* by Karrer (1866).

Distribution: Cosmopolitan, Cretaceous to Late Eocene.

Ammodiscus tenuissimus Grzybowski 1898
Plate 1, figure 14a-c

Ammodiscus tenuissimus GRZYBOWSKI 1898, p. 272, pl. 10, fig. 35. – KAMINSKI and GRADSTEIN, 2005, p. 163, pl. 20, figs 1a–7. – WAŚKOWSKA et al. 2020, p. 51, pl. 12, fig. C. – KAMINSKI et al. 2021, p. 347, pl. 2, fig. 15.

Diagnosis: Very thin planispiral test; circular-elliptical in shape; spherical proloculus; flat in both sides; around 6-7 whorls; involute coiling; growth of the whorl's diameter exhibits an initial steady increase, followed by a subsequent rapidly expansion; last whorl convolute, overlapping with the preceding one; significant depressed suture, wall finely agglutinated, with a smooth surface.

Remarks: This species has a notably thin test, thereby distinguishing it from *A. cretaceus*.

Distribution: Cosmopolitan, Late Cretaceous to Eocene.

Ammodiscus peruvianus Berry 1928
Plate 1, figure 15a, b

Ammodiscus peruvianus BERRY 1928, p. 392, fig. 27. – WAŚKOWSKA et al. 2020, p. 50, pl. 12, figs A, B. – KAMINSKI and GRADSTEIN 2005, p. 157, pl. 18, figs 1-6. – HIKMAHTIAR et al. 2022, p. 728-730, pl. 1, figs. 18-19. – FLORES et al. 2026, p. 342, pl. 1, fig. 20.

Diagnosis: Biconcave elliptical planispiral test; involute coiling; deepening toward the central part; around 4 to 5 whorls; tubular chamber slowly expands in both diameter and thickness; depressed coil suture; aperture is located at the end of the tube; wall finely agglutinated with a smooth surface.

Remarks: The specimen under investigation exhibits similarities to Berry's (1928) specimen. However, several micropalaeontologists propose that this species represents a deformed variant of the circular *Ammodiscus* species, maybe caused by sediment load. In contrast, we hold a different perspective since we have recovered distinctly circular *Ammodiscus* species. With the sediment overburden less than 500 m at this site, it is here suggested that sediment load did not induce deformation in *A. peruvianus*.

Distribution: Cosmopolitan, Late Cretaceous to Eocene.

Ammodiscus sp. cf. ***A. angustus*** Friedberg 1902
Plate 1, figure 16a, b

Cornuspira angusta FRIEDBERG 1901, p. 178, pl. 1, fig. 8.

Diagnosis: Biconcave elliptical planispiral test; involute coiling; umbilical area slightly deepening on both sides; around 4 to 5 whorls; tubular chamber slowly expands in both diameter and length; depressed coil suture; aperture located at the end of the tube; coarsely agglutinated, rough surface.

Remarks: The specimen shows strong similarities to the form described by Frenzel (2000) as *A. angustus*. However, Frenzel also referred to *A.* cf. *cretaceus*, which we find more consistent with Reuss' original description (1845), particularly concerning the rough surface. Many synonyms of *A. cretaceus* describe smooth surfaces, suggesting both designations by Frenzel might refer to a single species.

Distribution: Cosmopolitan, Late Cretaceous (Maastrichtian) (Frenzel 2000).

Subfamily AMMOVERTELLININAE Saidova 1981
Genus ***Glomospirella*** Plummer 1945

Glomospirella gaultina (Berthelin 1880)
Plate 1, figure 17a-c

Ammodiscus gaultinus BERTHELIN 1880, p. 19, pl. 1, fig. 13.
Ammodiscus gaultinus Berthelin. – emend. BARTENSTEIN 1954, p. 38, pl. 1, figs 17–20.
aff. *Glomospirella gaultina* (Berthelin). – TAPPAN 1962, p. 130, pl. 29, figs 17-20.
Glomospirella gaultina (Berthelin). – KUZNETSOVA 1974, pl. 1, figs 2a, b. – SLITER 1980, pl. 1, figs 11-13. – HOLBOURN and KAMINSKI 1997, p. 37, pl. 6, figs 4-6. – SZAREK et al. 2000, p. 452, pl. 1, fig. 12.

Diagnosis: Discoidal test, wall finely agglutinated with smooth surface; circular; proloculus in the center slightly swollen; spirally wound; second chamber is characterized by a tubular structure that lacks septa; in the early stage the coiling pattern changes with growth; later in ontogeny likely to appear planispiral.

Remarks: Our specimens present similarities to the species from Alaska documented by Tappan (1962), but shows a more circular periphery.

Distribution: Northeastern Brazil, Albian, Late Campanian to Early Maastrichtian (Koutsoukos 2000). Lower Cretaceous, Albian, Northeast Germany (Szarek et al. 2000).

Subfamily USBEKISTANIINAE Vyalov 1968

Genus ***Glomospira*** Rzehak 1885

Glomospira sp. cf. ***G. compressa*** Waters 1928
Plate 1, figure 18a-c

Glomospira compressa WATERS 1928, p. 273, pl. 32, fig. 5.

Diagnosis: Large test with rough surface; proloculus; second chamber irregularly coiled and oval in shape; aperture oval, located at end of chamber; wall coarsely agglutinated.

Remarks: Although *G. compressa* occur in older deposits, the material from Site U1512 shares notable similarities. Initial comparison with *Glomospira irregularis* (Upper Cretaceous) shows superficial resemblance, but coiling pattern and chamber structure diverge. Intraspecific variability in coiling is possible.

Distribution: *Glomospira compressa* Waters 1928 was documented from the upper Carboniferous of Texas, USA (Omara et al. 1966).

Family REOPHACIDAE Cushman 1927
Genus ***Reophax*** Montfort 1808

Reophax sp. 1
Plate 1, figure 19

Diagnosis: Angular coarse-grained agglutinated with rough surface; composed of two pyriform shape chambers that slightly overlapping; aperture is a circular opening that lacks a neck.

Remarks: The species description of *R. duplex* by Grzybowski (1896) included observations of very fine-grained agglutinated and two spherical chambers of nearly equal size, distinguishing it from our species. Kaminski (1993) rejected the name of *R. duplex* var. *acuta* by Dylążanka (1923) on the reason that he observed it to be a deformed representation of *R. pilulifer* by Brady. After careful review of the Dylążanka (1923) description, we observe that it matches our own description, but without any reference to the wall texture. Therefore, we propose that this species should be regarded as distinct from *R. duplex*. The shape of the pyriform chambers bears resemblance to *Reophax eckernex* Vieaux 1941, which is found in the lower Cretaceous deposits of northern Grayson County, Texas.

Distribution: Cosmopolitan, Cretaceous to Palaeogene.

Reophax sp. cf. ***R. globosus*** Sliter 1968
Plate 1, figure 20

aff. *Reophax globosus* SLITER 1968, p. 43, pl. 1, fig. 12.

Diagnosis: Uniserial straight test; strongly depressed globular chambers, slightly overlapping and moderately increasing; distinct sutures; terminal aperture without neck; coarse-grained agglutinated wall with rough surface.

Remarks: Sliter's (1968) original species featured globular chambers and a small neck. In contrast, our material lacks the neck and shows significantly depressed, disc-like chambers. Likely represents a separate morphotype.

Distribution: Cosmopolitan, Late Cretaceous (Campanian to Maastrichtian).

Family HORMOSINIDAE Haeckel 1894
Subfamily HORMOSINIDAE Haeckel 1894
Genus ***Pseudonodosinella*** Saidova 1970

Pseudonodosinella sp. cf. ***P. troyeri*** (Tappan 1960)
Plate 1, figure 21a-b

Reophax troyeri TAPPAN 1960 p. 291, figs 10-12.
Pseudonodosinella troyeri var. *scabra* TYSZKA 2004, pl. 1, figs 15-17.

Diagnosis: Test free, elongate, uniserial; rounded chambers. Sutures depressed and horizontal; wall finely agglutinated, surface roughened; aperture terminal, rounded, at the end of a distinct neck.

Remarks: *Pseudonodosinella troyeri* displays a distinctly produced neck.

Distribution: Cosmopolitan, Cretaceous (? middle and upper Albian) (Tyszka 2004).

Pseudonodosinella parvula (Huss 1966)
Plate 1, figure 22a-b

Reophax parvulus HUSS 1966, p. 21, pl. 1, figs 26-30.

Diagnosis: uniserial; slightly curved to straight test; slightly narrowing on both ends; 4-5 chambers, slightly overlapping and rapidly increasing in size; elliptical to pyriform in shape; curved horizontal sutures; single terminal aperture with low neck; fine-grained agglutinated with somewhat rough surface.

Remarks: *Pseudonodosinella parvula* can be distinguished from *P. troyeri* in presenting fewer chambers. Conflicting observations are reported with regard to the presence of a neck. Geroch and Kaminski (1995), reported the presence of a small neck in *P. parvula*, but Tyszka (2004) noted the absence of the structure.

Distribution: Apart from occurrences in the southern high latitudes, this taxon is known from Upper Cretaceous in Carpathians, In northwest of Germany Barremian to middle Albian (Tyszka 2004).

Family HAPLOPHRAGMOIDIDAE Maync 1952
Genus ***Haplophragmoides*** Cushman 1910

Haplophragmoides sp. cf. ***H. walteri*** (Grzybowski 1898)
Plate 2, figure 1a-c

cf. *Trochammina walteri* GRZYBOWSKI 1898, p. 290, pl. 11, fig. 31.
Haplophragmoides cf. *walteri* (Grzybowski). – HEMLEBEN and TROESTER 1984, p. 519, pl. 3, fig. 6.
Haplophragmoides cf. *walteri* (Grzybowski). – MOULLADE et al. 1988, p. 364, pl. 8, fig. 7.

Diagnosis: planispiral; round in shape; acute peripheral edge; involute in coiling; around six triangular chambers the last whorl; expanding in size rapidly; sutures extend straight illustrating a depression between chambers; fine-grained agglutinated with somewhat smooth surface.

Remarks: Differs from the *Haplophragmoides walteri* (Grzybowski) in possessing fewer chambers in the final whorl. According to Wolfgring et al. (2023), the species in question were

consolidated into the taxonomic category of *Haplophragmoides* sp. due to the presence of transitional forms that exhibited diverse degrees of excavation, straight or sigmoidal sutures, and a variable number of chambers. The presented form originates from the Turonian and is demonstrated at Site U1512.

Distribution: Late Cretaceous.

Haplophragmoides concavus (Chapman 1892)
Plate 2, figure 2a-c

Trochammina concava CHAPMAN 1892, p. 327, pl. 6, fig. 14 a-b.

Diagnosis: The test shows slight evolution and follows a planispiral pattern; five or six chambers depressed; sutures not clear; fine-grained agglutinated with smooth surface.

Remarks: Wolfgring et al. (2023) assigned the name *H. concavata* to this species. However, we respectfully disagree with Wolfgring's labeling, as we believe that the initial description of *Trochammina concava* (*H. concava*) by Chapman (1892) does not align with Wolfgring's findings, specifically due to the evident presence of depressed sutures. Furthermore, Szarek et al. (2000) provided a definition of *H. concava* that aligns with the characteristic features outlined in the original description.

Distribution: Confirmed through the Cretaceous, probably present in Cenozoic strata as well (see occurrence data in mikrotax.org/bforams).

Haplophragmoides petaliformis Wolfgring, Kaminski and Waśkowska 2023
Plate 2, figure 3a-c

Haplophragmoides petaliformis WOLFGRING, KAMINSKI and WAŚKOWSKA 2023, p. 8, pl. 2, figs 1-3.

Diagnosis: Test thin and compressed, with a distinct petal-like outline; wall composed of fine to moderately coarse agglutinated grains; sutures slightly depressed, giving a lobate appearance in lateral view.

Remarks: Wolfgring et al. (2023) documented the characteristic petal-shaped outline and compressed test, features that are consistently observed across specimens. Compared to other representatives of this group, *H. petaliformis* seems less prone to deformation and diagenesis.

Distribution: Upper Cretaceous of IODP Site U1512 and the western Australian margin, similar forms were documented by Setoyama et al. (2011) from the Campanian of the Lomonosov Ridge, Arctic Ocean.

Haplophragmoides tenellulus Wolfgring, Kaminski and Waśkowska 2023
Plate 2, figures 4a-c

Haplophragmoides tenellulus WOLFGRING, KAMINSKI and WAŚKOWSKA 2023, p. 8, pl. 2, figs 7-8.

Diagnosis: Planispiral compressed shape; coiling involute, with 4 to 5 chambers in the last whorl; sutures not clear; coarse-grained agglutinated with heterogenous composition of material; aperture is often unclear.

Remarks: The coarse wall structure composed of non-homogeneous, coarsely textured grains, as described by Wolfgring et al. (2023), *H. tenellulus* is characterized by a thin test and the inhomogeneous composition of building materials. While these features were confirmed in our material, the lobate outline described in the original diagnosis could not be clearly recognized.

Distribution: Cosmopolitan, Late Cretaceous (lower Turonian–Coniacian)

Haplophragmoides antarcticus Wolfgring, Kaminski and Waśkowska 2023
Plate 2, figure 5a-b

Haplophragmoides antarcticus WOLFGRING, KAMINSKI and WAŚKOWSKA 2023, p. 8, pl. 2, fig. 6.

Diagnosis: Planispiral test; involute, circular periphery; with 4.5 to 5 chambers in the last whorl; depressed straight sutures fine-grained agglutinated with smooth surface; aperture has a somewhat larger size toward the base of the final chamber.

Remarks: According to Wolfgring et al. (2023), the recently identified species has a periphery that is more rounded in form. It is characterized by a circular shape and chambers that vary in shape from globular to triangular. This is in contrast to *H. canariensis* d'Orbigny, 1839, which possesses globular chambers.

Distribution: Described from the Cretaceous of the Australo-Antarctic Gulf.

Genus ***Labrospira*** Höglund 1947

Labrospira nonioninoides (Reuss 1863)
Plate 2, figure 7a-c

Haplophragmium nonioninoides REUSS 1863, p. 30, pl. 1, fig. 8.
Labrospira nonioninoides (Reuss). – HAIG 1980, pl. 3, figs 12-19.
Haplophragmoides nonioninoides (Reuss). – SLITER 1980, pl. 2, figs 5-6. – MEYN and VESPERMANN 1994, pl. 1, figs 1-8.
Cribrostomoides nonioninoides (Reuss). – HOLBOURN and KAMINSKI 1997, p. 40, pl. 8, figs 9-10.

Diagnosis: Planispiral test; involute, circular periphery; 1.5-2.5 coils with 7-9 chambers in the last coil, wall smooth, fine grained. Aperture areal, rounded to slightly elongate, positioned at the end of the final chamber. Lacks a distinct lip, neck.

Remarks: The specimens show close similarity to *Labrospira* sp. However, several features differ slightly: the aperture is more distinctly areal and terminal, varying between a circular opening and a slit; the number of chambers is slightly lower; and the wall is composed of coarser agglutinated grains. The latter features seem to be consistent with the morphological features of *L. nonioninoides*, however, transitional forms were observed at Site U1512 (see *Labrospira* sp.).

Distribution: Cosmopolitan, Cretaceous.

***Labrospira* sp.**

Diagnosis: Coiling planispiral, biumbilical, compact, robust or squashed appearance, involute to slightly evolute test with compressed chambers. The wall is agglutinated, distinct sutures that are slightly depressed, and the aperture is aerial, a slit slightly above the base of the terminal chamber, produced without any lip or neck.

Remarks: *Labrospira* sp. can be differentiated from robust forms of *Haplophragmoides* by the distinctly different aperture.

Distribution: see *Labrospira nonioninoides* (Reuss 1863).

Family REOPHACELLIDAE Mikhalevich and Kaminski 2004
Genus ***Uvigerinammina*** Majzon 1943

Uvigerinammina jankoi Majzon 1943
Plate 2, figure 6a, b

Uvigerinammina jankoi MAJZON 1943, p. 158, pl. 2, fig. 15. – NEAGU 1990, p. 255, pl. 4, figs 7-15. – SETOYAMA et al. 2017, p. 197, pl. 4, figs 8, 9.

Diagnosis: Test elongate, triserial chamber arrangement, chambers clearly separated by deeply incised sutures. Wall agglutinated, composed of fine to moderately coarse grains, with a smooth to slightly uneven surface texture. Terminal aperture, rounded to slit-like, without a distinct neck or lip.

Remarks: *Uvigerinammina jankoi* is typically found in Upper Cretaceous flysch deposits and was emphasized by Geroch and Nowak (1984) for its biostratigraphic importance in Upper Turonian to Campanian deep-water sequences in the Tethyan realm, where it helps define zonal boundaries in agglutinated assemblages. At IODP Site U1512 *Uvigerinammina jankoi* was recovered as a rare component of the benthic assemblage.

Distribution: Documented from the Upper Cretaceous: the Coniacian to Santonian of Site U1512 and in the Turonian to Campanian in Tethyan agglutinated foraminiferal assemblages.

Family LITUOLIDAE de Blainville 1827
Subfamily AMMOMARGINULININAE Podobina 1978
Genus ***Ammobaculites*** Cushman 1910

Ammobaculites agglutinans (d'Orbigny 1846)
Plate 2, figure 9a-c

Spirolina agglutinans D'ORBIGNY 1846, p 137, Plate 7, figs 10-12.
Ammobaculites agglutinans (d'Orbigny). – BARTENSTEIN 1952, p. 318, pl. 1, fig. 1, pl. 2, figs 10-16.
Ammobaculites agglutinans var. *caucasica* d'Orbigny. – KHALILOV 1959, p. 27 fig. 3.

Diagnosis: Large extended oval-shaped test, planispiral at initial stage, uncoiling and becoming uniserial; planispiral part is involute with three lobate chambers, and the umbilicus is somewhat depressed, uniserial part has a circular cross section; circular periphery; with 4.5 to 5 chambers in the last whorl; depressed straight sutures in uniserial part, lower degree of depression throughout the coiled portion; oval terminal aperture; medium to coarse grained agglutinated with rough surface.
Remarks: The species identified at Site 1512 displays similarities to *A. agglutinans* d'Orbigny 1846, however it shows a greater a comparison to the Lower Cretaceous *A. abnormalis* Crespin 1963. However, because to its age range, it has been classified under the category of *A. agglutinans.*

Distribution: Cosmopolitan, Late Cretaceous to Recent.

Genus ***Sculptobaculites*** Loeblich and Tappan 1984

Sculptobaculites sp. 1
Plate 2, figure 8a-b

Diagnosis: Large sharply truncate test, planispiral at initial stage slightly enrolled; central area of test excavated; planispiral part with 8 inflated to angularly lobulate chambers; uniserial part is not clear; subrounded periphery; with 4.5 to 5 chambers in the last whorl; indistinct sutures; aperture not clear; coarse-grained agglutinated with rough finish.

Remarks: The species exhibits resemblance to the genus S*culptobaculites*; nevertheless, it is afflicted with a damaged and fragmented uniserial portion.

Distribution: Cosmopolitan, Maastrichtian to Recent.

Family AMMOSPHAEROIDINIDAE Cushman 1927
Subfamily RECURVOIDINAE Alekseychik-Mitskevich 1973
Genus ***Recurvoides*** Earland 1934

Recurvoides cf. ***trincherasensis*** Bermúdez 1949
Plate 2, figure 10a-c

Recurvoides trincherasensis BERMÚDEZ 1949, p. 50, pl. 1 figs 32-34.

Diagnosis: Biconvex test; rounded periphery; somewhat lobate; 5-6 chambers in the last whorl, increasing in size moderately; sutures slightly depressed; medium to coarse-grained agglutinated with rough surface; aperture unclear.

Remarks: There are some similarities between this species and *Recurvoides trincherasensis*; however, the sutures in the type specimens are more depressed and distinct.

Distribution: *R. trincherasensis* was described from the Upper Oligocene in the Gulf of Mexico.

Family AMMOBACULINIDAE Saidova 1975
Genus ***Bulbobaculites*** Maync 1952

Bulbobaculites problematicus (Neagu 1962)
Plate 3, figure 1a, b

Ammobaculites agglutinans subsp. *problematicus* NEAGU 1962, p. 61, pl. 2, figs 22-24.
Haplophragmium aequicameratum HUSS 1966, p. 68, pl. 9, figs 10-25.
Bulbobaculites problematicus (Neagu 1962). – KUHNT and KAMINSKI 1990, p. 465, text-fig. 5a, pl. 4, figs A-H.

Diagnosis: Test large; initial streptospiral part with 4-5 chambers; then uniserial with 7-8 chambers; rounded in cross-section; chambers that have been inflated are separated by sutures that are noticeably depressed; either coarsely or finely agglutinated with rough surface; the last chamber decreases in size until it terminates in a rounded aperture.

Remarks: Our specimens from Site 1512 serve as an excellent example of *B. problematicus* due to its diverse range of morphological characteristics. Nevertheless, Neagu's (1962) report included specimens with a small neck, a characteristic that was absent in our specimens.

Distribution: Cosmopolitan, Cretaceous (Cenomanian–Coniacian).

Bulbobaculites sp. 1
Plate 3, figure 2a-b

Diagnosis: Test large; first streptospiral section displays 2-3 chambers; followed by uniserial chamber alignment with 2-3 circular chambers; equal in size divided depressed sutures; either coarsely or finely agglutinated; last chamber globular with rounded terminal aperture.

Remarks: The species has resemblance to *B. inconstans* subsp. *gracile* Bartenstein and Brand 1951, which is a common species in the Lower Cretaceous. Furthermore, *B. inconstans gracile* displays a distinctive elongation of the last chamber with a pronounced narrowing towards the aperture, that is not present in our "spumante variety".

Distribution: Middle Turonian to Coniacian in Cores -17R, -47R, -48R, -49R, and -51R at Site U1512.

Bulbobaculites sp. 2
Plate 3, figure 3a, b

Diagnosis: Test large; streptospiral segment with 2-3 chambers; then uniserial with 8-10 chambers; rounded in cross-section; chambers slightly increase in size divided by depressed sutures; either coarsely or finely agglutinated with a rough surface; last chamber subrounded with a rounded terminal aperture.

Remarks: The form and amount of chambers in the uniserial portion differ from those seen in other species. The uniserial section of this species does not exhibit a straight configuration as observed in other members of this group.

Distribution: Middle to late Turonian in Cores -44R, -47R, and -48R at Site U1512.

Bulbobaculites sp. 3
Plate 3, figure 4

Diagnosis: Test large; streptospiral section comprising 2-3 chambers; uniserial portion with 8-10 chambers; chambers depressed and only show a slight increase in size; sutures depressed; coarsely agglutinated with rough surface; last chamber rounded with terminal aperture circular on a short neck.

Remarks: No previous documentation of depressed chambers in *Bulbobaculites* exists in the literature. Even when accounting for potential diagenetic alterations and preservational effects, the specimens display morphological characteristics that support its recognition as a distinct and previously undescribed species.

Distribution: Turonian at Site 1512 in Cores -44R to -66R.

Family SPIROPLECTAMMINIDAE Cushman 1927
Subfamily SPIROPLECTAMMININAE Cushman 1927
Genus ***Spiroplectammina*** Cushman 1927

Spiroplectammina navarroana Cushman 1932
Plate 3, figure 5a, b

Spiroplectammina navarroana CUSHMAN 1932, p. 96, pl. 1, fig. 14. – emend. GRADSTEIN and KAMINSKI 1989, p. 83, pl. 9, figs 1-12, text-fig. 5. – FLORES et al. 2026, p. 346, pl. 4, fig. 4a,b.
Textularia plummerae LALICKER 1935, p. 50, pl. 6, fig. 10.
Spiroplectammina lanceolata HUSS 1966, p. 36, pl. 5, figs 16-20.

Diagnosis: Elongated test, arched and tapering; initial part planispiral, subsequently it becomes biserial; chambers gradually expand in size as more are added, and they are about as high as they are wide; final two chambers are slightly inflated; sutures somewhat depressed; at first angled with regard to the test's long axis, then perpendicular to it; unclear aperture; moderately to finely agglutinated with a rough surface.

Remarks: *Spiroplectammina navarroana* documented at Site U1512, is very similar to the morphotype described in Gradstein and Kaminski (1989), with the exception of the reduced number of biserially aligned chambers recorded in our specimen. The specimens from Site U1512 are well-preserved and show the initial planispiral whorl.

Distribution: Cosmopolitan, Turonian to Eocene.

Family TEXTULARIOPSIDAE Loeblich and Tappan 1982
Genus ***Textulariopsis*** Banner and Pereira 1981

Textulariopsis texhomensis Loeblich and Tappan 1982
Plate 3, figure 6a-b

Textulariopsis texhomensis LOEBLICH and TAPPAN 1982, p. 68, pl. 2, fig. 38-39.

Diagnosis: Elongate narrow test; biserial chamber arrangement, either consistently throughout, or displaying a solitary adventitious chamber at the base, making it appear pseudotriserial (Loeblich and Tappan 1982); gradually increase in chamber size, chambers show little or insignificant expansion in early growth stages, late-stage chambers inflated. Sutures align with the surface and have a modest downward inclination towards the margin; aperture on the base of the terminal chamber, presents a large, low arch, extending over half of the terminal chambers surface. Test coarsely to finely agglutinated with a rough surface.

Remarks: The specimens differ from the original description test architecture and suture configuration: whereas Loeblich and Tappan (1982) show horizontal sutures only in the final stage, our material displays them consistently throughout development.

Distribution: Cosmopolitan, middle Cretaceous.

Textulariopsis rioensis (Carsey 1926)
Plate 3, figure 7a-b

Textularia rioensis CARSEY 1926, p.24, pl. 7, fig. 2.
Textulariopsis rioensis (Carsey). – LOEBLICH and TAPPAN 1982, pI. 2, figs 26-28.

Diagnosis: Elongated test; rarely irregularly decreasing during the initial stage; expanding at a later stage; occasionally weakly rotating around its axis; in cross-section circular; chambers biserially arranged; sutures are depressed and not always obviously noticeable; apical section often expanded, arched terminal chamber; aperture located on the inner margin of the last chamber; coarsely to finely agglutinated with a rough surface.

Remarks: The specimen is entirely consistent with the species as originally described by Carsey (1926).

Distribution: Cosmopolitan, middle Cretaceous.

Genus ***Eobigenerina*** Cetean, Setoyama, Kaminski, Neagu, Bubík, Filipescu and Tyszka, 2008

Eobigenerina variabilis (Vašíček 1947)
Plate 3, figure 8a, b

Bigenerina variabilis VAŠÍČEK 1947, p. 246, pl. 1, fig. 10-12.
Pseudobolivina variabilis (Vašíček). – NEAGU 1970, p. 41, pl. 5, figs 13-16.
Eobigenerina variabilis (Vašíček). – CETEAN et al. 2011, p. 21, pl. 1, figs 1-12.

Diagnosis: Test elongated; initially biserial with around 7-9 chambers; later stage characterized by a loosely biserial form with 2-3 chambers; terminal uniserial stage with 2 chambers; round in cross section; notable triangle zigzag sutures that are slightly depressed in the biserial stage; horizontal in the uniserial stage; terminal aperture small and circler; finely agglutinated with a smooth surface.

Remarks: Cetean et al. (2011) noted that the aperture was located on a short neck, a feature that is absent in our specimens. Furthermore, they state that Vašíček did not clearly discuss the form of the aperture. However, given that he first categorized the species under *Bigenerina*, it may be inferred that the aperture was located at the terminal end. We believe, however, that Vašíček would have provided a description of the aperture if he noticed a short neck; thus, our specimens have similarities to Vašíček's specimens.

Distribution: Late Cretaceous from the Carpathians, Germany and Italy.

Family PROLIXOPLECTIDAE Loeblich and Tappan 1985
Genus ***Gerochammina*** Neagu 1990

Gerochammina lenis (Grzybowski 1896)
Plate 3, figure 9a, b

Spiroplecta lenis GRZYBOWSKI 1896, p. 288, pl. 9, fig. 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., 2011, p. 271, pl. 10, fig. 7; pl. 11, fig. 15a–c. – SETOYAMA et al. 2017, p. 189, pl. 4, fig. 6.

Diagnosis: Elongated test; initial stage trochospiral later high trochospiral with 3 chambers increasing gradually in size until the onset of a biserial chamber arrangement; sutures not clear in the trochospiral segment; slightly depressed and curved in biserial stage; subterminal aperture within the interior edge of the final chamber finely agglutinated with somewhat rough surface.

Remarks: Other species of *Gerochammina* show notable differences in chamber arrangement: *G. lenis* (Grzybowski) displays greater prolongation and earlier transition to biseriality than *G. obesa* Neagu, while *G. stanislawi* Neagu exhibits a more developed trochospiral stage (Setoyama et al. 2011).

Distribution: Cosmopolitan, Late Cretaceous.

Gerochammina sp. 1
Plate 3, figure 10a-b

Diagnosis: Elongated test; initial stage trochospiral later high trochospiral with 3 chambers decreasing until the biserial stage; sutures not clear in the trochospiral stage; slightly depressed and curved in biserial stage; subterminal aperture within the interior edge of the final chamber medium to coarse-grained agglutinated with a rough surface.

Distribution: Upper Cretaceous at Site 1512.

Genus ***Rectogerochammina*** Kaminski, Cetean and Neagu 2010

Rectogerochammina sp. 1
Plate 3, figures 11a-b

Diagnosis: Elongated compressed test; initial stage high trochospiral with 3 to 4 chambers decreasing in size until transitioning to a biserial growth pattern; the biserial part contains around five rows, then a terminal uniserial stage with three or four chambers; sutures slightly depressed and curved in biserial stage and horizontal in uniserial; terminal aperture within the final chamber; medium grained agglutinated with a slightly rough surface.

Remarks: Differs from the type species *R. eugubina* in its more elliptical cross section and longer uniserial and biserial stages.

Distribution: Turonian at Site 1512 in Cores from -44R to -66R.

Genus ***Praedorothia*** Desai and Banner 1987

Praedorothia sp.
Plate 3, figure 12a-b

Diagnosis: Initially trochospiral with 3-4 chambers to a whorl, transitioning to a biserial arrangement in later stages. Aperture is interiomarginal, with slightly depressed and curved sutures in the biserial stage. The test is moderately to finely agglutinated, displaying a rough surface.

Remarks: Despite the poor preservation of the majority of the collected specimens, the specimens can be determined to belong to the genus *Praedorothia*, but not at the species level.

Distribution: Turonian at Site 1512 in Cores -44R to -66R.

Planktonic foraminifera
Family HETEROHELICIDAE Cushman 1927
Genus ***Planoheterohelix*** Georgescu and Huber 2009

Planoheterohelix globulosa (Ehrenberg 1840)
Plate 4, figure 1a-c

Textularia globulosa EHRENBERG 1840, p. 135, pl. 4, fig. 2ß, 5ß, 7ß, 8ß.

"*Heterohelix globulosa* Ehrenberg". – GEORGESCU and HUBER 2009, pl. 7, figs 9-12.
Planoheterohelix globulosa (Ehrenberg). – HAYNES et al. 2015, figs 11.1-11.14 (with synonyms). – ELNAHAS et al. 2025, pl. 1, fig. 12.

Diagnosis: Biserial subglobular chamber shape; test smooth macroperforate; unique deep sutures; from side view the chambers display a consistent pattern of gradual enlargement, moderately increasing in size toward the aperture, reaching their largest width at the last chamber. Interiomarginal symmetric primary aperture, low with partial lip in the upper part.

Remarks: This species from site U1512 differs from *G. globocarinata* (Cushman) in that the fine perforations have no elongate lines, whereas *T. globulosa* (Ehrenberg) is distinguished by the significantly flattened test and the roughened early chambers. While in the adult stage the smooth wall texture is similar.

Distribution: Late Cenomanian to Maastrichtian, in Colorado USA, Blake Plateau North west of Atlantic, Shatsky Rise Central Pacific, Tunisia northern Africa (Georgescu and Huber 2009). It occurs frequently in association with planktonic taxa and represents a common component of the assemblage

Family HEDBERGELLIDAE Loeblich and Tappan 1961
Genus ***Muricohedbergella*** Huber and Leckie 2011

Muricohedbergella delrioensis (Carsey 1926)
Plate 4, figure 2a-c

Globigerina cretacea var. *delrioensis* CARSEY 1926, p. 43, pl. 5, fig. 5a, 5b.
Muricohedbergella delrioensis Carsey. – FALZONI et al. 2016, fig. 5, 5a-c.

Diagnosis: Slightly biconvex low trochospire with two whorls of 8–9 chambers that increase in size fast with 4.0–4.5 chambers in the final whorl; rounded periphery; the surface of the test is characterized by a coarse microperforate to muricate to pustulose appearance in the earlier chambers and is ornamented with randomly scattered pores; chamber shape subglobular to globular; straight radial slightly depressed sutures; shallow umbilicus; primary aperture a low arch a umbilical-extraumbilical extending toward the periphery with a very thin lip.

Remarks: This is the type species of the genus *Muricohedbergella* Huber and Leckie. The species found at Site U1512 has similarities to *Hedbergella praelippa* Huber and Leckie (2011), that is restricted to the Aptian. The smooth microperforate wall texture of *H. praelippa* shows poorly developed perforation cones, a low number of chambers per whorl, and a lack of a distinct lip; therefore, this species was named *Mu. delrioensis*, which is similar except for the number of chambers in the final whorl (4.5-7 according to Huber and Leckie (2011)). Carsey (1926) based his initial description of the Mu. delrioensis species on samples taken from the Grayson Formation (Del Rio Clay). However, Carsey did not provide adequate illustrations of the species, nor did he provide the location where the type specimens are now preserved (Pessagno 1967; Petrizzo and Huber 2006). This species was compared with Petrizzo and Huber's 2006 description of *H. delrioensis*, which is similar.

Distribution: Range from late Albian to Maastrichtian globally (Huber and Leckie 2011). It is observed in Cores -43R to -66R at Site U1512.

Subfamily HEDBERGELLINAE Loeblich and Tappan 1961
Genus ***Whiteinella*** Pessagno 1967

Whiteinella baltica Douglas and Rankin 1969
Plate 4, figure 3a-c

Whiteinella baltica DOUGLAS and RANKIN 1969, p. 198, fig. 9, A-C.
Rugoglobigerina alpina Douglas and Rankin. – PORTHAULT 1969, pl. 2, fig. 2a-c.

Diagnosis: Medium-size test coiled in low trochospiral mode; perforate wall texture; rounded periphery from the axial; significantly lobulate around the equator. Subspherical inflated chambers; in the final whorl, 4-5 chambers; earlier chambers increase faster in size, while in the adult stage, chambers grow slowly in size. Sutures are depressed on both sides; spiral sutures are slightly curved; umbilical sutures are straight radial. Coarse pustulose texture on the chamber surface becoming stronger in the earlier chambers. Shallow umbilicus with a single large aperture from the extraumbilical to the umbilical side.

Remarks: The species documented at Site U1512 is identical to the type specimen *W. baltica* described by Douglas and Rankin (1969) from North America, including the coiling direction.

Distribution: Turonian to Early Santonian globally (Douglas and Rankin 1969); it is observed in Cores -6R through -66R at Site U1512.

Whiteinella sp. 1
Plate 4, figure 4a-c

Diagnosis: Medium-size plano-convex test coiled in low trochospiral mode; perforate wall texture; test shape rounded periphery; significantly lobulate around the equator. Subspherical inflated chambers; in the final whorl, 4-5 chambers; earlier chambers increase faster in size, while in the adult stage, chambers grow slowly in size. Sutures are depressed on both sides; spiral sutures are slightly curved; umbilical sutures are straight radial; pustulose texture on the chamber surface. Moderately deep umbilicus with a single large aperture from the extraumbilical to the umbilical side; with a thin lip very clear in lateral view.

Remarks: Differs from *W. baltica* in its larger aperture and with a thin lip, smoother wall texture, and plano-convex test.

Distribution: It is observed in Core -46R at Site U1512.

Whiteinella brittonensis (Loeblich and Tappan 1961)
Plate 4, figure 5a-c

Hedbergella brittonensis LOEBLICH and TAPPAN 1961, p. 287, pl. 4, fig. 1-8.
Whiteinella brittonensis (Loeblich and Tappan). – VAN EIJDEN and SMIT 1991, p. 108.

Diagnosis: Plano-convex test coiled in a medium to high trochospire; 2-3 whorls; all of them can be distinguished from the spiral side; 5-6 chambers of the final whorl; subrounded periphery; very coarse perforate wall texture; umbilicus deep and wide; subspherical chambers with slow growth rate; sutures are slightly depressed; surface strongly pustulate on umbilical side,

more so on the spiral side; aperture characterized by a high arch with a thin lip extending in the umbilical region.

Remarks: The distinguishing features of this species include a very rough, perforated wall texture and a distinct aperture shape. The distinction between this species and *W. aumalensis* lies in the different degrees of convexity on the spiral side.

Distribution: Cenomanian to Turonian (Pessagno 1967) in America, Norway and Greenland (Gradstein et al. 1999). It is observed in Cores -46R through -60R at Site U1512.

Whiteinella aumalensis (Sigal 1952)
Plate 4, figure 6a-c

Globigerina aumalensis SIGAL 1952, p. 28, fig. 29.

Diagnosis: moderately high trochospiral test; plano-convex asymmetrical subrounded periphery, no keel present; slightly compressed to subangular chambers, very coarse perforate wall texture; relatively deep and wide umbilicus; sutures are slightly depressed straight radial with a smooth surface in both sides, slightly curved in the adult stage; surface strongly pustulate; the interiomarginal aperture characterized by a high arch with an umbilical to extraumbilical lip.

Remarks: The aperture in this species is smaller than the aperture in *W. archaeocretacea*, and the sutures are also deeper. This species differs from *W. aprica* in having subangular chambers. The distinguishing features of this species include a very rough, perforated wall texture and a distinct aperture shape.

Distribution: Globally from late Cenomanian–early Turonian (Georgescu 2011). Observed in Cores -46R to -60R at Site U1512.

Genus ***Planohedbergella*** BouDagher-Fadel, Banner, Whittaker and McCarthy 1997

Planohedbergella prairiehillensis (Pessagno 1967)
Plate 4, figure 7a-c

Globigerinelloides prairiehillensis PESSAGNO 1967, p. 277, pl. 60, figs 2-3, pl. 83, fig. 1, pl. 90, figs 1, 2, 4, pl. 97, figs 3-4.
Planohedbergella prairiehillensis (Pessagno). – HUBER et al. 2022, p. 162, pl. 16, figs 1-9.

Diagnosis: Biumbilicate planispiral test; rounded periphery; moderately lobate from the equatorial side; umbilicus side shallow; rounded chambers, moderately increasing in size; finely perforate wall texture; 5.5–6.5 chambers in the final whorl; sutures straight radial, slightly depressed on both sides; a low arched equatorial symmetrical aperture.

Remarks: Despite the poor state of preservation shown by this particular species, it is still possible to discern the original wall texture in certain spots that show fine perforations. This characteristic assumes significance as it serves as a crucial distinguishing feature setting this species apart from others. Features may also exert a significant impact, such as the number of chambers, which can be established by x-ray analysis even in cases of excellent preservation.

Distribution: Santonian–Maastrichtian (Pessagno 1967). It is observed in Cores -49R and -51R at Site U1512.

Calcareous benthic foraminifera

Family ICHTHYOLARIIDAE Loeblich and Tappan 1986
Genus ***Prodentalina*** Norling 1968

Prodentalina oligostegia (Reuss 1845)
Plate 5, figure 1a, b

Nodosaria oligostegia REUSS 1845, p. 27, pl. 13, figs 19-20.
Marginulina nuda Reuss. – SCHWAGER 1865, p. 107, pl. 3, fig. 23
Dentalina oligostegia (Reuss). – SAMYSCHKINA 1983, pp. 1-167. – WEIDICH 1990, pl. 25, fig. 10, pl. 40, fig. 8.
Laevidentalina oligostegia (Reuss). – HOLBOURN and KAMINSKI 1997, p. 59, pl. 28, fig. 10; pl. 29, fig. 3. – KORIN et al. 2026, p. 275, pl. 1, fig. 23.

Diagnosis: Uniserial elongate calcareous test; curved to some extent; smooth wall; spine in the initial chamber; sutures depressed strongly; pyriform chambers shape; spherical to cylindrical; various in the length; gradually narrowing in the deration of the aperture end; radiate terminal aperture.

Remarks: This species at Site U1512 is found in the Upper Cretaceous. According to the findings of Cushman (1940), it was noted that *Dentalina catenula*, as described by Reuss in 1860, exhibits distinct dissimilarities from the species under discussion. However, Cushman did not explicitly specify the nature of these differences. It is plausible to examine the possibility that the dissimilarities might pertain to either the dimensions of the spine or the overall size of the species. In view of this ambiguity, we propose that *D. catenula* be regarded as a potential synonym for further investigation and clarification. In terms of *Nodosaria limbata* D'Orbigny 1840, and *Nodosaria* (*Laevidentalina*) *concinna* Reuss 1860, the difference is the presence of the spine in the base of the first chamber.

Distribution: Upper Cretaceous, documented globally, e.g., Germany, USA especially in the coastal plain, and Czech Republic (Cushman 1940). At Site U1512, dentalinids exhibit a sporadic distribution and are absent throughout the middle low-carbonate interval (samples 212–349), with a single exception (see ST 1).

Family NODOSARIIDAE Ehrenberg 1838
Genus ***Laevidentalina*** Loeblich and Tappan 1986

Laevidentalina sp. cf. ***L. communis*** (d'Orbigny 1826)
Plate 5, figure 2a, b

Nodosaria (*Dentalina*) *communis* D'ORBIGNY 1826, p. 254.
Dentalina communis (d'Orbigny). – BARTENSTEIN and BRAND 1951, pl. 9, figs 228-231.
Laevidentalina communis (d'Orbigny). – HOLBOURN and KAMINSKI 1997, p. 58, 13, 84; pl. 28, figs 4-5. – KORIN et al. 2026, p. 275, pl. 2, fig. 1.
Laevidentalina sp. d'Orbigny.– WOLFGRING, et al., 2021, p. 18.

Diagnosis: Elongate, uniserial calcareous test with a smooth wall, chambers slightly becoming cylindrical in adult stages; sutures slightly depressed and slightly inclined, straight to slightly curved test; terminal chamber asymmetrical; terminal aperture radiate, situated on a slightly projecting neck.

Remarks: Frequently grouped under *Dentalina.*

Distribution: A common morphotype globally and frequently recorded from the Austral high latitudes in the Upper Cretaceous.

Genus ***Pyramidulina*** Fornasini 1894

Pyramidulina sp.
Plate 5, figure 3

Diagnosis: Slender, uniserial calcareous test; chambers increasing regularly in size, sutures faintly depressed; densely ornamented with vertical ribs, terminal aperture produced on faint neck.

Remarks: In contrast to *Laevidentalina* and *Dentalina*, *Pyramidulina* displays a more acute chamber angle and prominent longitudinal ribs.

Distribution: Upper Cretaceous, widely reported globally.

Family VAGINULINIDAE Reuss 1860
Subfamily MARGINULININAE Wedekind 1937
Genus ***Hemirobulina*** Stache 1864

Hemirobulina arcuatula Stache 1864
Plate 5, figure 4a-b

Cristellaria (*Hemirobulina*) *arcuatula* STACHE 1864, p. 407, pl. 23, fig. 5a-b.

Diagnosis: A smooth, elongated calcareous hyaline test; rounded from side view; quite a few chambers arranged in a spire at the base. Uniserial in the adult stage. Chambers are straighter slightly depressed and somewhat tilted.

Remarks: The identification of this species is difficult due to the absence of distinctive features. Nevertheless, we can exclude *Marginulinopsis* and *Marginulina* as potential genera because this species lacks a coiled part in its base and shows a smooth wall texture. Additionally, *Saracenaria* may also be excluded as our species is rounded when observed from the front and does not display a triangular form in the frontal view (Loeblich and Tappan 1986). According to Loeblich and Tappan (1986), Stache designated several specimens as synonyms following a taxonomic revision. However, a re-examination of Stache's original 1864 description reveals the presence of a keel, a feature that was not mentioned in the original description of the genus, rendering their description highly comparable to our species.

Distribution: Cosmopolitan, Late Cretaceous.

Genus ***Marginulina*** d'Orbigny 1826

Marginulina obesa Cushman 1923
Plate 5, figure 5a-b

Marginulina glabra d'Orbigny. – BRADY 1884, p. 527, pl. 65, figs 5-6.
Marginulina glabra var. *obesa* CUSHMAN 1923, p. 835, pl. 4, fig. 11 a-b.

Diagnosis: A smooth, elongate calcareous hyaline test; slightly in the earlier chambers, then rectilinear; initially and terminally; somewhat flat from the cross section; illustrating a nearly circular chamber arrangement in the early stage; inflated chambers arranged uniserially; cylindrical, increasing in size gradually; sutures slightly depressed, curved; unornamented wall texture; radiate terminal aperture.

Remarks: The taxonomic classification of the species found at Site U1512 has been subject to misidentification in the past. This confusion arises from the similarity between *Marginulina elongata* d'Orbigny and our species, with the primary distinguishing factor being the variation in the number of chambers and the straightness of sutures.

Distribution: Cosmopolitan, Late Cretaceous

Subfamily FRONDICULARIINAE Reuss 1860
Genus ***Frondicularia*** Defrance 1826

Frondicularia intermittens Reuss 1866
Plate 5, figure 6a-c

Frondicularia intermittens REUSS 1866, p. 460, fig. 11a-b.
Frondicularia verneuiliana Reuss. – CUSHMAN 1930, pl. 5, figs 7-8. – CUSHMAN 1946, p. 88, pl. 35, figs 11-13.

Diagnosis: A smooth, elongate hyaline test; early chambers expanding minimally; rapidly increasing in diameter toward the aperture; rounded periphery; flat in side view; with a small spine at the base; chambers expanding in the length with equal height; globular proloculum; sutures strongly curved; slightly depressed; the surface intersected by delicate longitudinal ridges increasing in the middle of the chamber; smooth wall texture excluding the proloculum and the sutures which show the ridges; with radiate terminal apertures.

Remarks: Species from the high southern latitudes and *F. intermittens*, as established by Cushman (1946) can be distinguished. Cushman observed that the taxon in question displayed straight or slightly curved sutures, in contrast to the far stronger curvature displayed in this species

Distribution: This species has been recorded in the Upper Cretaceous in Europe and the USA; a rare element at Site U1512.

Family PLEUROSTOMELLIDAE Reuss 1860
Subfamily POLYMORPHINIDAE d'Orbigny 1839
Genus ***Ramulina*** T.R. Jones 1875

Ramulina sp. cf. ***R. wrightii*** Barnard 1972
Plate 5, figure 7a-b

Ramulina aculeata (d'Orbigny). – WRIGHT 1886, pl. 27, fig. 11.
Ramulina wrightii BARNARD 1972, p. 390, pl. 1, figs 2-3. – FRENZEL 2000, p. 125, pl. 22, figs 9-10 (with synonyms).
Ramulina cf. *wrighti* Barnard. – WOLFGRING and PETRIZZO 2024, pl. 3, fig. 8.

Diagnosis: Test free, hyaline, globular to subglobular chambers, connected by tubular necks, sometimes branching. Chambers are finely perforate and display a strongly aculeate surface where spinose elements often connect the pores. Tubular connections between chambers exhibit fewer spines than the chambers themselves. Test is mostly recovered in fragments, with rarely more than two chambers intact.

Remarks: The members of *Ramulina* recovered at Site U1512 were assigned tentatively to the taxon *R. wrightii* for their clearly aculeate chambers, and smooth tubular attachments. No complete specimen was recovered.

Distribution: This species is common throughout Upper Cretaceous (Santonian–Maastrichtian) deposits (Frenzel 2000).

Family PLEUROSTOMELLIDAE Reuss 1860
Subfamily PLEUROSTOMELLIDAE Reuss 1860
Genus ***Pleurostomella*** Reuss 1860

Pleurostomella incrassata Hantken 1883
Plate 5, figure 8a-b

Pleurostomella incrassata HANTKEN 1883, p. 145, pl. 1, figs 4, 7. – HAYWARD et al. 2012, p. 230, pl. 37, figs 16-21, pl. 38, figs 1-4 (with synonyms).

Diagnosis: Calcareous smooth hyaline finely perforated test; relatively biserial; chambers almost round in the cross section; increase fast in size in the earlier stage slowly in the final stage with very inflate chambers; sutures slightly depressed in the early stage distinct and deeper in the final stage; the aperture is a very small oval shape subterminal with a tooth.

Remarks: Based on the findings of Cushman (1947) and Hayward et al. (2012), it is often observed that this species is usually categorized as *P. alternans*. According to Hayward et al. (2012), there are notable differences in the behaviour of *P. alternans*, particularly its reduced tendency to adopt a staggered uniserial growth pattern in larger specimens. When comparing the species described by Cushman with that of Hayward, differences in the presence of apertural teeth become evident. Cushman did not provide a definitive account regarding the development of teeth, leaving their presence uncertain.

Distribution: Cosmopolitan, Late Cretaceous to late Pliocene according to Hayward et al. (2012).

Pleurostomella acuta Hantken 1875
Plate 5, figure 9a-b

Pleurostomella acuta HANTKEN 1875, p. 37, pl. 13, fig. 18. – HAYWARD et al. 2012, p. 227, pl. 35, figs 9-18 (with synonyms).
Pleurostomella cf. *P. obtusa* Berthelin. – WOLFGRING et al. 2021, fig. 4 (33).

Diagnosis: Calcareous smooth hyaline finely perforated test; biserial all over; chambers round in the cross section; increase moderately in size; very inflate chambers; sutures curved slightly depressed; the aperture is terminally subrounded with a big bifid tooth.

Remarks: According to Hayward et al. (2012), it is missing the *P. alazanensis* parallel sides. Both the holotypes of *P. aguafrescaensis* and *P. naranjoensis* have abnormally tiny and incompletely formed final chambers that are joined by terminal apertures that are also very small. Also, he mentioned this species is more inflated than *P. incrassata*, which is noted in site U1512 *Pleurostomella* species. *Pleurostomella acuta* was misidentified in Wolfgring et al. (2021) as *Pleurostomella* cf. *P. obtusa* Berthelin.

Distribution: Cosmopolitan, reported from the Cretaceous to the mid-Pleistocene according to Hayward et al. (2012).

Family VAGINULINIDAE Reuss 1860
Subfamily VAGINULININAE Reuss 1860
Genus ***Planularia*** Defrance 1826

Planularia* cf. *complanata (Reuss 1845)
Plate 5, figure 10a-c

Cristellaria complanata REUSS 1845, pl. 13, fig. 54a, b.
Planularia complanata (Reuss). – MAGNIEZ-JANIN 1975, pl. 9, figs 26-38, textfig. 83.

Diagnosis: Test calcareous, smooth hyaline, elongate to ovate in outline, strongly compressed. Chambers arranged in a uniserial sequence, increasing gradually in size; test may show a slight initial curvature, distinctly ornamented with faint costae or ridges parallelling the test margins. Straight to slightly curved depressed sutures. The aperture is terminal, typically situated at the dorsal margin, rounded to slightly slit-like in shape.

Remarks: This group shows a finely perforate and ornamented wall, and in contrast to the unornamented *Planularia* sp. recovered at Site U1512, it is tentatively assigned here to *Planularia* cf. *complanata*. This group was previously partially included within a broader morphogroup under *Citharina* sensu lato (Wolfgring et al. 2021), based on shared elongate morphology and uniserial chamber arrangement and the plausibly shared epifaunal to shallow infaunal habitat preference. At the time, the available material did not allow for a confident separation, and the specimens were informally grouped into a *Citharina*-like plexus. Upon re-examination, the presence of a moderately ornamented wall texture, stronger compression, and more clearly defined dorsal sutures supports a more specific attribution to *P.* cf. *complanata*.

Distribution: In addition to its common occurrence in middle- to Upper Cretaceous deposits on the western Australian margin (Wolfgring et al. 2023; Amaglio et al. 2025), the species *Planularia complanata* is also documented from the Valanginian to the Albian in the southern high latitudes (Holbourn and Kaminski 1997).

Planularia sp.
Plate 5, figure 11a-c

Diagnosis: Calcareous, smooth hyaline finely perforated test; large ovate shape; strongly compressed; early stage slightly coiled; chambers increase rapidly in size; the height increases more from the dorsal margin compared to the ventral side; unornamented wall texture; therefore, no chambers can be counted; however, the, sutures slightly curved.

Remarks: This species from Site U1512 has an unornamented wall texture, which differs from Loeblich and Tappan's (1987) description, and is less compressed.

Distribution: Cosmopolitan from Miocene to Holocene according to Loeblich and Tappan (1987).

Family VAGINULINIDAE Reuss 1860
Subfamily LENTICULININAE Chapman, Parr and Collins 1934
Genus ***Lenticulina*** Lamarck 1804

Lenticulina mariae Schijfsma 1946
Plate 5, figure 12a-c

Lenticulina mariae SCHIJFSMA 1946, pp. 56-57, pl. 3, fig. 9a,b. – FRENZEL 2000, p. 87, pl. 14, figs 9-10.

Diagnosis: Calcareous, smooth, hyaline, finely perforated test; planispiral lenticular; rounded outline; periphery weakly keeled; elongated, curved chambers, gradually increasing in size, around 8 chambers in the final whorl, which is difficult to see due to flat sutures; slightly curved; secondary aperture surrounded by a lip on both sides developed underneath the primary on the apertural surface; the primary aperture radiates on the peripheral angle of the last chamber; apertural face flat with limiting edges.

Remarks: The dissimilarities between *L. mariae* and *L. subangulata* may be attributed to the varying placement of their apertures. The aperture location of *L. mariae* is located on the peripheral angle of the final chamber, while the aperture position of *L. subangulata* is situated on the aperture surface. The aperture surface of *L. mariae* has a more rounded morphology, in contrast to the flat aperture surface seen in *L. subangulata*, which could be a different species and not synonyms. When comparing both synonyms with the U1512 species, despite the presence of a secondary aperture like that of *L. oligostegia* Reuss 1860, it is closely related to *L. subangulata*. Furthermore, *L. oligostegia* has a more rounded periphery with slightly depressed sutures and a small apertural surface, distinguishing it from our species.

Distribution: Coniacian – Maastrichtian in Northwest Germany, according to Frenzel (2000).

Lenticulina muensteri (Roemer 1839)
Plate 5, figure 13a-c

Robulina muensteri ROEMER 1839, p. 48, pl. 20, fig. 29a-b.
Lenticulina muensteri (Roemer). – JENDRYKA-FUGLEWICZ 1975, pls. 8-11, figs 1-6; pl. 19; pl. 20, figs 1-2. – SLITER 1980, pl. 9, figs 3-4. – HOLBOURN and KAMINSKI 1995, p. 214, pl. 6, fig. 11. – HOLBOURN and KAMINSKI 1997, pl. 32, fig. 3.

Diagnosis: Calcareous, smooth, hyaline, finely perforated test; planispiral, lenticular, with umbilical disc; rounded outline; periphery sharply keeled; elongated, crescent shaped chambers; slowly increasing in size; around 6 to 8 chambers in the final whorl; flat sutures; strongly curved; apertural surface flat with limiting edges.

Remarks: Specimens of comparatively large-sized lenticulinids, exhibiting 5 to 8 chambers in the final whorl and a smooth, circular test outline, correspond well to the diagnostic features of *Lenticulina muensteri* (Roemer). Given the considerable morphological variation observed in this considerably large, circular *Lenticulina species* (including transitional morphotypes with, e.g., *L. macrodisca*, *L. roemeri*, and *L. subalata*) and its extensive stratigraphic range from the Jurassic to at least the Lower to "middle" Cretaceous, we interpret the designation *Lenticulina muensteri* as encompassing a broad spectrum of morphological plasticity within this group (see: Holbourn and Kaminski 1995).

Distribution: A cosmopolitan species, widely recorded through the Jurassic to Upper Cretaceous.

Family CANCRISIDAE Chapman, Parr and Collins 1934
Genus ***Gyroidinoides*** Brotzen 1942

Gyroidinoides umbilicatus (d'Orbigny 1840)
Plate 5, figure 14a-c

Rotalina umbilicata D'ORBIGNY 1840, p. 32, pl. 3, figs 4-6.
Gyroidinoides umbilicatus (d'Orbigny). – FRENZEL 2000, p. 201, pl. 40, figs 6-9.

Diagnosis: Calcareous, smooth, hyaline, finely perforated test; spherical; trochospiral; planoconvex; spiral side flat and evolute; umbilical side convex and involute; periphery broadly sharped; the crests have a progressively convex shape; younger chambers slightly involuted from the umbilical side elongated; 6–8 chambers in the last whorl; sutures are not clear from the spiral side; from the umbilical side, they are very deep and become flat toward the periphery; aperture narrow with a slit-shape from umbilical to extraumbilical with a lip.

Remarks: The specimens from Site U1512 have similarities to *G. umbilicatus* as documented by Frenzel (2000), with the exception of the suture on the spiral side, which was not visible in our specimens. Upon comparing the original description, it becomes evident that d'Orbigny noted the existence of a keel in the original specimens.

Distribution: Cosmopolitan from Cenomanian to Campanian to Lower Eocene. Northwest Germany Coniacian – Maastrichtian, Eastern Poland Campanian to Maastrichtian according to Frenzel (2000). Tertiary according to d'Orbigny (1840) in Austria.

Gyroidinoides quadratus (Cushman and Church 1929)
Plate 5, figure 15a-c

Gyroidina quadrata CUSHMAN and CHURCH 1929, pl. 41, figs 7-9.
Gyroidinoides quadratus (Cushman and Church) subsp. martini. – SLITER 1968, p. 121, pl. 22, figs 9a-c.
Gyroidinoides quadratus (Cushman and Church). – BASOV and KRASHENINNIKOV 1983, p. 764, pl. 9, figs 4-6. – QUILTY 1992, pl. 7, figs 16-17. – WOLFGRING and PETRIZZO 2024, pl 2, figs 5a-c.

Diagnosis: Calcareous, hyaline, granular wall structure; coarse pores, test slightly subconical; planoconvex to sometimes biconvex; the peripheral surfaces of the cone gradually expand towards the outer edge, sometimes resulting in a subtly concave shape; umbilical cavity is located near the top in the umbilical side; a round periphery slightly keeled; chambers in the final whorl are around six and exhibit unclear features; slowly increasing in size; around 6 to 7 chambers in the final whorl; flat curved sutures, depressed in the umbilical side and flat on the spiral side; elongate aperture; umbilical to extraumbilical, strongly curved; aperture interiomarginal.

Remarks: The observed species exhibits characteristics of Sliter's (1968) species *Gyroidinoides quadratus* from the Upper Cretaceous of Southern California. Notably, the presence of peripheral spines observed in the description of Sliter (1968) was observed in some specimens in Australian Cretaceous localities. In agreement with our observations at Site U1512, and the doc-

umentation of Quilty (1992) of this species in the Upper Cretaceous of the Kerguelen Plateau, we observe strong morphological similarities to *Globorotalites* in some specimens, underlining the morphological variability of this taxon (exhibiting features similar to two other species, namely *G. micheliniana* d'Orbigny, which is larger and has a cone with a significantly higher and straighter side, and, an as-yet-undescribed species found in Texas, which has a lower cone compared to *G. subconica* and a prominently pointed keel around its edge.

Distribution: Frequently documented in mid- to Upper Cretaceous in mid to southern high latitudes, particularly from the Austral realm (Quilty 1992; Wolfgring et al. 2021, 2023; Wolfgring and Petrizzo 2024; Amaglio et al. 2025).

Family TURRILINIDAE Cushman 1927
Genus ***Praebulimina*** Hofker 1953

Praebulimina sp.
Plate 5, figure 16a-b

Diagnosis: Test calcareous, moderately large, inflated and broadly ovoid in outline; chambers arranged in a triserial pattern throughout, resembling *Bulimina*; sutures are depressed and oblique; wall smooth and finely perforate; aperture position not well preserved in the available material.

Remarks: Although not frequently observed from Site U1512, this morphotype is well documented throughout the Austral realm and globally mid- to upper-bathyal assemblages as well as slope assemblages. Its morphology suggests affinity with forms commonly associated with low-oxygen, soft-substrate settings, but environmental interpretation remains tentative without broader contextual data (Kaiho 1994; Jorissen et al. 2007).

Distribution: Frequently documented in mid- to Upper Cretaceous in mid to southern high latitudes, particularly from the Austral realm (Quilty 1992; Wolfgring et al. 2021, 2023; Wolfgring and Petrizzo 2024; Amaglio et al. 2025).

Family CONORBOIDIDAE Thalmann 1952
Genus ***Colomia*** Cushman and Bermúdez 1948

Colomia cretacea Cushman and Bermúdez 1948
Plate 5, figure 17a-b

Colomia cretacea CUSHMAN and BERMÚDEZ 1948, p. 12, pl. 2, figs 13-15.

Diagnosis: Elongate, conical, "bullet-shaped" test; biserial to uniserial in the terminal stage; aperture an arcuate slit in the terminal chamber.

Remarks: From Australian Cretaceous (Albian–Turonian) shelf carbonates, this species is known as a biostratigraphic marker in the Great Artesian Basin (e.g., Haig 1979). Its Tethyan affinity suggests warm, neritic to upper bathyal palaeoenvironments during this period.

Distribution: Globally from the Turonian to Maastrichtian (Loeblich and Tappan 1987), frequently documented in mid- to Upper Cretaceous in the southern high latitudes.

Family GAVELINELLIDAE Hofker 1956

Genus ***Notoplanulina*** Malumian and Masiuk 1976

Notoplanulina rakauroana (Finlay 1939)
Plate 5, figure 18a-c

Planulina rakauroana FINLAY 1939, pl. 29, figs 154-156. – HORNIBROOK 1968, p. 45, fig. 5.
Notoplanulina rakauroana (Finlay). – MALUMIAN and MASIUK 1976, p. 197, pl. 6, figs 2a-d. – WOLFGRING and PETRIZZO 2024, pl. 1, figs 1a-c, 3a-c.

Diagnosis: Test sub-discoidal, with three coils and dorsally slightly convex profile. Chambers are elongate, curved; dorsal sutures faint. The ventral side is more convex with a deep umbilicus; sutures deep and rounded. Interiomarginal aperture; overall size approximately 1 mm.

Remarks: Quilty (1992) suggested that *Notoplanulina rakauroana* (Finlay) represents the ancestor of *Notoplanulina* (*Gavelinella*) *compressa* (Sliter). However, we question this interpretation. The oldest distribution of *N. rakauroana* in the Austral realm was documented in the Coniacian (with questionable appearances in the upper Turonian). Although both taxa occur frequently in southern high-latitude settings, and occasionally co-occur in Upper Cretaceous strata, a form closely resembling *N.* (*G.*) *compressa* (Sliter) was documented significantly earlier in the record, with a range traceable back to the Turonian. Given its earlier first appearance in Turonian strata, we consider *N.* (*G.*) *compressa* (Sliter) the more likely ancestral form, with *N. rakauroana* representing a derived morphotype (Wolfgring and Petrizzo 2024). At Site U1512, *Notoplanulina rakauroana* occurs during intervals interpreted as phases of improved connection to the open ocean in the Australo-Antarctic Gulf.

Distribution: The genus *Notoplanulina* is a common element of outer neritic to upper–mid bathyal benthic foraminiferal assemblages in the southern hemisphere. The species *Notoplanulina rakauroana* was widely documented across the southern hemisphere through the Upper Cretaceous (Malumian and Nanez 1990).

ACKNOWLEDGMENTS

The International Ocean Discovery Program (IODP) is thanked for providing the samples used in this study. We are grateful for support given by the College of Petroleum and Geosciences, King Fahd University of Petroleum and Minerals. EW thanks the Austrian Science Fund (FWF), project P-4444 and is grateful for support from the Brian J. O'Neill memorial grant-in-aid awarded by the Grzybowski Foundation.

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PLATE 1

Scale bars are 100 μm unless otherwise indicated.

1 *a-b* *Bathysiphon* sp., sample U1512-14R-6W, 41-45 cm.

2 *a-b* *Psammosiphonella* sp. 1, sample U1512-6R-6W, 38-40 cm.

3 *a-b* *Psammosiphonella discreta* (Brady 1881), sample U1512-17R-6W, 40-42 cm.

4 *a-b* *Rhizammina* sp. 1, sample U1512-17R-6W, 40-42 cm.

5 *a-b* *Rhizammina* sp. 2, sample U1512-66R-6W, 40-44 cm.

6 *a-b* *Rhizammina* sp. 3, sample U1512-10R-6W, 40-44 cm.

7 *Kalamopsis grzybowskii* (Dylążanka 1923), sample U1512-17R-6W, 40-42 cm.

8 *Subreophax* sp., sample U1512-48R-6W, 40-44 cm.

9 *a-b* *Psammosphaera* sp. 1, sample U1512-6R-6W, 38-40 cm.

10 *a-b* *Psammosphaera* sp. 2, sample U1512-10R-6W, 40-44 cm.

11 *a-b* *Placentammina placenta* (Grzybowski 1898), sample U1512-15R-6W, 34-39 cm.

12 *a-b* *Hyperammina elongata* Brady 1878, sample U1512-18R-6W, 36-38 cm.

13 *a-c* *Ammodiscus cretaceus* (Reuss 1845), sample U1512-44R-6W, 40-44 cm.

14 *a-c* *Ammodiscus tenuissimus* Grzybowski 1898, sample U1512-49R-6W, 39-43 cm.

15 *a-b* *Ammodiscus peruvianus* Berry 1928, sample U1512-47R-6W, 40-44 cm.

16 *a-b* *Ammodiscus* sp. cf. *A. angustus* Friedberg 1902, sample U1512-46R-6W, 40-44 cm.

17 *a-c* *Glomospirella gaultina* (Berthelin 1880), sample U1512-55R-6W, 38-42 cm.

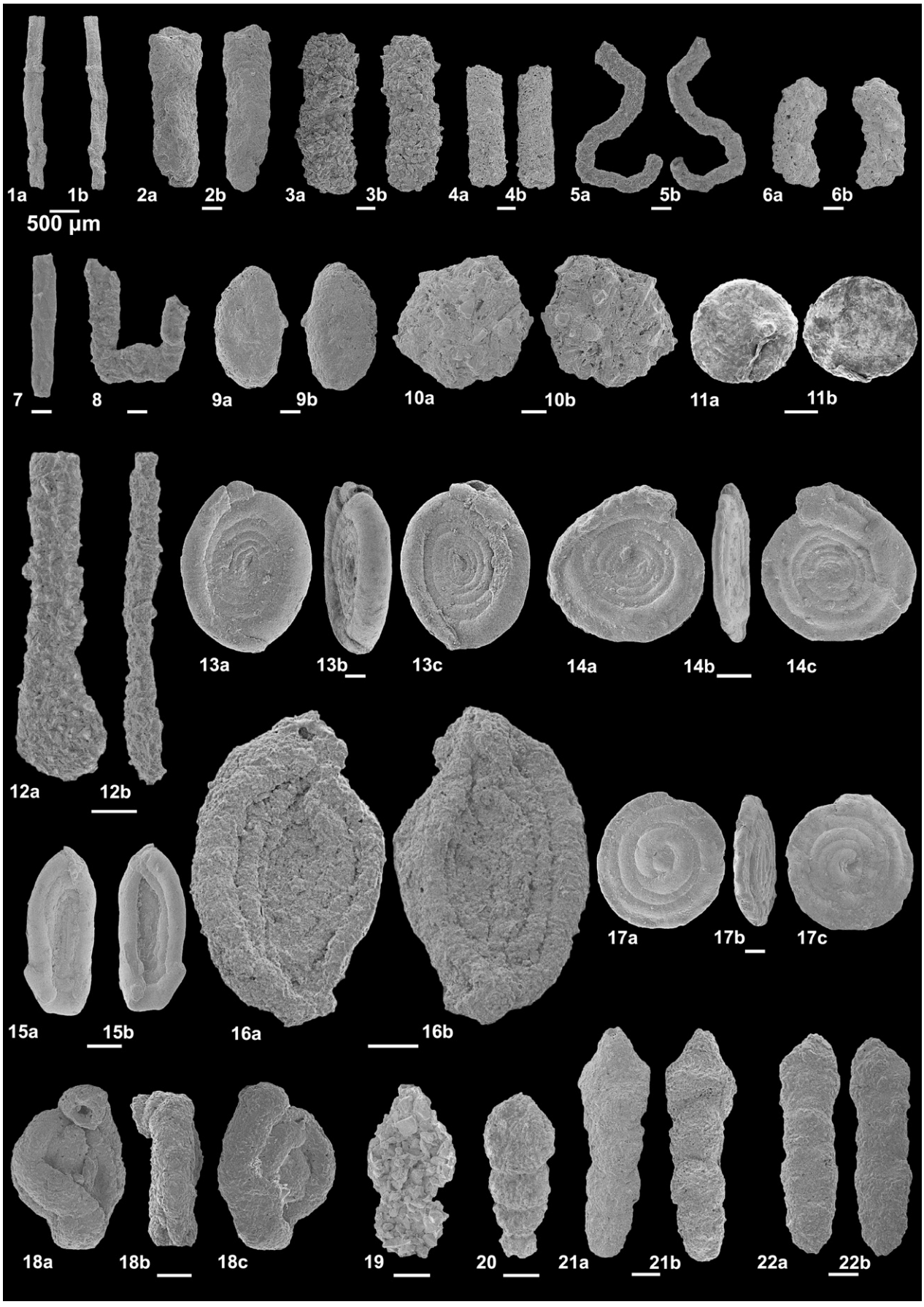
18 *a-c* *Glomospira* sp. cf. *G. compressa* Waters 1928, sample U1512-47R-6W, 40-44 cm.

19 *Reophax* sp. 1, sample U1512-18R-6W, 36-38 cm.

20 *Reophax* sp. cf. *R. globosus* Sliter 1968, sample U1512-53R-6W, 38-42 cm.

21 *a-b* *Pseudonodosinella* sp. cf. *P. troyeri* (Tappan 1960), sample U1512-58R-6W, 40-44 cm.

22 *a-b* *Pseudonodosinella parvula* (Huss 1966), sample U1512-53R-6W, 38-42 cm.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18c
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22b

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PLATE 2

All scale bars are 100 µm

1 *a-c* *Haplophragmoides* sp. cf. *H. walteri* (Grzybowski 1898), sample U1512-51R-6W, 38-42 cm.

2 *a-c* *Haplophragmoides concavus* (Chapman 1892), sample U1512-43R-6W, 40-44 cm.

3 *a-c* *Haplophragmoides petaliformis* Wolfgring, Kaminski and Waśkowska 2023 (previously published in Wolfgring et al. 2021) sample U1512A-46R-1W, 41-45 cm.

4 *a-c* *Haplophragmoides tenellulus* Wolfgring, Kaminski and Waśkowska 2023, sample U1512-51R-6W, 38-42 cm, (previously published in Wolfgring et al. 2023).

5 *a-b* *Haplophragmoides antarcticus* Wolfgring, Kaminski and Waśkowska 2023 sample U1512-60R-6W, 40-44 cm.

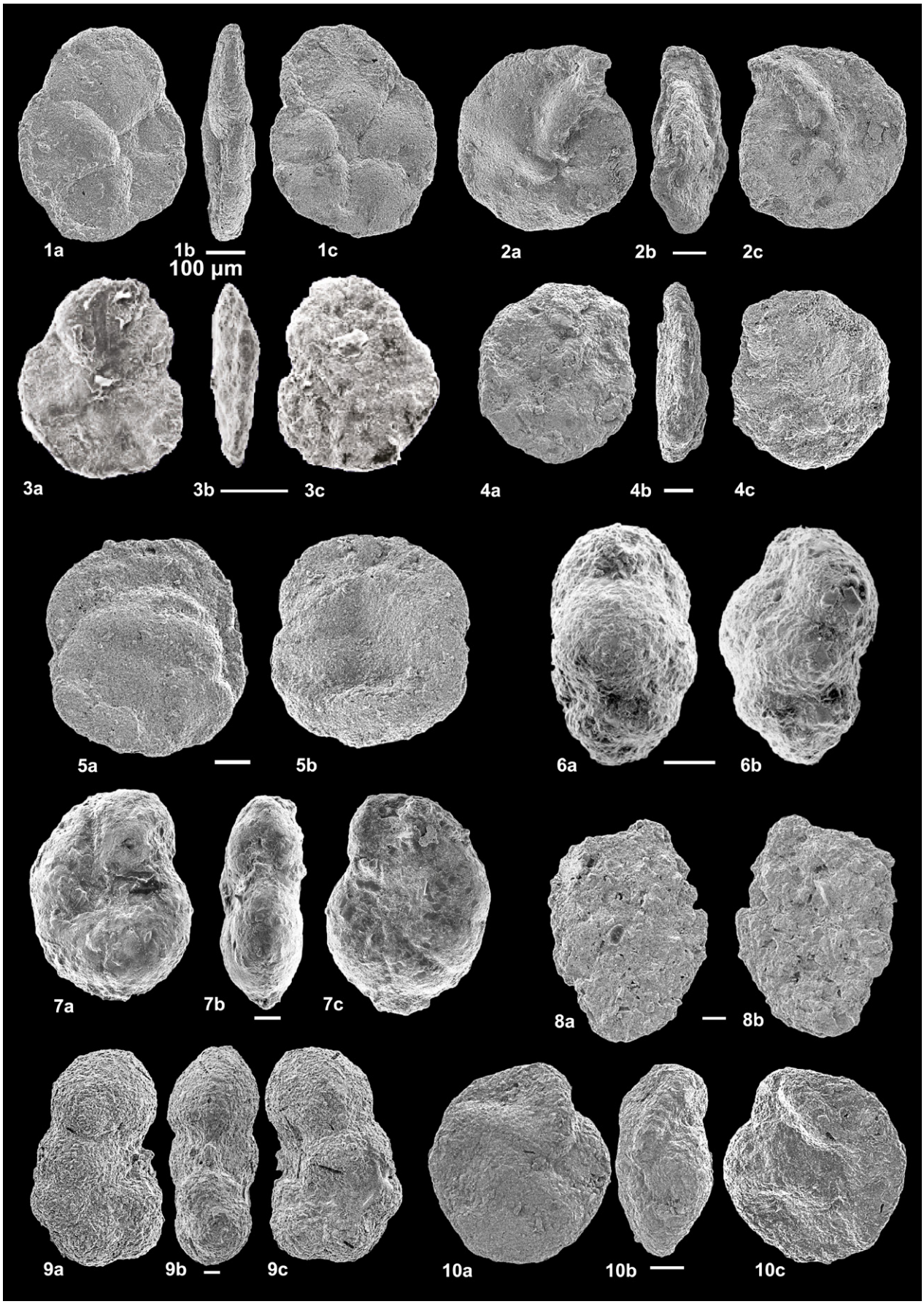
6 *a-b* *Uvigerinammina jankoi* Majzon 1943, sample U1512A-28R, CC (previously published in Wolfgring et al. 2021).

7 *a-c* *Labrospira nonioninoides* (Reuss 1863), sample U1512A-9R-1W, 38-42 cm.

8 *a-b* *Sculptobaculites* sp. 1, sample U1512-17R-6W, 40-42 cm.

9 *a-c* *Ammobaculites agglutinans* (d'Orbigny 1846), U1512-58R-6W, 40-44 cm.

10 *a-c* *Recurvoides* sp. cf. *R. trincherasensis* Bermúdez 1949, sample U1512-46R-6W, 40-44 cm.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9b
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10a
10b
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PLATE 3

All scale bars are 100 µm

1 *a-b* *Bulbobaculites problematicus* Neagu 1962, sample U1512-48R-6W, 40-44 cm.

2 *a-b* *Bulbobaculites* sp. 1., sample U1512-48R-6W, 40-44 cm.

3 *a-b* *Bulbobaculites* sp. 2. sample U1512-48R-6W, 40-44 cm.

4 *Bulbobaculites* sp. 3. sample U1512-60R-6W, 40-44 cm.

5 *a-b* *Spiroplectammina navarroana* Cushman 1932, sample U1512-56R-6W, 40-44 cm.

6 *a-b* *Textulariopsis texhomensis* Loeblich and Tappan 1982, sample U1512-56R-6W, 40-44 cm.

7 *a-b* *Textulariopsis rioensis* (Carsey 1926), sample U 1512-56R-6W, 40-44 cm.

8 *a-b* *Eobigenerina variabilis* (Vašíček 1947), sample U1512-66R-6W, 40-44 cm.

9 *a-b* *Gerochammina lenis* (Grzybowski 1896), sample U1512-60R-6W, 40-44 cm.

10 *a-b* *Gerochammina* sp. 1. sample U1512-46R-6W, 40-44 cm.

11 *a-b* *Rectogerochammina* sp. 1. sample U1512-54R-6W, 38-42 cm.

12 *a-b* *Praedorothia* sp., sample U1512-67R-6W, 40-44 cm.

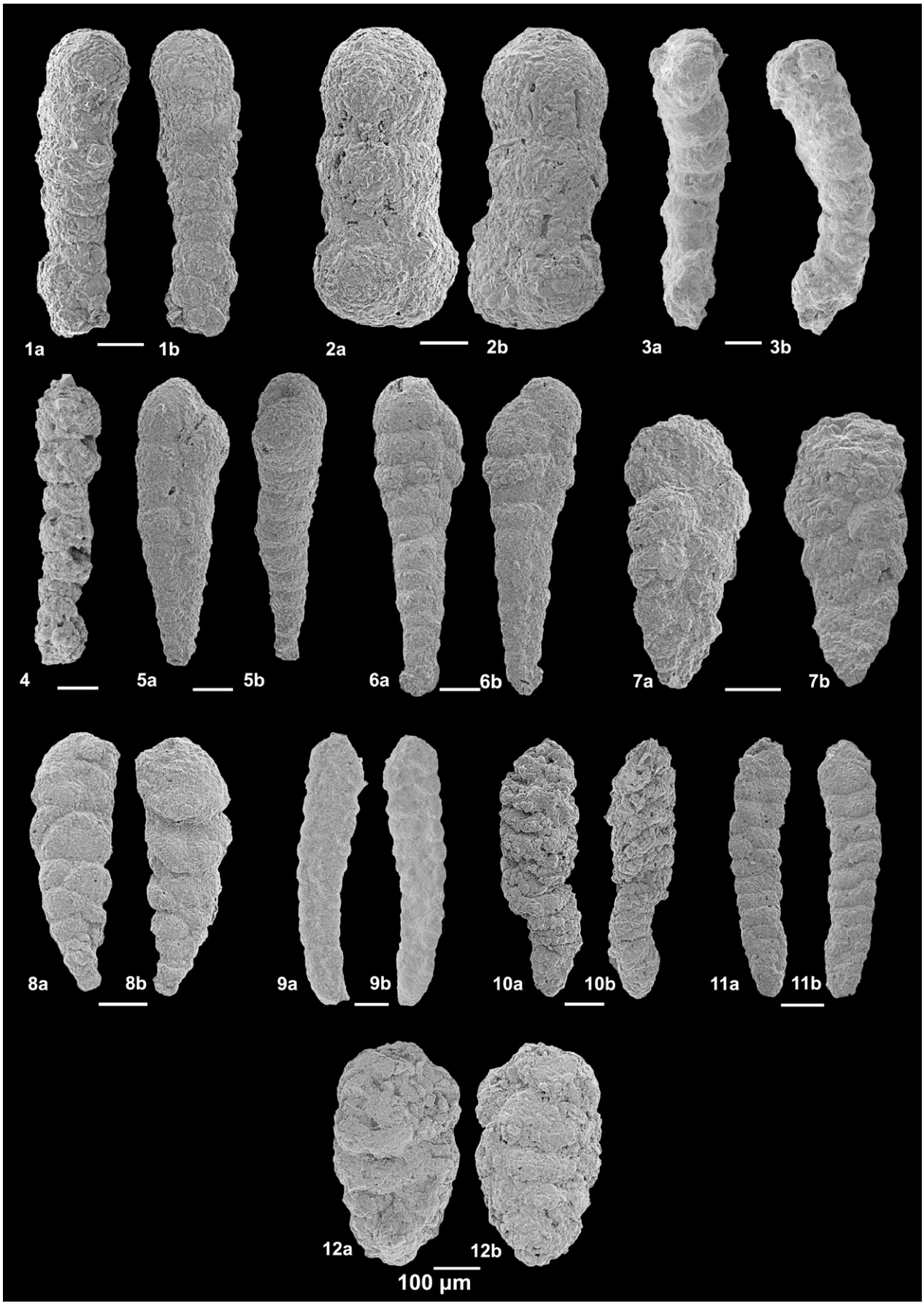
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PLATE 4

All scale bars are 50 µm

1 *a-c* *Planoheterohelix globulosa* (Ehrenberg 1840), sample U1512-65R-6W, 40-44 cm.

2 *a-c* *Muricohedbergella delrioensis* (Carsey 1926), sample U1512-48R-6W, 40-44 cm.

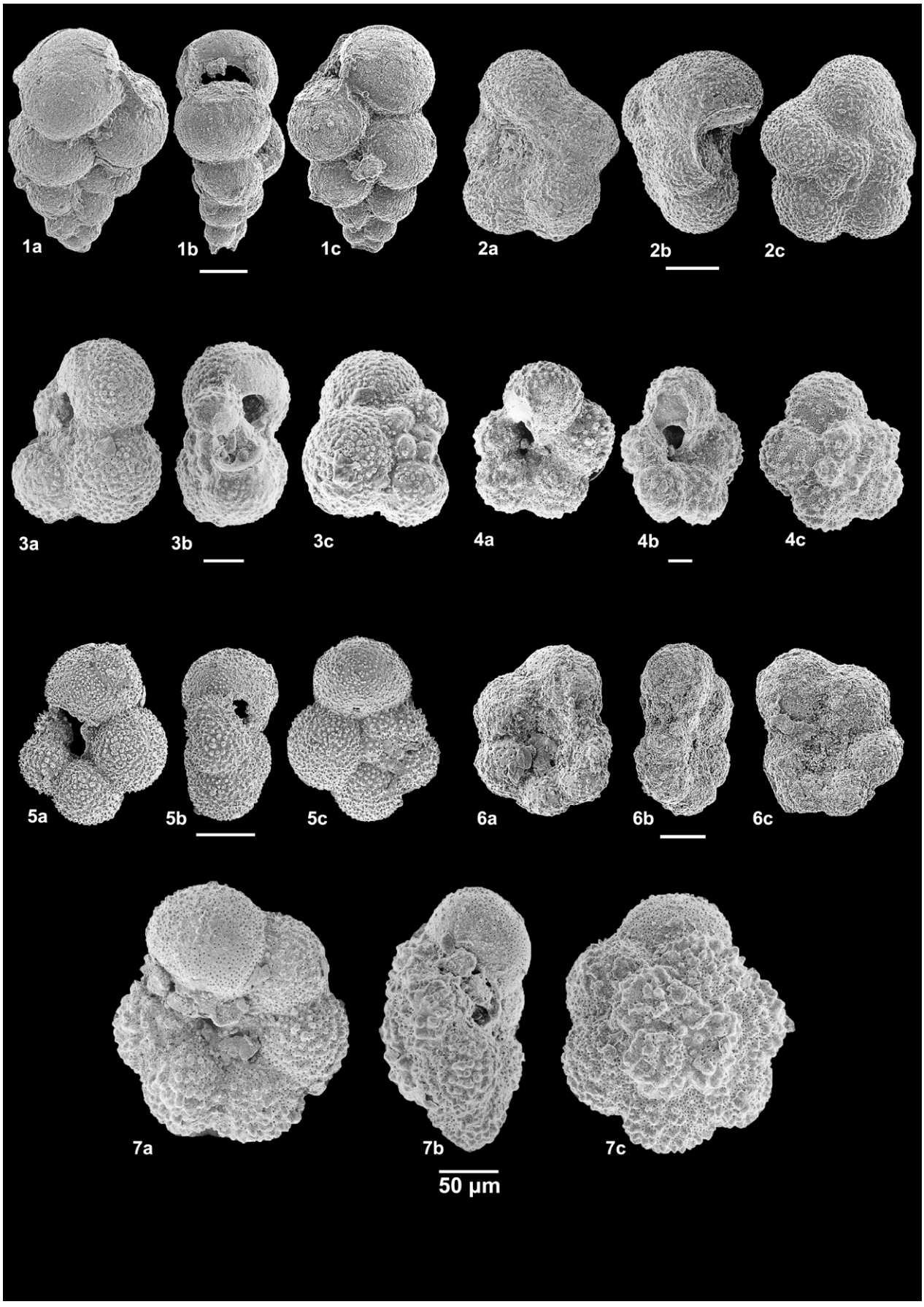
3 *a-c* *Whiteinella baltica* Douglas and Rankin, 1969, sample U1512-47R-6W, 40-44 cm.

4 *a-c* *Whiteinella* sp. 1, sample U1512-46R-6W, 40-44 cm.

5 *a-c* *Whiteinella brittonensis* (Loeblich and Tappan 1961), sample U1512-46R-6W, 40-44 cm.

6 *a-c* *Whiteinella aumalensis* (Sigal 1952), sample U1512-53R-6W, 38-42 cm.

7 *a-c* *Planohedbergella prairiehillensis* (Pessagno 1967), sample U1512-49R-6W, 39-43 cm.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3c
4a
4b
4c
5a
5b
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6a
6b
6c
7a
7b
7c
50 µm

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PLATE 5

Scale bars are 100 µm unless otherwise indicated.

1 *a-b* *Prodentalina oligostegia* (Reuss 1845), sample U1512-15R-6W, 34-39 cm.

2 *a-b* *Laevidentalina* sp., sample U1512 -20R-1W, 18-20 cm.

3 *Pyramidulina* sp., sample U1512-46R-1W, 41-45 cm.

4 *a-b* *Hemirobulina arcuatula* Stache 1864, sample U1512-47R-6W, 40-44 cm.

5 *a-b* *Marginulina obesa* Cushman 1923, sample U1512-47R-6W, 40-44 cm.

6 *a-c* *Frondicularia intermittens* Reuss 1866, sample U1512-58R-6W, 40-44 cm.

7 *a-b* *Ramulina* sp. cf. *R. wrightii* sample U1512-17R-1W, 42-44 cm.

8 *a-b* *Pleurostomella incrassata* Hantken 1883, sample U1512-55R-6W, 38-42 cm.

9 *a-b* *Pleurostomella acuta* Hantken 1875, sample U1512-43R-6W, 40-44 cm.

10 *a-c* *Planularia* cf. *complanata* (Reuss 1845), sample U1512-69R-1W, 40-44 cm.

11 *a-c* *Planularia* sp., sample U1512-46R-6W, 40-44 cm.

12 *a-c* *Lenticulina mariae* Schijfsma 1946, sample U1512-51R-6W, 38-42 cm.

13 *a-c* *Lenticulina muensteri* (Roemer 1839), sample U1512-51R-6W, 38-42 cm.

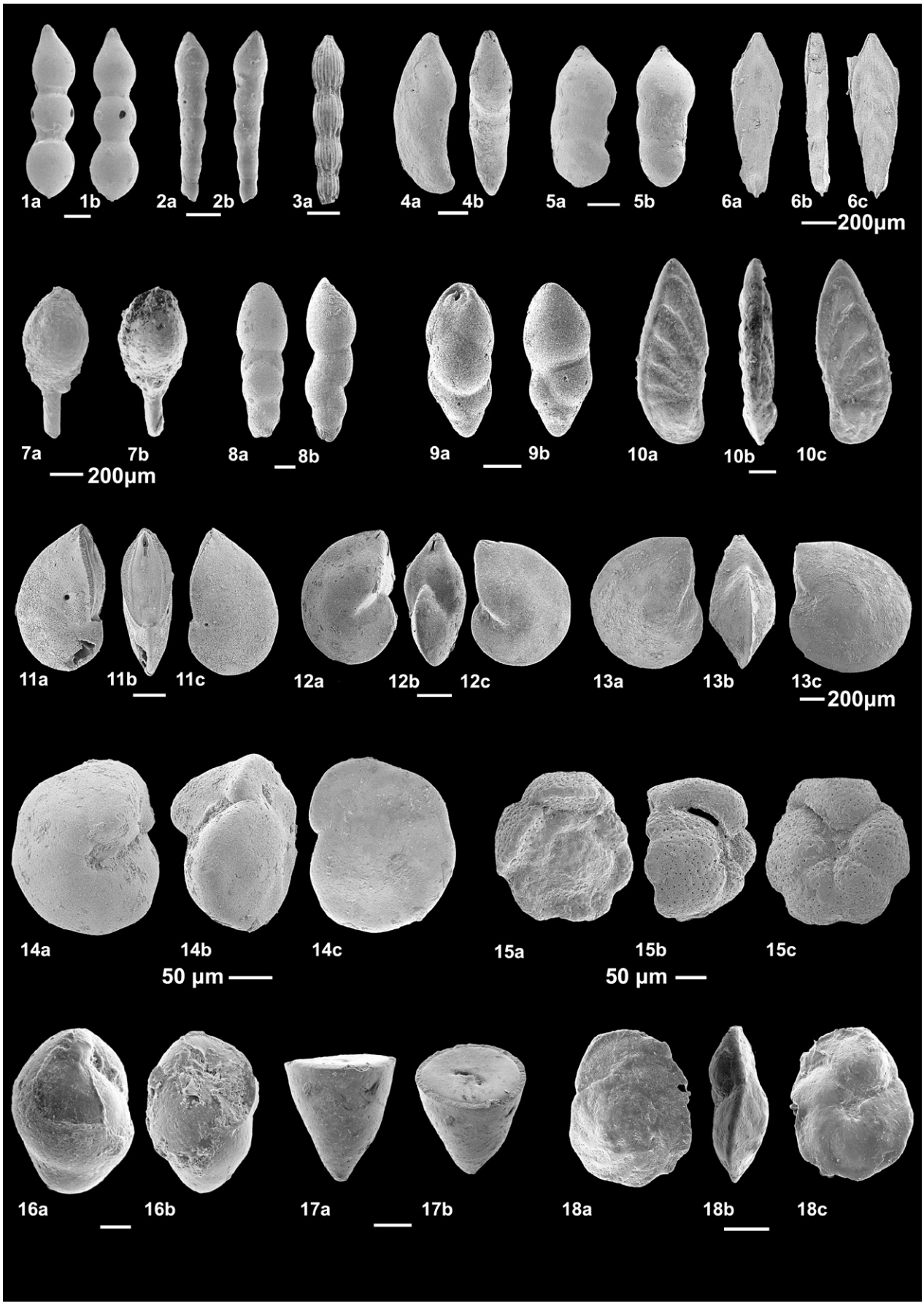
14 *a-c* *Gyroidinoides umbilicatus* (d'Orbigny 1840), sample U1512-49R-6W, 39-43 cm.

15 *a-c* *Gyroidinoides quadratus* (Cushman and Church 1929), sample U1512-65R-6W, 40-44 cm.

16 *a-b* *Praebulimina* sp., sample U1512-17R-1W, 42-44 cm (previously published in Wolfgring et al. 2021).

17 *a-b* *Colomia cretacea* Cushman and Bermúdez 1948, sample U1512-23R-1W, 42-44 cm.

18 *a-c* *Notoplanulina rakauroana* (Finlay 1939), sample U1512-6R-1W, 38-40 cm (previously published in Wolfgring et al. 2021).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