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„Foraminiferal assemblage analysis of Upper Cretaceous strata from wells within the Bad Hall – Pfarrkirchen Oil Field, Upper Austria“

verfasst von / submitted by

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Acknowledgments

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Zusammenfassung

Mikrofossilien und ihre spezifischen Anforderungen an ihren Lebensraum können interessante Einblicke in vielfältige Bereiche der Geologie geben. Deswegen wurde in dieser Untersuchung die Biostratigraphie mit Mikrofossilien (Foraminiferen und Nannofossilien) als Werkzeug gewählt um in erster Linie eine strukturelle Fragestellung, im Bereich des österreichischen Anteils der autochthonen Molasse, zu bearbeiten. Dabei soll eine neue plausible Interpretation der regionalen Seismikdaten überprüft werden. Das bisher gültige Modell zeigt steil stehende Abschiebungen als Haupttypus der Störungen in dem untersuchten Gebiet, wobei die Seismik aber auch die Neuinterpretation durch flach liegende, nach Süden einfallende Überschiebungen, zulässt. Diese primäre angewandt-geologische Fragestellung bietet ebenso eine Möglichkeit, die vorhandene Foraminiferenfauna aus ausgewählten Bohrkernproben mit diversem Artbestand neu und genauer zu beschreiben, da nur wenig publizierte Erkenntnisse aus dieser Region existieren. Bei der Untersuchung der Bohrkern- und Bohrkleinproben aus den Bohrungen PK-001, WEIBA-001, MG-001, V-043, GRUE-001, BH-001, SIER-001, SIER-003, ASCH-001, SIER-008, BH-N-001, konnte an den meisten Standorten durchgehend und eindeutig Oberkreide, vor allem Coniacium - Santonium durch Foraminiferen- und Nannofossilbestand festgestellt werden. Allerdings zeigen sich vereinzelte Bohrkernproben fossilfrei (MG-001_M, SIER-003_M, SIER-003_U und BH-N-001_O). Bei diesen kann keine Aussage über die Schichtbeziehungen und mögliche Duplizierungen getroffen werden, daher bleibt hier das mögliche Auftreten der interpretierten Überschiebungen offen. Abgesehen von diesen vier leeren Proben und der von Dr. Fred Rögl in seinem Bericht beschriebenen Mischung von Oligozän und Oberkreide in der Bohrung SIER-001 (1955 m), konnte ansonsten nur das bisher gültige Modell bestätigt werden, da keine eozänen oder oligozänen Schichtintervalle oder Faunenelemente in der ansonsten typischen Kreidevergesellschaftung nachgewiesen werden konnten.

Biostratigraphisch wichtige Planktonforaminiferen-Gattungen sind *Dicarinella, Marginotruncana* und *Globotruncana* wobei *Dicarinella concavata* und *Dicarinella asymetrica* im Wesentlichen ein Coniacium-Santonium Alter belegen. Mit dem Auftreten von *Dicarinella asymetrica* und *Globotruncana linneiana* kann in etwa die Coniacium-Santonium Grenze gefasst werden. Nannofossilien wie *Marthasterites furcatus* und *Micula staurophora*

belegen ein Coniacium-Alter, *Lucianorhabdus cayeuxii* den Coniacium-Santonium Grenzbereich, während *Broinsonia parca expansa* in diesen Abfolgen typisch ist für das Santonium.

Die Oberkreide-Foraminiferenassemblage zeigt eine starke Dominanz der Gattungen *Archaeoglobigerina* und *Gyroidinoides*. Diese Formen werden beide weitgehend als r-Strategen beschrieben die unter meso- bis oligotrophen Bedingungen bei verminderter Sauerstoffsättigung im marinen Bereich als Opportunisten auftreten. Dies könnte auf Grund der Einzeitung eine Ablagerung des Materials während des OAE3 bedeuten. Jedoch ist dies hier mit großer Wahrscheinlichkeit ein regional begrenzter Effekt am südlichen europäischen Schelf. Abschließend sollte noch erwähnt werden, dass durch die Abschätzung der Paläowassertiefe und Plankton/Benthos-Verhältnis eine Positionierung des analysierten Materials an den äußeren Schelf plausibel erscheint.

Abstract

Microfossils and their individual needs regarding their habitat and environmental parameters can provide valuable insight into many different fields in geology. This is why biostratigraphy (foraminifera and nannofossils) was chosen as a tool to resolve a question revolving around a structural concept in the autochton part of the Austrian Molasse Basin. A new seismic interpretation in this region is to be proven by this study. The so to say "old" model was interpreted through steep dipping normal faults posing as the main control in this region, although when looking at the seismic data southward dipping, in comparison shallow, thrust faults become plausible. Additionally, this poses a great opportunity to analyse and describe the found foraminiferal assemblage extracted from the sampled core sections and cuttings, because published material on this topic is sparse.

Most of the analysed samples from wells PK-001, WEIBA-001, MG-001, V-043, GRUE-001, BH-001, SIER-001, SIER-003, ASCH-001, SIER-008, BH-N-001 could be positioned around the Coniacian to Santonian boundary through their foraminiferal and nannofossil composition. Although most samples show solid Upper Cretaceous, some material was completely void of faunal or floral elements, namely MG-001_M, SIER-003_M, SIER-003_U and BH-N-001_O. Within these four samples no biostratigraphical assessment was possible and minding that Dr. Fred Rögl described a mixture of Oligocene and Upper Cretaceous taxa at SIER-001 (1955 m), it is applicable to keep the possibility for thrust faults in certain regions plausible. In all other instances mixing of Oligocene or Eocene taxa with Upper Cretaceous forms could not be proven, therefore verifying the "old" interpretation in most cases.

The biostratigraphically most important planktonic foraminifera found include *Dicarinella*, *Marginotruncana* and *Globotruncana*, with *Dicarinella concavata* and *Dicarinella asymetrica* showing a general Coniacian-Santonian age. Due to the combined presence of *Dicarinella asymetrica* and *Globotruncana linneiana* the material can be positioned at the Coniacian-Santonian boundary. Additionally, this can also be seen through the found nannofossils, where *Marthasterites furcatus* and *Micula staurophora* show Coniacian age and *Lucianorhabdus cayeuxii* reflects the Coniacian-Santonian boundary. *Broinsonia parca expansa* is typical for the Santonian in this succession.

The foraminiferal assemblage shows strong dominance of the genera *Archaeoglobigerina* and *Gyroidinoides*. Both are commonly interpreted as opportunistic r-strategists, which strive under meso- to oligotrophic conditions with generally lower levels of oxygenation. This could show a connection and a deposition while the OAE3, although it should be noted that this effect is more than likely a regional occurrence on the southern European shelf and limited in distribution. Finally, through reconstruction of the paleobathymetry and in regard to the ratio of planktonic to benthonic forms, a positioning of the material in an outer shelf environment seems applicable.

1. Introduction

Biostratigraphy and micropaleontology can resolve many different applied questions beyond paleobiology and stratigraphy itself. In this master thesis study the primary research question is revolving around giving additional stratigraphic information regarding two different seismic interpretations which appear plausible in the subsurface Molasse basin with the Bad Hall and Pfarrkirchen Oil-Field in Upper Austria. A new proposed structural concept for this region could hold very valuable data regarding production and general comprehension of the oil fields traits and parameters. Additionally, this applied research question poses an opportunity to refine biostratigraphy and to record and describe the foraminiferal assemblage, due to the fact that there are only sparse published data available in this region. Therefore these two goals are not entirely independent from one another and profit from the main goal of this endeavour to better understand and describe the foraminiferal fauna made accessible through multiple wells in the region. Generally speaking the study area lies within the Austrian North Alpine Foreland (NAFB) or Molasse Basin. The formation of this basin started with the north ward trend and shifting of the African plate during the late Mesozoic. This event led to a beginning constriction of the Tethys-Ocean and in the Paleogene, around 40 Ma, the southern margin of the European plate was also incorporated in the process. This caused a severe subsidence of the Eurasian plate, due to the overburden of the orogen and the marine transgression. Meanwhile, the slowly rising mountain ranges from the Alps to the Caucasus give rise to the partly isolated intercontinental marine basin, the Paratethys. This marks the last phase of the Alpine orogenesis and the beginning of the Molasse Basin. The basin fill consists mainly of erosional material from the rising Alps, but in the northernmost part of the basin also the input from the European main land is present (Malzer et al.,1993; Palzer-Khomenko et al., 2018). Later, the southern parts of this basin fill were reworked and overlain by the Alpine orogen. Therefore, autochthonous and allochthonous Molasse units must be distinguished. Through this northward thrusting, the creation of ramp geometries at the base of the Molasse succession, incorporating the “autochthonous” Cretaceous strata, becomes plausible which forms the main hypothesis for the primary research question of this study. Based on this new tectonic hypothesis, an alternative, close fitting, interpretation of the existing seismic data seems possible. The former “traditional” seismic interpretation shows solely steep dipping normal faults which separate blocks of undisturbed basement-Molasse stratigraphic succession. This “traditional” model would mean that the microfossil record should be undisturbed and in normal stratigraphic succession from Cretaceous to Paleogene, and shouldn’t show any abnormalities, especially repetitions or intervals of Cenozoic within Cretaceous strata. Nevertheless, the new model and its proposed interpretation become plausible when closely inspecting the seismic

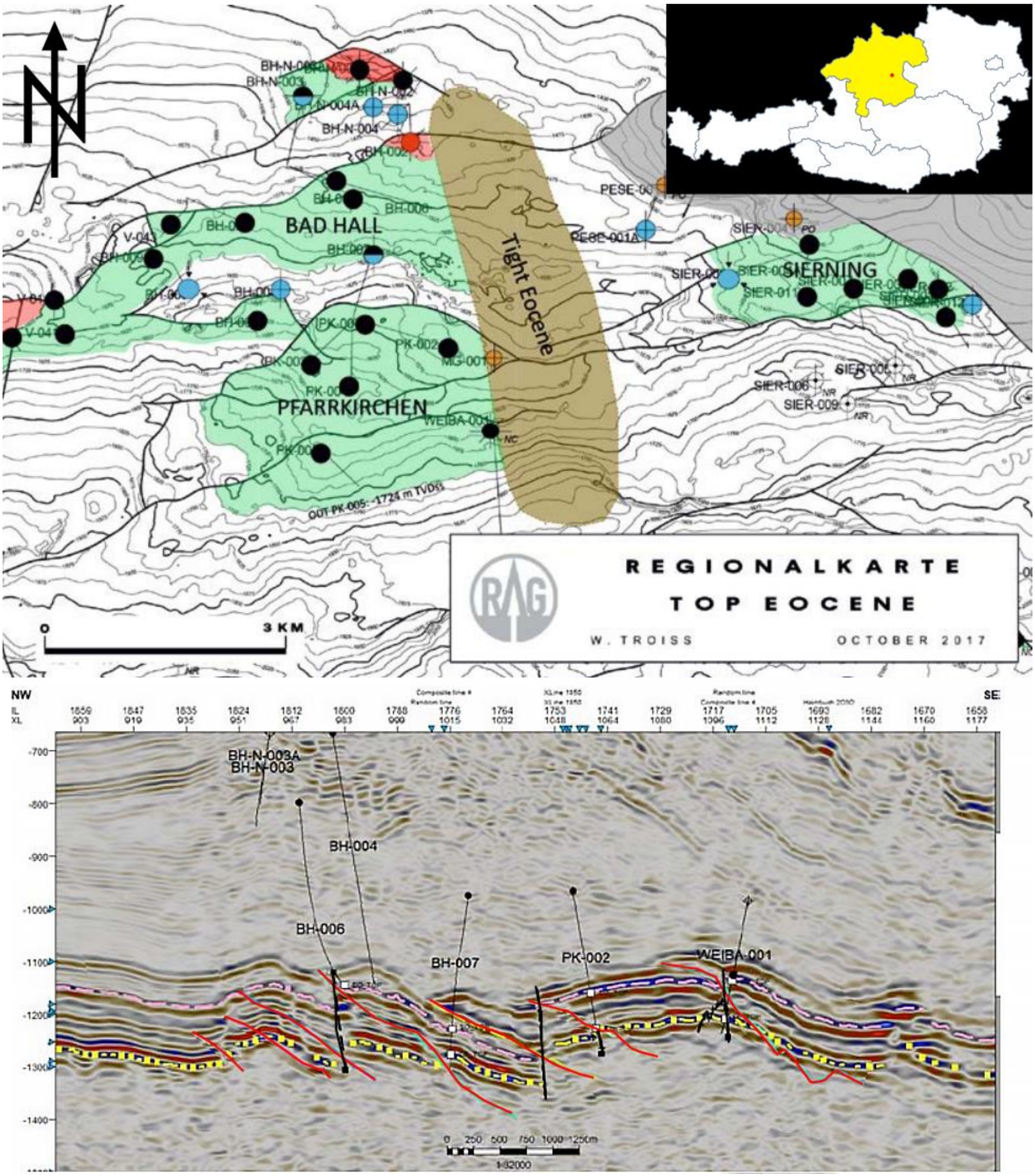

Figure 1: Regional map of the study area. The most prominent wells of this study can be seen here. In the top right an overview of Austria is shown with the location of the map view marked with a small red dot. Seismic Interpretation, Old: Black lines, Alternative: Red lines. Copyright: RAG

data, which may be alternatively interpreted to represent shallow thrust faults dipping from the northwest to the southeast, repeating parts of the stratigraphic successions. Such thrusting events could impose that older strata overlie younger ones. If this new hypothesis is correct the biostratigraphical record should be able to identify wells where younger material is overlain by older strata, therefore contributing a major part in further consolidating the possible presence of assumed interpreted thrust geometries. In the following pages the micropaleontological assemblages of tested wells in the study area will be analysed and described. The sampled wells all lie in the vicinity of Bad Hall, Pfarrkirchen and Sierning in Upper Austria. Exact position and seismic interpretations can be seen in Figure1.

2. Geological Setting

The study area of the Molasse Basin and its subground in Upper Austria is characterized by the so-called “Autochthonous Mesozoic Units” (Rupp et al., 2011) overlain by mainly Eocene deposits. Published investigations on this part of the Molasse Basin are rare: Malzer et al. (1993), Fuchs et al. (1985), Wessely et al. (1981) and Rupp et al. (2011). Micropaleontological assessments by Wessely et al. (1981) and Fuchs et al. (1985) describe a variable diversity and abundance of the foraminiferal and nannofossil taxa over multiple wells in the alpine foreland. Additionally, the assemblages described in unpublished paleontological microfossil RAG well reports, e.g. from Dr. Fred Rögl, contribute a major part in understanding the biostratigraphic distribution of taxa in this region. This faunal and floral analysis is very important in defining the stratigraphic succession through these paleontological biomarkers. Nevertheless, it seems to be in order to give a brief overview of the regional stratigraphy, which is illustrated in Figure 2. The basement is formed by the crystalline of the Bohemian Massif, which is in general directly overlain by Upper Cretaceous strata in the interim regions between Bad Hall and Tulln, Austria, due to the fact that most of the Permo-Carboniferous, Triassic, Jurassic and Lower Cretaceous is missing in these parts (Pfleiderer et al., 2016). Additionally, it is noted that the distribution of these units is strongly affected by erosional processes and that they are only found within few wells. This first sedimentation cycle is overlain by the transgression of the lowermost Upper Cretaceous in the Cenomanian on the European shelf, which is mostly represented by sandstones and clay rich marls (Globotruncanid – marls and clays) and vastly affected by erosion during the Paleogene

Tethyan regression (Rupp et al., 2011). The basal layers of the Upper Cretaceous succession are characterized by crystalline debris, violet, red or greenish in discoloration, along with poorly sorted angular grains, which imply a terrigenic influence (Wessely et al., 1981) called the Schiedlberg Formation. The Cenomanian is dominated by tempestitic deposits in the lowermost part followed by glauconitic sandstones, attributed to a shelf environment, topped by bioturbated layers alternating with tempestites Finally, in the upper part of the Cenomanian, subsidence of the area continued, and mainly marly calcareous layers of a marly shelf can be found, in between glauconitic sandstones, called Piberbach Formation (Malzer et al., 1993).

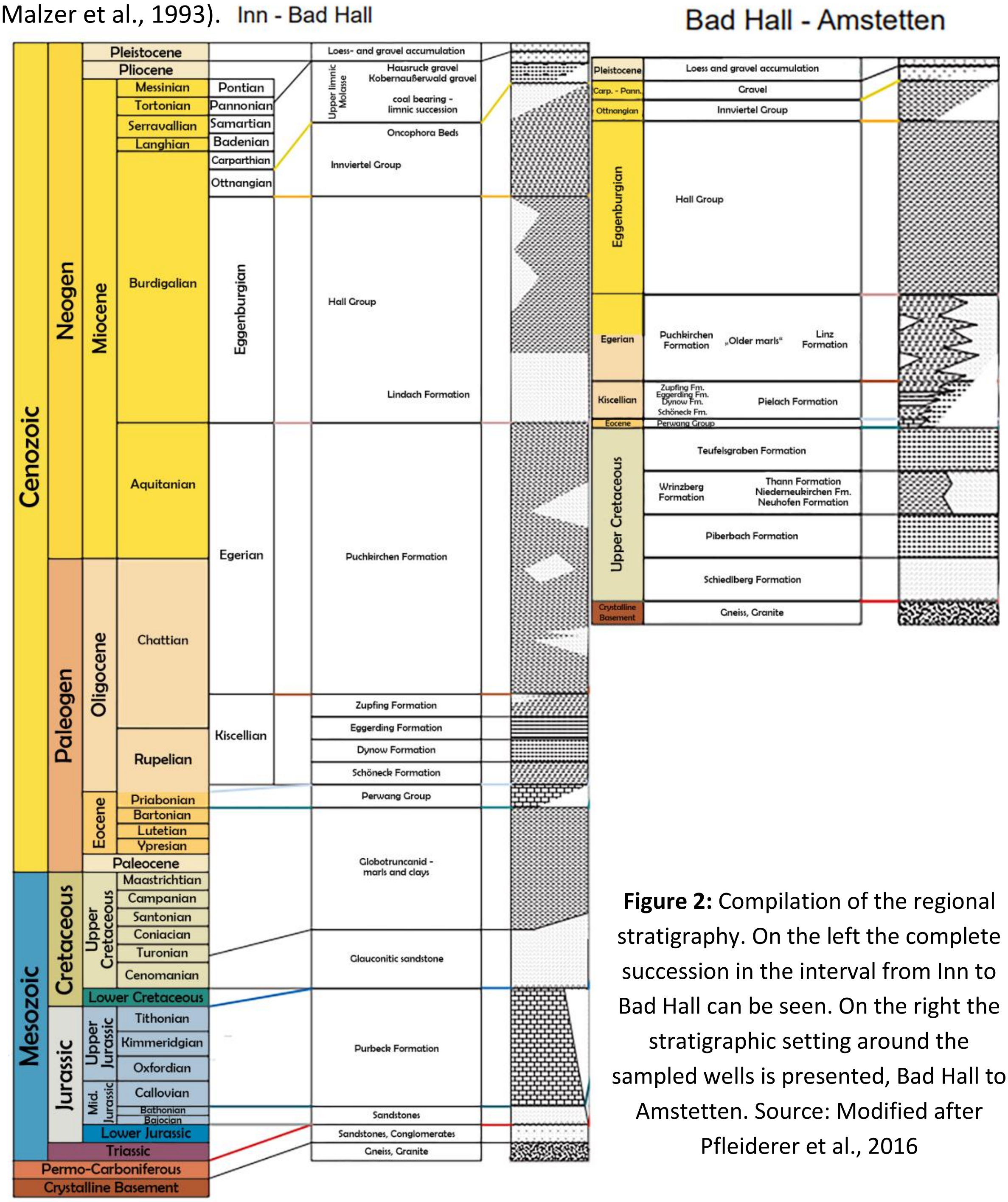

Figure 2: Compilation of the regional stratigraphy. On the left the complete succession in the interval from Inn to Bad Hall can be seen. On the right the stratigraphic setting around the sampled wells is presented, Bad Hall to Amstetten. Source: Modified after Pfleiderer et al., 2016

The lower Turonian is characterized by the deposition of black, clay rich marls, often greenish or gray in color. In the Coniacian, two facies regimes can be distinguished, where towards the northeast coarse terrigenic material from delta fan deposits dominates and to the west the sedimentation of fine-grained marls typical for a more central basin facies carries on, with the boundary of these two domains being intercalated. These marls are termed the Wirnzberg Formation (Fuchs et al., 1985). This facies scheme is continued throughout the uppermost Coniacian to Santonian, whereas Campanian to Paleocene is missing in the study area. Sampling during this master thesis was mainly concentrated on such marly intervals of the Wirnzberg Formation. In the upper Eocene the marine habitat expanded again northwards generating the rhodophyte limestones, nummulite bearing sandstones and discocycline marls, which are placed into the Perwang Group, and this marks the 3rd main cycle of sedimentation atop the Variscan Crystalline (Rupp et al., 2011). Following this succession the lower Oligocene is seen as the beginning of the actual development of the Molasse Basin as a typical deeper-marine basin with the independent floral and faunal evolution of the Paratethys (Dohmann, 1991).

2.1 Petroleum System

In the Molasse Basin the primary control on reservoirs and hydrocarbon migration is through fault systems (Nachtmann et al., 1995) and a prominent channel belt (Ruig et al., 2006; Hubbard et al., 2005). In general the most important source rocks lie within the Lower Oligocene succession of Schöneck Formation, Dynow Formation and Eggerding Formation,

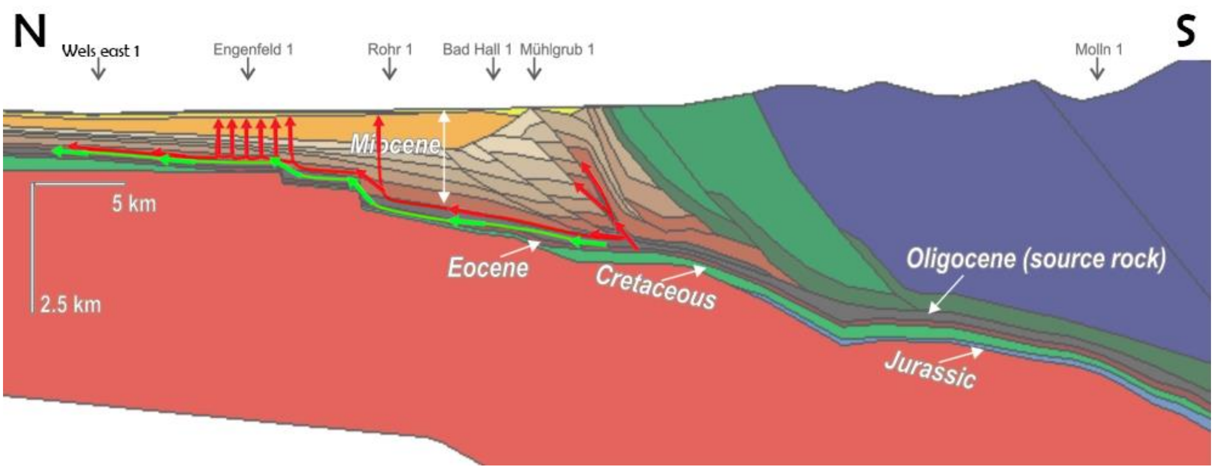

Figure 3: General migration path of liquid and gaseous hydrocarbons generated in Oligocene source rocks underneath the northern margin of the alpine orogeny. Migration path of liquids shown as bright green line with arrows, path of gas shown as red line with arrows. Source: Modified after Gusterhuber et al., 2013.

where the organic rich marls and shales of the Schöneck Formation show the highest source potential (Sachsenhofer et al., 2010). Upper Eocene sandstones are described as the main reservoirs for oil and thermal gas, but hydrocarbons can also be found in traps within Upper Cretaceous glauconitic sandstones and Lower Oligocene strata (Malzer et al., 1993). In Addition to that, also parts of the autochthonous successions of the Lower Oligocene show source rock facies, as discovered in wells west of the Lindach Fault (Gratzer et al., 2011). This first major petroleum system for the Molasse Basin in Austria is mainly fed by Oligocene source rocks situated underneath the northern margin of the Alpine orogen (Figure 3), migrating into connected reservoir lithologies in the Alpine foreland (Gusterhuber et al., 2013).

The second hydrocarbon system found in this setting revolves around the biogenic generation process. These bacterial methane gas accumulations occur within Upper Oligocene to Lower Miocene clastic deep-water sediments within the basin and are generated from organic rich strata like the Puchkirchen Formation, where in addition it should be stated that bacterial methane gas is often associated with thermally immature source rocks containing predominantly kerogen type III material with a TOC higher than 0.5% (Schulz and van Berk, 2009).

3. Material and Methods

Samples were taken from cores and minor amounts of cuttings from several RAG wells suspected to incorporate thrusts. On the 15.5.2020 under supervision of Dr. Ulrike Exner, geologist at ADX-Vienna GmbH, and Dr. Michael Wagreich, University of Vienna, the samples were taken from core material at the RAG core storage facility in Pettenbach, Upper Austria. Samples were taken in form of loose rock chips on strategically critical points of the drilled core, focussing on marly-clayey intervals. Two to three samples were taken on each of the selected well intervals and sample bags were filled to roughly 300 g to 500 g each. Samples were also tagged “Oben - Upper”, “Mittel - Middle” and “Unten - Lower” respective to their relative position along the sampled succession of the core section. Table 1 summarizes all samples including borehole depth, core and core box number, and sampled depth position.

Table 1: Designations and positions of sampled core material.

Well/Designation	Depth	Core	Box	Sampled Position
PK-001_O	2029.5 m – 2047.5 m	1	14	2036.0 m
PK-001_M	2029.5 m – 2047.5 m	1	6	2037.5 m
PK-001_U	2048.5 m – 2051.0 m	3	1	2048.5 m
WEIBA-001_O	2508.5 m – 2526.5 m	2	16	2512.8 m
WEIBA-001_M	2508.5 m – 2526.5 m	2	15	2513.5 m
WEIBA-001_U	2508.5 m – 2526.5 m	2	1	2526.4 m
MG-001_O	1988.0 m – 2006.0 m	1	18	1991.6 m
MG-001_M	1988.0 m – 2006.0 m	1	17	1992.6 m
MG-001_U	1988.0 m – 2006.0 m	1	1	2005.9 m
V-043_O	2111.0 m – 2129.0 m	1	13	2120.0 m
V-043_M	2111.0 m – 2129.0 m	1	6	2124.5 m
V-043_U	2111.0 m – 2129.0 m	1	1	2128.8 m
GRUE-001_O	1701.0 m – 1710.0 m	3	10	1701.6 m
GRUE-001_U	1701.0 m – 1710.0 m	3	1	1708.5 m
BH-001_O	2146.0 m – 2151.0 m	3	5	2146.7 m
BH-001_U	2146.0 m – 2151.0 m	3	2	2149.2 m
SIER-001_O	1835.0 m – 1844.0m	3	9	1835.3 m
SIER-001_U	1835.0 m – 1844.0 m	3	1	1843.7 m
SIER-003_O	1824.0 m – 1842.0 m	1	14	1824.3 m
SIER-003_M	1824.0 m – 1842.0 m	1	7	1835.0 m
SIER-003_U	1824.0 m – 1842.0 m	1	1	1841.5 m
ASCH-001_O	2608.5 m – 2621.5 m	2	1	2620.7 m
ASCH-001_U	2621.0 m – 2632.0 m	3	1	2631.5 m
SIER-008_U	2111.0 m – 2129.0 m	2	1	2128.5 m
BH-N-001_O	1816.0 m – 1834.0 m	2	6	1827.6 m
BH-N-001_U	1816.0 m – 1834.0 m	2	1	1833.7 m
Cuttings SIER-001	**Depth**	**Cuttings SIER-001**	**Depth**	
1	1948.0 m	6	2008.0 m	
2	1952.0 m	7	2024.0 m	
3	1966.0 m	8	2036.0 m	
4	1972.0 m			
5	2004.0 m			

O…. Upper; M…. Middle; U…. Lower

3.1 Processing of samples

To free the microfossils and disintegrate the calcareous, clay rich, marls even further, to enable effective sieving, REWOQUAT© was used. This tenside is commonly used in the preparation of fossils within marly as well as in clay rich lithologies. The chemicals facilitate thorough penetration of the rock and separate the clays from another, therefore disintegrating and breaking down the rock into thick sediment slurry (Schwitalla, 2006). This process doesn't affect calcitic fossil tests and so it is relatively easy to separate the specimen through careful sieving. To ensure a fast and thorough reaction with the sampled rocks, bigger pieces were crushed into material of about 2 mm in diameter, using a hammer to increase the available surface area for the reaction to take place. Typically, the following process of freeing the fossils took about 1 to 2 days, depending strongly on the composition of the rock samples. The deposited slurry was carefully transferred into a sieve stack. Using warm water, the material was washed to consecutive finer grades. Two grain fractions were kept for further analysis, >63 µm and >125 µm, as most of the expected foraminiferal species should be around this size. The material was then dried in an oven for about a day at around 80 °C to get rid of the residual water. It should be noted here, that overall the dissolution of the rocks was mostly very thorough and almost always enough sediment residue could be acquired for further analysis.

3.2 Picking of specimens and documentation

Separation of the foraminiferal specimen has been achieved with the help of a binocular, where only nearly complete taxa in relative good condition were picked and transferred in cells respective to their drilling operation and relative position. After a rough separation of grains and fossils, another sorting procedure was performed, where the picked specimens were moved in new cells respective to their taxonomy to ease the following step of identifying and counting the taxa. Finally, to better illustrate, identify and describe the found assemblage of foraminifera, scanning electron microscope (SEM) images were taken. A JEOL-6000 Plus SEM-device was used, which is situated at the Department of Geology of the University of Vienna. To guarantee that the specimens can be scanned from multiple directions and views, transparent adhesive tape (Tesa©-Film) was cut to size and glued with their non-sticking side towards the stubs surface. As the regular gluing surface of the film presents very good properties in manipulating the specimens it also holds them securely in position, although a short check after evacuation is good practice, due to the possibility of trapped air in the gluing agent of the tape might compromise the intricate positioning of the pieces when escaping the material. Overall usage of this preparation method yielded satisfying results, nevertheless some specimen shifted during the evacuation process in the SEM itself and therefore are not in the most perfect orientation.

In addition to the foraminifera also nannofossil slides (modified settling method, e.g. Wolfgring et al., 2016) were analysed, done by Dr. Michael Wagreich, to present a second micropaleontological method for enhanced precision and have additional resolution in dating the processed samples and biostratigraphy. Three of the foraminiferal samples were selected for a quantitative investigation of foraminiferal assemblages based on their relative high diversity in specimens and overall good preservation. These following three samples are also used for assessing the assemblage and identification of taxa:

PK-001_M; V-043_U; BH-N-001_U

In the following analysis 200 g of each sample were processed in the same manner as described before and sieved. After this step all the present foraminifera were extracted, counted and identified.

3.3 Taxonomy and Biostratigraphy

Taxonomy of foraminifera is based on Premoli Silva and Verga (2004), BouDagher-Fadel (2015) and Mikrotax (http://www.mikrotax.org/pforams/) for planktonic and for benthonic taxa Hofker (1957), Noth (1951) was used. Biostratigraphy is based on Premoli Silva and Verga (2004) and BouDagher-Fadel (2015) for planktonic forms and for benthonic various publications were used (e.g. Wessely et al., 1981; Dubicka et al,. 2014; Hradecka et al., 1999). Taxonomy and biostratigraphy of calcareous nannofossils uses a light pol-microscope (Zeiss Orthoplan, objective 100x oil immersion) and is based on Burnett (1998) and Nannotax3 (http://www.mikrotax.org/Nannotax3/).

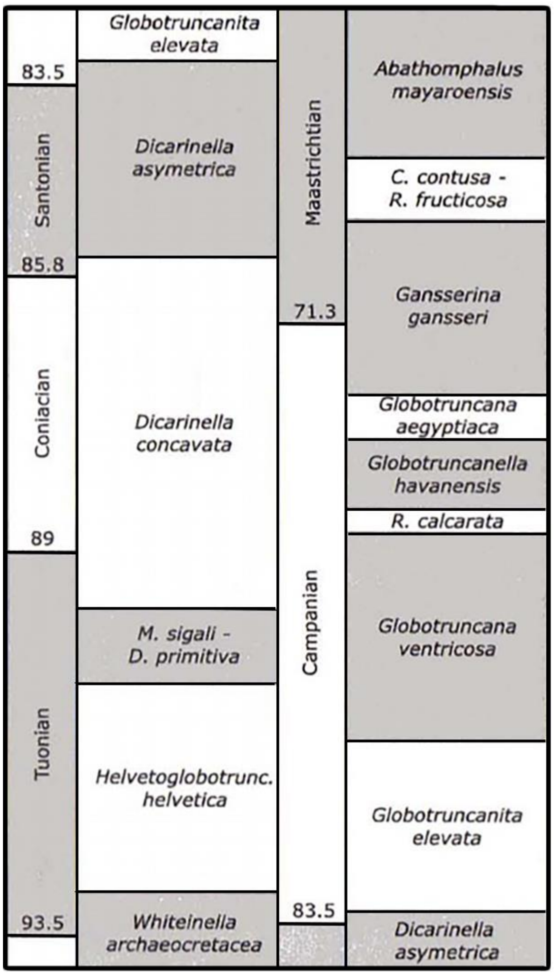

Figure 4: Foraminiferal zonation of the Upper Cretaceous from the Turonian to the Maastrichtian. Modified after Premoli Silva and Verga (2004).

The planktonic foraminiferal zonation (Figure 4) of the Coniacian-Santonian interval is mainly based on *Dicarinella* species. *Dicarinella concavata* evolved in the late Turonian, probably from *Dicarinella primitiva*, and is typical for the Coniacian. In the latest Coniacian, slightly before the base of the Santonian, *Dicarinella asymetrica* evolved (third keel-like structure on the umbilical, lowermost parts of each chamber element), being typical for the Santonian, and becoming extinct at the base of the Campanian (Marks, 1984; Fraass et al., 2015).

Marginotruncanids also provide some additional biostratigraphic information, such as *M. marginata*, *M. coronae,* M. *coronata, M. pseudolinneiana, M. sinuosa* (Turonian-Santonian) and *M. angusticarenata* (Turonian-Coniacian).

3.4 Paleobathymetry

Through the obtained quantitative data an attempt to reconstruct the paleo-water-depth of the examined material can be made. Here we want to use two methods which are based upon different approaches to tackle this question. The first method after Van der Zwaan (1990) is using the ratio of planktonic to benthonic individuals. Calculations are done through the use of this equation:

$$D = e(3.58718 + (0.03534 * \%P*))$$

Where **D** is the estimated depth in meters, e the exponential function and **%P*** the ratio of planktonic to benthonic foraminifera. The two used constants seen in the formula are derived from several different models in the work of Van der Zwaan (1990). The calculations accuracy should be satisfying within a depth interval of 36 m to 1250 m according to Van der Zwaan (1990).

For the second method, as stated above a different approach is used based on Hohenegger (2005). This calculation is based on the presence or absence of benthonic taxa and their respective depth range in which they are normally expected (listed in Table 2).

Table 2: Benthonic Foraminiferal depth range compilation.

Taxa	Depth - Range	Taxa	Depth - Range
Anomalina	1500 - 4000	***Recurvoides***	400 - 3000
Lenticulina	50 - 3500	***Planularia***	100 - 500
Gyroidinoides	200 - 2700	***Nodosaria***	50 - 4000
Vaginulina	100 - 250	***Marginulina***	50 - 4000
Dentalina	50 -2500	***Spiroplectammina***	50 - 1900
Arenobulimina	50 - 1500	***Gaudrynopsis***	200 - 2000
Dorothia	200 - 4000	***Textularia***	20 - 500
Ammobaculites	50 - 4100	***Verneuilinoides***	500 - 1500
Praebulimina	50 - 1000	***Marssonella***	200 - 4000
Ramulina	200 - 1500	***Globorotalites***	150 - 2700
Frondicularia	100 - 500	***Cibicidoides***	50 - 2500
Gaudryina	200 - 2000		

Table 2: Depth ranges of benthonic foraminifera used for paleo-depth reconstruction. All ranges are given in metres and were inferred from following sources: Ashkenazi-Polivoda at al., 2018; Leckie, 1987; Naz et al., 2018; Mancin et al., 2002; Frontalini et al., 2016; Widmark et al., 1997; Speijer et al., 1998; Koutsoukous et al., 2000; Pardo et al., 1996; Wolfgring et al., 2016; Wagreich

So a mean paleo-depth can be estimated when taking all of the individual depth-ranges into account. The equation after Hohenegger (2005) was used:

$$g = \sum_{i=1}^{m} l_i d_i^{-1} \Big/ \sum_{i=1}^{m} d_i^{-1}$$

Where **li** is the mean depth in which the taxon can be expected and **di** the depth range of said taxon. Finally **g** stand for the estimated paleo-depth calculated using this data.

4. Results

Of the 26 core samples and 8 packs of cuttings in tested critical positions, most had enough microfossils to confidently assess an undoubted Late Cretaceous age through biostratigraphic markers. Unfortunately, in some samples neither foraminifera nor nannofossils could be found, therefore no biostratigraphic analysis could be performed and the significance of such samples for the primary research question could not be evaluated. In the following section all of the samples results will be presented briefly. A more in depth micropaleontological presentation and discussion will be given for three selected samples with abundant foraminiferal specimen.

Assemblages in general are characterized by a mixture of planktonic and benthonic foraminifera, here one can see that some of the taxa are dominating over all three samples (e.g. *Archaeoglobigerina* or *Gyrodinoides*). Furthermore, it can be stated that important and indicative marker fossils, like *Dicarinella*, *Globotruncana* and *Marginotruncana*, are also abundant in all of these samples. When calculating the individuals per volume it can be seen that BH-N-001_U carries the highest amount of foraminiferal individuals per cm^3 of material with 3.76 planktonic (PF) and 3.74 benthonic (BF) foraminifera. V-043_U is showing also a similar density of microfossils with 3.22 PF and 3.24 BF per cm^3 of rock. The sample with the least amount of individuals in this comparison is PK-001_M with 1.72 PF and 2.02 BF per cm^3. Nevertheless all three samples show a very similar ratio of planktonic to benthonic forms around 1 (ca. 50% planktonic, 50% benthonic foraminifera), with 1.06 as a mean value. For all of these calculations marl with a mean density of 2.2 g/cm^3 was assumed.

4.1 Description of the assemblage

The foraminiferal counts are converted into the percentage of the total for each sample and genus. The resulting taxon ratios are represented in the graphs in Figure 2. When looking at the most abundant taxa in these three samples it becomes clear that in case of planktonic specimen the genus *Archaeoglobigerina* is predominant here. Roughly 32% to nearly 50% of the assemblage in the planktonic category is covered by this taxon seen in all of the samples. The second spot isn’t as easy to assign as the first one, but it can be seen that *Planoheterohelix* is also highly abundant in two of the samples (BH.N-1_U and V-043_U). For PK-001_M a rather small percentage can be seen in comparison with the first two samples.

With abundances from almost 35% to as little as 5% it should be noted that certain variability becomes evident. Next, the biostratigraphically very important genus *Marginotruncana* should be mentioned. Here a somewhat stable abundance can be seen over all samples ranging from 10% to about 15% total. PK-001_M gains the highest cut of this taxon with around 15%. The next very important planktonic genus would be *Globotruncana*. Their cut ranges from as little as 5% to slightly over 10% in the analysed samples. Last but not least the genus *Dicarinella* is present in all of the samples with a very even abundance in each if the three cores. This genus is represented by a little more than 5% overall. Only in PK-001_M all of the found taxa are present. In the other two *Laeviheterohelix* is completely absent. A somehow similar distribution presents itself among the benthonic taxa. Here *Gyroidinoides* takes the top spot on the diagram. Although the number of genera is higher and thus more diverse in comparison with the planktonic forms, *Gyroidinoides* is by far the most abundant taxon here. With percentages from 45% to almost 65% it clearly can be seen as the dominating form in the three samples. Then again the second place isn't as clear, as before *Lenticulina* takes this spot in two of the samples (PK-001_M and BH.N-1_U) with 15% to 20% and is only present by 7% in V-043_U. Here the genus *Praebulimina* takes the second spot with around 15%, closely followed by *Anomalina* with 10%. The remaining taxa are present with low abundances, of around 5%.

Within this assemblage the following zonal planktonic foraminifera marker species could be identified:

Dicarinella asymetrica (uppermost Coniacian to uppermost Santonian)

Dicarinella concavata (Turonian to upper Santonian)

In addition, biostratigraphically important planktonic taxa are:

Globotruncana linneiana (uppermost Coniacian to middle Maastrichtian)

Marginotruncana angusticarenata (lower Turonian to upper Coniacian)

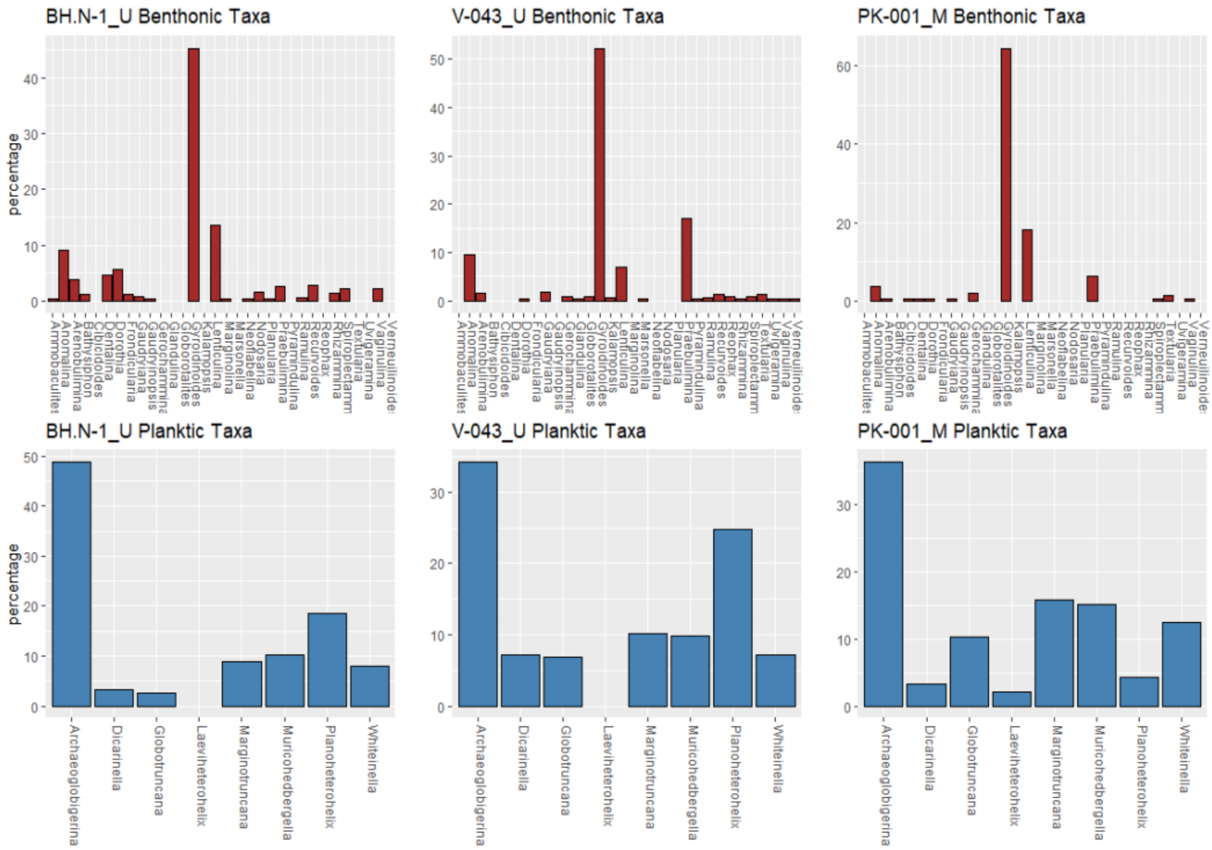

Figure 2: Foraminiferal abundance per genus in percent for all of the three analysed cores. Planktonic and benthonic forms are separated into individual plots.

4.2 Paleobathymetry results

The calculated results from the used equations after Van der Zwaan (1990) and Hohenegger (2005) can be seen in **Table 4**:

Table 4: The calculated paleodepths from both approaches

Well/Designation	Van der Zwaan	Hohenegger
PK-001_M	239 m	576 m
V-043_U	202 m	570 m
BH-N-001_U	200 m	560 m

Both methods show a southwards deepening trend in paleo-depth reconstruction, BH-N-001_U being the northernmost, V-043_U in between and PK-001_M representing the southernmost well of this study. For the second method benthonic foraminiferal depth habitats were inferred from multiple studies. The values used for this calculation are stated in Material and Methods (Table 2).

5. Discussion

5.1 Description and interpretation of analysed samples

The results of each core sample and box of cuttings will be listed in the following section with short description of the biostratigrapically most important taxa and overall abundance of specimen. Also the nannofossils used for dating will be mentioned here. An overview of the biostratigraphic interpretation can be seen in **Table 3**.

Table 3: Overview of the biostratigraphical interpretation of each sample.

Well/Designation	Age	SIER-001-CUT	Age
PK-001_O	Santonian	1942 m	Oligocene / Eocene
PK-001_M	early Santonian	1952 m	late Cretaceous
PK-001_U	early Santonian	1966 m	late Coniacian / Santonian
WEIBA-001_O	late Coniacian / ealry Santonian	1972 m	late Coniacian / Santonian
WEIBA-001_M	late Coniacian / early Santonian	2004 m	late Coniacian
WEIBA-001_U	late Coniacian	2008 m	late Coniacian/ early Santonian
MG-001_O	Cretaceous	2024 m	middle / late Coniacian
MG-001_M	Barren of microfossils	2036 m	Coniacian
MG-001_U	Cretaceous		
V-043_O	Eocene		
V-043_M	late Coniacian		
V-043_U	late Coniacian		
GRUE-001_O	late Cretaceous		
GRUE-001_U	late Cretaceous		
BH-001_O	late Coniacian / early Santonian		
BH-001_U	late Coniacian / early Santonian		
SIER-001_O	Cretaceous		
SIER-001_U	Cretaceous		
SIER-003_O	Rupelian		
SIER-003_M	Barren of microfossils		
SIER-003_U	Barren of microfossils		
ASCH-001_O	middle Coniacian / Santonian		
ASCH-001_U	middle Coniacian / Santonian		
SIER-008_U	Santonian		
BH-N-001_O	Barren of microfossils		
BH-N-001_U	late Coniacian		

PK-001

This triplet of samples bears enough microfossils and can be set around the Santonian - Coniacian boundary interval through a combination of foraminiferal and nannofossil biostratigraphy.

PK-001_O: 2036.0 m; Core 1; Box 14

Through the presence of *Dicarinella asymetrica*, a Santonian age can be assumed (Premoli Silva and Verga, 2004; Jaff et al., 2020) and in addition the biserial planktonic form *Planoheterohelix reussi* is also readily abundant in this sample. Therefore, the assumption of a Santonian age is further consolidated (Haynes et al., 2015). Other Cretaceous taxa such as *Archaeoglobigerina cretacea* are also very abundant in this sample. No nannofossils could be found here**.**

PK-001_M: 2037.5 m; Core 1; Box 6

Dicarinella concavata shows a Coniacian age in this sample (Premoli Silva and Verga, 2004). Besides many other taxa like *Marginotruncana marginata*, *Globotruncana linneiana*, *Globotruncana bulloides* and *Marginotruncana caronae*, one should note the increased abundance of *Planoheterohelix*, *Gyroidinoides* and *Archaeoglobigerina*. Taking all the found taxa into account, the positioning into upper Coniacian to lower Santonian seems substantiated. This can also be seen through examination of the found nannofossils, namely *Broinsonia parca expansa* (*B.p. expansa*) poses a hint towards Coniacian - Santonian boundary (Burnett, 1998).

PK-001_U: 2048.5 m; Core 3; Box 1

Due to the lack of critical marker fossils in this sample, looking at foraminifera, only Upper Cretaceous can be assumed. Only the presence of genus *Planoheterohelix* isn’t enough to give a more accurate result, due to its relative broad range from the Turonian to upper Santonian (Haynes et al., 2015). The nannofossil *Lucianorhabdus cayeuxii* (*L. cayeuxii*) shares part of the range of found *Planoheterohelix* taxa. *L. cayeuxii* ranges from the upper Coniacian/lower Santonian to the upper Maastrichtian (Burnett, 1998). Therefore at least an age of Santonian can be assumed.

WEIBA-001

Only the uppermost sample of this series bears no fossils in the examined volume. The other two samples present enough specimen to date them. Especially through the usage of nannofossils dating the material can be set around the Coniacian - Santonian boundary.

WEIBA-001_O: 2512.8 m; Core 2; Box 16

Only a very sparse selection of foraminiferal taxa presents itself. The few specimens that can be found and identified, point at a common Late Cretaceous age, for example *Archaeoglobigerina cretacea* (Premoli Silva and Verga, 2004). This taxon ranges from the lower Turonian to upper Maastrichtian and is therefore covering a relatively long range. Nannofossil abundance was high and through the presence of again *B.p. expansa* and the genus *Micula* middle Coniacian to Santonian can be assumed.

WEIBA-001_M: 2513.5 m; Core 2; Box 15

With *Dicarinella concavata* as guiding fossil and the presence of *Marginotruncana angusticarenata* this sample can be dated to middle Coniacian to Santonian. Although other taxa were also present, they were not significant enough to influence dating. Nannofossils also yielded similar results with *B.p. expansa* being the prominent marker taxon.

WEIBA-001_U: 2526.4 m; Core 2; Box 1

Both guide fossils of the genus *Dicarinella* are found here, namely *D. asymetrica* and *D. concavata*. This alone would mean that this sample is situated around the Coniacian-Santonian boundary interval. This assumption is offset by the presence of *Marginotruncana angusticarenata*, with its range from Lower Turonian to Upper Coniacian. Therefore an age of late Coniacian can be assumed for this sample.

MG-001

A very sparse and incomplete representation of the expected microfossil assemblage presents itself here. This means only very rough and crude dating can be applied to the three samples in this series. Overall dating can only be described as Cretaceous.

MG-001_O: 1991.6 m; Core 1; Box 18

The processed volume of this sample yielded no foraminiferal individuals. Nannofossils are also rarely found in this sample. The few that could be identified point to a general Cretaceous age.

MG-001_M: 1992.6 m; Core 1; Box 17

The processed volume of this sample yielded no foraminiferal individuals. Also nannofossil data could not be obtained in this sample, thus a Cenozoic age cannot be excluded.

MG-001_U: 2005.9 m; Core 1; Box 1

The processed volume of this sample yielded no foraminiferal individuals. Again only a general positioning in Cretaceous age was possible using nannofossils.

V-043

The uppermost sample out of this series is rather poor in individuals compared to the middle and lowermost, where plenty of foraminiferal individuals could be found. In addition to the high abundance also the presence of the taxon *Praebulimina* is to note here.

V-043_O: 2120.0 m; Core 1; Box 13

Here only one individual could be identified, clearly not enough for an accurate call regarding dating. The presence of the planktonic foraminifera *Alicantina lozanoi* is, although very similar in general morphology to Cretaceous globigerinid individuals, points to a Paleogene age. When only considering this taxon the sample could be dated in Bartonian/Ypresian (Soldan et al., 2018), but again very few individuals were found in this sample. In contrast the nannofossils extracted from this sample point towards a general Cretaceous age, but reworking cannot be excluded.

V-043_M: 2124.5 m; Core 1; Box 6

This middle sample is dated to the Coniacian - Santonian due to the presence of *Dicarinella concavata*, plus *Marginotruncana angusticarenata* further narrowing down the range to upper Coniacian. Again only a rough dating as Cretaceous age was possible using nannofossils.

V-043_U: 2128.8 m; Core 1; Box 1

Here a great abundance of foraminiferal taxa presents itself and taking all the different ranges into account an age of late Coniacian is applicable. *Dicarinella concavata* and *Marginotruncana angusticarenata* are the critical individuals here, but also other forms like *Marginotruncana caronae*, *Marginotruncana bulloides* as well as *Globotruncana linneiana* are present. The first occurrence of G. linneiana is reported as the best approximation for the base of the Santonian (Lamolda et al., 2014), thus an earlymost Santonian age cannot be excluded, although *D. asymetrica* is not present. Furthermore, the genus *Planoheterohelix* shows moderately high abundances. *Marthasterites furcatus*, a nannofossil, shows an age range of late Turonian to early Campanian.

GRUE-001

These core samples yielded not much information in respect to foraminiferal assemblages or nannofossil biostratigraphy. Nevertheless, through the presence of a few individuals Upper Cretaceous can be ascertained with high certainty.

GRUE-001_O: 1701.6 m; Core 3; Box 10

Here *Archaeoglobigerina cretacea* is the only indicator for a Late Cretaceous age here. All other foraminifera in this sample are not helpful in increasing the precision of dating in this case. Generally speaking, the examined volume of rock bears not enough microfossils. Also the nannofossil assemblage is very sparse and only individuals with broad ranges could be identified, for example *Eiffellithus eximus*. Therefore only Upper Cretaceous is applicable.

GRUE-001_U: 1708.5 m; Core 3, Box 1

Also this sample can only be dated roughly as Upper Cretaceous, due to the lack of indicative taxa. This holds also true for the only nannofossil found, *Micula staurophora* (ranges from middle Coniacian upwards, Burnett, 1998).

BH-001

The fossil record in this sampled interval is rich and important indicative species can be identified. The combination of foraminiferal and nannofossil assemblages contribute to an age around the Coniacian - Santonian boundary.

BH-001_O: 2146.7 m; Core 3; Box 5

Both *Dicarinella asymetrica* and *D. concavata* can be found in this sample. Although there are only few individuals of this indicator species found, other taxa like *Marginotruncana coronata* and *Marginotruncana angusticarenata* narrow down the range to the Coniacian - Santonian boundary interval (Premoli Silva and Verga, 2004). Nannofossil individuals only show Late Cretaceous age with the taxon *Gartnerago obliquum*.

BH-001_U: 2149.2 m; Core 3; Box 2

The presence of *Dicarinella concavata* certainly places this sample in the Coniacian. Other taxa of the genus *Dicarinella* and *Archaeoglobigerina cretacea* are also found here readily. In combination with the nannofossil *Lucianorhabdus cayeuxii* this sample can also be placed around the Coniacian - Santonian boundary.

SIER-001

Precise dating isn't possible, as far as biostratigraphy, due to the lack of critical taxa.

SIER-001_O: 1935.7 m; Core 3; Box 9

No foraminifera could be found in the examined rock volume.

Also nannofossils yield only rough data. Through the taxon *Watznaueria barnesiae* only general Cretaceous age can be ascertained.

SIER-001_U: 1943.7 m; Core 3; Box 1

Foraminiferal assemblage only shows taxa with wide ranges within the Upper Cretaceous, for example *Planoheterohelix reussi*. All other important critical taxa are absent therefore no precise range can be given. Again *Watznaueria barnesiae* point at a general Cretaceous age.

SIER-003

This series of core samples can only be describes as almost empty regarding microfossils. Only the uppermost sample bears hints towards an Oligocene to Eocene (Rupelian) age. This should fit with the assumption that the sampled material can be accounted to the Paleogene Zupfing Formation.

SIER-003_O: 1824.3 m; Core 1; Box 14

This sample shows individuals untypical for the Cretaceous. The found taxa include *Uvigerina mexicana*, *Reusella* sp. and *Bolivina* sp. and a cautious assumption would be Rupelian age. The nannofossil - record supports this hypothesis through the presence of Eocene to Oligocene forms of *Discoaster* spp..

SIER-003_M: 1835.0 m; Core 1; Box 7

No foraminifera and nannofossils could be found in the examined rock volume, thus a nonmarine Paleogene attribution may be possible.

SIER-003_U: 1841.5 m; Core 1; Box 1

No foraminifera and nannofossils could be found in the examined rock volume, thus a nonmarine Paleogene attribution may be possible

ASCH-001

Unfortunately in these samples no foraminifera were found, only the analysis of nannofossils yields a biostratigraphic result here.

ASCH-001_O: 2620.7 m; Core 2; Box 1

No foraminifera could be found in the examined rock volume, although the presence of *Micula staurophora* could place this material in the middle Coniacian to Santonian up to the Maastrichtian.

ASCH-001_U: 2631.5 m; Core 3; Box 1

No foraminifera could be found in the examined rock volume, but similarly to the last sample middle Coniacian to Santonian age can be assumed.

SIER-008

Only a single sample was taken from this core. Here on behalf of the good foraminiferal record and supporting nannofossils, a Santonian age can be attributed.

SIER-008_U: 2128.5 m, Core 2; Box 1

This sample bears the indicative taxon *Dicarinella asymetrica*. Additional to common Cretaceous taxa with a broader range, also *Globotruncana linneiana* can be described here. This means the material is of Santonian age. The nannofossils *B.p. expansa* and *Lucianorhabdus cayeuxii* are largely supporting this assumption.

BH-N-001

The uppermost sample seems to be void of fossils, no foraminifera nor nannofossils are found here. The latter one on the other hand gives a diverse overview of the micro faunal assemblage. Therefore a late Coniacian age can be assumed.

BH-N-001_O: 1827.6 m; Core 2; Box 6

No foraminifera or nannofossil could be found in the examined rock volume.

BH-N-001_U: 1833.7 m; Core 2; Box 1

A high diversity in foraminiferal taxa can be noted here. Whilst many common species can be found, also highly indicative individuals like *Dicarinella concavata*, *Marginotruncana marginata* and *Globotruncana linneiana* can be seen. Under the consideration of all specimens, a late Coniacian to Santonian age should be assumed, although *D. asymetrica* is missing. Again support is given by the nannofossil *Micula staurophora*, due to its similar biostratigraphical range.

Cuttings (SIER-001)

SIER-001

First of all it seems that the findings of Cenozoic foraminifera by Dr. Fred Rögl, in his micropaleontological RAG Report on SIER-001 (unpublished) from a side core in a similar location, can be confirmed. Our analysis shows a mix of Cretaceous and younger foraminifera. This was also described by Dr. Rögl in his report. From 1966 m depth downward only solid Upper Cretaceous material can be identified without any suspect admixture. No nannofossil assessment was done for these cuttings.

SIER-001-CUT: 1942 m

This sample presents similar individuals as already found in the material of SIER-003_U, like *Uvigerina* sp., *Reusella* sp. and *Bolivina* sp.. These specimens also show a similar grade of preservation. Nevertheless the observed taxa are highly untypical for the Cretaceous time period and therefore younger ages of Eocene to Oligocene should be assumed.

SIER-001-CUT: 1952 m

The next sample downwards shows already a more typical Cretaceous assemblage. Here, the non-Cretaceous taxa from before are completely absent. Although many individuals with a very broad range are present, through the taxon *Archaeoglobigerina cretacea* a general Upper Cretaceous trend can be marked. It should be noted that preservation was very good and consistent in this sample. Dr. Rögl also described *A. cretacea* at this depth of SIER-001.

SIER-001-CUT: 1966 m

In this sample the most important marker taxon is *Dicarinella asymetrica*, with its indicative range placing this material into the uppermost Coniacian to Santonian. The observed abundance of fossils was very poor in this sample.

SIER-001-CUT: 1972 m

Dicarinella asymetrica is also found at this depth, placing the material in the same range as before. Abundance of individuals is slightly increased compared to the last sample. Also the taxon *Archaeoglobigerina cretacea* could be identified, being typical for the Upper Cretaceous.

SIER-001-CUT: 2004 m

The appearance of *Dicarinella asymetrica* paired with *Marginotruncana angusticarenata* shifts the age trend into the late(st) Coniacian. All other found taxa are typical for the Upper Cretaceous.

SIER-001-CUT: 2008 m

Both *Dicarinella asymetrica* and *D. concavata* are present, which means the material can be placed again around the Coniacian - Santonian boundary when taking the individual ranges into account.

SIER-001-CUT: 2024 m

Out of the many common species with broad ranges, the trend to increasing Coniacian specimen can be observed. With *Dicarinella concavata*, *Marginotruncana marginata* and *Marginotruncana angusticarenata* upper to middle Coniacian can be assumed.

SIER-001-CUT: 2036 m

Also within this deepest sample, one can assume a Coniacian age, due to the presence of *Dicarinella concavata*.

5.2 Seismic interpretation assessment

The data extracted from all the 34 samples suggest that the original model of steep dipping normal faults cannot be falsified by the micropaleontological data and is still applicable to most of the successions. Due to the fact that a consistent biostratigraphical age succession of the Upper Cretaceous could be assessed through the means of foraminifera and nannofossil taxa, it is rather unlikely based on our study that section repetitions due to faulting occur in the investigated wells and that north to south dipping comparatively shallow thrust faults have occurred in the analysed region. Therefore, this new interpretation is not valid for most of the investigated wells considering the data acquired in this study, due to the fact that many samples display a clear undisturbed Upper Cretaceous timeframe without any interference of younger material in the analysed core interval of PK-001_O, PK-001_M, PK-001_U, WEIBA-001_O, WEIBA-001_M, WEIBA-001_U, V-043_M, V-043_U, BH-001_O, BH-001_U, SIER-008_U, BH-N-001_U. In addition to that no signs of strong reworking or re-deposition could be seen in the microfauna recovered from the material. This further supports a verification of the former interpretation in the sense of normal faults rather than the inferred ramp geometries. Nevertheless, some of the samples analysed showed very little to no fossils what so ever, but were also taken in critical key positions along the core. So, for some of the wells or in some areas, thrusting cannot be excluded such as in SIER-001 where we could replicate the findings of Dr. Rögl and a mix of Upper Cretaceous and younger, maybe Eocene or Oligocene taxa, was discovered. Furthermore, the micropaleontological seemingly empty samples MG-001_O, SIER-003_M, SIER-003_U and BH-N-001_O could still hold valuable information regarding strata repetitions according to the proposed thrust interpretation, but denser sampling and other methods of analysis have to be applied for verification.

5.3 Foraminiferal assemblage and ecology

Benthonic foraminiferal assemblage

It is well known that oxygenation and nutrient flux are the two main controlling factors when it comes to benthonic foraminiferal assemblages and their distribution (Ashckenazi et al., 2018). Due to these distinct specializations benthonic foraminiferal taxa are used to reconstruct past environmental parameters. Oxygen and food availability also seem to directly affect the chosen microhabitat in which foraminiferal taxa reside (Widmark, 2000). Both eutrophic and oligotrophic situations can lead to shallow depth habitats (<3 cm) in contrast to mesotrophic conditions, in which infaunal depths of up to 5 cm are reported (Widmark et al., 1997). Here also a general relationship of test morphology and depth habitat can be seen. Epifaunal specimens dwelling near the top of the sediment are often dominated by trochospiral tests, whereas infaunal specimens exhibit a form of uni-, bi-, tri- or multi-serial and planispiral morphologies (Widmark et al., 1997). In addition to that epifaunal taxa are also considered to be less tolerant to low oxygen levels compared to individuals inhabiting deeper sections. The latter being seen as more oriented towards r-selected, meaning they are believed to be more opportunistic and are able to reproduce fast when conditions are right ,able to profit from eutrophic conditions the most, whereas epifaunal taxa are seen as k-selected meaning they represent equilibrium taxa which can sustain themselves under more oligotrophic conditions (Widmark , 1995). Also a dominance of low trochospiral minute calcareous forms associated with primitive agglutinated taxa is seen as characteristic for low oxygen environments (Erbacher et al., 1998). It can clearly be seen in the studied material that the genus *Gyroidinoides* is dominant over all three samples analysed in detail in this study and is also abundantly present in almost all of the other samples screened for biostratigraphic assessment. *Gyroidinoides* is believed to inhabit a shallow infaunal to low epifaunal depth habitat, to be a deposit feeder and is rather tolerant of low oxygen concentrations in general (Erbacher et al., 1998L; Holbourn et al., 1998). Furthermore some agglutinated taxa are also readily available in the samples. This strong dominance of a single low oxygen tolerant form hints towards a relatively low oxygenation of the bottom waters in this region. This is further supported by the presence of the genus *Gavelinella*, which is also described as being tolerant to dysoxic conditions with a shallow infaunal habitat depth (Erbacher et al., 1998). Additionally the taxon *Praebulimina* was found in all three analysed samples to a varying extent, with V-043_U leading with *Praebulimina* occupying almost 20% of all benthonic foraminifera. Buliminids are known to be fairly abundant in outer shelf to upper slope environments and abyssal depths, due to their ability to tolerate low levels of oxygenation (Dawy et al., 2002), being present in the oxygen-minimum zones. Also, the overall test shape of the genus fits the description of low oxygen environment dwellers.

In general, the studied time interval of the Coniacian-Santonian is correlated to oceanic anoxic event 3 (OAE3), characterized by the distribution of organic-rich mud rocks in the Atlantic-Tethyan-Carribean realm, leading to the assumption that the Coniacian-Santonian is a time of fairly widespread marine dysoxia/anoxia in low latitudes (Locklair et al., 2011; Wagreich, 2012). This may be also applicable to the studied area, being connected to the Atlantic Ocean.

Another ecological concept revolving around nutrient flux and bottom water oxygenation is provided by the Benthonic Foraminiferal Number (BFN). This is a useful proxy to reconstruct such variable environments in ancient times. In oxygen depleted sediments the BFN generally decreases, when in contrast an increase can be noted if a higher food flux is present (Friedrich et al., 2007). This in turn would also mean that the available oxygen is used up rather quickly and dysoxic or anoxic conditions could arise through the heightened input of organic matter and microbial activity. Variations in BFN are caused by numerous parameters in the water column above these bottom bound assemblages and are believed to be very sensitive to small changes in fertility of surface water regimes. Within the samples of our study we can see a moderate to high number of benthonic foraminifera and a somewhat moderate but stable diversity in all of the samples. When comparing these results to the scheme presented by Friedrich et al. (2007), it becomes clear that at least a moderate nutrient flux could have been present and oxygenation was relatively low in bottom water regimes.

Planktonic foraminiferal assemblage

The most prominent and dominating taxon within the planktonic forms is the genus *Archaeoglobigerina*, ranging from 35% to almost 50% of the total planktonic count, which could hint towards a more oligotrophic, warmer and stable environment in the water column in which these keeled and large (e.g.: *Globotruncana, Marginotruncana*), high trochospiral foraminifera (e.g.: *Whiteinella, Archaeoglobigerina*) prefer to live (Dubicka et al., 2014). Interestingly also the taxon *Planoheterohelix* is quite abundant in two of the quantitively assessed samples with 20% to almost 25%. Those bi-serial forms are generally interpreted as opportunistic r-selected cosmopolitan taxa that could strive whilst a significant event of environmental stress. Together with the high abundance of *Archaeoglobigerina* and the presence of *Whiteinella*, both r/k-selected genera, it can be inferred, that more nutrient rich close to meso- or eutrophic conditions become plausible (Petrizzo, 2002).

Typical k-strategists like *Globotruncana* and *Marginotruncana* are also abundant in all of the samples and, in contrast to the aforementioned meso- to eutrophic conditions, are known to inhabit more oligotrophic waters. When taking all the ecological preferences and traits of the found taxa into account this could point to a stable well mixed normal marine planktonic fauna within a stratified water column that provides the needed ecological niches. But due to the high abundance of *Archaeoglobigerina* as well as *Planoheterohelix* and their ecological needs, it can be assumed that mesotrophic conditions primarily dominated. Preceding or during Cretaceous Oceanic Anoxic Event (OAE) 1 and OAE 2 it can be seen that a turnover in microfauna composition took place and specialist taxa or k-strategists numbers were reduced significantly, whereas opportunists or r-strategists like *Heterohelix* proliferate (Premoli Silva, 1999). A similar state can be inferred through the foraminiferal assemblage and abundance found in this study, due to the increased presence of taxa like *Archaeoglobigerina* and *Planoheterohelix*. The material analysed can be ranged into the broader interval around the Coniacian-Santonian boundary using foraminiferal biostratigraphical markers, which would largely coincide with OAE3 timeframe, which in turn is supposedly mainly limited to the Atlantic Ocean and connected seaways (Friedrich, 2010;

Wagreich, 2012). This could mean that similar conditions were present in the northwesternmost part of the Tethyan Ocean System (e.g. Gebhardt et al., 2010), at least periodically and regionally, during this timeframe. It seems plausible when looking at the relative long duration and variability of OAE3 of several million years (Coniacian-Santonian, Wagreich, 2012) in comparison to other well defined OAE´s, which only lasted less than 1 Ma (Jenkyns, 1980).

5.4 Comparison of assemblages

Comparison with shelf assemblages from coeval Austrian sections

A comparison of foraminiferal faunas from other Austrian study areas of the same time interval seems to be in order to further characterise the described faunal composition of this work and to interpret the regional environment. As described by Wessely et al. (1981) for similar Cretaceous autochthonous strata in the base of the Molasse of Upper Austria a normal marine regime, outer shelf to bathyal depths, can be assumed through the PB-ratio of the foraminiferal assemblage (here 1.06) and foraminiferal taxa fitting this range can be found (e.g.: *Gyroidinoides, Lenticulina, Praebulimina*). Additionally also the presence of primitive agglutinated taxa, which can also be seen in this study, is reported. The material analysed in Wessely et al. (1981) was taken mainly from wells about 14 kilometres to the north of the region of this study. Fuchs et al. (1985) also described the absence of the genus *Dicarinella* in similar positions in Lower Austria, around the southernmost part of the Bohemian Massif.Another coeval shelf foraminiferal assemblage described by Egger et al. (2013) is found in the Gosau Group at Salzburg, Austria, several kilometres west of the here analysed region. Originally, these strata were situated palaeogeographically at the southern margin of the Penninic Ocean. However, this section shows strikingly similar results regarding the foraminiferal assemblage described from the Coniacian-Santonian, although the PB-ratio is reported at 2.46 compared to 1.06 of this study. Furthermore, the typical Cretaceous genus *Globotruncana* seems to be missing at the Gosau Group, but other planktonic taxa that are absent in this study are readily found, like *Globigerinelloides, Schackonia, Sigalia, Fingeria, Praeglobotruncana* or *Contusotruncana* for example. Although the assemblages seem to only differ in detail when looking at the present genera and species, the strong dominance of *Gyroidinoides* and *Archaeoglobigerina* was not found in all these other studies and seems to be typical of the study area at the European shelf of the Penninic Ocean.

Comparison with other coeval assemblages

While the correlation with studies in the relative close vicinity seems to be plausible, it seems to be a valuable addition to also compare habitats from elsewhere, to better understand the dominating ecological and environmental framework of the Coniacian – Santonian. Dubicka et al. (2014) presents results from the Dubivsti succession in western Ukraine, broadly matching the found taxa and also stating a decline in more complex k-selected specimen like *Globotruncana* and *Marginotruncana*. This can also be seen in the result of this study with the relative low abundance of these taxa compared with *Archaeoglobigerina* and *Whiteinella*, which represent intermediate r/k – selected taxa. Therefore here the relative low number in complex keeled taxa could hint towards the onset of a post Coniacian-Santonian cooling (Premoli Silva et al., 2002) due to the preference of the k-selected taxa being described as mesotrophic warm environments. A heightened abundance of *Planoheterohelix* is also stated herein, which holds true for the assemblage described in this study. Such high abundance of this genus is believed to be indicative of moderate to high nutrient saturation and rather low oxygenation (Nederbragt et al., 1998). Thus, it seems plausible that in addition to *Planoheterohelix* numbers also the more r-selected planktonic forms (*Archaeoglobigerina, Whiteinella*) were able to profit from the increased availability of organic material. Petrizzo et al. (2017) report an again very similar assemblage of typical Cretaceous taxa around the Coniacian-Santonian boundary from the Ruvuma Basin in southern Tanzania, with high numbers of *Marginotruncana* and *Globotruncana*, but only small numbers of *Archaeoglobigerina* and *Muricohedbergella*, never exceeding more than 20%. This can be seen as almost the opposite of the data acquired here in Bad Hall – Pfarrkirchen wells, where abnormally high numbers of *Archaeocretacea* and moderate numbers of *Muricohedbergella* and *Whiteinella* are present. The Tanzanian record is believed to reflect an outer shelf to upper slope environment, which also can be assumed from the data acquired from the analysed wells. Just like in the comparison with Cretaceous deposits in Austria the main striking difference in foraminiferal faunas seems to be the strong presence of *Archaeoglobigerina, Planoheterohelix* and *Gyroidinoides* that differentiates this very location from all other regions.

5.5 Paleobathymetric interpretation

Both methods used in this attempt of reconstructing the water depth in this region yielded plausible results, although a difference of roughly 350 m separates the two calculations. In general this can be seen as a possible depth range for the analysed region, due to the fact that the overall foraminiferal assemblage is reflecting a normal marine environment, regarding the PB-ratio of 1.06, with depths around the outer shelf (80 - 300 m) to upper bathyal (200 - 500 m) range (Wagreich et al., 1994). Furthermore the fact that both calculations use different approaches, with Van der Zwaan et al. (1990) using a complex system of many different factors influencing the distribution of planktonic forms in relation to benthonic forms. This in turn is strongly dependant on many different ecological parameters in the marine ecosystem (e.g.: chemical water composition, temperature, salinity, organic matter flux, Ph, etc.) and could be altered by a localized effect, as the benthonic biomass follows less predictable patterns as being sometimes unexpectedly high in places as for example anoxic basins (Van der Zwaan et al., 1990). This could also affect the bathymetric results in this study due to the strong dominance of benthonic forms as *Gyroidinoides* and the evidences for dysoxic to anoxic bottom water conditions. On the contrary Hohenegger´s (2005) method of estimating paleodepth is first and foremost only dependant on the presence and absence of taxa, therefore only using one paleo-proxy, which in turn is easier to control. Thus, it can be inferred, as the method is dependent on only one factor, it appears to be more reliable in the sense of its general application. Method one yielding a paleodepth of around 210 m and the second approach around 570 m one must note that when using two different models with distinctly different way of addressing one problem such a discrepancy of values is to be expected. Nevertheless as described before, due to the method of Hohenegger being supported by a subjectively more independent proxy, paleodepths of around 300 to 400 m become plausible in this context.

6.Taxonomic notes

All taxa found in the three in detail studied samples will be described shortly in the following section. Benthonic as well as planktonic specimens are listed here. Additionally stratigraphic ranges will be stated. Described specimens can be seen on the respective plates, where a unified magnification is used to better show relative size of the foraminifera as it would present itself to the observer through the microscope.

Genus *Archaeoglobigerina*

***Archaeoglobigerina blowi* (Pessagno, 1967)**

Plate 1, 1a-c

Description: Only four to five chambers in last whorl, rapidly increasing in size. Chambers appear to be spherical, with the last one being slightly elongate. Radial depressed sutures, straight on spiral and umbilical side, with a deep umbilicus. No keel shown in observed specimen. Earlier chambers again somewhat rugose, with the last one displaying a smoother texture compared to the earlier ones.
Stratigraphic Range: Santonian

***Archaeoglobigerina bosquensis* (Pessango, 1967)**

Plate 1, 2a-c

Description: Six to seven chambers in the last whorl, whereas coiling was observed with no extant preference for sinistral or dextral, but it should be noted that normally this species is considered to be typically coiled sinistral. Chambers are as wide as long, therefore appearing to be rather regular. Radial depressed sutures in both the spiral and umbilical side, with a relative deep umbilicus. The earlier chambers of the last whorl are somewhat rugose, with the final chamber showing a smooth texture.
Stratigraphic Range: upper-Turonian to middle-Campanian

Archaeoglobigerina cretacea (d ´Orbigny, 1840)

Plate 1, 3a-c

Description: The five to six chambers in the last whorl show a rough surface ornamentation consisting of small pustules, whereas the last chamber is significantly smoother than the rest. A keel is not present in every specimen but when observed often consists of the aforementioned pustules and is very weak. Shows strongly depressed radial sutures on the umbilical side of the test. Side view only displays slight bulge of the entire specimen.
Stratigraphic Range: upper-Turonian to Maastrichtian

Genus *Dicarinella*

Dicarinella asymetrica (Sigal, 1952)

Description: Trochospiral test with a strikingly asymmetrical shape, almost flat on the spiral and slightly convex on the umbilical side. The last whorl is comprised of up to six flat chambers arranged in a petaloid way on the spiral face, whereas the elements around the umbilicus appear to be slightly inflated and higher. The periphery is seamed by a narrow double-keel typical for the genus. Here the 3rd keel-like structure should be mentioned, located at the lower most part of the umbilical chambers. The umbilicus is deep and wide. Sutures on the spiral side are curved and moderately raised, whereas on the umbilical side they appear radial and straight with strong depression.
Stratigraphic Range: uppermost Coniacian to uppermost Santonian

Dicarinella canaliculata (Reuss, 1854)

Plate 2, 1a-c

Description: Trochospiral test, both flattened on the spiral and umbilical side. Periphery ornamented by a wide double keel. Six to seven chambers in the last whorl, shaped in petaloid to crescent way spirally, distinctly wedge shaped umbilically. Sutures on the spiral side curved and slightly raised, but straight on the umbilical side and slightly depressed.
Stratigraphic Range: lower Turonian to upper Santonian

Dicarinella concavata (Brotzen, 1934)

Plate 2, 2a-c

Description: Spiral side fattened maybe slightly concave. Large and very deep umbilicus, chambers five to seven show a narrow keel. Earlier chambers rough, somewhat rugose last chamber smoother in texture than those before. Typical for the genus *Dicarinella* a rather deep test is displayed with tightly pressed keels around the perimeter of the test.
Stratigraphic Range: upper Turonian to upper Santonian

Dicarinella hagni (Scheibnerová, 1962)

Plate 2, 3a-c

Description: Six to eight chambers can be found in the last whorl, whereas the last chamber is slightly bigger in size and more inflated. Tight keels on the periphery, somewhat deep and narrow umbilicus are typical for the genus. Chambers on the umbilical side show little pustules, the spiral side in comparison appears to be smoother. Sutures are ever so slightly curved on the spiral side and radial and straight on the umbilical side.
Stratigraphic Range: lower Turonian to upper Coniacian

Dicarinella primitiva (Dalbiez, 1955)

Plate 3, 1a-c

Description: Five to six chambers in the last whorl, increasing in size towards older chambers with slight inflation visible. Very close or doubled keels present on the periphery of the test seen in the side view. Rather large and deep umbilical area. Sutures on spiral side appear curved, whereas on the umbilical side straight radial sutures are displayed. Furthermore it can be seen that younger chambers appear to retain a smoother surface texture.
Stratigraphic Range: lower Turonian to upper Santonian

Genus *Globotruncana*

***Globotruncana bulloides* (Vogler, 1941)**

Plate 3, 2a-c

Description: Five to seven chambers are common in the last whorl; all chambers appear to be vaulted on the spiral as well as on the umbilical side. The typical double keel is mostly well developed and tends to grow narrower towards the younger chambers. Again the Last chamber is displaying a smoother texture. Large umbilical area compared to test size. On the spiral side arced sutures can be seen, whereas on the umbilical side they only appear as slightly curved.
Stratigraphic Range: upper Coniacian to upper Maastrichtian

***Globotruncana lapparenti* (Brotzen, 1936)**

Plate 3, 3a-c

Description: Five to six chambers observed in the last whorl, with a well-developed wide double keel around the periphery of the entire test. Spiral side displays chambers in a petaloid arrangement, bordered by a slightly raised bead on the curved sutures. This beaded sutures can also be observed on the umbilical side, where they are more strongly raised in comparison to the spiral side. The umbilical area appears to be rather large. Overall a relative smooth surface texture can be seen relative to other specimen from these samples.
Stratigraphic Range: lower Santonian to upper Maastrichtian

***Globotruncana linneiana* (d´Orbingy, 1839)**

Plate 4, 1a-c

Description: Five to six laterally slightly compressed chambers in the last whorl, therefore appearing a little elongate. Test appears to be almost flat on top and bottom, almost compressed. The periphery is showing a typical double keel that is well developed and revolving around the entire shell. Sutures on the spiral side appear to be arced and bordered by a strongly raised bead. The same features can be found on the umbilical side but the sutures are strongly curved and appear more tongue-shaped.
Stratigraphic Range: uppermost Coniacian to middle Maastrichtian

Laeviheterohelix sp. (Nederbragt, 1991)

Plate 13, 1-2

Description: Very similar in shape and chamber arrangement to the genus *Planoheterohelix,* but its chambers are more of a flattened to ovate shape. The nine to ten elements are separated by strongly depressed sutures, which are mostly straight and are canted at a steep angle towards the median axis. The last two chambers seem to be inflated and are also of the characteristic sub- spherical to flattened ovate shape. The surfaces are covered in similar striae and costae as in *Planoheterohelix,* but seem to be finer and more irregular in placement.

Genus *Marginotruncana*

Marginotruncana angusticarenata (Gandolfi, 1942)

Plate 5, 2a-c

Description: The trochospiral test features six to seven chambers in the final whorl. The shape is best described as tongue-shaped on the umbilical side, with clear overlaps between each single one clearly visible. Size of the chambers is increasing steadily and in a regular manner. From old to young a more elongate shape is achieved, hence tongue-shaped. A very narrow double keel lines the outside of the test. Sutures on both sides are beaded, more so on the umbilical side. The umbilical area appears to be rather wide and deep. Again the whole specimen shows a rather rough surface, except for the last chamber.
Stratigraphic Range: lower Turonian to upper Coniacian

Marginotruncana caronae (Peryt, 1980)

Plate 5, 3a-c

Description: Five to six chambers in last whorl and a trochospiral arrangement with a nearly flat spiral side. Petaloid chamber arrangement can be observed on the spiral side, whereas the umbilical side of the chambers is sub-rectangular. The periphery of the test is lined with a broad double keel, getting significantly wider on the last chamber. Sutures are moderately raised on both sides and slightly beaded. All chambers with exception of the last two show a somewhat rugose surface with singular pustules randomly scattered. The two last ones are of a smoother surface texture.

Stratigraphic Range: lower Turonian to upper Santonian

Marginotruncana marginata **(Reuss, 1845)**

Plate 6, 1a-c, 2a-c

Description: Six to seven chambers in the last whorl, relative to other foraminifera this taxon is very big in comparison. Test is slightly compressed and a trochospiral chamber arrangement can be observed. Chambers are vaulted on the spiral side and inflated on the umbilical side. Due to the greater size a large and wide umbilicus can be seen. On the periphery of the test a double keel can be seen on the older chambers, which slowly fuses into one singular keel the younger the chambers get. Sutures can be seen slightly beaded and curved on the spiral side as well as the umbilical side with a slighter curve and more beading. Test ornaments strongly present in form of pustules, except for the last chamber which again shows a much smoother surface.

Stratigraphic Range: lower Turonian to upper Santonian.

Marginotruncana pseudolinneiana **(Pessango, 1967)**

Description: The test presents itself as very planar in comparison with other taxa of the genus, although it seems to exert trochospiral coiling. The periphery is ornamented with a clearly visible, somewhat wide, double keel. The chambers are visibly separated by raised and slightly beaded sutures. The same holds true for the umbilical side where also curved and beaded sutures border the chambers. The umbilicus can be described as large and moderately deep on this specimen. Overall the test seems to be covered in small pustules, only for the roughness to get weaker on the surface of the last chambers.

Stratigraphic range: lower Turonian to middle Campanian

Marginotruncana sinuosa **(Porthault, 1970)**

Plate 7, 1a-c

Description: Five to six chambers in the last whorl, with a flattened trochospiral test. The two keels on the periphery of form a sinuous outline. Chambers on the spiral side also display a somewhat sinuous or undulating habitus. Furthermore they are arranged in a petaloid manner with raised beads. On the umbilical side the chambers seem to be elongated in coiling direction and overlapping with a strongly raised bead. The umbilicus is rather wide and strongly curved sutures can be seen.

Stratigraphic Range: lower Turonian to upper Santonian

Genus *Muricohedbergella*

***Muricohedbergella crassa* (Bolli, 1959)**

Plate 7, 2a-c

Description: Low trochospiral coiling and globular almost inflated chambers present themselves. The specimen seems to be of rather small size relatively speaking. Due to the strongly depressed sutures on the periphery the outline can be described as somewhat lobulate. The umbilicus can be described as narrow and deep. The five chambers of the last whorl are increasing in size only gradually. The test seems to be covered by a texture of medium roughness, whereas again the last chamber is somewhat smoother.

Stratigraphic range: lower Turonian to upper Coniacian

***Muricohedbergella delrioensis* (Carsey, 1926)**

Plate 7, 3a-c

Description: Test with a lobulate outline can be seen with low trochospiral coiling. Sutures are well depressed. Pustules cover the entire shell except for the last chamber. Five to six chambers in the last whorl getting gradually bigger with each element added. The last one seems to be slightly offset towards the umbilicus and appears to be inflated towards the umbilical side.

Stratigraphic range: uppermost Albian to lower Turonian

***Muricohedbergella portsdownensis* (Williams-Mitchell, 1948)**

Plate 7, 4a-c

Description: Trochospiral test with six to seven chambers in the last whorl with moderately to deeply incised sutures. The shape of the elements seems to be irregular and slightly compressed in some cases, whereas the surface roughness isn’t present on the last chamber, it appears to be almost perfectly smooth. The umbilical area is moderately wide and deep.

The extension of the chambers is most prominent on the last one.
Stratigraphic range: Cenomanian to upper Coniacian

Genus *Planoheterohelix*

***Planoheterohelix globulosa* (Ehrenberg, 1840)**

Plate 16, 1

Description: Test is generally of small size and stacks its eight to thirteen mostly globular chambers in a biserial manner. The elements increase gradually with each stage added, whereas the final two pieces seem to be larger and more inflated. The outline appears to be triangular due to the mode of stacking. The sutures seem to be slightly slanted away from the median axis and appear to be mostly straight with a moderate extent of depression. The aperture is often hard to distinguish in the examined specimen but seems to be somewhat rounded to half spherical on the lower most part of the final chamber, oriented towards the middle axis. The surface ornamentation of the hyaline walls consists of costae or striae which are small in size and tightly packed on the surface. It is of note here that the orientation of this features seems to be the same for most of the taxa in this genus in the way that the length of the costae is mostly parallel to the median axis.
Stratigraphic range: upper Cenomanian to upper Maastrichtian

***Planoheterohelix praenuttalli* (Huber & MacLeod, 2015)**

Plate 16, 2

Description: The comparatively small test consist of nine to eleven biserially stacked chambers, gaining in size only slowly as each element is added. The final two chambers are much larger relative to the rest and appear to be canted towards one side. The outline is of triangular shape, which is only disturbed by the final chambers being slightly out of alignment. The sutures meet the median axis generally at an angle, are mostly straight and are moderately to strongly depressed. Again the typical surface ornamentation if this genus is present but the striae or costae seem to be the slightest bit larger in comparison.
Stratigraphic range: lower Turonian to upper Coniacian

Planoheterohelix reussi **(Cushman, 1938)**

Plate 16, 3

Description: The small size of the shell relative to other taxa fits the genus and the stretched triangular outline of the ten to twelve chambers presents the specimens typical form. Here the elements increase in size is more gradual, this also holds true for the uppermost chambers, although they seem to be sub spherical compared to the earlier more rounded stages. Sutures are more or less straight and at a slight angle respective to the median axis, with a moderately depression. The striae or costae which make up the surface ornamentation are also typical and are evenly spaced on the entire test.
Stratigraphic range: lower Turonian to upper Santonian

Planoheterohelix sphenoides **(Masters, 1976)**

Plate 16, 4

Description: The biserial chamber arrangement of the test with its gradual increase in size per element forms a triangular outline. Initially the elements seem to be of sub-spherical shape but as more are added a distinct lentil looking, flattened shape takes over. Generally speaking it seems as if the entire test is more flattened when compared to other species of the genus. Otherwise the sutures are mostly straight and meet the median axis at a right angle. The last two chambers are slightly curved inwards. The aperture can be found medial at the bottom of the highest camber. Costae and striae are mostly straight on the tests surface, but seem be follow the inwards curve on the last two elements.
Stratigraphic range: lower Coniacian to upper Santonian

Genus *Whiteinella*

Whiteinella archaeocretacea **(Pessango, 1967)**

Plate 5, 1a-c

Description: Four to six chambers arranged in the last whorl, first starting relatively small in earlier whorls and becoming rather large in comparison. Chambers are shaped slightly ovate, which is becoming more prominent in the youngest ones. Strongly depressed straight sutures are displayed on both the umbilical and spiral side. The umbilical area appears to be very large but no overly deep. All chambers are covered by pustules, except the final one. It features a smooth surface texture.

Stratigraphic Range: upper Cenomanian to upper Santonian

Whiteinella baltica **(Douglas & Rankin, 1969)**

Plate 4, 3a-c

Description: Four to five sub globular chambers in the last whorl. Rather big increase in chamber size from first to final chamber. Umbilical area wider than deep, with radial slightly curved to straight moderately depressed sutures.

Stratigraphic Range: upper Cenomanian to lower Campanian

Whiteinella brittonensis **(Pessagno, 1967)**

Plate 4, 2a-c

Description: Five to seven chambers in the final whorl, whereas the chamber size appears to be rather irregular. Surface texture is rough consisting of small pustules, except for the final chamber being smooth in surface finish. Chamber shape appears to be globular, with deeply incised sutures on the umbilical side rather than the moderately depressed ones on the spiral side. A deep and large umbilical area with radial straight sutures can be seen.

Stratigraphic Range: lower Turonian

Benthonic Foraminifera

Ammobaculites agglutinans **(d´Orbigny, 1846)**

Plate 8, 1

Description: Overall the test seems to be elongate, with a straight portion at the upper part and a tightly planispiral coiled bottom. Here the shown specimen is very rough and therefore no exact chamber count can be discerned. Nevertheless the initial coiling can be seen and seems to consist of one to two whorls. The coarse agglutinated walls make it hard to see further detail, which might have something to do with the preservation of this individual.

Stratigraphic Range: Upper Cretaceous to recent

***Anomalina* sp. (d´Orbingy, 1840)**

Plate 8, 2

Description: The last whorl of this taxon's test shows seven to nine chambers in an involute arrangement, whereas the last elements could be seen as nearly planispiral. On the spiral side the test can be described as vaulted and on the umbilical face a nearly flat suface presents itself. Sutures are only slightly depressed in this specimen, although individual chambers can be distinguished. The outline of the test can only be described as slightly lobulate, due to the more prominent sutures on the periphery. The last chamber appears to be strongly inflated compared to the rest of the elements.
Stratigraphic range: Coniacian to Campanian

***Arenobulimina preslii* (Reuss, 1845)**

Plate 8, 3

Description: This taxon has a rather large acute ovate test with approximately three to five whorls of chambers. The walls consist of fine to middle grained material. Last chamber is somewhat kidney-shaped and envelops half of the last whorl. Sutures are slightly depressed and the bigger chambers can be clearly distinguished. The aperture seems to be drop-shaped and is located on top of the coiling axis.
Stratigraphic range: Turonian to Maastrichtian

***Bathysiphon* sp. (Samuel, 1977)**

Plate 8, 4

Description: The test is tubular in some cases a slight lateral compression can be observed. Normally this taxon incorporates sponge spicules in its agglutinated test, but in this case many pyritic elements can be seen. The habitus of these grains ranges from angular to more framboid like geometries held together by the initially organic cement.
Stratigraphic range: upper Ordovician to recent

***Bolivina incrassata* (Reuss, 1851)**

Plate 9, 1

Description: Slender test acute at the bottom and more rounded on top, due to the form of the last two chambers. Approximately eight elements can be counted in the specimen described, which are of elongated narrow elliptical shape. The sutures seem to be straight and at a steep angle towards the median axis, while being weakly depressed. Unfortunately it should be noted that small areas of the test are covered in residual glue stemming from the mounting procedure. Otherwise the surface seems to be smooth, as expected from the hyaline material.
Stratigraphic range: Upper Cretaceous

***Cibicidoides* sp. (Brotzen, 1936)**

Plate 9, 2

Description: Again a vaulted spiral side and a nearly flat to concave umbilical side can be seen on this specimen. The sutures are slightly depressed and somewhat curved. The last whorl shoes seven to eight chambers, with a lobulated circular outline due to the sutures.
Stratigraphic range: Upper Cretaceous

Genus *Dentalina*

***Dentalina cylindroides* (Reuss, 1860)**

Plate 9, 5

Description: The smooth, large and elongate uniserial test is made up of three chambers, which are of ovate to elliptical form. They are delimited by gentle to moderate constrictions. The first two elements are of similar size, whereas the third seems larger and overall more elongate than the other ones. At the apex of this final chamber the basket like aperture is found, with its radial striae surrounding the point.
Stratigraphic range: Lower Cretaceous to Palaeocene

Dentalina laevigata (Schwager, 1865)

Plate 9, 4

Description: The test is of relative large overall size. The uniserial stacked chambers present an ovate to elliptical form and increase in size only gradually in the first three elements. The final one is noticeably bigger both in length and cross section. The basket like aperture is located at the apex of the last chamber, which is typical for the genus. Otherwise the hyaline surface is smooth without any ornamentation to speak of.
Stratigraphic range: Cretaceous

Dentalina sp.

Plate 9, 3 & 6

Description: Mostly fragments that display enough typical features are placed under this designation. They vary in size and unfortunately are missing key features needed for further identification. In general typical elongate cylindrical tests to broken of spherical, sub-spherical and ovate elements are placed here. Some final chambers with intact apertures are found, but miss the main body. The few apertures can be described as basket like with radial striae around the point. All show a smooth hyaline surface which would also be typical for the genus.

Dorothia pupa (Reuss, 1860)

Plate 9, 7

Description: This specimen displays a somewhat poor preservation, hence it is not possible to easily distinguish the chambers or sutures. The overall shape can be described as ovate with the last chambers slightly more inflated. Normally it would be typical for this taxon to display spiral whorls in the first few chambers and after that switch to a biserial arrangement. This is not perfectly evident in this case, but the overall shape of the taxon fits the description. Additionally to that the walls seem to be of a fine agglutinated material.
Stratigraphic range: Santonian to lower Maastrichtian

Genus *Frondicularia*

***Frondicularia angusta* (Cushman, 1943)**

Plate 10, 1

Description: The same type of test shape as in most taxa of this genus can also be seen here, although the shape is more aggressively elongated. The same is true for the individual chambers. They appear to strongly elongate bordered by slightly depressed striated sutures. Here the first chamber cannot be seen due to breakage, but the typical aperture is displayed, with its drawn out last chamber and basket like opening. Overall the test appears to be relatively flat, without such a prominent lateral groove.
Stratigraphic range: Coniacian to Maastrichtian

***Frondicularia angustissima* (Reuss, 1860)**

Plate 10, 2

Description: The fragment shown here can be identified due to its very good state of preservation and the taxon can be inferred. An overall elongate shape can be assumed which is typical for this genus. The sutures can only be described as regularly positioned ribs that form a steep angle towards the median axis of the test. These ribs clearly distinguish the chambers from each other, appear to be slightly beaded and form an acute point (v-shaped) in the middle of the surface.
Stratigraphic range: Turonian to Upper Cretaceous

***Frondicularia archiaciana* (d´Orbigny,1840)**

Plate 10, 3

Description: The specimen shown here all miss their last chambers, due to them breaking off. Nevertheless the remaining parts of the test are indicative enough. The elongated chambers again are angled in steep fashion towards the median axis. Also the ribs, clearly displaying the separation of the chambers, are angled in a similar fashion, therefore forming the distinct v-shape. Although this shape can also be seen in other taxa, here a grove exactly in the middle is left open. The first camber is also ribbed and spherical.
Stratigraphic range: Santonian to Maastrichtian

***Frondicularia* sp.**

Plate 11, 1-2

Description: The first specimen under this designation is of relative small size when compared to the other taxa of the genus. It features a ovate outline with a drawn out aperture on the top and a more rounded dull elongated bottom. The side is flat and narrow, except for the spherical bulge in the centre of the shell. Very weak raised sutures can be seen bordering the rounded medial bulge. The second individual placed here is of bigger overall shape and area. The test is flat and narrow in the side view. Its stepped outline is increasing rapidly with each step and element added. The chambers are clearly delimited by the moderately raised sutures, which are placed at a steep angle towards the median axis. The v-shaped sutures aren't meeting in the middle, here a well visible gap can be described.

Genus *Gaudryina*

***Gaudryina cretacea* (Karrer, 1870)**

Plate 11, 3

Description: Test is of triangular shape in both outline and cross section, whereas the outline could also be described as acute ovate. From the initial point the chambers grow in size with each element added. Nearly flat to slightly concave surfaces can be seen on the three sided test, which ultimately terminate in also three ridge lines on the corners. The test is very smooth in texture making it very hard to discern features like sutures or individual chambers. On the rare occasion they can be seen, it seems that they are slightly slanted away from the medial axis. A half circular or crescent shaped aperture can be assumed located centred between the last two slightly inflated chambers.

Stratigraphic range: Upper Cretaceous

***Gaudryina helvetica* (Hagn, 1953)**

Plate 11, 4

Description: From the acute point the relatively small test gains in size gradually with each chamber added. The cross section is of triangular shape, whereas the sides are slightly concave ultimately ending in ridges along the three corners. Suture lines are not easily discerned therefore individual chambers are also hard to distinguish. Nevertheless they appear to be slightly slanted away from the medial axis. The aperture is also not readily seen and can only be vaguely described as crescent or half circular. The walls seem to be of a fine agglutinated material.

Stratigraphic range: Upper Cretaceous to Danian

Gaudryina pyramidata **(Cushman, 1926)**

Plate 11, 5

Description: Compares nicely to *Gaudryina helvetica* or *Gaudryina cretacea*. It is of very similar shape to the mentioned taxa with its triangular shape. Whereas here the side walls seem to be flat to almost a little convex in comparison. Also the ridges on the corners appear to be not as sharply defined as in other specimens the top last two chambers are also not as strongly inflated. Aperture is in a similar central position. Wall material is of fine grain size and agglutinated.

Stratigraphic range: middle Coniacian to lower Campanian

Gaudryina **sp.**

Plate 11, 7

Description: Tests are of more or less ovate shape with a slightly triangular outline and also triangular cross section. Some individuals switch to a biserial chamber arrangement within the older chambers, which is often very hard to discern due to bad preservation or very rough and coarse agglutinated material of the walls.

Gaudryina supracretacea **(Hofker, 1956)**

Plate 11, 6

Description: Test is of ovate shape with a somewhat acute point at the bottom. Most prominent in this taxon is the switch from a triangular to what can only be described as biserial, may be rounded rectangular cross section slightly below the half point of the test. The first few chambers also display the flat to concave sidewalls seen in other taxa of this genus, with also the ridges on the corners being present. Above this initial part seemingly inflated chambers are seen, whereas the last two appear to be more rounded. The aperture

can be seen again in the middle between the last two chambers and is of half circular shape. Overall wall texture is smooth, consisting of fine agglutinated material.
Stratigraphic range: Upper Cretaceous

Gavellinella pertusa **(Marsson, 1878)**

Plate 11, 8

Description: The lenticular shaped test seems to be vaulted on the spiral side and flat on the umbilical side. Trochospiral coiling can be seen and the periphery is rounded. Chambers are hard to see in the earlier section of the test and become more prominent in the oldest part, due to the smooth surface hiding the nearly non depressed sutures.
Stratigraphic range: Santonian to lower Maastrichtian

Gerochammina lenis **(Grzybowski, 1896)**

Plate 12, 1

Description: Unfortunately the switch from triserial to biseral isn’t very easy to seen in the REM-pictures but more prominent under the binoculars when wetting the specimens. Overall an elongate ovate shape with a dull point at the bottom best describes the outline of this specimen. The walls are agglutinated and of medium to coarse grains. The aperture is found on the upper most part of the biserial section, exactly on the median axis. Additionally the last chamber is somewhat kidney shaped and slightly inflated.
Stratigraphic range: upper Turonian

Glandulina **sp. (d´Orbigny, 1839)**

Plate 12, 2

Description: The test is of elliptical shape and has two drawn out apexes on top and bottom. Only the outer most chamber is visible, which displays a rather featureless smooth surface. The aperture on top seems to be a perforated disk of some sort. Another specimen shows a slight constriction at the midpoint between the apexes.

***Globorotalites michelinianus* (d´Orbigny, 1840)**

Plate 12, 4a-b

Description: Trochospiral test with a very unique shape. The overall conical shape of the test is flat both on top and bottom and high along the coiling axis. Due to the surfaces smooth appearance neither sutures nor chambers are easily discerned. Periphery is angular and of trapezoid like shape.

Stratigraphic range: Turonian to Maastrichtian

Genus *Gyroidinoides*

***Gyrodinoides nitidus* (Reuss, 1844)**

Plate 12, 6a-b

Description: Trochospiral test with a half- spherical to conical shape with a flat umbilical side. Chambers can only be distinguished within the last few elements due to the sutures being more visible there. Therefore a five to six chambers are present in final whorl. On the umbilical side only shows the last one to one and a half whorls and presents the slightly inflated bottom of the last few chambers, only visible due to the weakly depressed sutures. The aperture is located at the proximal edge of the last chamber and is of slit-like form.

Stratigraphical range: Lower and Upper Cretaceous

***Gyrodinoides preaglobosus* (Brotzen, 1936)**

Plate 12, 5a-b

Description: Small trochospiral, half-spherical test with a flat umbilical side. Chambers are not easily discerned due to the weakly depressed sutures and the smooth surface. The last three to four chambers can be seen and therefore the final whorl should consist of five to six chambers total. On the umbilical side the almost flat surface presents one and a half whorls overall. The aperture is a fine slit along the proximal edge of the last chamber.

Stratigraphic range: Santonian to Maastrichtian

***Gyrodinoides umbilicatus* (d´Orbigny, 1840)**

Plate 12, 7a-b

Description: Half-spherical to only slightly conical trochospiral test with a smooth surface, again with a flat umbilical side. From the spiral view chambers are very hard to see, due to the only delimitation being the weakly depressed sutures on this side, but on the umbilical side depression of the same feature is to be describes as moderate to strong, therefore enabling a chamber count of six to nine in the last whorl. Chambers seem to be slightly inflated on the umbilical side. The aperture is slit like and narrow, located at the proximal edge of the last chamber.
Stratigraphic range: Lower and Upper Cretaceous

***Kalamopsis grzybowski* (Dylazanka, 1923)**

Plate 12, 3

Description: It should be noted that the described specimen is most likely a fragment and is missing some features. Overall the test seems to exert a cylindrical shape, with moderate constrictions along its axis. The sections between the constrictions appear to be stretched along the main axis and therefore appear slightly elongate. Usually the test wall should display fine agglutinated material, but in this case again spherical grains can be discerned which might be of pyritic origin.
Stratigraphic range: Upper Jurassic to recent

Genus *Lenticulina*

***Lenticulina comptoni* (Sowerby, 1818)**

Plate 13, 3

Description: Overall very large test, symmetrical and lenticular in shape and form. The periphery is formed by a sharp keel running from the tip of the last chamber until it enters the triangular face of the last chamber on top of which the aperture is situated. The umbilical area is thicker and represented by a symmetrical bulge equal on both sides in the middle of the test. Surface texture of the hyaline shell can be described as very smooth, making it hard to distinguish individual sutures and chambers. These features are more prominent under the binocular and slightly curved radial sutures bordering tight chambers can be seen.

Stratigraphic range: Cenomanian to Danian

Lenticulina gibba **(d´Orbigny, 1839)**

Plate 13, 4

Description: Here also a relatively large test with a somewhat elongate rounded outline presents itself, with the aperture positioned on the apex of this form. The test is symmetrical and peripherally seamed by a sharp keel. The keel is present from the aperture until it enters the slightly convex triangular face of the last chamber. In the middle of the symmetrical shape the umbilical area seems to be inflated and raised compared to the more distal parts. As said before the aperture sits at the apex of the elongate part of the shell and can be described as basket like with its multiple striae radially placed around the point. The surface is smooth, hence sutures and chambers are hard to distinguish.

Stratigraphic range: Turonian to recent

Lenticulina macrodisca **(Reuss, 1862)**

Plate 13, 5

Description: Again comparatively speaking this taxon shows a very large test with a more circular outline. The umbilical area is determined by the symmetrically inflated area in the middle of the test. A sharp keel lines the periphery, which starts at the top at the aperture and terminates in the frontal triangular face that shows a convex bulge. The aperture itself can be described as basket like with radial striae around the centre of the point. The tests surface is smooth, but sutures and chambers can be seen under the binocular. Six to eight chambers are bordered by ever so slightly curved sutures.

Stratigraphic range: Lower Cretaceous to middle Upper Cretaceous

Lenticulina nuda **(Reuss, 1862)**

Plate 14, 1

Description: Here a large flattened acute ovate test presents itself, with a flat triangular somewhat convex frontal face of the last chamber. Laterally this specimen seems to be a little compressed, but as seen in other taxa of this genus is lined on the periphery by a sharp keel terminating in the frontal face of the last chamber. The basket like aperture is located at the apex and again consists of radial striae around the centre point. The umbilical area is inflated on both sides. The test is smooth on the surface with not sutures or chambers seen in the REM-picture, but under the binocular almost straight septae with eight to nine elements can be discerned.

Stratigraphic range: Lower and Upper Cretaceous

Lenticulina rotulata **(Lamarck, 1804)**

Plate 14, 2

Description: An overall large size and circular outline with a high triangular frontal face of the last chamber best describe the shape. The periphery is lined with a keel, although here it seems to be somewhat dull in comparison with other taxa, but originates at the apical aperture and terminates at the bottom of the frontal face. The umbilical area isn't overly inflated as in other specimen but seems to be moderately high on both sides. Surface texture is smooth to the point that neither sutures nor chambers can be discerned. The aperture at the apex seems to be broken and only striae on the side of the frontal face can be seen.

Stratigraphic range: Cretaceous to recent

Lenticulina secans **(Reuss, 1860)**

Plate 14, 3

Description: Rather large test with a sub circular outline, with a relatively small frontal triangular chamber face and a sharp keel lining the periphery until its termination at the frontal face. The umbilical bulge is clearly visible and is symmetrical. The sutures can be seen as small undulations in the otherwise smooth surface. They seem to be curved and originate in the centre of the umbilical bulge. Therefore eight to ten chambers can be counted in the final whorl. The aperture seems to be broken off in several specimens but can be described again as basket like.

Stratigraphic range: Albian to lower Campanian

***Lenticulina* sp.**

Plate 13, 6

Description: Somewhat typical for the genus is the large size observed. The test seems to display a circular outline which is broken by angled segments with well rounded corners. The shell is symmetrical with the umbilical inflated bulge in the centre. The periphery is lined by a sharp keel that terminates in the triangular face of the last chamber. The aperture is located at the apex of the last chamber and can again be described as basket like with radial striae. Some undulations can be seen in a radial pattern on the otherwise smooth surface of the taxon, which represent the overly strait sutures. Therefore six to eight chambers in the last whorl can be counted.

***Marsonella trochus* (d´Orbigny, 1840)**

Plate 14, 4-5

Description: The test is of conical shape and tapers to a dull point at the bottom. Its cross section can be described as circular and increases gradually in size as more chambers are added. The last few chambers seem to be organized in biserial manner, as they are positioned opposite of one another. In general the surface of the specimen displays a fine to medium grained agglutinated wall and is therefore rather featureless. The upper most chambers seem to be larger in the horizontal plane as compared to the low vertical height and are slightly inflated. The last two chambers seem to be positioned at a slight angle, dipping away from the aperture and the median axis.
Stratigraphic range: Lower and Upper Cretaceous

Genus *Nodosaria*

***Nodosaria filiformis* (d´Orbigny, 1826)**

Plate 15, 1

Description: Very long and slender test with many chambers delimited by gentle constrictions normal to the medial axis of the specimen. Overall the shell seems to be slightly curved. The individual elements are of elongate ovate to oval shape and increase slowly in size as more are added. The surface is very smooth and lacks any ornamentation.

The specimen shown here is most likely a fragment of the middle part and lacks the first and last chambers.
Stratigraphic range: Upper Cretaceous

Nodosaria monile **(Hagenow, 1842)**

Plate 15, 2

Description: Specimen is of large size and consists of sub spherical to ovate chambers stacked on top of each other. The elements increase only marginally in size, appear bulbous or inflated and are separated by strongly depressed sutures. The surface is smooth but seems to be a little rougher in direct comparison with other specimen. The aperture lies at the dull apex of the last chamber and appears to be a disk with radial striae. Unfortunately the lower part of the test is missing as it seems to have broken off.
Stratigraphic range: Maastrichtian to Campanian

Nodosaria **sp. (Lamarck, 1816)**

Plate 15, 3

Description: Long tubular shaped tests with a smooth surface are places in this genus here. The upper most part shows two slight to moderate constrictions and the aperture at the top is crested. The two individuals shown are of rather large size in comparison and both miss their lower end. One assumed lower end is also shown in the plates which is of similar size and surface smoothness.

Planularia liebusi **(Brotzen, 1936)**

Plate 16, 5-6

Description: The overall oval test with a more acute tip on the aperture and a rounded bottom shows a very gently sweeping curvature on the ventral side and a longer stronger one on the dorsal border. The initial coil is smaller in diameter than the oval older part and is hardly pronounced. The aperture is of a basket like type with radial striae around the point. The surface of the test is very smooth, where no sutures can be discerned, only in the second individual found the sutures can be described as raised and are easily seen. When examined under the binocular, the hyaline transparent test is see through and chambers and septae can be seen. Chambers appear to be narrow and slightly curved.

Stratigraphic range: Cenomanian to Santonian

Genus *Praebulimina*

***Praebulimina hofkeri* (Brotzen, 1936)**

Plate 15, 4

Description: Small somewhat elongate acute ovate shape of the test, with a circular cross section gaining in size only gradually as every element is added. The final whorl consists of three to four chambers, which appear to be stretched in the direction of the coiling axis. This last part only envelops about half of the entire specimen. Moderately depressed sutures delimit the chambers. The aperture lies on the upper most part of the suture separating the last and second to last chamber and can be described as a drop-like slit. The entire test is covered in by a smooth surface.

Stratigraphic range: Upper Cretaceous

***Praebulimina pusilla* (Brotzen, 1936)**

Palte 15, 5

Description: Small acute ovate test with a somewhat circular crossection, which increases gradually with every whorl added, whereas the final one consists of three to four elements and almost envelops two thirds of the entire shell. The moderately depressed sutures delimit the chambers clearly, most prominent in the oldest part. The aperture lies on top of the coiling axis, in between the last few chambers. Its shape can be describes as and slightly elongated drop-shape. The hyaline surface is rather smooth and imperforate.

Stratigraphic range: Coniacian to Santonian

***Praebulimina ventricosa* (Brotzen, 1936)**

Plate 15, 6

Description: Acute ovate test with a pointier or narrower lower part. The circular cross section increases rapidly in size and three to four chambers form the last whorl. This few final elements again envelop well over two thirds of the entire specimen, where also the moderately depressed sutures can be seen. The aperture lies at the apex of the last chamber

and is formed like a drop shaped slit. The surfaces smooth texture is only disturbed by debris clinging to it.
Stratigraphic range: Coniacian to Maastrichtian

Pyramidulina sp. (Fornasini, 1894)

Plate 16, 7

Description: Very large individual, which is likely a fragment, missing its top and bottom. Nevertheless the five uniserial chambers observed grow gradually in size with each element and are of sub-spherical shape. The sutures between them are easily discerned due to the strongly depressed constrictions. The surface is ornamented with thick and wide ridges, orientated parallel to the median axis of the test. Otherwise the surface is very smooth as expected from the hyaline test material.

Ramulina wrightii (Barnard, 1972)

Plate 16, 8-10

Description: Spherical to ovate main elements connected by slender tubes on top and bottom. The connecting tube is smooth and lacks any form of surface ornamentation, whereas the main test compartment is covered in small stubs or spikes all over the sphere. A maximum of two connected orbs can be described in the here examined specimens.
Stratigraphic range: Lower Cretaceous to recent

Recurvoides sp. (Earland, 1934)

Plate 17, 1-2

Description: The test is of circular outline, with the inner whorl being of streptospiral coiling, whereas the final or outer whorl seems to exert planispiral to very low trochospiral coiling. The chamber count is not easily discerned, due to the coarse nature of the agglutinated walls and only weakly depressed sutures. The aperture appears to be a narrow slit lining the proximal vertical part of the last chamber.

Genus *Reophax*

Reophax scalaris (Grzybowski, 1896)

Plate 17, 3

Description: The chambers are arranged in a uniserial manner and grow in size only slowly with the addition of each element. Overall the test appears to be visibly curved and slightly flattened. Looking at the shape of the chambers, it can be said that they seem to be somewhat crushed or deflated. Comparatively speaking the agglutinated walls are of medium sized grains.

Stratigraphic range: Lower Cretaceous to Middle Oligocene

Reophax sp.

Plate 17, 4

Description: The test is consists of spherical to sub-spherical chambers arranged in a uniserial manner. In some of the found specimen a gradual increase in size of the elements can be noted, whereas in others a more uniform rather elongated rectangular outline presents itself. A slight overall curvature can be seen in some specimen. Generally cambers are clearly delimited by the moderately depressed sutures, although the rough texture of the agglutinated walls can obscure some of the finer details.

Genus *Spiroplectammina*

Spiroplectammina flexuosa (Grzybowski, 1898)

Plate 17, 5

Description: As seen in other taxa of this genus the overall shape of the specimen is elongate here with a somewhat dull initial planispiral part at the bottom. In this specimen the coiling of the first few chambers can be distinguished somewhat better than in other forms due to its relative big size. Chamber arrangement then switches to a biserial form with many chambers slightly angled from the median axis. Towards the older chambers a rapid increase in volume of the flattened elements can be observed. The walls are again agglutinated consisting of very fine grained material.

Stratigraphic range: Upper Cretaceous to Eocene

Spiroplectammina navarroana (Cushman, 1932)

Plate 17, 7

Description: The specimen appears to be slightly elongate with an acute triangular shape. The chambers seem to be as long as they are wide and increase gradually in size as more are added. Finally the last one to two elements are somewhat bigger than the previous ones. The agglutinated wall appears to incorporate medium to fine sized grains. In this specimen the sutures appear to be only slightly depressed and are not easily visible.
Stratigraphic range: Turonian to Eocene

Spiroplectammina spectabilis (Grzybowski, 1898)

Plate 17, 6

Description: Test starts of as planispiral in for the first very small chambers, later it becomes biserial. In comparison with the first planispiral part the chambers increase rapidly in size and count. Chambers seem to be low only gaining little height with each element added, though gradually increasing in overall size. Sutures as well as chambers are inclined towards the medial axis of the specimen. The wall displays a finely agglutinated texture.
Stratigraphic range: Upper Cretaceous to Upper Eocene

Spirophthalmidium cretaceum (Reuss, 1854)

Plate 18, 1

Description: The porcelaneus test is of oval shape with acute tips at the end of the longer half axis. Its cross section seems to be rectangular and multiple whorls, four to five, of two chambers each can be distinguished. Generally speaking the chambers can be described as narrow and elongate rectangular elements which are slightly curved and therefore conformed to the earlier parts of similar form. Sutures are visible and seem to be slightly raised and minutely beaded.
Stratigraphic range: Cenomanian to Maastrichtian

Textularia sp.

Plate 18, 2

Description: The biserial test shows a rapid increase in chamber size in the first elements. After this initial part the chambers are of uniform sub-spherical form, with only a very slight increase of volume towards the top. Sutures seem to be moderately depressed and well visible on the majority of the tests surface. Furthermore they appear to be mostly straight, angled towards the median axis and might be somewhat curved. The agglutinated walls are made of medium grain size relatively speaking.

Uvigerinammina sp.

Plate 18, 4

Description: Biserial test with somewhat compressed spherical chambers, showing gradual size increase with each element added. Sutures seem to be weakly depressed and are not all that clear. The surface of the test seems to be rather rough due to the medium to coarse grained wall material. It should be noted that the specimen described here also shows a certain similarity to *Reophax* sp. also found in the samples.

Vaginulina trilobata (d´Orbigny, 1840)

Plate 18, 3

Description: No complete specimen could be found in the analysed samples, therefore the described features are all derived from fragments, mostly lacking the upper part of the individual. The test is elongated and gains only little in size with each element added. The cross section seems to be elliptical. The lower most part appears to sown some kind of slight coiling, but is very small compared to the rest of the shell. The individual chambers are distinctly wider than high and delimited by strong and sharply formed bulges, which represent the sutures. This septae are nearly horizontal to slightly canted towards one side. The hyaline test seems to be very smooth.

Stratigraphic range: Coniacian to Maastrichtian

***Verneuilinoides* sp.**

Plate 18, 5

Description: Seems to display a triserial arrangement of its chambers, with a gradual increase in size of each element added. The shape of the individual chamber can be described as spherical or rounded, delimited by weakly depressed hard to discern sutures. The last chamber seems to be positioned a little bit higher than the rest. The agglutinated wall displays are rather rough texture.

6.1 SEM-Plates

The following SEM image compilations show the found and identified taxa out of the three analysed cores. A unified magnification is used to better show the relative size of specimen. The main measure is placed at the middle to the far right of each plate and for very large specimen individual measures are provided at the bottom right of the taxon, next to the individual's number.

Plate 1

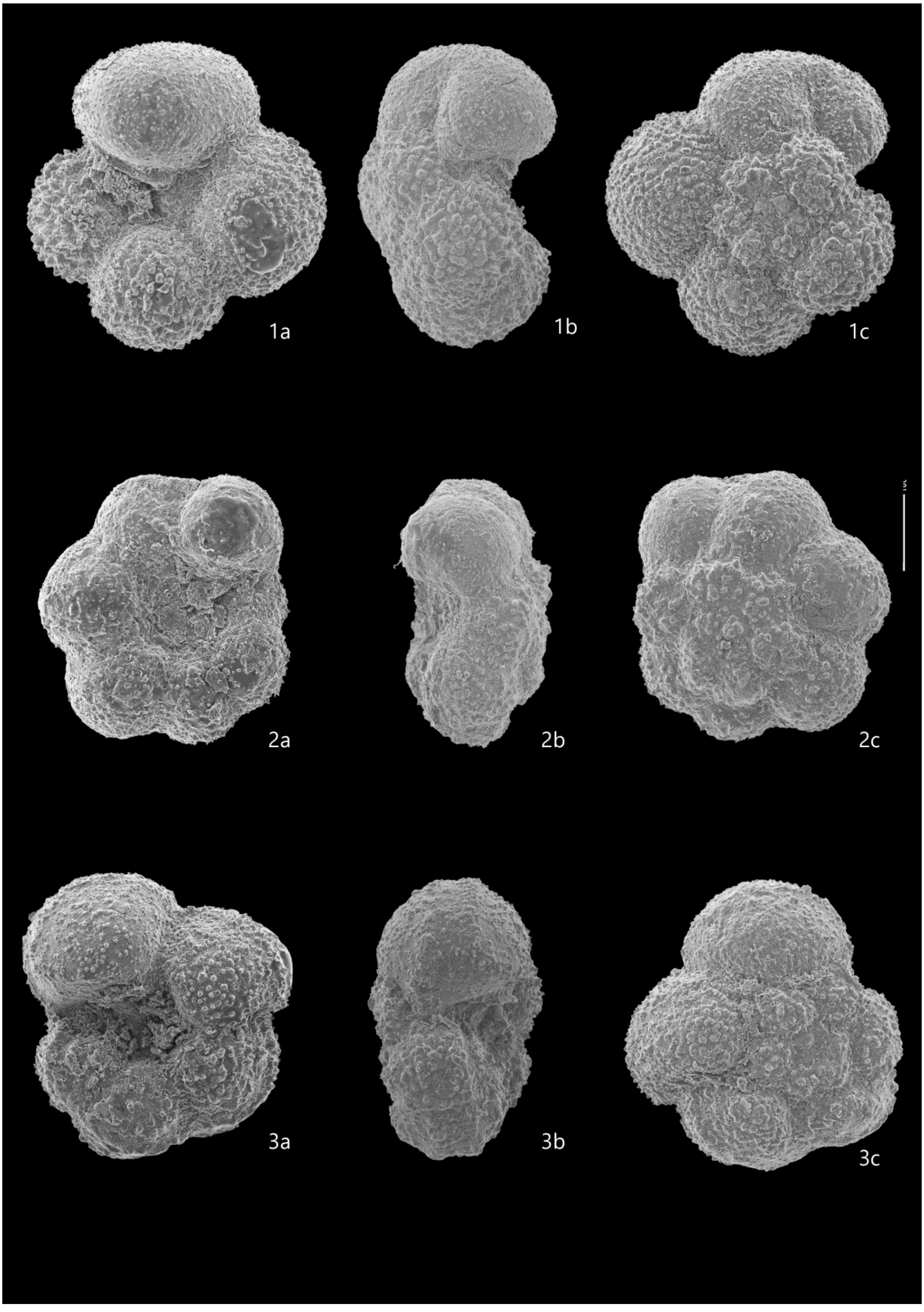

Plate 1: *Archaeoglobigerina blowi*, 1a-c; *Archaeoglobigerina bosquensis*, 2a-c; *Archaeoglobigerina cretacea*, 3a-c;

Plate 2

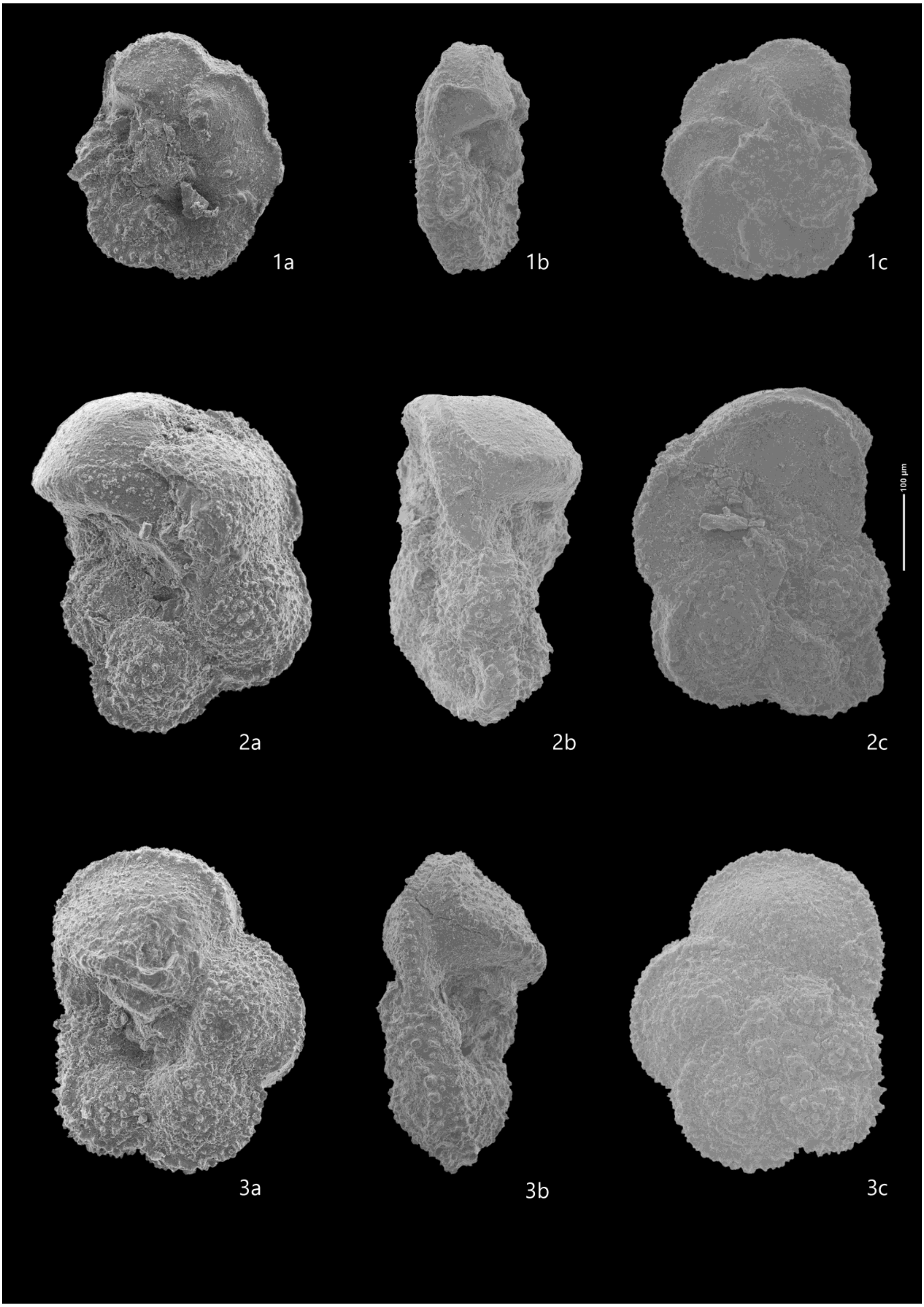

Plate 2: *Dicarinella canaliculata*, 1a-c; *Dicarinella concavata*, 2a-c; *Dicarinella hagni*, 3a-c;

Plate 3

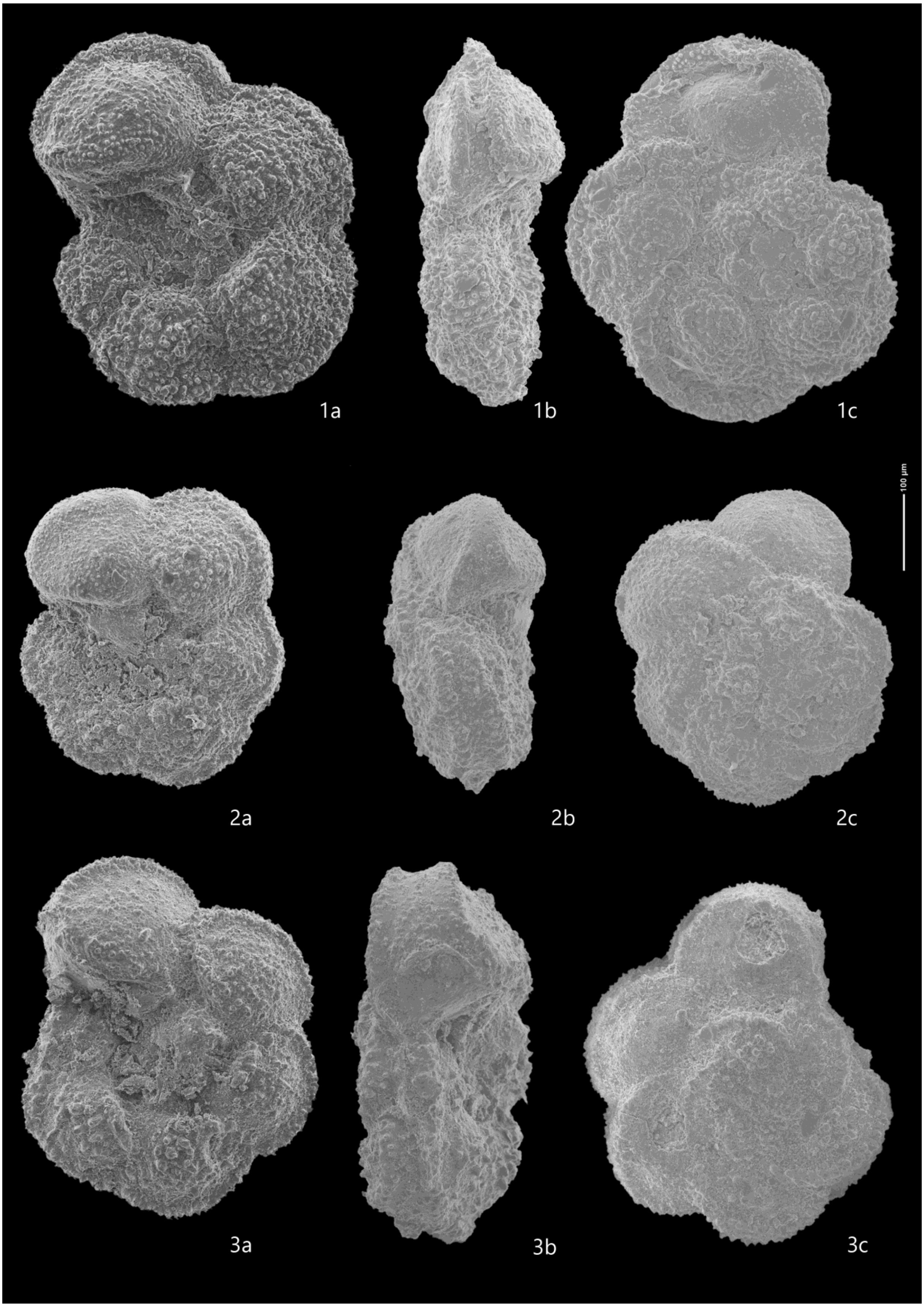

Plate 3: *Dicarinella primitiva*, 1a-c; *Globotruncana bulloides*, 2a-c; *Globotruncana lapparenti*, 3a-c;

Plate 4

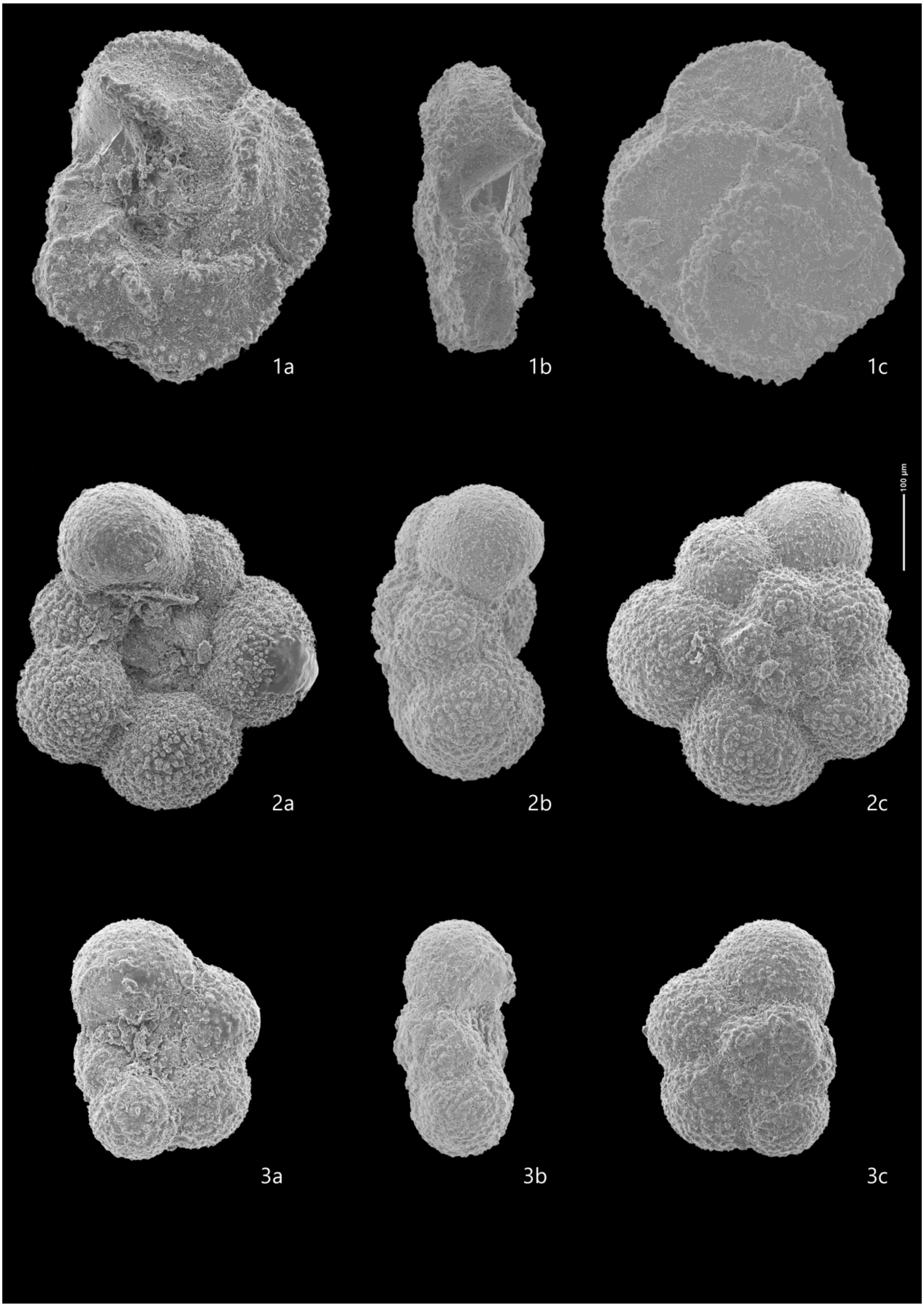

Plate 4: *Globotruncana linneiana*, 1a-c; *Whiteinella brittonensis*, 2a-c; *Whiteinella baltica*, 3a-c;

Plate 5

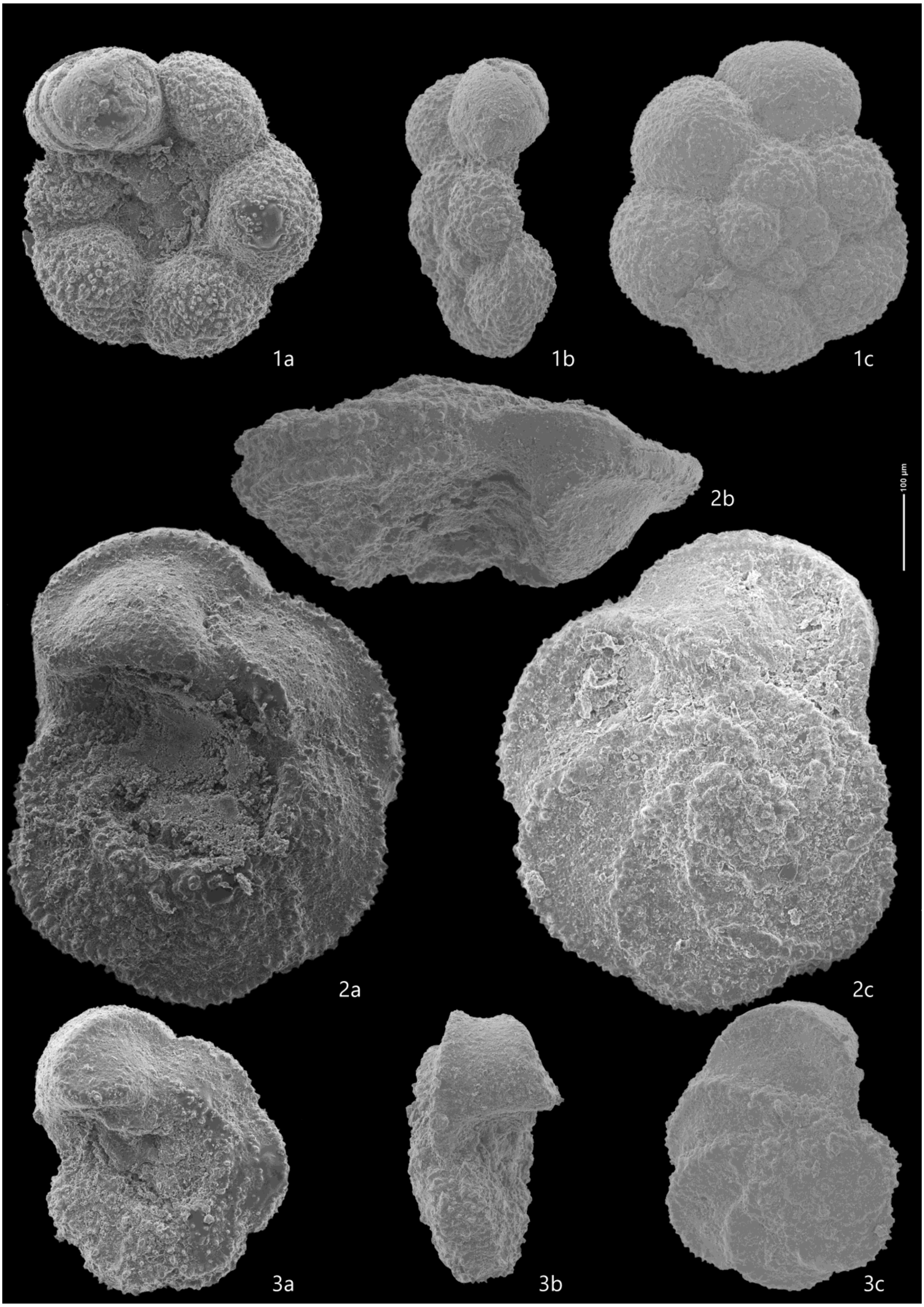

Plate 5: *Whiteinella archaeocretacea*, 1a-c; *Marginotruncana angusticarenata*, 2a-c; *Marginotruncana caronae*, 3a-c;

Plate 6

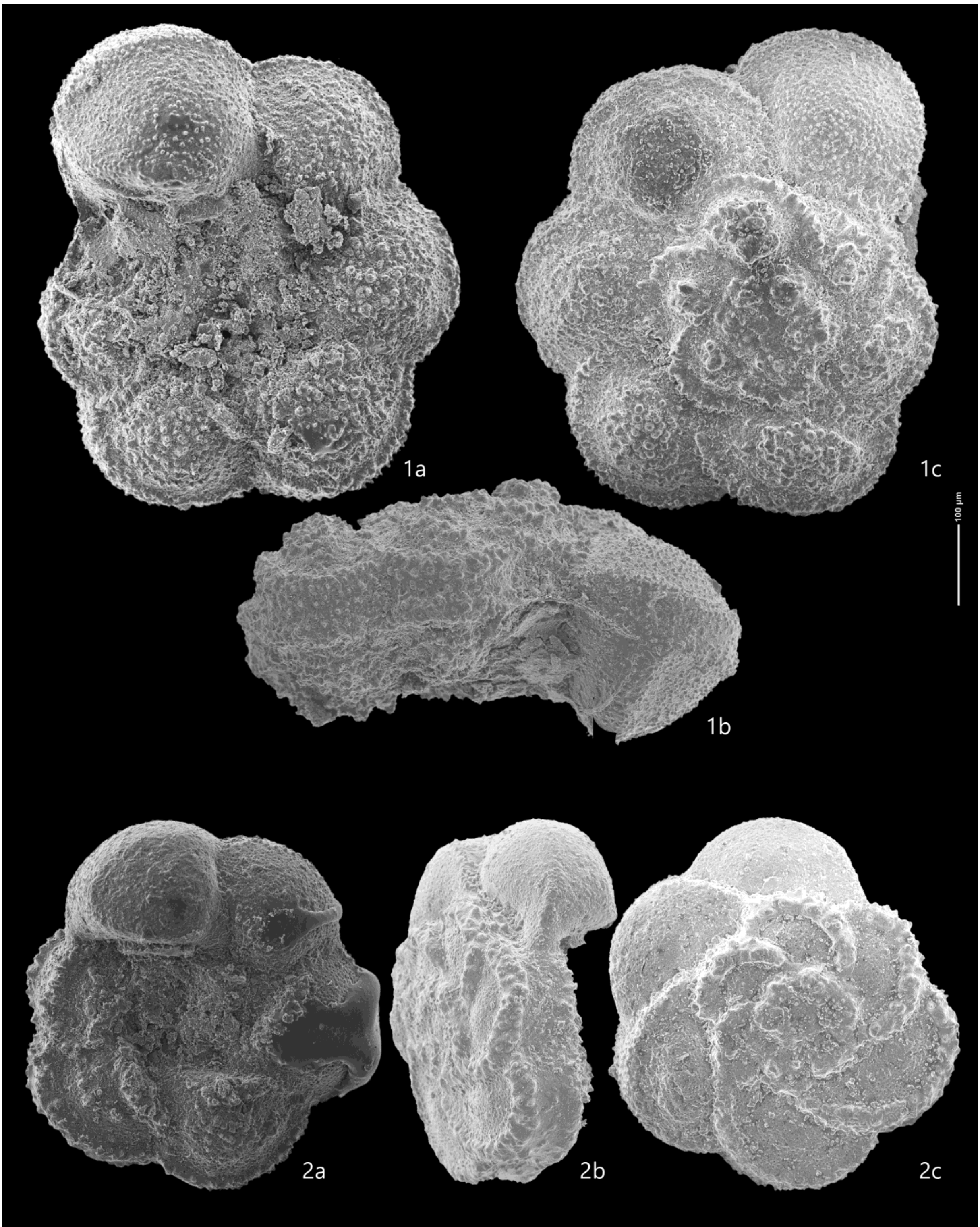

Plate 6: *Marginotruncana marginata*, 1a-c; *Marginotruncana marginata*, 2a-c;

Plate 7

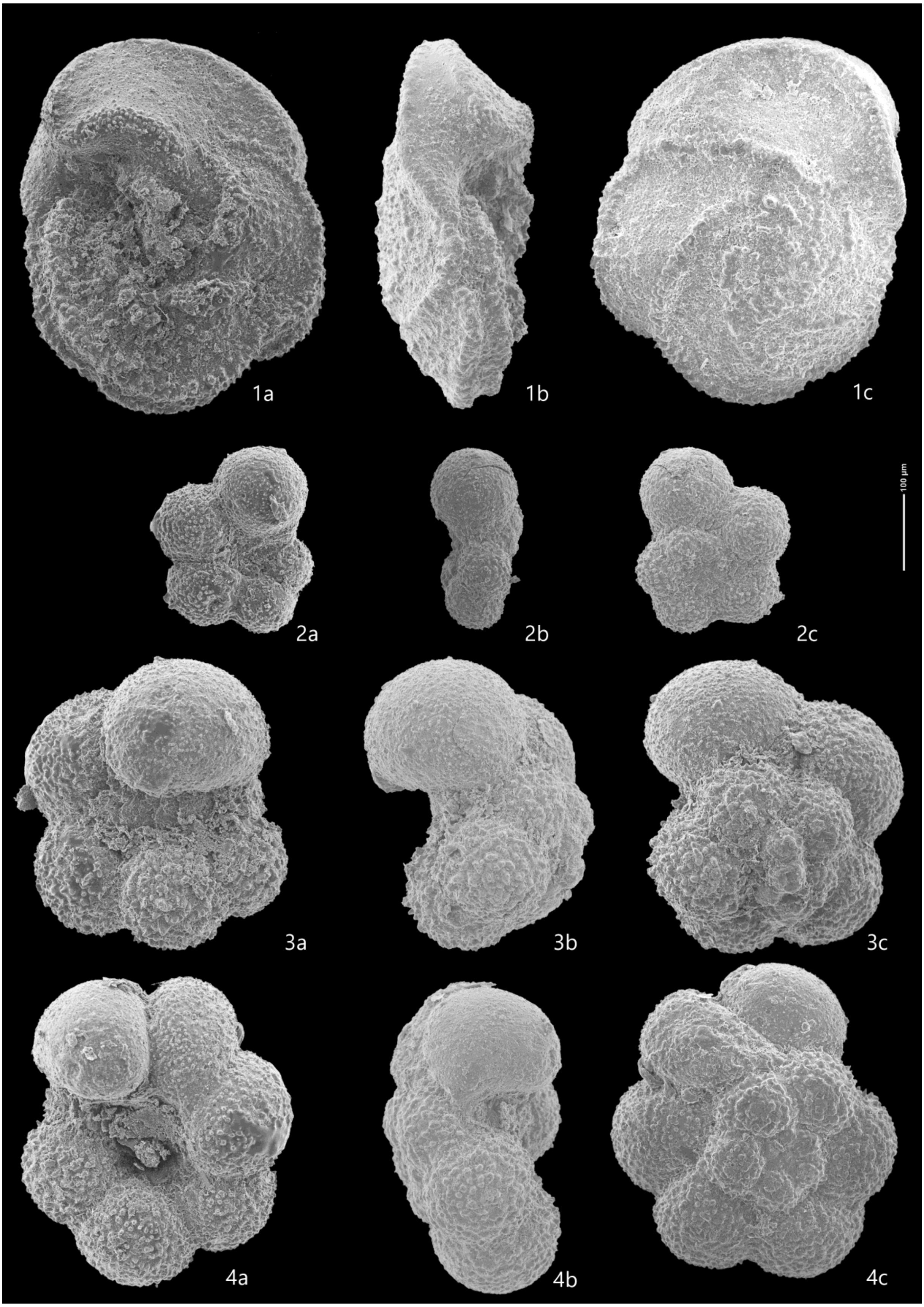

Plate 7: *Marginotruncana sinuosa*, 1a-c; *Muricohedbergella crassa*, 2a-c; *Muricohedbergella delrioensis*, 3a-c; *Muricohedbergella portsdownensis*, 4a-c;

Plate 8

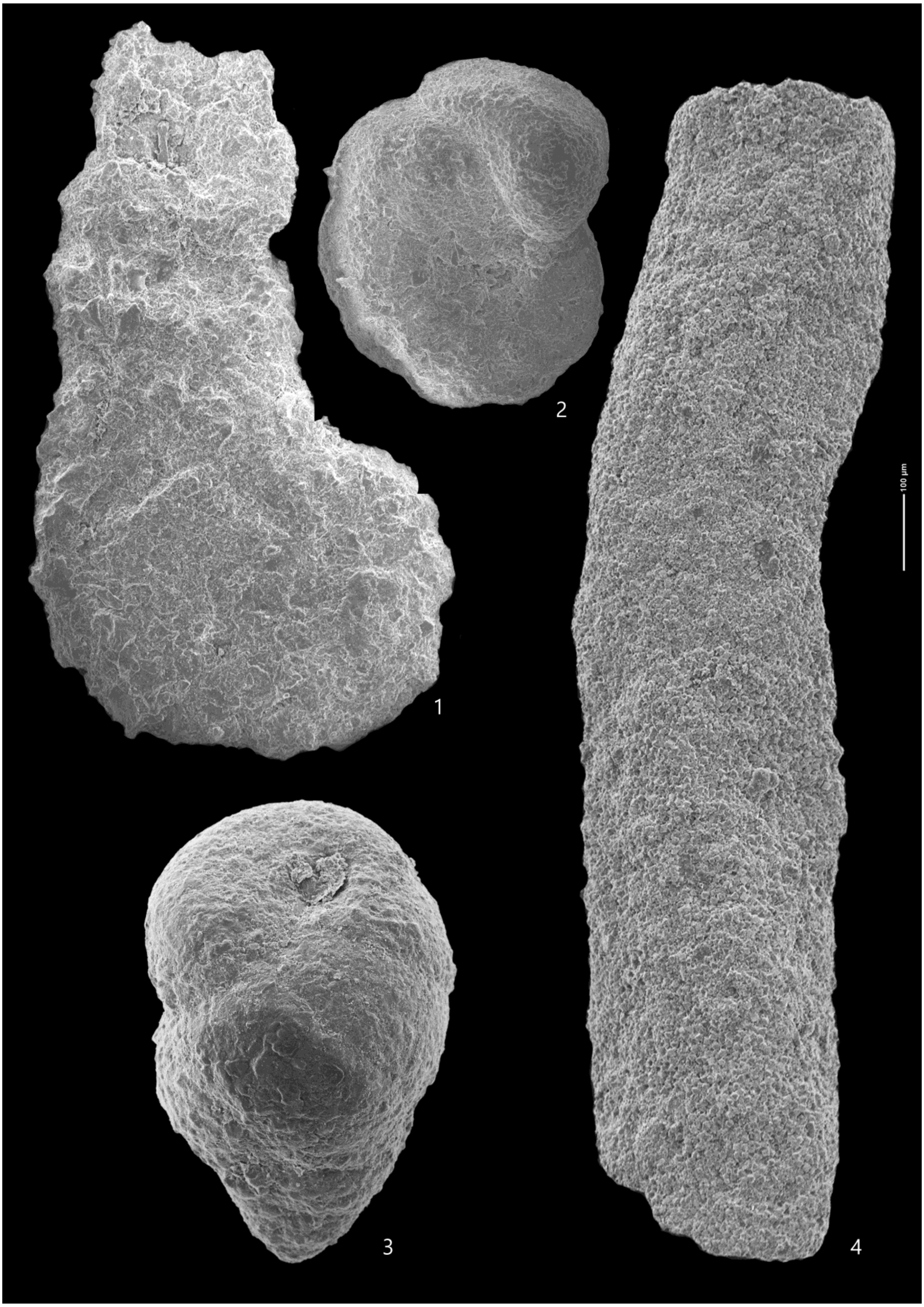

Plate 8: *Ammobaculites agglutinans*, 1; *Anomalina* sp., 2; *Arenobulimina preslii*, 3; *Bathysiphon* sp., 4;

Plate 9

Plate 9: *Bolivina incrassata*, 1; *Cibicidoides* sp., 2; *Dentalina* sp., 3; *Dentalina laevigata*, 4; *Dentalina cylindroides*, 5; *Dentalina* sp., 6; *Dorothia pupa*, 7;

Plate 10

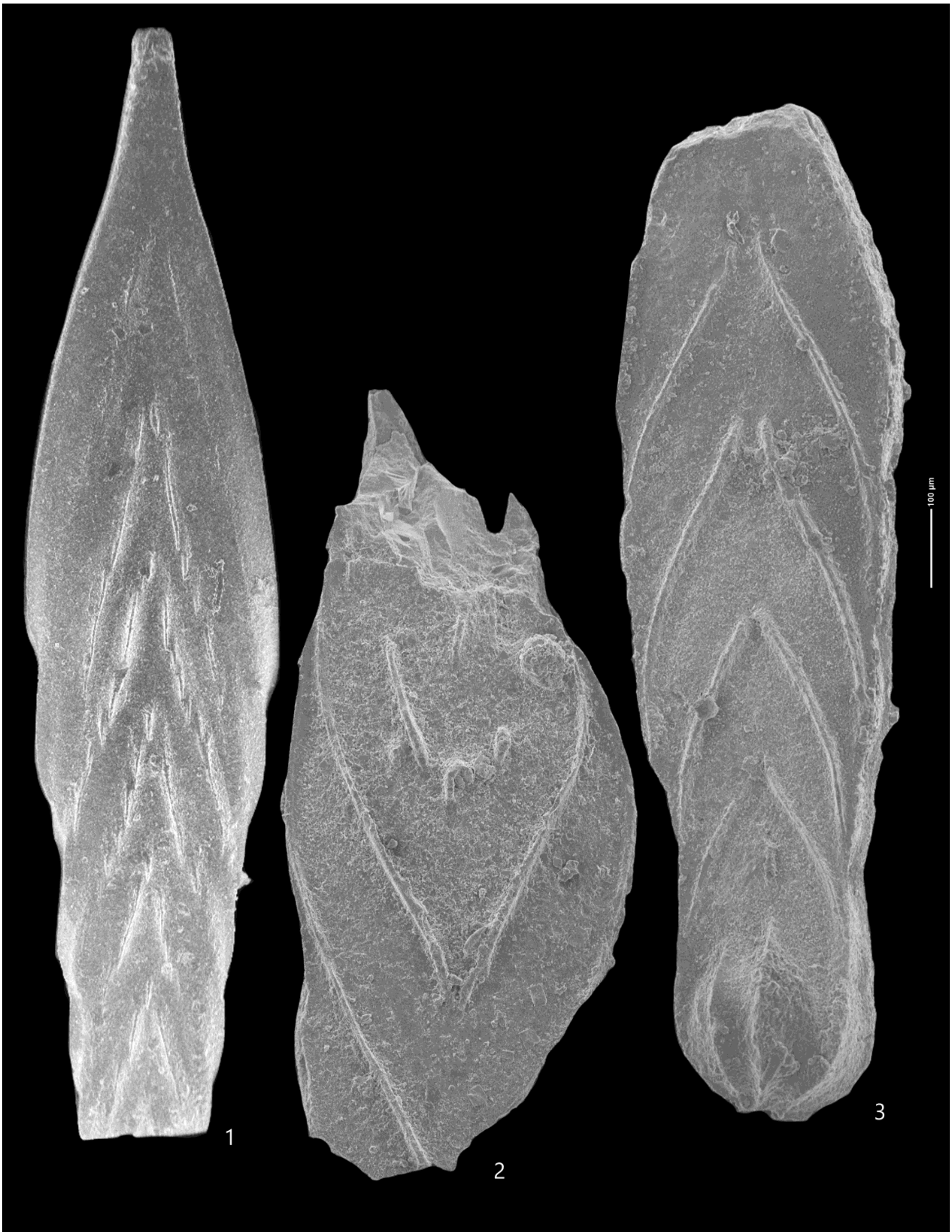

Plate 10: *Frondicularia angusta*, 1; *Frondicularia angustissima*, 2; *Frondicularia archiacia*, 3;

Plate 11

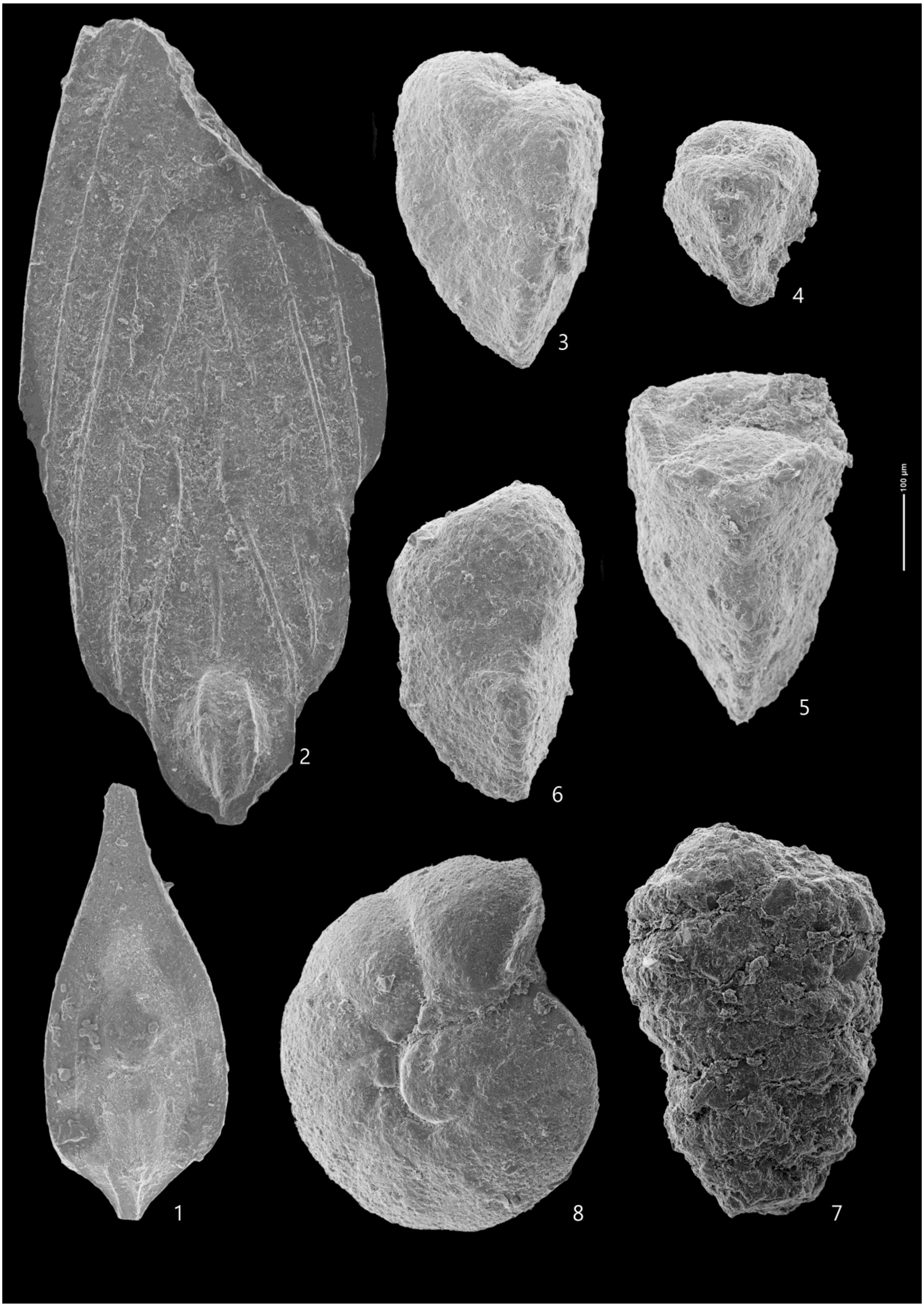

Plate 11: *Frondicularia* sp., 1; *Frondicularia* sp., 2; *Gaudryina cretacea*, 3; *Gaudryina helvetica*, 4; *Gaudryina pyramidata*, 5; *Gaudryina supracretacea*, 6; *Gaudryina* sp., 7; *Gavellinella pertusa* , 8;

Plate 12

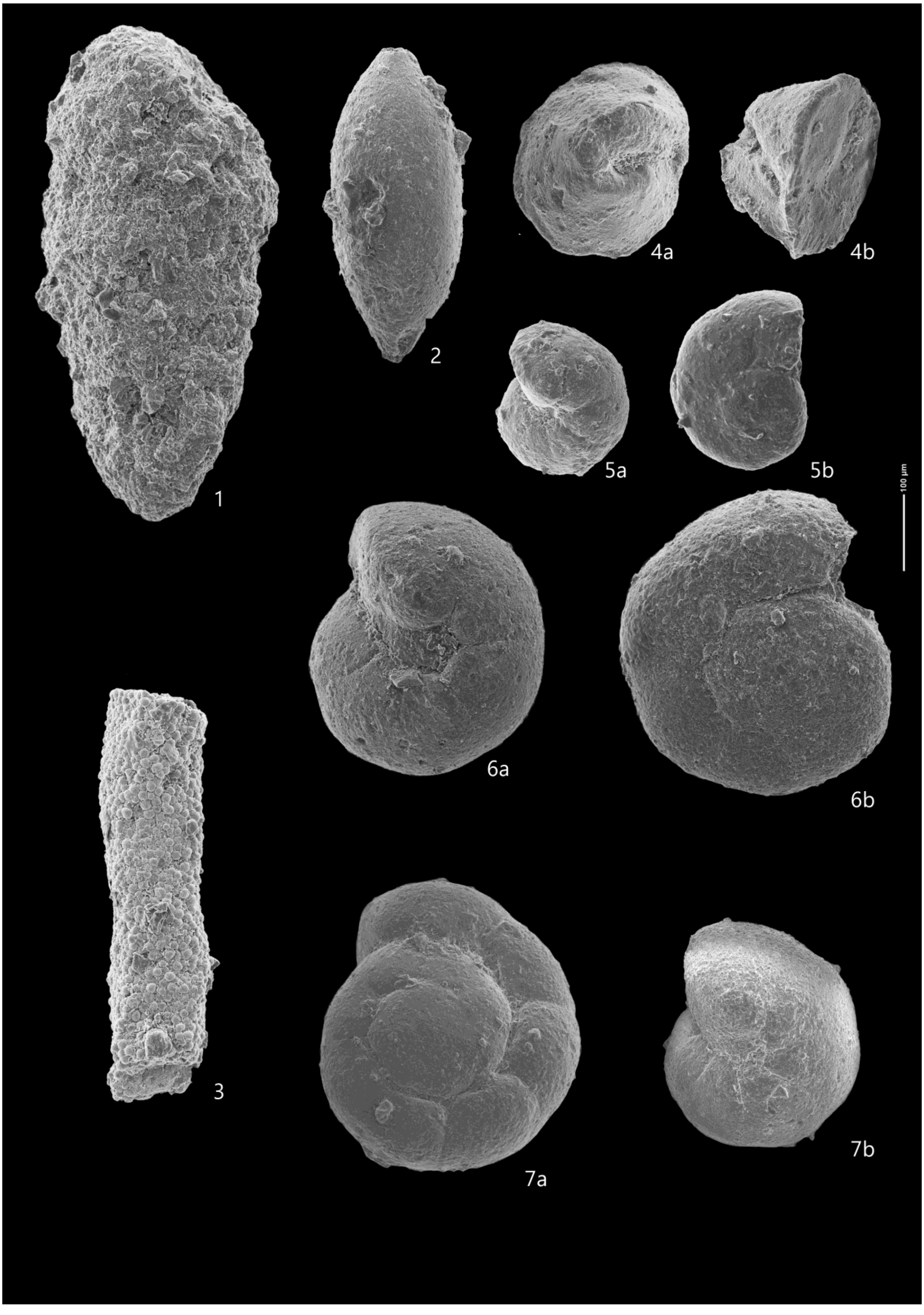

Plate 12: *Gerochammina lenis*, 1; *Glandulina* sp., 2; *Kalamopsis grzybowski*, 3; *Globorotalites michelinianus*, 4a-b, *Gyroidinoides praeglobosus*, 5a; *Gyroidinoides* sp., 5b; *Gyroidinoides nitidus*, 6a-b; *Gyroidinoides umbilicatus*, 7a; *Gyroidinoides* sp., 7b;

Plate 13

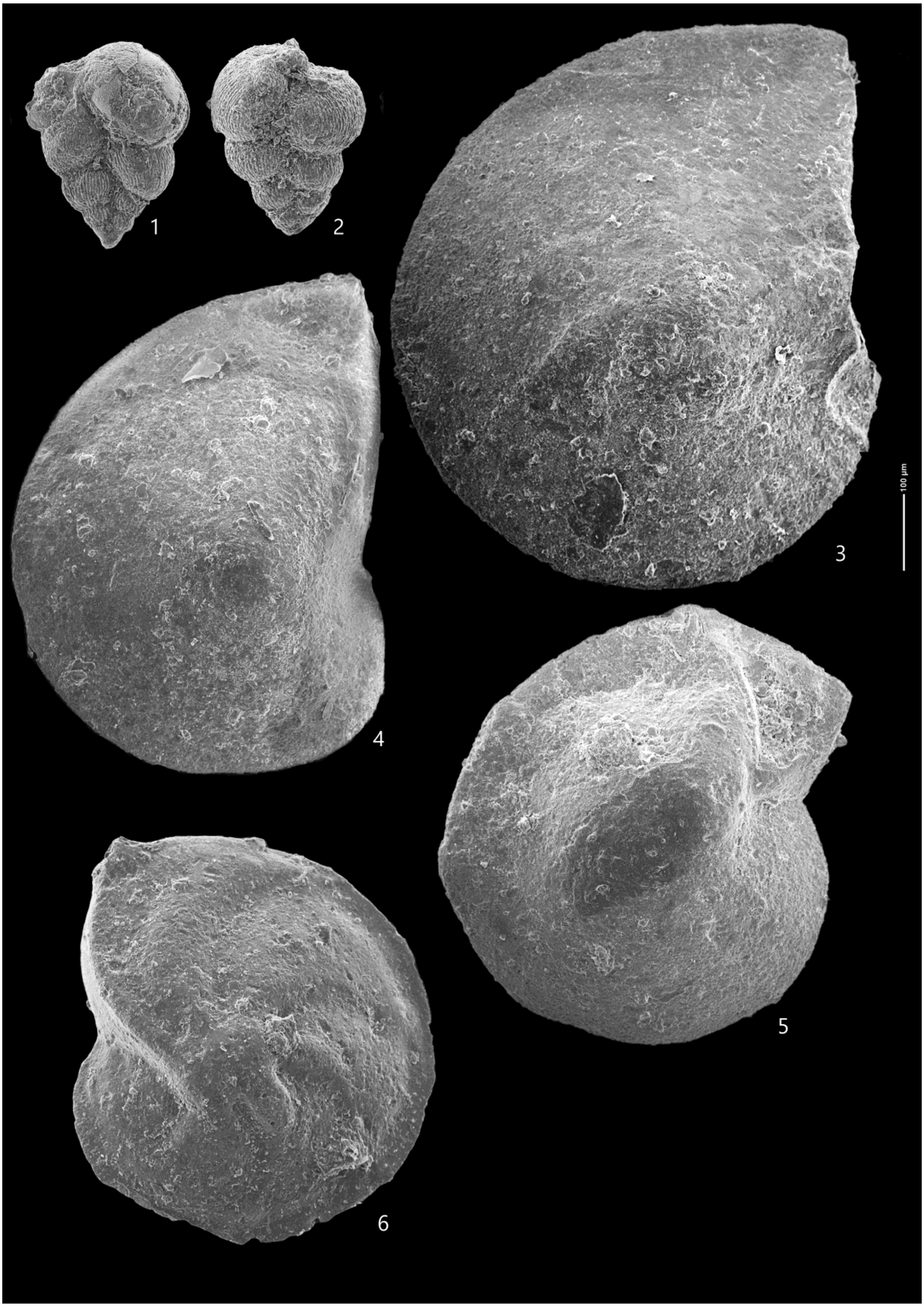

Plate 13: *Laeviheterohelix* sp., 1; *Laeviheterohelix* sp., 2; *Lenticulina comtoni*, 3; *Lenticulina gibba*, 4; *Lenticulina macrodisca*, 5; *Lenticulina mariae*, 6;

Plate 14

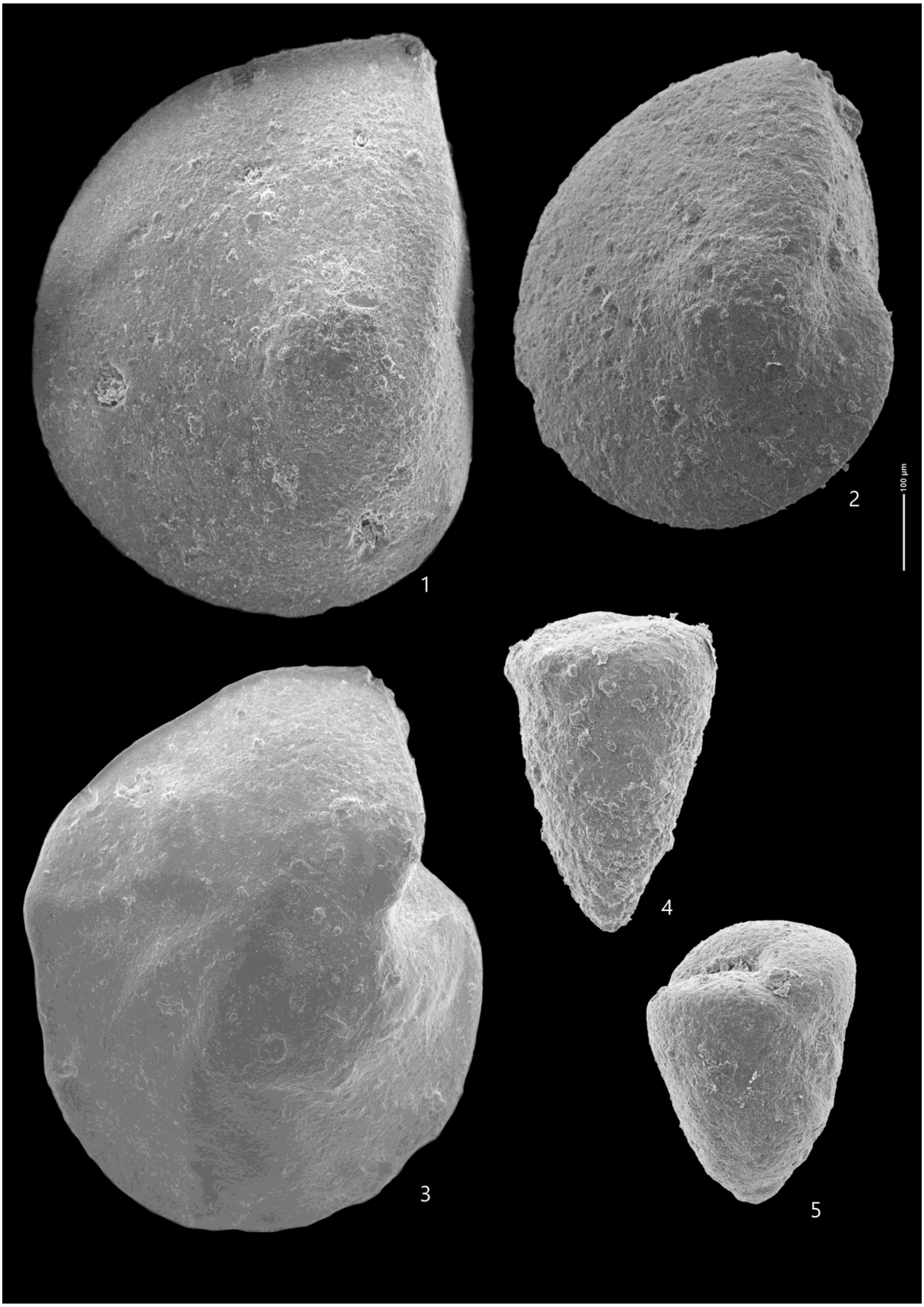

Plate 14: *Lenticulina nuda*, 1; *Lenticulina rotulata*, 2; *Lenticulina secans*, 3; *Marssonella trochus*, 4-5;

Plate 15

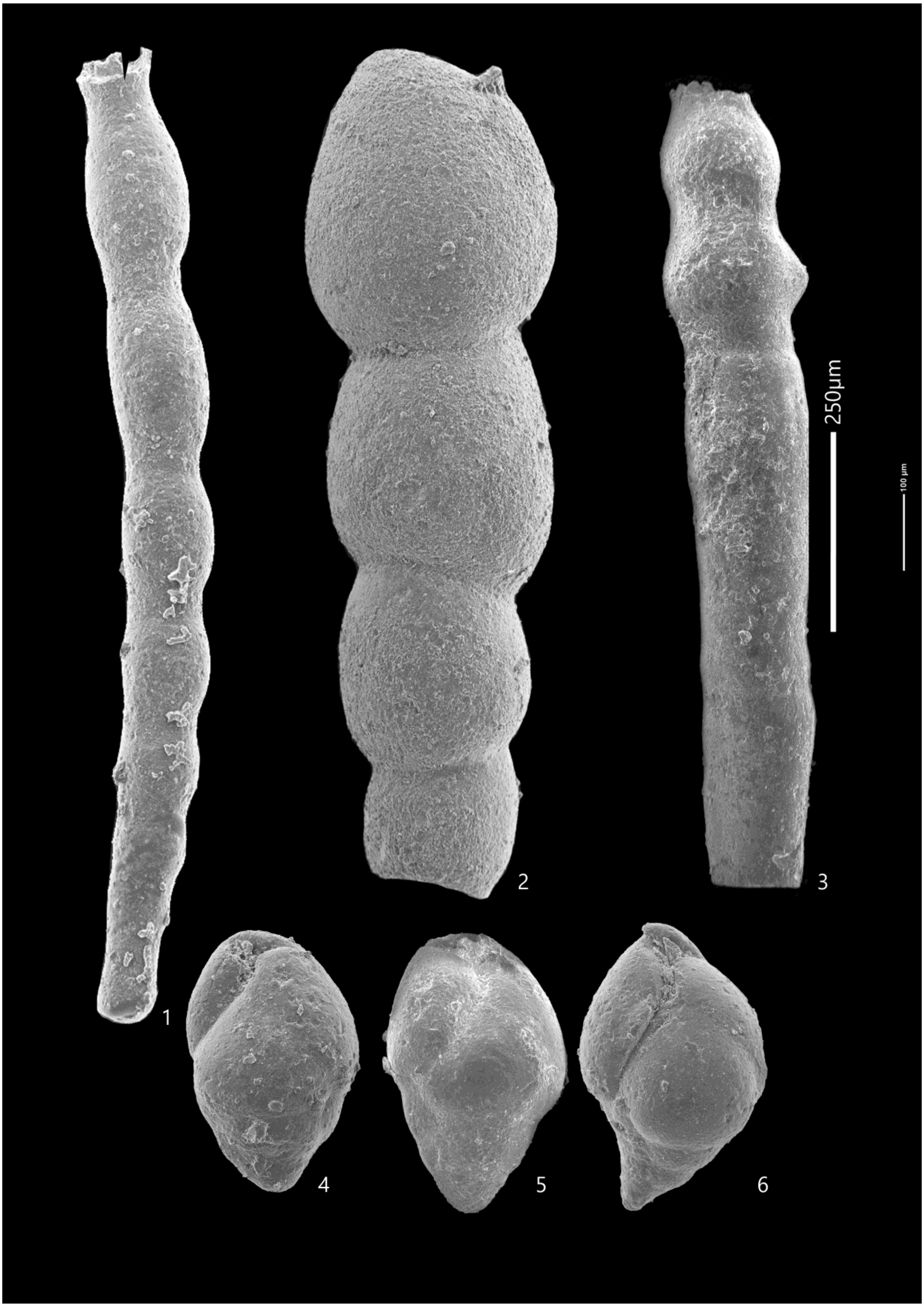

Plate 15: *Nodosaria filiformis*, 1; *Nodosaria monile*, 2; *Nodosaria* sp., 3; *Praebulimina hofkeri*, 4; *Praebulimina pusilla*, 5; *Praebulimina ventricosa*, 6;

Plate 16

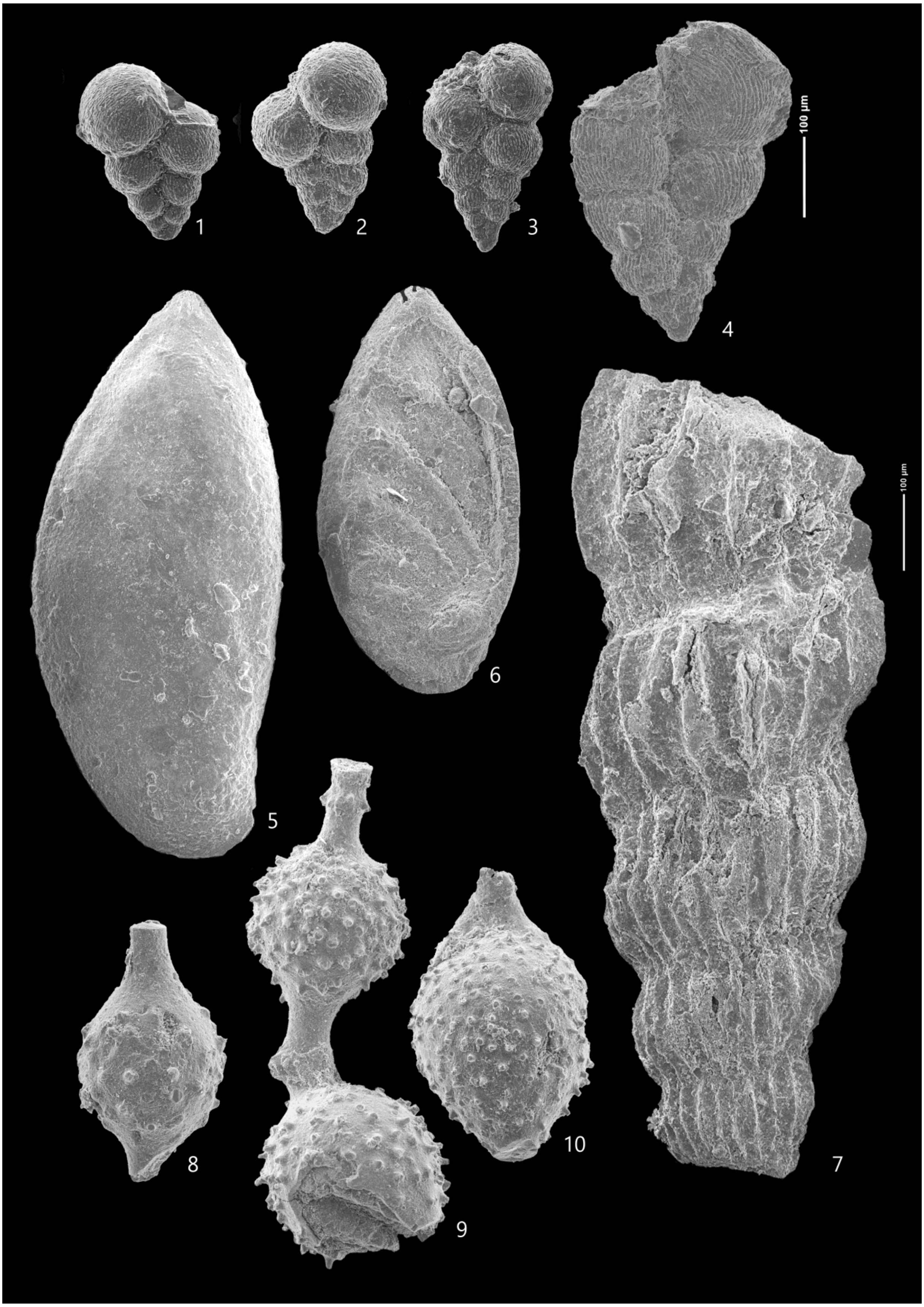

Plate 16: *Planoheterohelix globulosa*, 1; *Planoheterohelix praenuttalli*, 2; *Planoheterohelix reussi*, 3; *Planoheterohelix sphenoides*, 4; *Planularia liebusi*, 5-6; *Pyramidulina* sp., 7; *Ramulina wrightii*, 8-10;

Plate 17

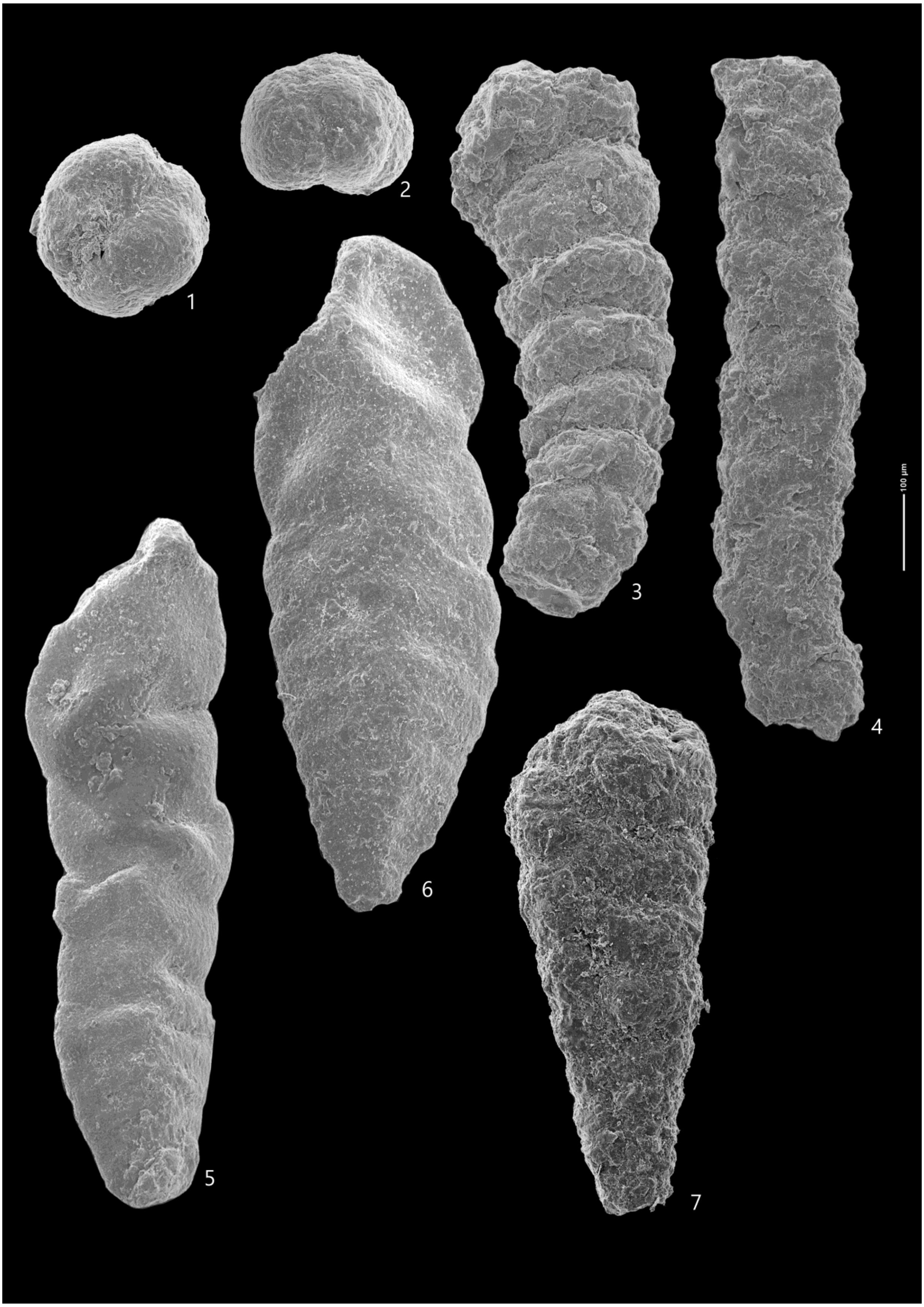

Plate 17: *Recurvoides* sp., 1-2; *Reophax scalaris*, 3; *Reophax* sp., 4; *Spiroplectammina flexuosa*, 5; *Spiroplectammina navarroana*, 7; *Spiroplectammina spectabilis*, 6;

Plate 18

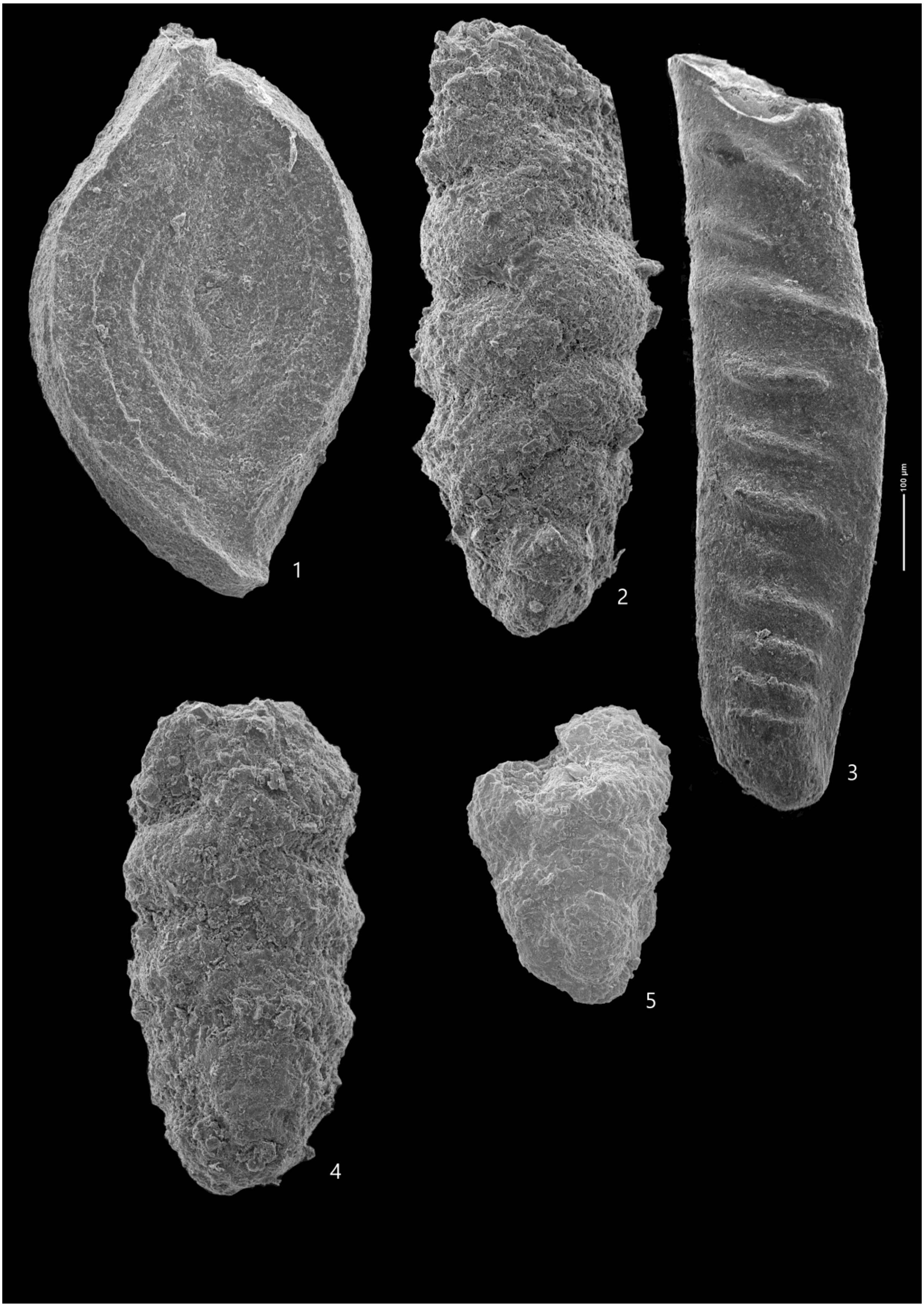

Plate 18: *Spirophthalmidium cretaceum*, 1; *Textularia* sp., 2; *Vaginulina trilobata*, 3; *Uvigerinammina* sp., 4; *Verneuilinoides* sp., 5;

7. Conclusions

This study is based on core and cuttings materials from 12 RAG oil wells from Upper Austria, oil field in the region Bad Hall-Pfarrkirchen-Sierning. The Coniacian – Santonian foraminiferal assemblage found and described in the analysed well sections of this study can be attributed to a normal marine environment situated in outer shelf to upper bathyal depths (300 - 400 m). The foraminiferal microfauna has shown to be rather diverse and is rather unique when compared to other studies, due to the unusually high abundance of *Archaeoglobigerina* (35 – 50 %) and *Gyroidinoides* (45 – 63%) in the samples. The three samples which were analysed in detail show a rather similar composition and are correlative to other assemblages in many different regions, of course only differing due to the strong dominance of certain taxa. The ecological parameters extracted from the collected data seem to point towards meso- to slightly eutrophic conditions through the abundance of r- selected to intermediate r/k- selected taxa along the planktonic fauna. The benthonic faunal composition on the other hand reflects more oxygen depleted oligotrophic to mesotrophic conditions indicated by the strong presence of *Gyroidinoides* a typical epifaunal to shallow infaunal taxon able to sustain itself under such conditions along other species supporting this assumption. Although this interpretation seems to link deposition with the OAE3 event around the Coniacian – Santonian boundary, it seems to be best described as a local or at most regional effect, which would need additional data from other wells to clarify this interesting and unique occurrence. Last but not least the reassessment of the seismic interpretations through biostratigraphical analysis shows that for the most part only continuous and undisturbed Upper Cretaceous stratigraphic successions could be identified. Due to this outcome the current or old interpretation of steeply dipping normal faults as control on the petroleum system in this section of the Austrian Molassis Basin seems to be still valid for some areas. Unfortunately the microfauna was void of any hard evidence supporting an alternative interpretation through thrust faults and ramp geometries, due to the absence of mixing of Cretaceous microfaunal elements with younger Eocene or Oligocene. Although it seems clear that this study doesn’t support the new interpretation, some of the samples were completely barren when looking at the microfossil record, so non-fossiliferous Cenozoic intervals cannot be ruled out for wells MG-001_M, SIER-003_M, SIER-003_U and BH-N-001_O.

In conclusion, it can be said that this study provides interesting insight and contributes to a better understanding of the microfaunal ecology and distribution of the Upper Cretaceous Coniacian – Santonian strata in the Austrian part of the Molasse Basin.

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