MIDDLE MIOCENE CALCAREUS NANNOPLANKTON OF NE SLOVENIA (WESTERN CENTRAL PARATETHYS)

MILOŠ BARTOL

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Paleontološki inštitut Ivana Rakovca ZRC SAZU, Ljubljana

Ljubljana 2009

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Jezikovni pregled / Language review
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Izdajatelj / Issued by
Paleontološki inštitut Ivana Rakovca ZRC SAZU
Za izdajatelja / Represented by
Špela Goričan

Založnik / Published by
Založba ZRC / ZRC Publishing, ZRC SAZU, Ljubljana
Zanj / For the publisher
Oto Luthar
Glavni urednik / Editor-in-Chief
Vojislav Likar

Oblikovanje platnic / Cover design
Boštjan Bugarič

Tisk / Printed by
Present d.o.o., Ljubljana
Naklada / Printrun
200 izvodov / copies

Izdajo je finančno podprla / The publication was financially supported by
Javna agencija za knjigo RS / Slovenian Book Agency

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

56(497.41)

BARTOL, Miloš
Middle Miocene calcareous nannoplankton of NE Slovenia (western Central Paratethys) / Miloš Bartol ; [izdajatelj] Paleontološki inštitut Ivana Rakovca ZRC SAZU, Ljubljana. - Ljubljana : Založba ZRC, ZRC SAZU, 2009

ISBN 978-961-254-149-1
247181312

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CONTENTS

Abstract

In the early Middle Miocene the Central Paratethys had reached its maximum extent and consisted of a series of basins linking the Mediterranean and (via the Eastern Paratethys) the Indo-Pacific. The Badenian is a Central Paratethys stage which can be correlated with the Langhian and the Lower Serravallian of the Mediterranean and with the standard nannoplankton biozones NN4 (top part), NN5, and NN6 (lower part). It also corresponds to the final stage of the Miocene Climatic Optimum (MCO), when favourable environmental conditions allowed for the thriving of calcareous nannoplankton producing a substantial fossil record.

The Badenian deposits, composed of marl, lithothamnium limestone and subordinate sand, sandstone, and clay are widely exposed in Slovenske Gorice. Palaeogeographicaly this area was part of the Mura Depression on the western margin of the Pannonian Basin System at the eastern mouth of the Slovenian Corridor – a seaway linking the Central Paratethys and the Mediterranean.

Twenty-two sections in Slovenske gorice were studied for nannoplankton. A total of 109 species of calcareous nannoplankton were determined, belonging to 34 different genera, of which *Helicosphaera*, *Reticulofenestra* and *Discoaster* were represented by the highest number of species. A precise local biostratigraphic scheme for the Badenian was established. Lateral and vertical environmental changes in the Mura Depression were studied. The development of nannoplankton assemblages was compared to that of the Mediterranean.

The rich and well preserved nannoplankton assemblages and the use of several biostratigraphic zonations enabled the stratigraphic correlation of individual sections and the reconstruction of the local ranges of individual species. Six interval zones (MuN4, MuN5a-d and MuN6) were defined on the basis of the LO of *Heliosphaera ampliaperta*, the FO and LO of *Helicosphaera waltrans*, the FO of *Helicosphaera walbersdorfensis*, the LO of *Sphenolithus heteromorphus* and the FCO of *Reticulofenestra pseudoumbilica* (>7 μm).

Sand interbeds in some predominantly marl successions as well as the dynamic pattern of occurrences of *Braarudosphaera bigelowii* (possibly indicating fresh water influences) and typical pelagic species indicate considerable sea-level fluctuations attributed to eustatic changes of the 3rd order cycles TB2.3, TB2.4 and TB2.5.

Distinctly different lithologies assigned to a single short interval zone were fund to occur in short distances from one another. This confirms that the Mura Depression was a heterogeneous depositional environment with deeper basins existing in close proximity of shallow marine settings. In the Late Badenian, a shallow carbonate platform existed in the southeastern part of the study area, while deeper marine environment had developed in the northwestern part.

The vertical changes in nannoplankton assemblage composition reflected considerable environmental fluctuations, particularly in terms of nutrient availability (associated with water depth), temperature and seasonality. The high species diversity, the presence of discoasters and sphenoliths, and the abundance of helicoliths indicate relatively warm water throughout the entire interval studied. A strong but gradual increase in seasonality is detected through the Badenian.

An interesting interval, enriched with several species of the warm water genera *Discoaster* and *Sphenolithus*, was observed at the NN5/NN6 boundary, which was correlated with the Mi3 event (a rise of $\delta^{18}O$) that represented a major cooling step at the end of the MCO. Though it is quite controversial, the abundance of warm water indicators in deposits of this age is not an isolated event and has also been reported from the vicinity of Belgrade. It is possible that the cooling at the end of the Middle Badenian had already affected the deeper benthic environments, while surface waters remained warm enough to sustain warm water assemblages in at least the southwest part of the Central Paratethys.

Badenian nannoplankton assemblages from the Mura Depression closely resemble those from the North Mediterranean. This parallelism is most clearly demonstrated for the youngest deposits studied - assigned to MuN6 (lower part of NN6) - when several biostratigraphic events occur in the same sequence in both regions. This suggests that the Slovenian Corridor was still active in the beginning of Late Badenian, corresponding to the global eustatic cycle TB2.5. While the exact time of its closure cannot be determined, it can be narrowed down to a 400 ky interval between the FCO of *Reticulofenstra pseudoumbilica* (>7 μm) at 13.1 Ma and the beginning of the Sarmatian at 12.7 Ma.

Povzetek

V spodnjem srednjem miocenu je Centralna Paratetida dosegla največji obseg in je v nizu povezanih sedimentacijskih bazenov povezovala Mediteran in (preko Vzhodne Paratetide) Indopacifik. Badenij, stopnjo Centralne Paratetide, je mogoče korelirati z langhijem in spodnjim serravalijem in s standardnimi nanoplanktonskimi conami NN4 (zgornji del), NN5 in NN6 (spodnji del). Sovpada tudi z zadnjim obdobjem miocenskega klimatskega optimuma (MCO), ko so ugodne razmere omogočile uspevanje kalcitnega nanoplanktona.

Badenijski skladi vzhodne Slovenije so sestavljeni iz laporja, litotamnijskega apnenca in podrejenih peskov, peščenjakov in glin ter se raztezajo čez Slovenske gorice. Paleogeografsko je to območje pripadalo Murski udorini na zahodnem robu Panonskega sistema bazenov ob vzhodnem ustju Slovenskega koridorja – morske povezave med Centralno Paratetido in Mediteranom.

V okviru raziskave je bilo v Slovenskih goricah posnetih in vzorčevanih 22 profilov, v vzorcih iz katerih je bilo določenih 109 vrst kalcitnega nanoplanktona iz 34 rodov, med njimi so z največjim številom vrst zastopani *Helicosphaera*, *Reticulofenestra* in *Discoaster*. Izdelana je bila natančna lokalna biostratigrafska conacija badenija. Preučene so bile lateralne in vertikalne paleoekološke spremembe v Murski udorini, najdene nanoplanktonske združbe pa so bile primerjane s tistimi iz Mediterana.

Bogate in dobro ohranjene združbe so ob uporabi več obstoječih biostratigrafskih zonacij omogočile stratigrafsko korelacijo posameznih profilov in rekonstrukcijo lokalnih stratigrafskih rangov posameznih vrst. Na podlagi prisotnosti vrst *Helicosphaera ampliaperta, H. waltrans*, *H. walbersdorfensis* in *Sphenolithus heteromorphus* ter porasta pogostosti vrste *Reticulofenestra pseudoumbilica* (>7 µm) je bilo definiranih šest intervalnih biocon (MuN4, MuN5a-d in MuN6).

Interkalirane peščene plasti med laporji v sedimentarnih razvojih nekaterih profilov in dinamičen vzorec prisotnosti vrste *Braarudosphaera bigelowii* (ki morda odraža občasne sladkovodne vplive) ter tipičnih pelagičnih vrst nakazujejo precejšnja nihanja morske gladine, povezane z evstatičnimi spremembami v okviru globalnih evstatičnih ciklov 3. reda TB2.3, TB2.4 in TB2.5.

Litologija nekaterih profilov podobne starosti se izrazito razlikuje, čeprav so med seboj oddaljeni le nekaj kilometrov. To potrjuje, da je bila Murska udorina heterogeno sedimentacijsko okolje, kjer so plitvejši in globlji deli ležali v neposredni bližini. V zgornjem badeniju se je na jugovzhodnem delu obravnavanega območja nahajala plitva karbonatna platforma, na severozahodu pa je sedimentacija potekala v globljemorskem okolju.

Spremembe v sestavi nanoplantonskih združb odražajo precejšnje spremembe skozi čas, posebej kar zadeva dostopnost hranil (ki je povezana z globino), temperaturo in sezonski značaj podnebja. Velika vrstna pestrost ter prisotnost diskoastrov, sfenolitov in številnih helikolitov kažejo na razmeroma visoke temperature skozi celoten obravnavani interval. Opažen je bil trend velikega a postopnega povečanja sezonskega značaja podnebja skozi badenij.

Na meji biocon NN5 in NN6 je bil opažen zanimiv interval, obogaten s številnimi vrstami indikatorskih rodov tople vode *Discoaster* in *Sphenolithus*. Korelirati ga je mogoče z dogodkom Mi3 (porastom $\delta^{18}O$), ki odraža ohladitev ob koncu MCO. Čeprav je pojav toplovodnih vrst v plasteh take starosti precej nenavaden, ne gre za osamljen primer, saj o podobnem poročajo iz bližine Beograda. Morda je ohladitev ob koncu MCO vsaj v jugozahodnem delu centralne Paratetide najprej prizadela globlje bentoške ekosisteme, medtem ko so površinske vode ostale dovolj tople, da so omogočale uspevanje toplovodnih vrst.

Razvoj badenijskih nanoplanktonskih združb Murske udorine je na moč podoben opisanim razvojem iz severnega Mediterana. Vzporednost vztraja vse do najmlajših plasti, obravnavanih v tej študiji, ki pripadajo spodnjemu delu standardne nanoplanktonske biocone NN6, ko je mogoče v obeh regijah slediti istemu sosledju biostratigrafskih dogodkov. To kaže, da je bil Slovenski koridor vsaj na začetku zgornjega badenija (in globalnega evstatičnega cikla TB2.5) še odprt. Natančnega časa zaprtja te morske povezave ni mogoče določiti, možen čas zaprtja Slovenskega koridorja pa lahko zožimo na 400 tisoč letni interval med porastom pogostosti vrste *Reticulofenestra pseudoumbilica* (>7 µm) pred 13,1 milijoni let in začetkom sarmatija pred 12,7 milijoni let.

1. INTRODUCTION

1.1. Problem outline and research objectives

During the Middle Miocene the Central Paratethys region underwent significant palaeogeographical and palaeoclimatic changes; in the early Middle Miocene, the Badenian, the Central Paratethys reached its maximum extent and consisted of an unbroken chain of epicontinental basins linking the Mediterranean and (via the Eastern Paratethys) the Indopacific (Rögl 1998; Goncharova et al., 2004; Báldi, 2006). The climate in the entire Paratethys realm was subtropical - warm and humid (e.g., Ivanov et al., 2002; Jiménez-Moreno et al., 2006), owing to the final stage of the Miocene Climatic Optimum (MCO). By the late Middle Miocene, the Sarmatian, the situation had changed dramatically; the Central Paratethys had lost its open oceanic connections and salinity had become regionally-specific, with a strong decrease in the Pannonian Basin (Paramontova et al., 2004). The climate had become temperate and marked by strong seasonal changes and latitudinal gradients (eg., Bicchi et al., 2003; Jiménez-Moreno & Suc 2007; Utescher et al., 2007a). Many aspects of palaeoclimatic changes associated with the end of the MCO and the exact time of termination of communication between the central Paratethys and the Mediterranean are still the subjects of scientific debate.

The Miocene Paratethyan deposits in eastern Slovenia were deposited in several depressions on the western margin of the Pannonian Basin System, which resulted from the crustal extension in the late Early Miocene (Márton et al., 2002; Vrabec & Fodor, 2006; Jelen et al., 2008). The Mura Depression (or the western part of the Mura-Zala Basin) formed the eastern mouth of the Slovenian Corridor, a seaway between the Central Paratethys and the Mediterranean. Marine deposits from this basin stretch across northeast Slovenia and have been biostratigraphically assigned to the Karpatian, Badenian, Sarmatian and Panonian. Stratigraphy relies mostly on foraminifera (Rijavec, 1976; 1978), however in some cases calcareous nannoplankton was used as a supplementary biostratigraphic tool (e.g., Mioč & Marković, 1997; nannoplankton analyses by J. Pavšič).

In past research, diverse and well-preserved nannofossil assemblages have been found in the Middle Miocene Badenian deposits of the Mura Depression (Pavšič, 2002; Bartol & Pavšič, 2005), and the basic geological maps (Aničić & Juriša 1985; Žnidarčič & Mioč, 1988) show that the largest part of Badenian deposits stretches across the Slovenske Gorice hill range in eastern Slovenia. The Badenian sedimentary successions consist of conglomerate, marl, sandstone, and lithothamnium limestone and can exceed 2000 meters in thickness (Mioč & Žnidarčič,1996; Gosar, 2005), however, outcrops are extremely rare and of limited extent.

The aim of this work is to present an integral study of calcareous nannoplankton in the Middle Miocene deposits of eastern Slovenia. The primary research objectives were the taxonomic analyses of nannofossils from Slovenske Gorice and interregional, as well as global biostratigraphical correlations. Another goal of this research was the reconstruction of palaeoecological and palaeogeographical events taking place in this area during the Middle Miocene, as reflected in the composition of Badenian nannoplankton assemblages and their changes through time.

1.2. The Central Paratethys region in the Middle Miocene

1.2.1. Palaeogeography

The Central Paratethys consisted of epicontinental tectonic basins of lower and Middle Miocene age (Rögl, 1998), situated between the Carpathians, the Dinarides, and the Eastern Alps. The geological development of this region has received a great deal of scientific attention (e.g., Cloetingh et al., 2002). During the Miocene, the topography of the Central Paratethys area along with marine connections to the neighbouring seas underwent repeated changes as a consequence of intensive teconic activity (Royden & Báldi, 1988; Royden, 1988) and several successive transgressions and regressions (e.g., Kováč et al., 2007).

The Central Paratethys consisted of a series of interconnected deep basins, separated by shallows and carbonate platforms. The Mura Depression (western part of the Mura-Zala Basin in Fodor et al., 2002 and Márton et al., 2002) was one of the smaller basins in the west Central Paratethys. The South Burgenland Swell separated this basin from the Styrian Basin in the north, Pohorje and Kozjak lay on its western coast, while its southern boundary ran near the Donat fault (Márton et al., 2002); sediments from the Mura Depression can be found in northeast Slovenia and extend into neighbouring Austria, Hungary, and Croatia (Gosar, 2005). The Middle Miocene Central Paratethys deposits in Slovenia were also studied in the Krško basin and the Tuhinj syncline south of the Periadriatic lineament (Horvat, 2004) and in the Planina syncline (Oblak, 2006).

From the Oligocene until the end of Middle Miocene, the time resolution of isotopic events in the Central Paratethys region is comparable with global trends (Abreu & Haddad, 1998), which indicates good communication between the Central Paratethys and the neighbouring seas. During the Badenian period of the Middle Miocene, the Central

Fig. 1.1. Palaeogeographical reconstructions of the Central Paratethys realm during the Karpatian and the Badenian (simplified after Rögl, 1998; 1999). The red circle marks the position of the Mura Depression.

Paratethys reached its maximum extent and communicated with the Mediterannean and (via the Eastern Paratethys) the Indo-Pacific (Rögl, 1998; Meulenkamp & Sissingh, 2003; Goncharova et al., 2004; Báldi, 2006). The Badenian was also the last fully marine period in the life of the Central Paratehys, as communication with the neighbouring seas had ceased by the beginning of the Sarmatian (Rögl, 1998; Kováč et al., 1999), with salinity becoming regionally-specific (Paramontova et al., 2004).

General palaeogeographical reconstructions of the Central Paratethys region during the Badenian and the Sarmatian are shown in Fig. 1.1. According to Rögl (1998, 1999), the Slovenian Corridor, linking the Central Paratethys and the Mediterranean, had already closed in the Upper Badenian; however, some other authors (e.g., Ilyina et al., 2004; Báldi, 2006) are uncertain whether this seaway was open or closed.

The structural development of the southwestern part of the Central Paratethys took place in three successive phases: the beginning extension at the transition of the Oligocene and the Miocene, the main extension in the middle Miocene, and the transpression in the Pliocene and Quarternary (Prelogović et al., 1998). The most important tectonic process for the development of the basins was the lateral extrusion of tectonic microplates from the collision zone between the African and the Eurasian plate; the tectonic interaction of the Eurasian and the Adriatic plate caused thrusting and folding in the Alps and the Dinarides as well as dextral strike-slip faults along the Periadriatic tectonic zone (Royden & Baldi, 1988). The Eastern Alps moved in an eastward direction along the Periadriatic Lineament, which separates the Eastern and the Southern Alps then bifurcates (or trifurcates) in southeastern Slovenia and northeastern Croatia and continues as a double central-Hungarian and Balaton fault (Jelen & Rifelj, 2002) and the Drava fault (Tomljenović & Csontos, 2001). The eastward continental escape in the Eastern Alps was accompanied by the lithospheric extension and subsidence (Royden, 1988; Fodor, 1995; Prelogović et al., 1998; Tari & Pamić, 1998; Lučić et al., 2001; Márton et al., 2002; Vrabec & Fodor, 2006), and the lateral extrusion associated with the extension caused the development of the epicontinental basins of the Central Paratethys where marine sedimentation begun (Saftić et al., 2003); fresh water sedimentation began simultaneously in some smaller basins, which had developed in the Dinarides (Pavelić et al. 1998; Ilić & Neubauer, 2005; Krstić et al., 2007).

The most intense episode of tectonic activity occurred during the Early and Middle Badenian, when eustatic changes were about an order of a magnitude smaller than the changes induced by tectonic activity (Báldi et al., 2002). The multi-phase tectonic activity during the transition of the Lower and Middle Miocene (the Karpatian and the Badenian) is often referred to as the Styrian tectonic phase, and this multi-phase event (Pleničar & Nosan, 1958; Spezzaferri et al., 2002; Rögl et al., 2007a) caused the uplift of the Burgenland Swell, which separated the Styrian Basin and the Mura Depression (Ebner & Sachsenhofer, 1995). Several discordances associated with the Styrian phase are marked by tuff beds indicating volcanic activity (Royden & Báldi, 1988). The tuffs have been radiometrically dated, and the first tectonically-generated break in sedimentation comprises the time interval between 16.5 and 16.1 or 16.2 Ma, the second one between 15.4 and 14.8 Ma (Handler et al., 2005), while the third one (the existence of which is not entirely certain) cannot be radiometrically dated and belongs to the upper part of the biozone NN5 (Rögl et al., 2007a).

The subsidence in the entire Central Paratethys region lasted until the end of the Badenian, though its intensity gradually decreased (Fodor et al., 2002). The Upper Badenian is characterized by a relatively small rate of subsidence and low tectonic activity, so bathymetric changes were controlled primarily by eustatic fluctuations (Báldi et al., 2002; Kováč et al., 2007).

1.2.2. Palaeoclimate

The Miocene was a time of global climatic changes. The Early and Middle Miocene were marked by a several million-year period of warm climate, the Miocene Climatic Optimum (MCO), which came to an end during the Middle Miocene global climate transition. The MCO is reflected in the oxygen isotope values from the deep-sea sediment cores from the ocean floor (Flower & Kennett, 1994; Zachos et al., 2001), as well as the marine and continental fossil record (e.g., Ivanov et al. 2002; Böhme, 2003; Bicchi et al., 2003; Jiménez-Moreno, 2006). The Miocene Climatic Optimum (MCO) reached its maximum within standard nannoplankton zones NN4 and NN5 (Müller, 1989).

Most palaeoecological reconstructions of the Central Paratethys region were made through interpretations of fossil flora and fauna. Ivanov et al. (2002), Palmarev & Ivanov (2004), Kvaček et al. (2006), Jiménez–Moreno (2006), Jiménez-Moreno et al. (2006), and Jiménez-Moreno & Suc (2007) analysed the Badenian vegetation and concluded that the Badenian was a period of stable, very warm and humid, subtropical climate with a moderate cooling and drying trend towards the end.

Badenian faunas of bryozoans (Moisette et al., 2006), echinoderms (Kroh, 2007), and molluscs (Harzhauser et al., 2003) were very diverse and similar throughout the entire Central Paratethys realm; foraminifera were also very diverse (Rijavec, 1978; Oblak, 2006). Minimal winter water temperatures, estimated on the basis of echinoderm fauna, reached between 15 and 18°C (Kroh, 2007) or between 14 and 16°C, when estimated on the basis of mollusc fauna (Harzhauser et al., 2002).

The Late Karpathian and the Early Badenian climate was warm and wet (Ivanov et al., 2002; Böhme, 2003; Palmarev & Ivanov, 2004; Böhme et al., 2007). During this time period, mixed mesophytic forest with diverse broadleaved evergreens was the most common type of vegetation in the Central Paratethys region, while the southern shores of the Central Paratethys were covered with evergreen vegetation (Utescher et al., 2007a, b).

During the Middle Badenian, a minor cooling occurred, reflected in the migration of warm water species of echinoderms towards the south (Kroh, 2007). In the Middle Badenian, the environmental conditions in Central Europe were favourable for ectothermic vertebrates adapted to dry conditions (Böhme et al., 2007). Utescher et al. (2007b) report that, by that time in the Central Paratethys realm, the mixed mesophytic vegetation was largely replaced by deciduous forests; though, in some areas mesophytic vegetation remained present, while flora with a xerophytic aspect primarily reflected local conditions. Böhme et al. (2007) argue that during this time temperatures remained high, but there was a change in the distribution of precipitation, which became seasonal and brought on long dry periods.

During the Early and Middle Miocene, the Central Paratethys was warmer than the Eastern Paratethys, while in the Late Miocene the difference was greatly reduced (Kroh, 2007). At 14 Ma, cooling and increased seasonality occurred in both regions (Syabyraj et al., 2007; Bojar et al., 2004). By the end of NN5, most tropical bryozoans had disappeared from the Central Paratethys (Moisette et al., 2006); in the Styrian Basin, a drop in temperatures occurred (as indicated by the $\delta^{18}O$ content of pectinid and brachiopod shells) at 14 Ma (Bojar et al., 2004). In the Karpathian Foredeep, the warm water planktonic foraminifera disappeared within the NN5 biozone, while in the Mediterranean the drop in temperature was less pronounced (Bicchi et al., 2003); the cooling trend during NN5 was stronger in the eastern part of the Central Paratethys (Bicchi et al., 2003).

However, some parts of the Central Paratethys realm appear to not have undergone significant climatic changes until the end of the Badenian, or rather, there are mixed signals concerning this issue. Late Badenian vegetation in Serbia was thermophyllous and evergreen (Utescher et al., 2007b), which reflects a warm climate. Additionally, Randazzo et al. (1999) report that most of the lithothamnium limestone in the Central Paratethys realm was deposited in relatively cool water; however, the limestone from the Danube and Zala Basins (the Hungarian part of the Mura-Zala Basin) have accumulated at a faster rate and can be associated with warm water. Furthermore, though Schmidt et al. (2001) associate the low biodiversity found in the lithothamnium limestone in southeast Austria with temperate climate, Kroh (2004) calls this into question by discussing the presence of two tropical echinoderm species in Austrian Badenian deposits of the same age.

The end of the MCO was diachronous in different parts of the world, as climatic changes were closely associated with palaeogeographic and tectonic changes (Bruch et al., 2007). Stable oxygen isotope records from deep sea sediment cores indicate a global cooling trend at approximately 15 Ma (Zachos et al., 2001). Böhme (2003) notes that the end of the MCO in continental Central Europe occurred between 14 and 13.5 Ma - somewhat later than in Americas and the oceans.

By the end of the MCO, global ocean circulation had changed and the East Antarctic Ice Sheet had developed (Flower & Kennett, 1994; Shevenell & Kennett, 2004). Báldi (2006) asserts that the type of circulation had changed in the Central Paratethys as well. In the Central Paratethys region, the MCO ended during the Badenian; however, the exact time of the cooling seems to vary considerably among different regions.

1.3. Stratigraphic correlation of the Badenian

1.3.1. Biostratigraphy

Though comparable to the neighbouring bioprovinces, the Central Paratethys is a distinct bioprovince where the specific character of fauna and flora required and enabled an elaboration of a local stratigraphic system (e.g., Steininger et al., 1976; Steininger et al., 1988; Piller et al., 2007). The Badenian is a Central Paratethys stage, a chronostratigraphic unit of the early Middle Miocene age. The stage name derives from the town of Baden in south Austria where the unistratotype is exposed (Steininger et al., 1976; Rögl et al., 2008)

The definition of the Badenian relies mostly on mollusc and benthic foraminiferal stratigraphy. A biostratigraphic survey of Slovenske Gorice, based on foraminifera (Rijavec, 1976; 1978), confirmed that the age of the sediments increases in from east to west. Evidence of three Badenian foraminiferal biozones has been found: the *Praeorbulina - Orbulina suturalis* Zone (corresponding to the Lower and the Upper Lagenidae Zone), the *Spiroplectammina carinata* Zone (corresponding to the Agglutinated Foraminifera Zone), and the *Bolivina dilatata* Zone (corresponding to the *Bulimina-Bolivina* Zone). The Upper Badenian *Ammonia* (*Rotalia*) *beccarii* Zone was missing due to erosion.

The standard nannoplankton zonations of Martini (1971) Bukry (Bukry, 1971a; Okada & Bukry, 1980) are based on the same stratigraphic events, but only the former is used in this work.

The correct correlation of the Badenian sub-stages defined by benthic organisms and the planktic world-zonations is still missing (Kováč et al., 2007). Steininger et al. (1976) correlate the base of the Badenian with the lower part of NN5, and though this correlation can still be traced in recent literature (e.g., Švabenická, 2002a), most authors (including Steninger et al., 1988; Kováč et al., 2007; Piller et al., 2007 and Rögl et al., 2007b) place the beginning of the Badenian in the upper part of NN4.

The time of the transition between the Badenian and the Sarmatian is debatable; Steininger et al. (1976) correlate this transition with NN8 but recent publications have shifted this boundary further back in time. The Badenian/Sarmatian boundary is placed differently by different authors in the interval between the lower part of NN7 (e.g., Steininger et al., 1988) and the transition of NN5 and NN6 (e.g., Vakarcs et al., 1998). Most authors place the end of the Badenian in the middle of NN6 at 13 Ma (e.g., Steininger & Wessely, 2000; Ćorić et al., 2004) or 12.7 Ma (e.g., Piller et al. 2007; Rögl et al., 2007b; Kováč et al., 2007).

The age of the oldest Badenian deposits in different parts of the Central Paratethys varies due to the complex structure of the sea floor. In northeast Austria (Molasse Basin), the oldest Badenian deposits are assigned to the upper part of NN4 (Ćorić et al., 2004), while in northern Bosnia (Jerković & Ćorić, 2006) and Transylvania (Chira in Vulc, 2003) they belong to the bottom part of NN5. In the Styrian Basin, the oldest Badenian deposits – in Wagna and Retznei, approximately 10 km north of Šentilj - are correlated with NN4 and NN5 respectively (Rögl et al., 2007a; Hohenegger et al., 2009).

In this work, the datums of nannoplankton events of Lourens et al. (2004) for the Neogene Period were used.

1.3.2. 3rd order eustatic cycles and O-isotope stratigraphy

Correlation of the depositional sequences of the Central Paratethys with the global sea-level changes is not a simple task because of the strong interference of regional factors. Individual sedimentary sequences often do not correspond to global sea-level changes (Kováč et al., 2007). The Middle Miocene sequences from the western and Southern part of the Central Paratethys (Vienna Basin, Styrian Basin, Danube Basin and Transylvanian Basin according to Kováč et al. (2007) can be correlated with three global 3rd order eustatic cycles TB2.3, TB2.4 and TB2.5 of Haq et al. (1988) and Hardenbol et al. (1998). They have been recalibrated by Rögl et al. (2007b) and correspond to Early, Middle, and Late Badenian respectively (Fig. 1.2). Kováč et al.

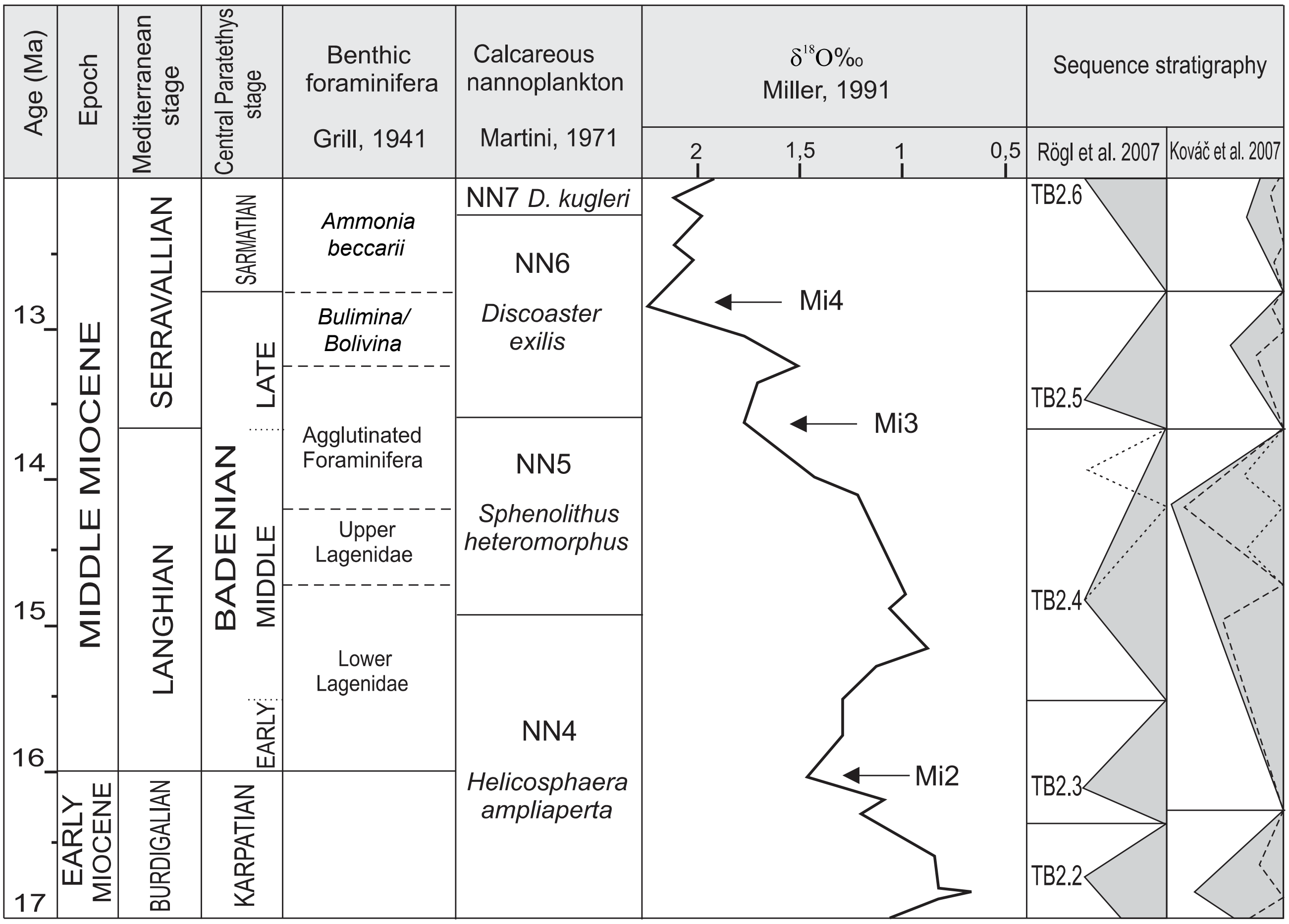


Fig. 1.2. The stratigraphic correlation of Mediterranean and Central Paratethys stages, biozonation based on foraminifera and nannoplankton, oxygen isotope data and 3rd order sequences plotted against an absolute time scale.

(2007) subdivide the Badenian only into Early (roughly corresponding to TB2.3 and TB2.4) and Late Badenian (corresponding to TB2.5) (Fig. 1.2).

The Lower Badenian corresponds to the global cycle TB2.3 (Kováč et al., 1999; Márton et al., 2002; Harzhauser & Piller, 2007). The transgression at the beginning of the Badenian has been described in several locations in Slovenia (Pleničar et al., 1991), Austria (Ebner & Sachsenhofer, 1995; Kováč et al., 2004), and Croatia (Lučić et al., 2001; Saftić et al., 2003). The end of the Lower Badenian eustatic cycle (TB2.3) is marked by a rapid sea-level drop of more than 100 m (Rögl et al., 2002).

The TB2.4 cycle roughly corresponds to the Middle Badenian (Harzhauser & Piller, 2007; Rögl et al., 2007b). During the NN5, the sea in the wider Pannonian region was at a relative highstand, reaching the maximal depth of the neritic (Kováč et al., 1999); the transgression covered the entire Central Paratethys, including the Transylvanian Basin (Rögl et al., 2007b). A regression at the end of the global cycle TB2.4 in the upper part of NN5 is a well recognizable palaeobatimetric event. In southeast Slovenia, it is marked by a hiatus between the Middle and the Upper Badenian (Pavšič & Aničić, 1998; Oblak, 2003). During the sea-level lowstand, fresh-water influences occurred in marginal areas, while the deeper basins remained unaffected (Pezelj & Sremac, 2007). In the Carpathian Foredeep and the Transylvanian Basin, the advanced stage of this regression is associated with the deposition of fresh water evaporites (Peryt, 2006; Cendón et al., 2004). These evaporites are directly overlain by marine sediments (Ślaczka & Oszczypko, 2002), reflecting the transitional nature of the sea-level drop.

Some authors (e.g., Vakarcs et al., 1998) correlate the TB2.5 eustatic cycle with the Sarmatian, however this cycle is usually correlated with the Upper Badenian (e.g., Strauss et al., 2006, Schreilechner & Sachsenhofer, 2007; Piller et al., 2007; Rögl et al., 2007b).

Sedimentary cycles in Fig. 1.2 are plotted against the oxygen isotope curve from the reference site 608 of Miller et al. (1991). The Badenian can be correlated with three Miocene oxygen stable isotope zones: Mi1b (upper part), Mi2, and Mi3 (Fig. 1.2). The most notable stable oxygen isotope stratigraphic event of this time interval is the maximum $\delta^{18}O$ value at the beginning of the Mi3 zone of Miller et al. (1991); it represents one of the major cooling steps during the long-term decrease in global temperatures during the entire Cenozoic and is also referred to as the 'Mid-Miocene event'. It is dated at 13.6 Ma and slightly precedes the LO of *Sphenolithus heteromorphus*, marking the boundary of the standard nannoplankton biozones NN5 and NN6.

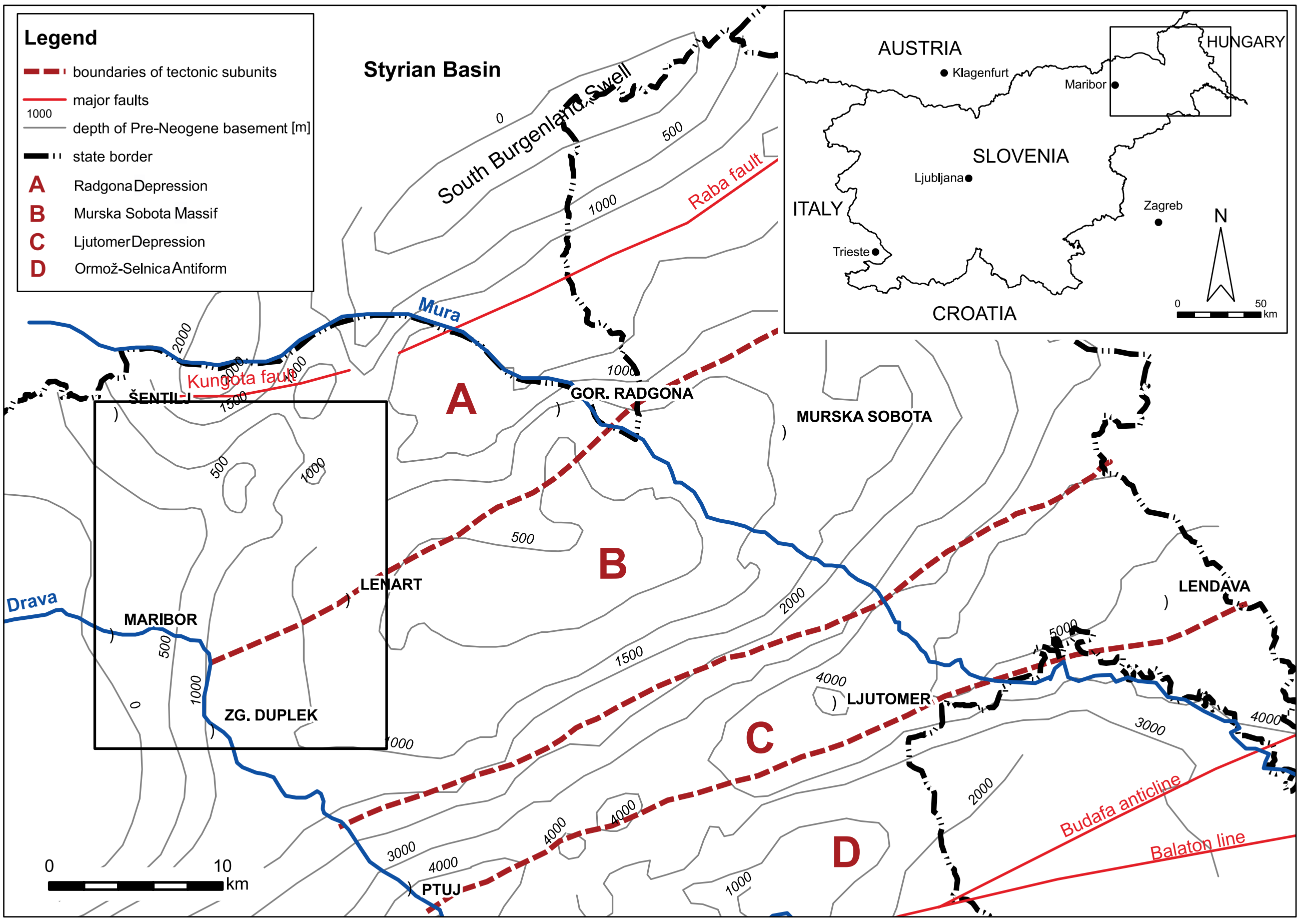


Fig. 1.3. A map of the Mura Depression showing the inferred position of boundaries between tectonic subunits (Mioč & Žnidarčič, 1996) and the depth of Pre-Neogene basement (Gosar, 2005). The study area is marked with a square (enlarged in Fig. 1.4).

1.4. The Mura Depression – geological setting and description of sections

1.4.1. Geological setting

Geologically, the Mura Depression can be divided into three distinct units: the Pre-Neogene basement, the Tertiary sediments, and Quarternary cover (Mioč & Žnidarčič, 1996). The Pre-Neogene basement of the Mura Depression represents the eastern extension of the Alps. Pre-Miocene tectonic activity resulted in the disintegration of this structure into several tectonic subunits, separated by faults running in a northeast-southwest direction (Pleničar et al., 1991); these tectonic subunits are the Radgona Depression, the Murska Sobota Massif, the Ljutomer Depression, and the Ormož-Selnica Antiform (Mioč & Žnidarčič, 1987; 1996) (Fig. 1.3). The thickness of Neogene deposits varies considerably in different parts of the Mura Depression, reaching 2000 m in the Radgona Depression and even as much as 4000 m in the Ljutomer Depression, but only 500-1000 m in the Murska Sobota Massif (Mioč & Žnidarčič, 1996; Gosar, 2005). The structural and stratigraphic relations between the Pre-Neogene basement and Neogene deposits and within the Miocene deposits (Novak et al., 1976) are evidence of synsedimentary tectonic activity and indicate that the Mura Depression was not a uniform sedimentary basin but, rather, a quite heterogeneous one.

The age of the oldest marine sediments in different parts of the Central Paratethys is also variable. The Badenian and the Karpatian are separated by an unconformity; the youngest Karpatian and the oldest Badenian deposits are missing and a concordant sequence has not yet been described, though it presumably exists in the Transylvanian basin (Sorin Filipescu, oral communication). A well marked transgression characterises the oldest Badenian facies in the entire Central Paratethys realm (Harzhauser et al., 2003), and it is also noticeable in the Mura Depression (Márton et al., 2002); first, the sea flooded the deepest parts of the confined depressions (half-grabens) and in turn separate basins were united as the transgression advanced (Fodor et al., 2002).

Slovenske Gorice, along with Haloze, Dravinjske Gorice, Goričko, and the lowlands surrounding the rivers Mura and Drava represent the Slovene part of the Mura Depression (Žnidarčič & Mioč, 1989). In the Upper Miocene and Pliocene, this independent tectonic unit disintegrated into several tectonic blocks. The Badenian deposits extend in a patch, a few kilometres wide, which stretches between Šentilj, Lenart, and Zgornji Duplek (Fig. 1.4).

The Badenian successions in Slovenske Gorice usually begin with conglomerate or breccia (Mioč & Žnidarčič,

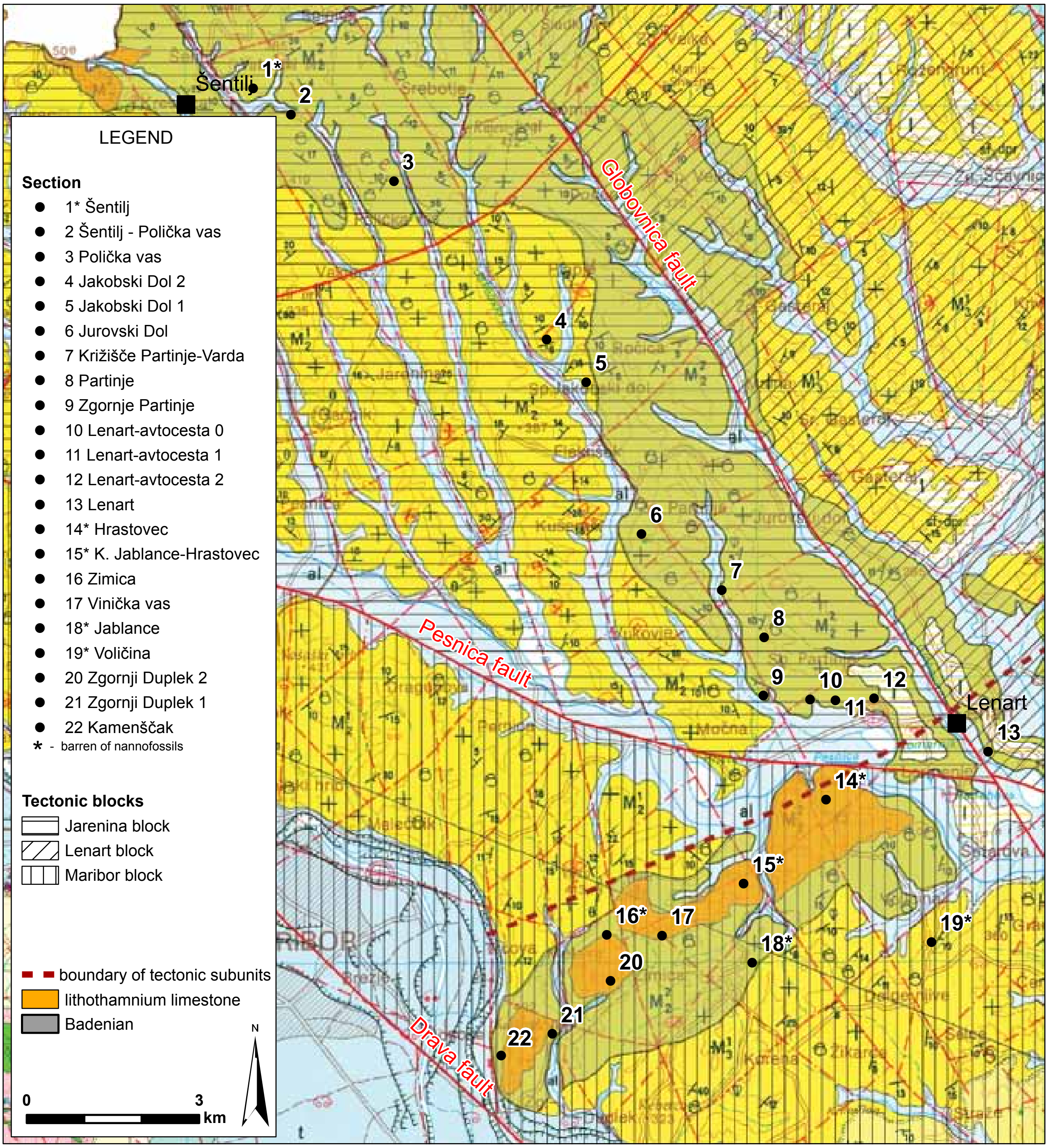


Fig. 1.4. Geological map of the study area (modified after Mioč & Žnidarčič, 1987) with the localities of all sampled sections. The positions of the Badenian deposits, lithothamnium limestone, and boundaries of the tectonic subunits of Slovenske gorice (Mioč & Žnidarčič, 1996) are indicated.

1987). In the central part of Slovenske Gorice, fine-grained Karpatian sediments are overlain by fine-grained sediments of the Lower Badenian age instead of gravel (Novak et al., 1976). The Badenian facies successions include sands and clays and are dominated by sandy, clayey, and silty marls, while lithothamnium limestone and calcarenite are characteristic of the youngest Badenian beds (Mioč & Žnidarčič, 1987). Badenian deposits throughout the Central Paratethys are characterized by considerable lateral lithological variability (e.g., Vrsaljko et al., 2005), reflecting the complexity of sea-floor topography.

In certain localities in Slovenia (Rižnar et al., 2002), Croatia (Vrsaljko et al., 2006), and Serbia (Mihajlović & Knežević, 1989), the transition of the Badenian and the Sarmatian is marked by a hiatus, while in others (Vrsaljko et al., 2006) the transition is concordant. This is another indication of the heterogeneity of the depositional environment.

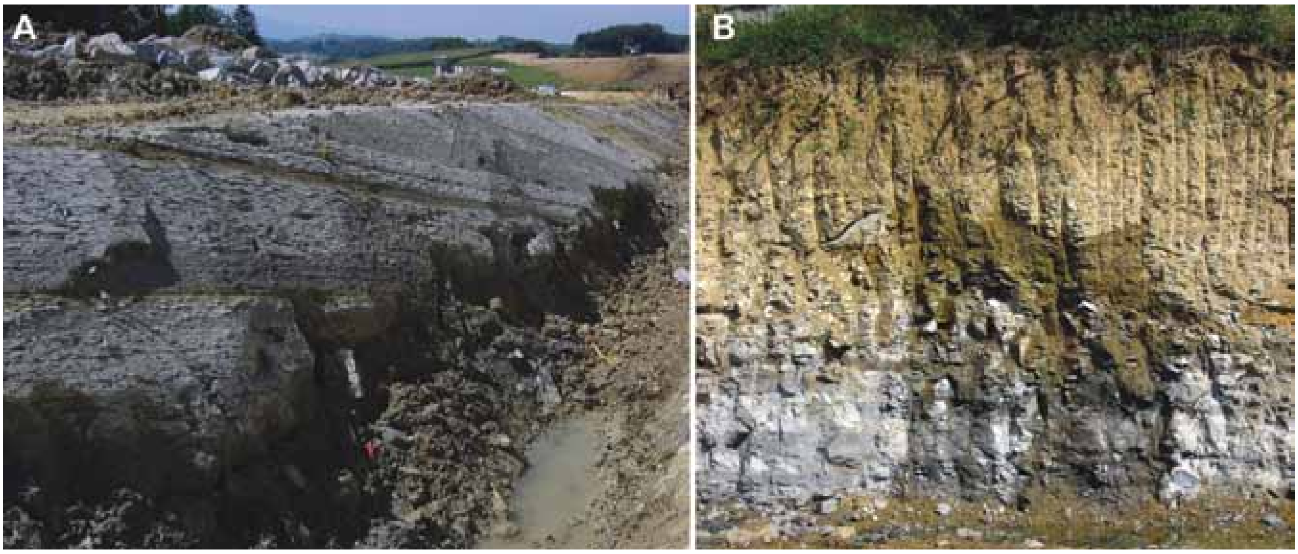


Fig. 1.5. Marl successions in the Lenart avtocesta 2 (A) and Jakobski Dol (B) sections.

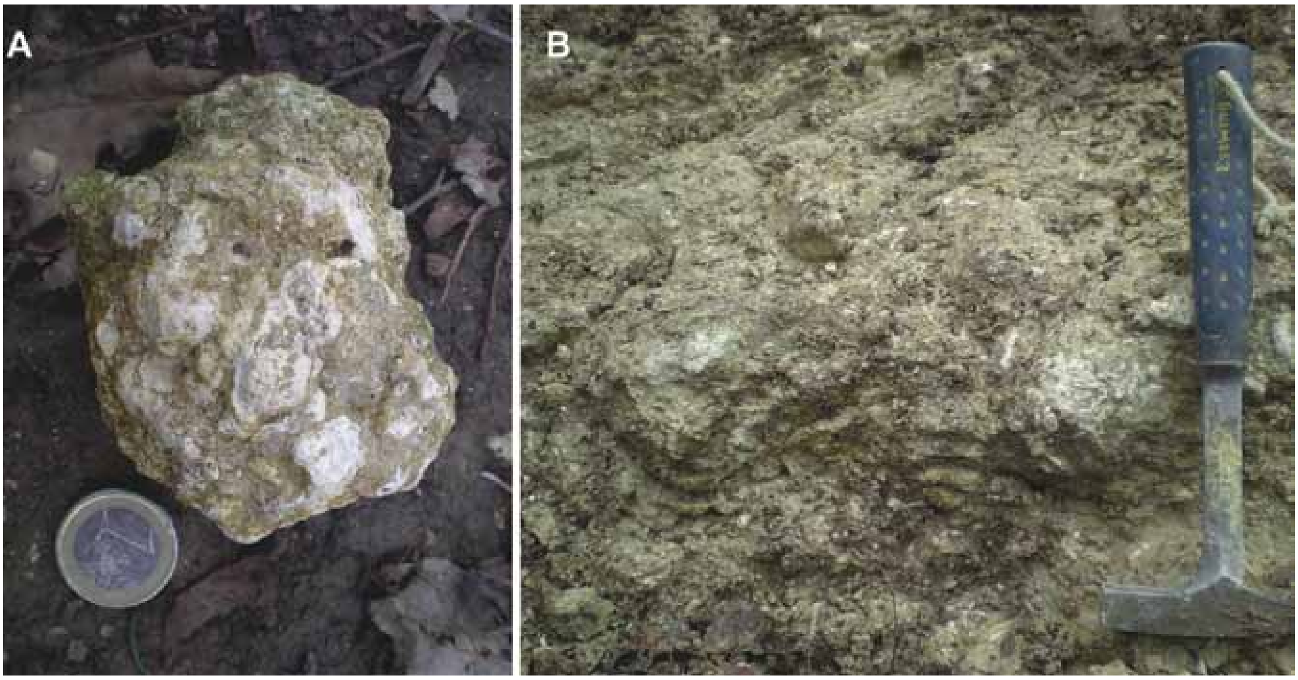


Fig. 1.6. A rhodolith (A) and rudstone consisting of rhodoliths in fine-grained hard marl matrix (B), both from the Vinička vas section.

1.4.2. Description of sampled sections

There are virtually no natural outcrops of Miocene rocks and sediments in the hill range of Slovenske Gorice, as the terrain is gently sloping and overgrown with thick natural vegetation or is used for agricultural purposes. All sections sampled in Slovenske Gorice were of anthropogenic origin and were found in road or housing construction sites. In the scope of this study, 22 sections were sampled; nannofossils were found in samples from 17 sections, 5 were barren of nannofossils. The localities of all sampled sections are shown in Fig. 1.4.

Several of the sampled sections recorded in Slovenske Gorice consisted exclusively of marl (Fig. 1.5). The carbonate fraction of Badenian marls from Slovenske Gorice consists mainly of nannofossils while the clastic components are predominantly clay and silt. The marls usually contained no fossils visible to the naked eye, but were rich in calcareous nannofossils.

Lithothamnium limestone is common in the Badenian deposits in Slovenske Gorice as well. It occurs in a continuous belt between Hrastovec and Kamenščak (Fig. 1.4). The Vinička vas section is a small cart track going up a slope of a hill, situated in the middle of the limestone patch between

Hrastovec and Kamenščak. The lithothamnium limestone in the Vinička vas section is rudstone, consisting of rhodoliths imbedded in a fine-grained hard marl matrix (Fig. 1.6). Individual layers within this section were very difficult to discern. A few thin and irregular hard marl interbeds were sampled and proved to be rich in nannofossils.

Five sections are represented below in the form of stratigraphic columns; they were selected because they consist of more than one lithofacies and are among the thickest sections sampled in Slovenske Gorice.

The Lenart –avtocesta 0 section (Fig. 1.7) consists mostly of grey marl; this clastic component varies in grain size from clay to sand. The marl is relatively rich in mica, and several sand and sandstone interbeds (up to 20 cm thick) occur within the predominantly marl sequence. Some marl beds are normally-graded, and a transition from sandy to silty or clayey marl can be observed.

Between meters 4 and 5.5, several thin (up to 1 cm) horizons of fine sand with numerous pteropod fragments occur (Fig. 1.12); the sample for micropalaeontological analyses was taken at 4.90 m (sample Lat-1). At 11.40 m, marl is replaced by a thick bed of normally-graded sand to silt with several horizons containing solidified sandstone concretions. The succession continues with an erosional contact with the overlying marl bed, which is grey and rather monotonous. The uppermost part of the recorded section consists of sand.

The Lenart–avtocesta 1 section (Fig. 1.8) cuts through a sedimentary succession of grey marl with a relatively high content of mica. No fossils, visible to the naked eye, were observed in the marl, except for some fragments of mollusc shells, concentrated in a few thin layers of somewhat coarser grained marl. The marl sequence is interrupted by several thin (up to 10 cm) sand and sandstone interbeds. The 13 samples from this section were collected at 50 cm intervals.

The lower part of the Jurovski Dol section (Fig. 1.9) is composed of interbedded grey clayey marl, yellow silt, sand, and sandstone. Samples from this part of the section were collected at 10 cm intervals. The marl was rich in nannofossils, while the sand and sandstone contained poorly-preserved assemblages or were entirely barren of nannofossils. After a vegetation-covered 20 m gap in the section, the section continues with a 9 m thick bed of lithothamnium limestone conglomerate (Fig. 1.13). The solid conglomerate consists of various fossils, mostly concretions of red algae, but also fragments of corals and large foraminifera; it also contains chert pebbles, ranging in size from a few millimetres to several centimetres (Fig. 1.14). The conglomerate contains numerous lenses of grey marl measuring a few centimetres to over 1 m (Fig. 1.15) that seem to occur in discrete strata (Fig. 1.13). Samples for nannoplakton analyses were collected from these marl lenses.

The Lenart section (Fig. 1.10) consists of rather uniform succession of grey clayey marl beds without any fossils visible to the naked eye. The succession is interrupted by two sand interbeds at 17 and 18.5 m. In the lowermost marl bed, some pteropod shells were found. From the 21st m onward,

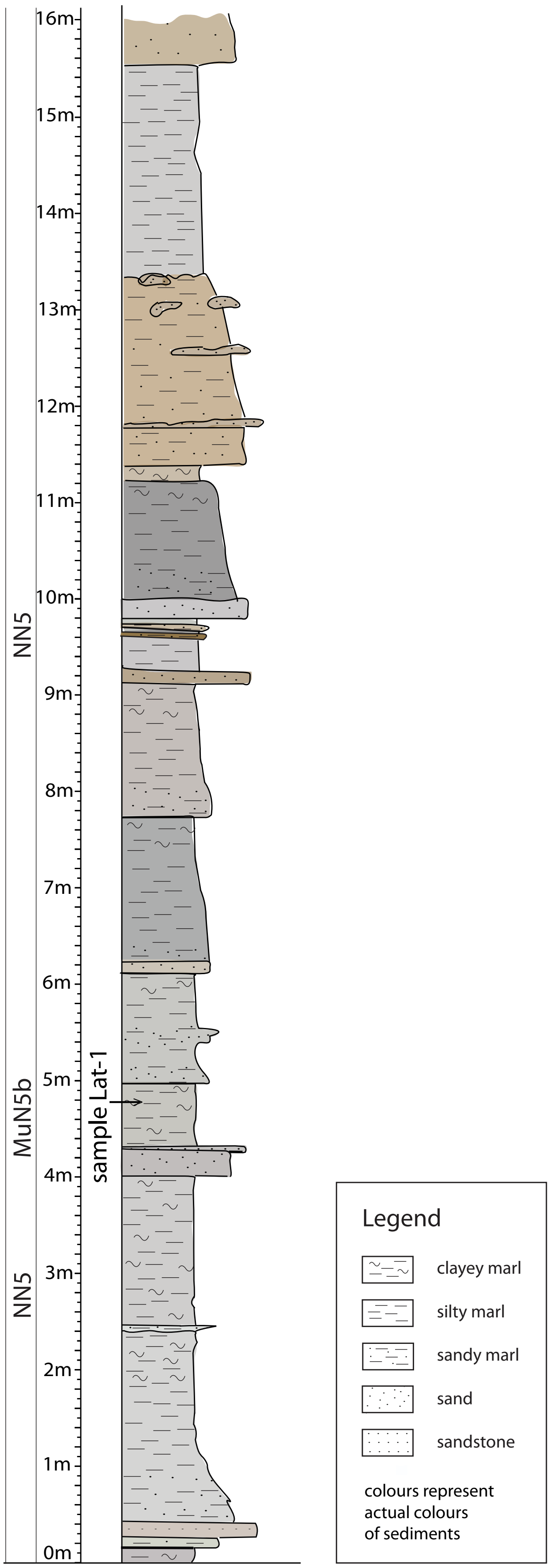


Fig.1.7. The stratigraphic column of the Lenart–avtocesta 0 section. The position of the sample is indicated.

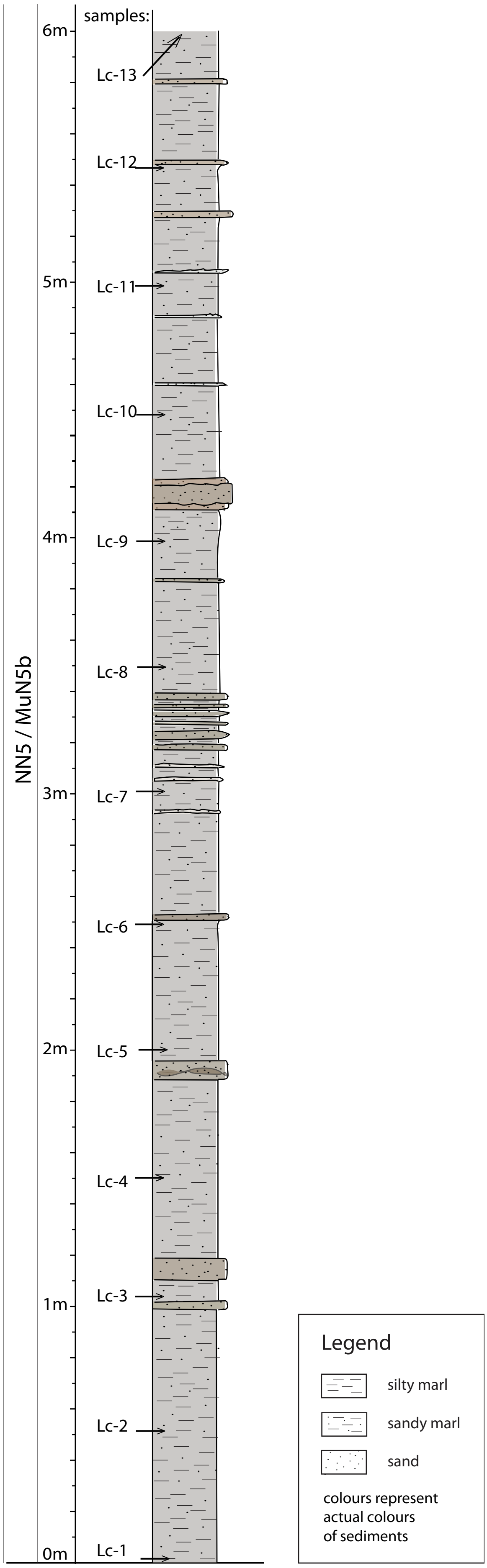


Fig. 1.8. The stratigraphic column of the Lenart–avtocesta 1 section. The positions of the samples are indicated.

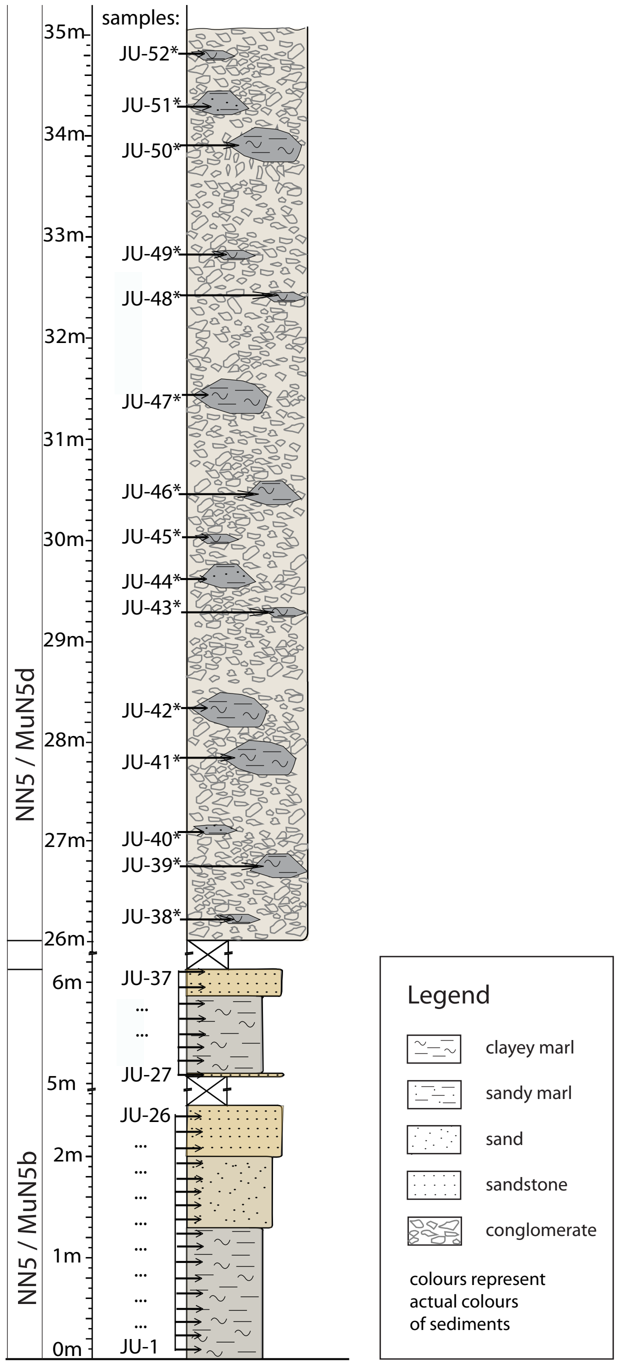


Fig. 1.9. The stratigraphic column of the Jurovski Dol section. The positions of the samples are indicated.

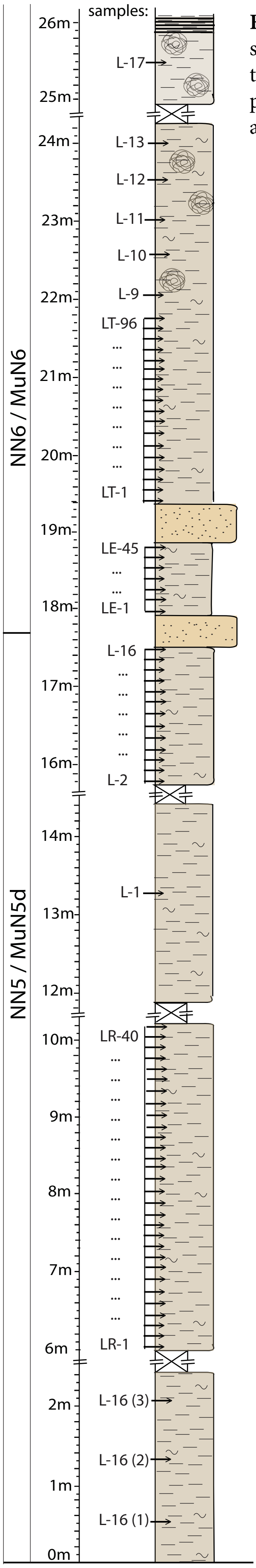
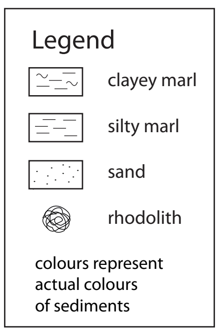


Fig. 1.10. The stratigraphic column of the Lenart section. The positions of the samples are indicated.



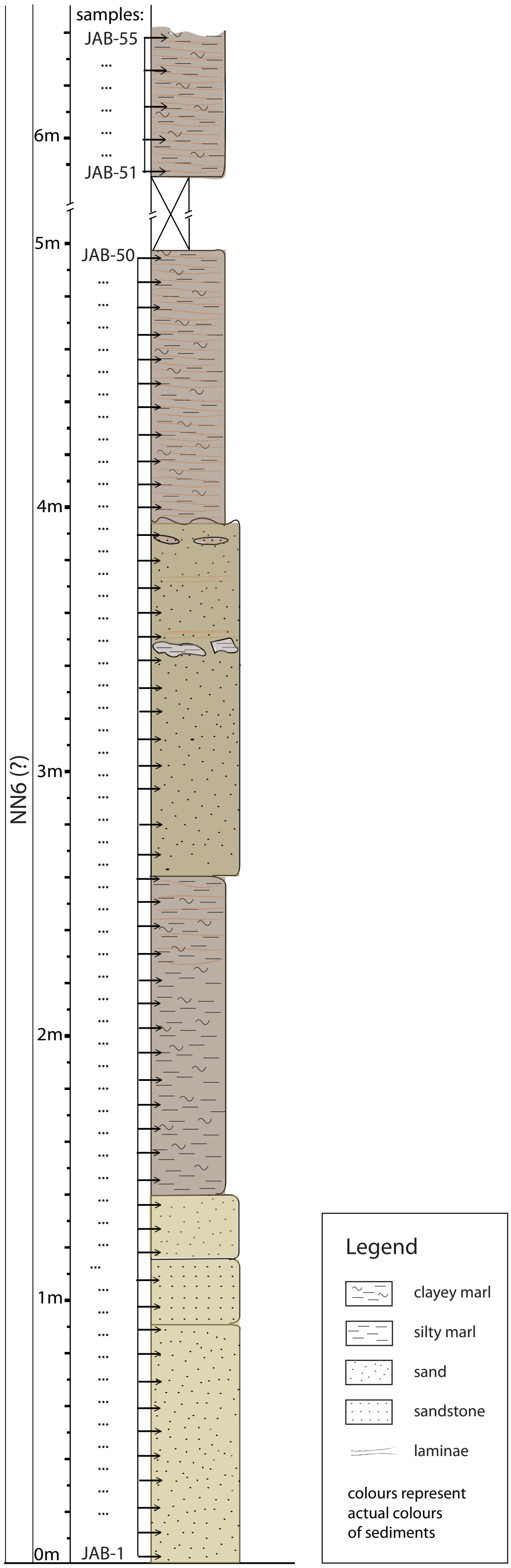


Fig. 1.11. The stratigraphic column of the Jablance section. The positions of the samples are indicated.

individual rhodoliths, imbedded in marl, were observed (Fig. 1.10). Fragments of plant remains were observed in a horizon at 23 m. Rhodoliths become more common towards the top of the section. At the very top of the section the carbonate content of marl increases, and the marl becomes much harder and lamellate.

The Jablance section sequence (Fig. 1.11) begins with a thick bed of sand with a 30 cm thick interbed of solid sandstone. Wave-formed ripple marks were observed on the upper surface of the sandstone bed (Fig. 1.17A).

Succession continues with stratified clayey marl with orange laminae in the upper part. This is followed by another thick sand bed with orange laminae (Fig. 1.18A) and intraclasts consisting of clayey marl (Fig. 1.17B).

Near the top of the section, there is a horizon with sandstone concretions. An irregular contact separates the sand from the overlying clayey marl with orange laminae (Fig. 1.18B). All samples from this section were barren of nannofossils and only a few isolated foraminifera tests were found, making them insufficient for any substantial biostratigraphic analysis.

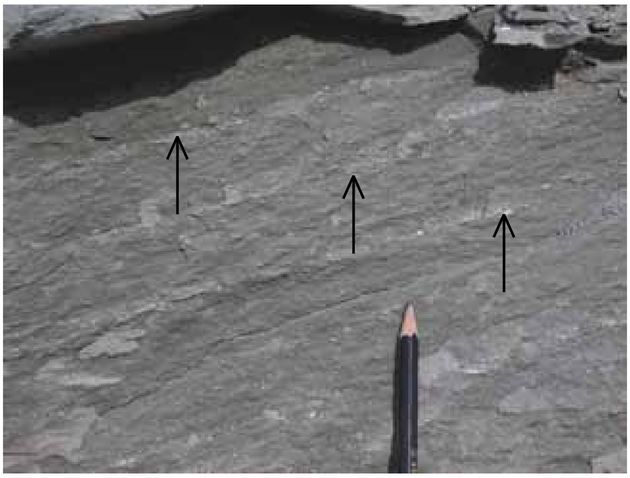


Fig. 1.12. Fine sand with numerous pteropod fragments arranged in laminae (arrows). Lenart–avtocesta 0 section (photo: T. Popit).

Fig. 1.13. The upper part of the Jurovski Dol section, composed of conglomerate containing marl lenses of various sizes.

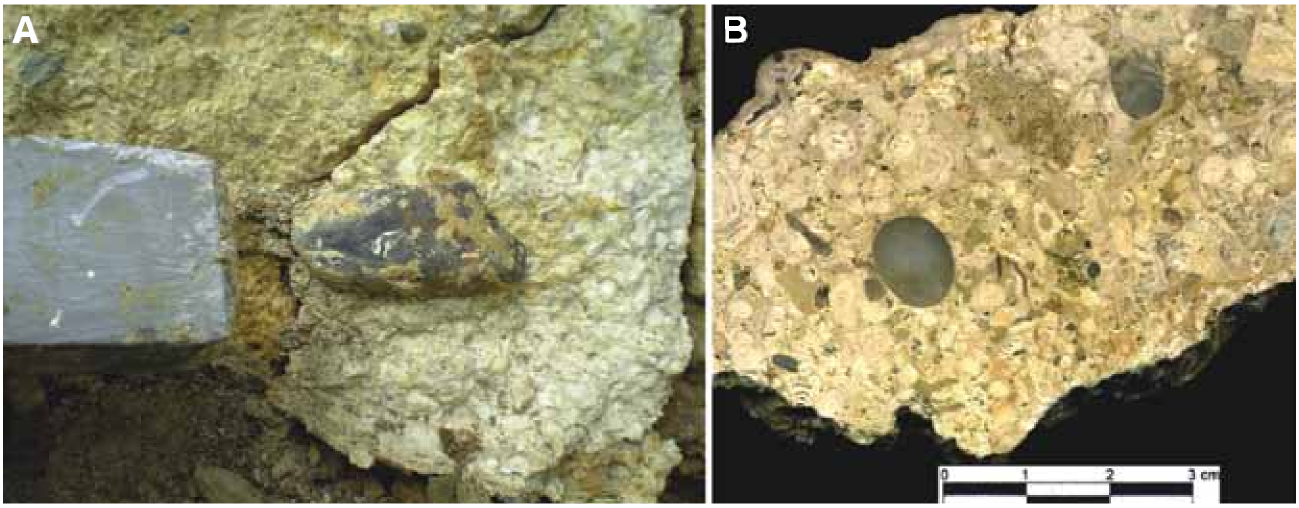


Fig. 1.14. The conglomerate from the upper part of the Jurovski Dol section with chert pebbles. A – close view, B – polished surface.

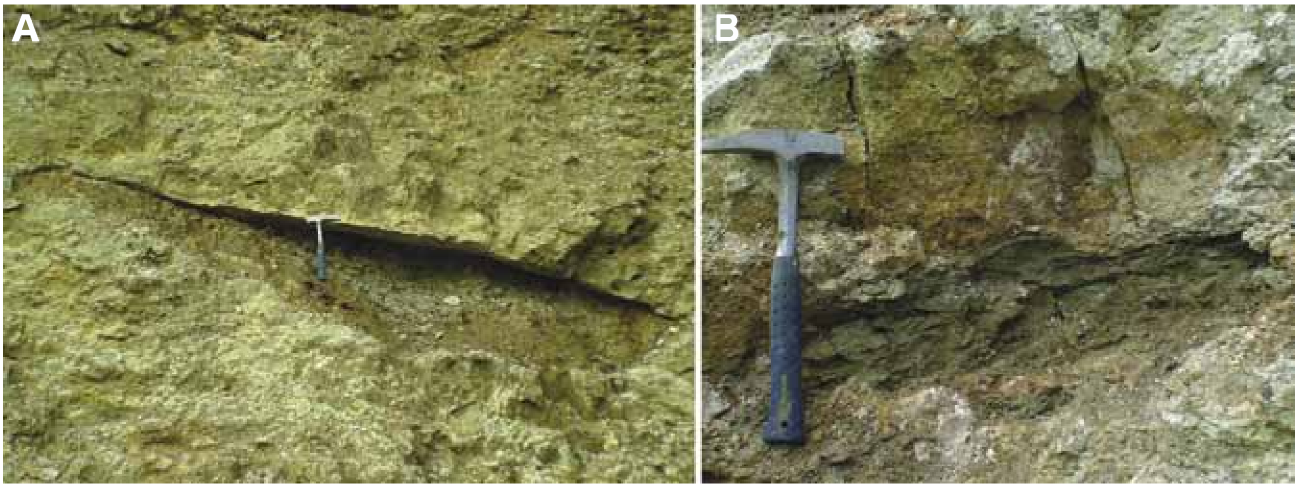


Fig. 1.15. Large (A) and small (B) marl lens in the upper part of the Jurovski Dol section.

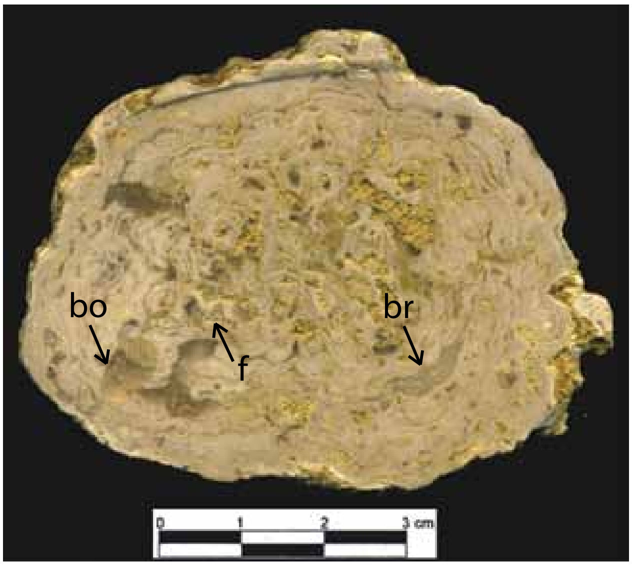


Fig. 1.16. A cross section through a rhodolith from the Lenart section. Crustose coralline algae are arranged in concentric layers, foraminifers (f), bryozoans (br), and borings of various organisms (bo) can also be observed.

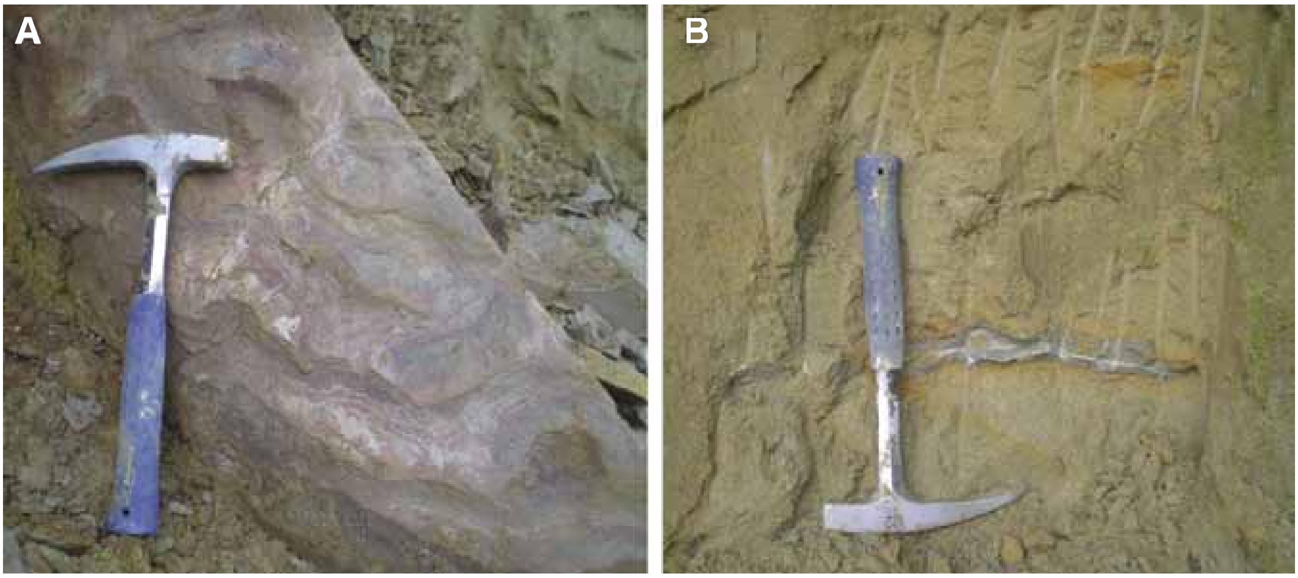


Fig. 1.17. Wave formed ripple marks on the upper surface of a sandstone bed (A) and clayey marl intraclast in a sand bed (B), both in the Jablance section.

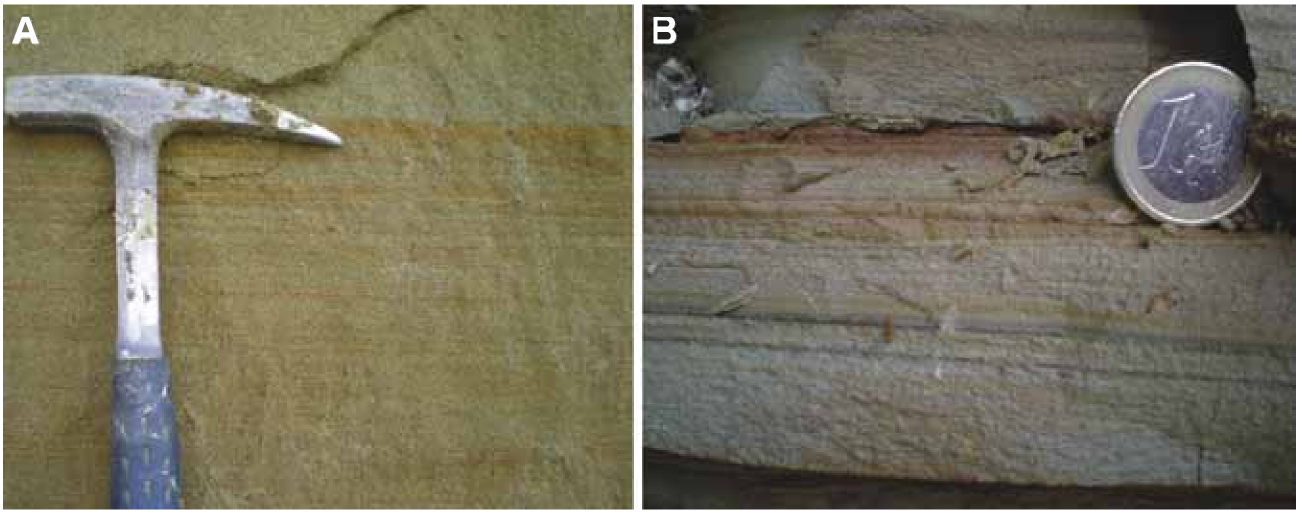


Fig. 1.18. Laminated sand (A) and marl (B) in the Jablance section.

2. MATERIAL AND METHODS

2.1. Sampling

Most of the samples for the micropalaeontological analyses were collected at 10 cm intervals. In the lithothamnium limestone sections (Spodnji Duplek 1 and 2, Zimica, Vinička vas), 1-3 samples were collected from thin marl beds within the limestone. In the sections from highway construction sites Lenart–avtocesta 1 and 2, samples were collected at 50 and 100 cm intervals, respectively.

One to three samples from the sections Vinička vas, Jablance, Križišče Jablance-Hrastovec, Voličina, Zimica, and Zgornji Duplek 1 and 2 were collected for foraminiferal analyses.

2.2. Sample preparation

Smear slides were prepared from all collected samples. Hand specimens were cleaned by paring the outer surfaces off and scraping fine dust of material onto a glass slide. This was then moistened with distilled water and spread across a glass slide, which was placed on a hot plate to dry. Once dry, the slide was covered with a cover slip glued to a slide using Canada Balsam. All sediment samples were routinely examined under a light microscope at a magnification of 1000× under plane polarized light (PPL) and cross polarized light (XPL). Light microscopy was carried out using a Zeiss Axioplan 2 microscope, a Zeiss AxioCam HRc digital camera, and an analogue camera located at the Department of Geology in the Faculty of Natural Sciences and Engineering at the University of Ljubljana.

Five samples (LR-34, LR-35, LR-38, LT-51 in PV-1) selected for the excellent state of preservation of microfossils and high species diversity of the nannoplankton assemblages, were prepared for the SEM. First, the samples were centrifuged by scraping a dust of material into a centrifuge tube, topping it up with distilled water, and spinning it at 350 rpm in the centrifuge for about one minute. The supernatant was then re-suspended and centrifuged at 1000 rpm for three minutes. The pellet was re-suspended and centrifuged at 1000 rpm several times. After centrifuging the sample was diluted with distilled water, strewn onto a cover slip, placed on a hot plate, and left to dry. The cover slip was then mounted on a stub, coated with gold, and examined under magnifications 3,500-20,000× using a JEOL JSM-T330A SEM at the Ivan Rakovec Institute of Paleontology of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Ljubljana.

Some samples from the Jablance, Voličina, Zgornji Duplek 1 and 2, Vinička vas, and Zimica sections were prepared for foraminiferal analysis by mechanical breaking, treatment with a weak solution of hydrogen peroxide, and washing through a sieve with 0.1 mm mesh.

2.3. Nannoplankton analyses

Determination of species relied mostly on Farinacci (1969), Perch-Nielsen (1985a, b), Young (1998), Burnett (1998), Varol (1998), Wise et al. (2002), and the Nannotax web page (http://nannotax.org/). The biostratigraphic analyses are based on zonations proposed by Martini (1971), Theodoridis (1984), Fornaciari et al. (1996), and Di Stefano et al. (2008).

All determined species are listed in chapter 3, and specimens of all species are figured in Pl. 1-25. The terminology used follows the guidelines given in Young & Bown (1997), Bown & Young (1997), and the INA web page (http://www.nhm.ac.uk/hosted_sites/ina/). The synonymy has already been exhaustively dealt with in several works (e.g., Wise et al., 2002), so only the original name of each species and the name(s), which is (are) currently in use, were listed in this work. No descriptions of species have been included, except where the observed specimens varied from original and other generally accessible descriptions.

For each sample the overall preservation of nannoplankton was evaluated (Appendix). Each sample was assigned into one of the four categories according to the following criteria:

B (barren): Samples contained no nannofossils.

P (poor): Severe dissolution, fragmentation, and/or overgrowth had occurred. Primary features may have been destroyed, and many specimens cannot be identified to the species level. Species diversity is greatly reduced.

M (moderate): Dissolution and/or overgrowth are evident. A significant proportion (up to 10%) of the specimens cannot be identified to species level with certainty. Fragile forms may be removed from the assemblage.

G (good): There is little or no evidence of dissolution and/or overgrowth. Diagnostic characteristics are preserved, and nearly all specimens can be identified to species level.

The relative abundance of individual species in individual samples was estimated (Appendix) by using a semi-quantitative method proposed by Hay (1970). Abundance estimates were expressed in the following manner:

Abundant: over 10 specimens per field of view,
Common: 1-10 specimens per field of view,
Rare: 1 specimen per 2 to 10 fields of view,
Few: 1 specimen per 11 to 100 fields of view.

To enable comparisons between different sections, estimates of nannofossil abundance for entire sections were made (see Fig. 6.4). The estimates are based on the semi-quantitative abundance estimates of species in individual samples described above. The total abundance of coccoliths was estimated in the following manner:

- + : less than 50 % of all samples contain one or more common species;
- ++ : more than 50 % of all samples contain at least one common species, less than 50 % of all samples contain at least 1 abundant species or more than 20 autochthonous species;
- +++ : more than 50 % of all samples contain at least 1 abundant species or more than 20 autochthonous species.

The presence of select species or genera in individual sections was analysed as well (see Fig. 6.4). The percentage of samples, containing individual taxa, and the abundance of specimens in individual samples were considered. Average abundances for individual taxa were determined on the basis of all samples containing these taxa. Then abundance estimates for individual sections were made in the following manner:

- / : the taxon is not present in any of the samples from the section,
- + : the taxon is present and occurs in abundances below average,
- ++ : the taxon is present and occurs in average abundances,
- +++ : the taxon is present and occurs in above-average abundances.

The abundance estimate marks were printed in bold when the taxa were continuously present – that means they were found in at least 80 % of all samples (or 70 % for dissolution sensitive forms, absent mostly from poorly-preserved samples). Samples barren of nannofossils were excluded from the total sum of samples.

3. SYSTEMATIC PALAEONTOLOGY

3.1. Coccolithophores

The classification scheme of Young & Bown (1997) was used. Species within individual genera are listed in alphabetical order.

A total of 106 species of coccolithophores were determined, belonging to 33 different genera (Pls. 1-25). *Helicosphaera*, *Reticulofenestra* and *Discoaster* are represented by the highest number of species.

Phylum: Haptophyta (Hibberd, 1972) Cavalier-Smith, 1986
Class: Prymnesiophyceae Hibberd, 1976

3.1.1. Heterococcoliths

Order: Zygodiscales Young & Bown, 1997
Family: Helicosphaeraceae Black, 1971

Genus: *Helicosphaera* Kamptner, 1954

Helicosphaera ampliaperta Bramlette & Wilcoxon, 1967
Pl. 5, figs. 8-12, 15

1967 *Helicosphaera ampliaperta* n. sp. - Bramlette & Wilcoxon, p. 105, pl. 6, figs. 1-4.

Helicosphaera carteri (Wallich, 1877) Kamptner, 1954
Pl. 1, figs. 1-8, 14, 15, 17-19

1877 *Coccosphaera carteri* n. sp. - Wallich, p. 348, pl. 17.
1954 *Helicosphaera carteri* (Wallich, 1877) Kamptner - Kamptner, pp. 21, 73, figs. 17-19.

Helicosphaera compacta Bramlette & Wilcoxon, 1967
Pl. 5, figs. 1, 18

1967 *Helicosphaera compacta* n. sp. - Bramlette & Wilcoxon, p. 105, pl. 6, figs. 5-8.

Remarks: The observed specimens were smaller (7-9 µm) than those of the original description (9-12 µm).

Helicosphaera euphratis Haq, 1966
Pl. 2, figs. 3, 4, 8

1966 *Helicosphaera euphratis* n. sp. - Haq, p. 33, pl. 2, figs. 1, 3.

Helicosphaera granulata (Bukry & Percival, 1971) Jafar & Martini, 1975
Pl. 1, figs. 9-13, 16

1971 *Helicopontosphaera granulata* n. sp. - Bukry & Percival, p. 132, pl. 5, figs. 1, 2.
1975 *Helicosphaera granulata* (Bukry & Percival) Jafar & Martini - Jafar & Martini, p. 390.

Helicosphaera intermedia Martini, 1965
Pl. 2, figs. 5-7, 9-15

1965 *Helicosphaera intermedia* n. sp. - Martini, p. 404, pl. 35, figs. 1, 2.

Remarks: The observed specimens were smaller (~9 µm) than those of the original description (11-14 µm) and highly variable.

Helicosphaera mediterranea Müller, 1981
Pl. 4, figs. 1-4

1981 *Helicosphaera mediterranea* n. sp. - Müller, p. 428, pl. 5, figs. 1-4.

Helicosphaera minuta Müller, 1981
Pl. 3, figs. 1-5, 16, 17

1981 *Helicosphaera minuta* n. sp. - Müller, pl. 1, figs. 1-6, 16, 17.

Helicosphaera obliqua Bramlette & Wilcoxon, 1967
Pl. 5, figs. 6, 7

1967 *Helicosphaera obliqua* n. sp. - Bramlette & Wilcoxon, p. 106, pl. 5, figs. 13, 14.

Remarks: Only a few specimens were observed. They were smaller (7 µm) than those of the original description (8-10 µm).

Helicosphaera perch-nielseniae (Haq, 1971) Jafar & Martini, 1975
Pl. 4, figs. 9-15

1971 *Helicopontosphaera perch-nielseniae* n. sp. - Haq, p. 116, pl. 10, figs. 5-7.
1975 *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini - Jafar & Martini, p. 391.

Helicosphaera recta (Haq, 1966) Jafar & Martini, 1975
Pl. 5, figs. 2-5

1966 *Helicosphaera seminulum recta* n. sp. - Haq, p. 34, pl. 2, fig. 6, pl. 3, fig. 4.
1975 *Helicosphaera recta* (Haq, 1966) Jafar & Martini - Jafar & Martini, p. 391.

Helicosphaera scissura Miller, 1981
Pl. 5, figs. 13, 14, 16, 17

1981 *Helicosphaera scissura* n. sp. - Miller, p. 433, Pl. 3, figs. 10a-c, 11a, 11b.

Helicosphaera* cf. *truempyi Biolzi & Perch-Nielsen, 1982
Pl. 2, figs. 1, 2

cf. 1982 *Helicosphaera truempyi* n. sp. - Biolzi & Perch-Nielsen, p. 171-175, pl. 1, figs. 1-8.

Remarks: The observed specimens were very rare and considerably smaller (~10 µm) than those of the original description (18-20 µm).

Helicosphaera vedderi Bukry, 1981
Pl. 3, figs. 11, 12

1981b *Helicosphaera vedderi* n. sp. - Bukry, p. 463, pl. 6, figs. 8-17.

Helicosphaera walbersdorfensis Müller, 1974
Pl. 3, figs. 6-10, 20

1974 *Helicosphaera walbersdorfensis* n. sp. - Müller, pp. 392, 393, pl. 2, fig. 15, pl. 4, figs. 35-37, 45-46.

Helicosphaera wallichii (Lohman, 1902) Okada & McIntyre, 1977
Pl. 3, figs. 13-15, 18, 19, 21

1902 *Coccolithosphaera wallichii* n. sp. - Lohmann, p. 138, pl. 5, figs. 58, 58b, 59, 60.
1977 *Helicosphaera wallichii* (Lohman, 1902) Okada & McIntyre - Okada & McIntyre, pl. 4, fig.8.

Remarks: The observed specimens were slightly smaller (~8 µm) than those of the original description (9-9.5 µm).

Helicosphaera waltrans Theodoridis, 1984
Pl. 4, figs. 5-8

1984 *Helicosphaera waltrans* n. sp. - Theodoridis, 1984, p. 124, pl. 13, fig. 2, pl. 20, fig. 5-9, pl. 26, fig.2

Family: Pontosphaeraceae Lemmermann, 1908

Genus: *Pontosphaera* Lohmann, 1902

Pontosphaera callosa (Martini, 1969) Varol, 1982
Pl. 6, figs. 6-10, 21, 22

1969 *Discolithina callosa* n. sp. - Martini, p. 287, pl. 26, figs. 7-9.
1982 *Pontosphaera callosa* (Martini, 1969) Varol - Varol, p. 253.

Remarks: The size range of the observed specimens was larger (8-13.5 µm) than that of the original description (9-12 µm).

Pontosphaera desueta (Müller, 1970) Perch-Nielsen, 1984
Pl. 6, figs. 11-13

1970 *Discolithina desueta* n. sp. - Müller, p. 113, pl. 3, figs. 3-5.
1984 *Pontosphaera desueta* (Müller, 1970) Perch-Nielsen - Perch-Nielsen, p. 43.

Pontosphaera desuetoidea Bartol, 2009
Pl. 6, figs. 4, 23

2009 *Pontosphaera desuetoidea* n. sp. – Bartol, pl. 1, figs. 1-10.

Pontosphaera geminipora Bartol, 2009
Pl. 6, figs. 18-20

2009 *Pontosphaera geminipora* n. sp. – Bartol, pl. 1, figs. 11-14.

Pontosphaera latelliptica (Báldi-Beke & Báldi, 1974) Perch-Nielsen, 1984
Pl. 6, figs. 14, 15

1974 *Discolithina latelliptica* n. sp. - Báldi-Beke & Báldi, pl. 9, figs. 1, 4, tab. 3, figs. 9, 11, 12.
1984 *Pontosphaera latelliptica* (Báldi-Beke & Báldi, 1974) Perch-Nielsen - Perch-Nielsen, p. 43.

Pontosphaera multipora (Kamptner, 1948) Roth, 1970
Pl. 6, figs. 1-3, 16, 17

1948 *Discolithus multiporus* n. sp. - Kamptner, p. 5, pl. 1, fig. 9a, 9b.
1970 *Pontosphaera multipora* (Kamptner, 1948) Roth - Roth, p. 860.

Remarks: The observed specimens varied greatly in size (4-12 µm), while the original description only includes a single measurement - 9 µm.

Pontosphaera plana (Bramlette & Sullivan, 1961) Haq, 1971
Pl. 6, fig. 5

1961 *Discolithus planus* n. sp. - Bramlette & Sullivan, p. 143, pl. 3, figs. 7a-c.
1971 *Pontosphaera plana* (Bramlette & Sullivan, 1961) Haq - Haq, p. 143, pl. 10, fig. 1.

Genus: *Scyphosphaera* Lohman, 1902

Scyphosphaera amphora Deflandre, 1942
Pl. 7, figs. 5, 22

1942a *Scyphosphaera amphora* n. sp. - Deflandre, p. 132, figs. 21, 22.

Genus: *Transversopontis* Hay, Mohler & Wade, 1966

Transversopontis exilis (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971
Pl. 7, figs. 1, 2

1961 *Discolithus exilis* n. sp. - Bramlette & Sullivan, p. 142, pl. 2, figs. 10a-c.
1971 *Transversopontis exilis* (Bramlette & Sullivan, 1961) Perch-Nielsen - Perch-Nielsen, p. 38, pl. 27, figs. 3, 5, 6, pl. 31.

Transversopontis pulcher (Deflandre, 1954) Perch-Nielsen, 1967
Pl. 7, fig. 4

1954 *Discolithus pulcher* n. sp. - Deflandre - Deflandre & Fert, p. 142 pl. 12, figs. 17, 18.
1985 *Transversopontis pulcher* (Deflandre, 1954) Perch-Nielsen, 1967; Perch-Nielsen, p. 497, figs. 51.12, 13.

Remarks: The observed specimens were considerably smaller (~5 μm) than those of the original description (9 μm).

Transversopontis pulcheroides (Sullivan, 1964) Báldi-Beke, 1971
Pl. 7, figs. 6, 7

1964 *Discolithus pulcheroides* n. sp. - Sullivan, 1, p. 183, pl. 4, figs. 7a, 7b.
1971 *Transversopontis pulcheroides* (Sullivan, 1964) Báldi-Beke - Báldi-Beke, p. 17, tab. 3.

Transversopontis sigmoidalis Locker, 1967
Pl. 7, fig. 3

1967 *Transversopontis sigmoidalis* n. sp. - Locker, 763, pl. 1, fig. 3, pl. 2, fig. 4.

Order: Stephanolithiales Bown & Young, 1997
Family: Calcisoleniaceae Kamptner, 1927

Genus: *Calciosolenia* Gran 1912 emend. Young et al. 2003

***Calciosolenia* sp.**
Pl. 8, figs. 6-10

1954 Scapholithus fossilis n. sp. - Deflandre - Deflandre & Fert, p. 165, pl. 8, figs. 12, 16, 17.

Calciosolenia brasiliensis (Lohmann, 1919) Young et al. 2003
Pl. 8, figs. 16-18

1919 *Cylindrotheca brasiliensis* n. sp. – Lohman, p. 187, fig. 56.
2003 *Calciosolenia brasiliensis* (Lohman, 1919) Young - Young et al. 2003, p. 35.

Order: Syracosphaerales Ostenfeld, 1899
Family: Syracosphaeraceae Hay, 1977

Genus: *Syracosphaera* Lohman, 1902

Syracosphaera pulchra Lohmann, 1902
Pl. 8, figs. 1-3, 5, 14

1902 *Syracosphaera pulchra* n. sp. - Lohmann, p. 133, 134, pl. 4, figs. 33, 36, 37.

Syracosphaera histrica Kamptner, 1941
Pl. 8, figs. 4, 11-13, 15

1941 *Syracosphaera histrica* n. sp. - Kamptner, p. 84, 104, pl. 6, figs. 65-68.

Order: Rhabdosphaerales Ostenfeld, 1899
Family: Rhabdosphaeraceae Lemmermann, 1908

Genus: *Blackites* Hay & Tove, 1962

Blackites trochos Bybell, 1975
Pl. 7, fig. 19

1975 *Blackites trochos* n. sp. - Bybell, p. 230, pl. 6.

Genus: *Rhabdosphaera* Haeckel, 1894

Rhabdosphaera crebra (Deflandre, 1954) Bramlette & Sullivan, 1961
Pl. 7, figs. 12, 16

1954 *Rhabdolithus creber* n. sp. - Deflandre - Deflandre & Fert, p. 157, text figs. 81, 82, pl. 12, figs. 31-33.
1961 *Rhabdosphaera crebra* (Deflandre, 1954) Bramlette & Sullivan - Bramlette & Sullivan, p. 146, pl. 5, figs. 1-3.

Rhabdosphaera procera Martini, 1969
Pl. 7, figs. 13-15

1969 *Rhabdosphaera procera* n. sp. - Martini, p. 289, pl. 26, figs. 10, 11.

Rhabdosphaera sicca (Stradner, 1963) Fuchs & Stradner, 1977
Pl. 7, figs. 9-11, 17, 18, 20, 21

1963 *Rhabdolithus siccus* n. sp. - Stradner - Bachmann et al., p. 158, pl. 24, fig. 8, text-figs. 3: 3, 3a.
2002 *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner 1977; Wise et al., 2002.

Rhabdosphaera vitrea (Deflandre, 1954) Bramlette & Sullivan, 1961
Pl. 7, fig. 8

1954 *Rhabdolithus vitreus* n. sp. - Deflandre - Deflandre & Fert, p. 157, pl. 12, figs. 28, 29, text-figs. 83, 84.
2002 *Rhabdosphaera vitrea* Bramlette & Sullivan, 1961; Wise et al. 2002.

Order: Prinsiales Young & Bown, 1977
Family: Noelrhabdaceae Jerković, 1970

Genus: *Cribrocentrum* Perch-Nielsen, 1971

Cribrocentrum reticulatum (Gartner & Smith, 1967) Perch-Nielsen, 1971
Pl. 9, figs. 1, 2, 6

1967 *Cyclococcolithus reticulatus* n. sp. - Gartner & Smith, p. 4, pl. 5, figs. 1-3, 4a-d.
1971 *Cribrocentrum reticulatum* Perch-Nielsen - Perch-Nielsen, p. 28, pl. 25, figs. 1-9.
1972 *Reticulofenestra reticulata* (Gartner & Smith, 1967) Roth & Thierstein, 1972 – Roth & Thierstein, p. 436.

Genus: *Cyclicargolithus* Bukry, 1971

Cyclicargolithus abisectus (Müller, 1970) Bukry, 1973
Pl. 9, figs. 10, 17, 18

1970 *Coccolithus*? *abisectus* n. sp. - Müller, p. 92, pl. 9, figs. 9, 10, pl. 12, fig. 1.
1973a *Cyclicargolithus abisectus* (Müller, 1970) Bukry - Bukry, p. 703.

Cyclicargolithus floridanus (Roth & Hay, 1967) Bukry, 1971
Pl. 9, figs. 7, 8, 12, 13, 16

1967 *Coccolithus floridanus* n. sp. - Roth & Hay – Hay et al., p. 445, pl. 6, figs. 1-4.
1971a *Cyclicargolithus floridanus* (Roth & Hay, 1967) Bukry - Bukry, p. 312.

Genus: *Reticulofenestra* Hay, Mohler & Wade, 1966

Reticulofenestra bisecta (Hay, Mohler & Wade, 1966) Roth, 1970
Pl. 10, figs. 13, 17

1966 *Syracosphaera bisecta* n. sp. - Hay, Mohler & Wade, p. 393, pl. 10, figs. 1-6.
1970 *Reticulofenestra bisecta* (Hay, Mohler & Wade, 1966) Roth - Roth, p. 847, pl. 1, fig. 8.
1971 *Dictiococcites bisectus* (Hay, Mohler & Wade, 1966) Bukry & Percival - Bukry & Percival, p. 127, pl. 2, figs. 12, 13.

Remarks: According to an alternative taxonomic subdivision the name is used for specimens <10 µm, while specimens >10 µm are assigned to *R. stavensis*.

Reticulofenestra callida (Perch-Nielsen, 1971) Bybell, 1975
Pl. 10, figs. 1-4, 19

1971 *Dictyococcites callidus* n. sp. - Perch-Nielsen, p. 28, pl. 22, figs. 1-4, pl. 23, fig. 3, pl. 61, figs. 30, 31.
1975 *Reticulofenestra callida* (Perch-Nielsen, 1971) Bybell - Bybell, p. 197.

Reticulofenestra dictyoda (Deflandre, 1954) Stradner, 1968
Pl. 10, figs. 5-8, 11

1954 *Discolithus dictyodus* n. sp. Deflandre -Deflandre & Fert, p. 140, text- figs. 15, 16, 18.
1968 *Reticulofenestra dictyoda* (Deflandre, 1954) Stradner - Stradner & Edwards, p. 19, pl. 12, figs. 1-4, pl. 13, figs. l, 2, pl. 14. figs. 1-5, pl. 22, fig. 4, text-fig. 2c.

Reticulofenestra gelida (Geitzenauer, 1972) Backman, 1978
Pl. 11, figs. 12-19

1972 *Coccolithus gelidus* n. sp. - Geitzenauer, p. 407, pl. 1, figs. 1,2, 5, 6.
1978 *Reticulofenestra gelida* (Geitzenauer, 1972) Backman – Backman, p. 112.

Reticulofenestra haqii Backman, 1978
Pl. 12, figs. 1-6, 10, 15-17

1978 *Reticulofenestra haqii* n. sp. – Backman, p. 110, 111, pl. l, figs. l-4.

Reticulofenestra hillae Bukry & Percival, 1971
Pl. 10, fig. 12

1971a *Reticulofenestra hillae* n. sp. - Bukry & Percival, p. 136, pl. 6, figs. 1-3.

Reticulofenestra lockeri Müller, 1970
Pl. 10, figs. 9, 10, 14

1970 *Reticulofenestra lockeri* n. sp. - Müller, p. 116, pl. 6, figs. 1-5.

Remarks: The observed specimens were considerably smaller (5-8 µm) than those of the original description (8-12 µm).

Reticulofenestra minuta Roth, 1970
Pl. 12, figs. 11-14, 21-23

1970 *Reticulofenestra minuta* n. sp. - Roth, p. 850, pl. 5, figs. 3, 4.

Reticulofenestra minutula (Gartner, 1967) Haq & Berggren, 1978
Pl. 12, figs. 7-9, 18-20

1967 *Coccolithus minutulus* n. sp. - Gartner, p. 3, pl. 5, figs. 3-4, 5a-c.
1998 *Reticulofenestra minutula* (Gartner, 1967) Haq & Berggren, 1978; Young, p. 247, pl. 8.3, fig. 20.

Reticulofenestra perplexa (Burns, 1975) Wise, 1983
Pl. 10, figs. 20-24

1975 *Dictyococcites perplexa* n. sp. – Burns, p. 583-585.
1983 *Reticulofenestra perplexa* (Burns, 1975) Wise - Wise, pl. 3, figs. 1-3, pl. 4, figs. 1-7.

Reticulofenestra pseudoumbilica (Gartner, 1967) Gartner, 1969
>7 µm: Pl. 11, figs. 1-5, 23-25
<7 µm: Pl. 11, figs. 6-11, 20-22

1967 *Coccolithus pseudoumbilicus* n. sp. - Gartner, p. 4, pl. 6, figs. 1-2, 3a-c, 4a-c.
1969 *Reticulofenestra pseudoumbilica* (Gartner, 1967) Gartner – Gartner, p. 587-589, 591, 592, 598, pl. 2, figs. 4a-c.

Reticulofenestra scrippsae (Bukry & Percival, 1971) Roth, 1973
Pl. 10, figs. 15, 16, 18

1971 *Dictyococcites scrippsae* n. sp. - Bukry & Percival, p. 128, pl. 2, figs. 7, 8.
1973 *Reticulofenestra scrippsae* (Bukry & Percival, 1971) Roth – Roth, p. 732.

Remarks: According to an alternative taxonomic subdivision specimens <10 µm are assigned to *R. bisecta*.

Order: Watznaueriales Bown, 1987
Family: Watznaueriaceae Rood, Hay & Barnard, 1971

Genus: *Watznaueria* Reinhardt, 1964

Watznaueria barnesae (Black, 1959) Perch-Nielsen, 1968
Pl. 9, figs. 3-5, 9

1959 *Tremalithus barnesae* n. sp. - Black – Black & Barnes, p. 325, pl. 9, figs. 1, 2.
1968 *Watznaueria barnesae* (Black, 1959) Perch-Nielsen - Perch-Nielsen, pl. 22, figs. 1-7, pl. 23, figs. 1, 4, 5, 16.

Order: Arkhangelskiales Bown & Hampton 1997 (in Bown & Young 1997)
Family: Arkhangelskiellaceae Bukry, 1969 emend. Bown & Hampton 1997

Genus: *Broinsonia* Bukry, 1969

Broinsonia parca (Stradner, 1963) Bukry, 1969
Pl. 9, figs. 20, 21

1963 *Archangelskia parca* n. sp. - Stradner, p. 10, pl. 1, figs. 3, 3a.
1969 *Broinsonia parca* (Stradner, 1963) Bukry – Bukry, p. 23, pl. 3, figs. 3-6.

Order: Podorhabdales Rood et al., 1971 emend. Bown, 1987
Family: Cretarhabdaceae Thierstein, 1973

Genus: *Retecapsa* Black, 1971

***Retecapsa* sp.**
Pl. 9, fig. 22

Order: Coccosphaerales Haeckel, 1894
Family: Coccolithaceae Poche, 1913

Genus: *Coccolithus* Schwartz, 1894

Coccolithus formosus (Kamptner, 1963) Wise, 1973
Pl. 13, figs. 14-16, 19, 20

1963 *Cyclococcolithus formosus* n. sp. - Kamptner, p. 163, pl. 2, fig. 8, text-figs. 20a, 20b.
1973 *Coccolithus formosus* (Kamptner, 1963) Wise - Wise, p. 593, pl. 4, figs. 1-6.

Coccolithus miopelagicus Bukry, 1971, emend. Wise, 1973
Pl. 13, figs. 8, 11-13; Pl. 14, figs. 5, 6

1971a *Coccolithus miopelagicus* n. sp. - Bukry, p. 310, pl. 2, figs. 6-9.
1973 *Coccolithus miopelagicus* Bukry, 1971, emend. Wise - Wise, p. 593, pl. 8, figs. 9-11.

Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Pl. 13, figs. 1-7, 9, 10; Pl. 14, figs. 1-4, 7-12

1877 *Coccosphaera pelagica* n. sp. - Wallich, p. 348.
1930 *Coccolithus pelagicus* (Wallich, 1877) Schiller - Schiller, p. 246, figs. 123, 124.

Remarks: In pl. 14, figs. 7-12 the form with central cross (figured in Bown et al., 2008, fig. 3M).

Coccolithus streckeri Takayama & Sato, 1987
Pl. 13, figs. 17, 18, 21, 22

1987 *Coccolithus streckeri* n. sp. - Takayama & Sato, p. 690, pl. 1, figs. 4a, 4b.

Remarks: Young (1998) interprets this form as an early ontogenetic phase of *C. pelagicus* with a central bridge.

Genus: *Coronocyclus* Hay, Mohler & Wade, 1966

Coronocyclus nitescens (Kamptner, 1963) Bramlette & Wilcoxon, 1967
Pl. 9, figs. 11, 14, 15, 19

1963 *Umbilicosphaera nitescens* n. sp. - Kamptner, p. 187, pl. 1, fig. 5, text-figs. 37a-c.
1967 *Coronocyclus nitescens* (Kamptner, 1963) Bramlette & Wilcoxon - Bramlette & Wilcoxon, p. 103, pl. 1, fig. 4, pl. 5, figs. 7-8.

Remarks: The specimens found were considerably smaller (6-9 μm) than those of the original description (8.5-9.5 μm).

Family: Calcidiscaceae Young & Bown 1997

Genus: *Calcidiscus* Kamptner, 1950

Calcidiscus carlae (Lehotayova & Priewalder, 1978) Janin, 1992
Pl. 15, figs. 16-18

1978 *Cycloperfolithus carlae* n. sp. - Lehotayova & Priewalder, pp. 487, 489, pl.10, fig.1.
1992 *Calcidiscus carlae* (Lehotayova & Priewalder, 1978) Janin – Janin, p. 171.

Calcidiscus leptoporus (Murray & Blackman, 1898) Loeblich & Tappan, 1978
Pl. 15, figs. 4, 8-10

1898 *Coccosphaera leptopora* n. sp. - Murray & Blackman, p. 430, 493, pl. 15, figs. 1-7.
1978 *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loeblich & Tappan - Loeblich & Tappan, p. 1391.

Calcidiscus macintyrei (Bukry & Bramlette, 1969) Loeblich & Tappan, 1978
Pl. 15, figs. 11, 12

1969 *Cyclococcolithus macintyrei* n. sp. - Bukry & Bramlette, p. 132, pl. 1, figs. 1-3.
1978 *Calcidiscus macintyrei* (Bukry & Bramlette, 1969) Loeblich & Tappan - Loeblich & Tappan, p. 1392.

Calcidiscus premacintyrei Theodoridis, 1984
Pl. 15, figs. 1-3, 13-15

1984 *Calcidiscus premacintyrei* n. sp. - Theodoridis, p. 81, pl. 2, figs. 1-3.

Calcidiscus tropicus Kamptner, 1956
Pl. 15, figs. 5-7

1956 *Calcidiscus tropicus* n. sp. – Kamptner, p. 9.

Genus: *Ubmilicosphaera* Lohman, 1902

Umbilicosphaera jafari Müller, 1974
Pl. 16, figs. 3, 4, 7, 8, 10, 11, 13, 15, 16, 18, 19

1974 *Umbilicosphaera jafari* n. sp. - Müller, p.394, pl.1, figs. 1-3, pl. 4, figs. 43, 44.

Umbilicosphaera rotula (Kamptner, 1956) Varol, 1982
Pl. 16, figs. 1, 2, 5, 6, 9, 12, 14, 17

1956 *Cyclococcolithus rotula* n. sp. - Kamptner, p. 7.
1980 *Geminilithella rotula* (Kamptner, 1956) Backman - Backman, p. 52, pl. 1, figs. 14-15, pl. 8, fig. 3.
1982 *Umbilicosphaera rotula* (Kamptner, 1956) Varol - Varol, p. 248, pl. 4, fig. 5.

3.1.2. Holococcoliths

Family: Calyptrosphaeraceae Boudreaux & Hay, 1969

Genus: *Syracolithus* Deflandre, 1952

Syracolithus schilleri (Kamptner 1927) Kamptner, 1956
Pl. 17, figs. 1-7, 16-19

1927 *Syracosphaera schilleri* n. sp. – Kamptner, p. 179, figs. 4, 5.
1970 *Holodiscolithus macroporus* (Deflandre, 1954) Roth - Roth, p. 866.
2002 *Syracolithus schilleri* (Kamptner 1927) Kamptner 1956; Cros & Fortuño, p. 169, fig. 107b.

Syracolithus dalmaticus (Kamptner, 1927) Loeblich & Tappan, 1966
Pl. 17, figs. 10-12, 20

1927 *Syracosphaera dalmatica* n. sp. - Kamptner, 1927, p. 178, text-fig. 2.
1989 *Homozygosphaera wettsteinii* (Kamptner, 1927) Halldal & Markali, 1955; Mihajlović & Knežević, 1989.
2002 *Syracolithus dalmaticus* (Kamptner, 1927) Loeblich & Tappan, 1966; Cros & Fortuño, p. 169, fig. 107a.

Remarks: This holococcolith is presumably produced by the haploid generation of *Helicosphaera wallichii* (Geisen et al., 2004).

Genus: *Zygrhablithus* Deflandre, 1959

Zygrhablithus bijugatus (Deflandre, 1954) Deflandre, 1959
Pl. 17, figs. 8, 9, 13, 14

1954 *Zygolithus bijugatus* n. sp. - Deflandre - Deflandre & Fert, p. 148, pl. 11, figs. 20, 21, text-fig. 59.
1959 *Zygrhablithus bijugatus* (Deflandre, 1954) Deflandre - Deflandre, p. 135.

Genus: *Clathrolithus* Deflandre, 1954

?*Clathrolithus spinosus* Martini, 1961
Pl. 17, fig. 15

1961 *Clathrolithus spinosus* n. sp. - Martini, pl. 4, fig. 38.

3.1.3. Nannoliths

Family: Braarudosphaeraceae Deflandre, 1947

Genus: *Braarudosphaera* Deflandre, 1947

Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947
Pl. 18, figs. 12, 13

1935 *Pontosphaera bigelowi* n. sp. - Gran & Braarud, p. 388, fig. 67.
1947 *Braarudosphaera bigelowi* (Gran & Braarud, 1935) Deflandre - Deflandre, p. 439, figs. 1-5.

Genus: *Micrantholithus* Deflandre, 1950

Micrantholithus flos (Deflandre, 1950) Deflandre, 1954
Pl. 18, fig. 18

1950 *Micrantholithus flos* n. sp. - Deflandre, p. 1158, figs. 8-11, (without description).
1954 *Micrantholithus flos* (Deflandre, 1950) Deflandre - Deflandre & Fert, p. 169, pl. 13, figs. 10, 11.

***Micrantholithus* sp.**
Pl. 18, figs. 14, 19

Family: Lithostromationaceae Deflandre, 1959

Genus: *Lithostromation* Deflandre, 1942

Lithostromation perdurum Deflandre, 1942
Pl. 18, 1-3, 24, 25

1942b *Lithostromation perdurum* n. sp. - Deflandre, p. 918, figs. 1-9.

Remarks: The observed specimens were smaller (9-12 μm) than those of the original description (12-16 μm).

Family: Triquetrorhabdulaceae Lipps, 1969

Genus: *Triquetrorhabdulus* Martini, 1965

Triquetrorhabdulus auritus Stradner & Allram, 1982
Pl. 18, figs. 8, 9; ? Pl. 20, fig. 12

1982 *Triquetrorhabdulus auritus* n. sp. - Stradner & Allram, p. 595, pl. 7, figs. 1-8, text-figs. 3a-c.

Genus: *Orthorhabdus* Bramlette & Wilcoxon, 1967

Orthorhabdus serratus Bramlette & Wilcoxon, 1967
Pl. 18, figs. 6, 7; Pl. 20, figs. 10, 13-15

1967 *Orthorhabdus serratus* n. sp. - Bramlette & Wilcoxon, p. 114, pl. 9, figs. 5-10.
1989 *Triquetrorhabdulus serratus* (Bramlette & Wilcoxon, 1967) Olafsson - Olafsson, p. 22, pl. 1, fig. 12.

Remarks: The observed specimens were considerably smaller (8-9 μm) than those of the original description (10-20 μm).

Order: Discoasterales Hay, 1977
Family: Discoasteraceae Tan, 1927

Genus: *Discoaster* Tan, 1927

Discoaster adamanteus Bramlette & Wilcoxon, 1967
Pl. 22, figs. 4, 5, 10

1967 *Discoaster adamanteus* n. sp. - Bramlette & Wilcoxon, p. 108, pl. 7, fig. 6.

Discoaster aulacos Gartner, 1967
Pl. 21, figs. 13, 14, 16, 17

1967 *Discoaster aulacos* n. sp. - Gartner, p. 2, pl. 4, figs. 4a, 4b, 5a.

Discoaster binodosus Martini, 1958
Pl. 21, fig. 5

1958 *Discoaster binodosus* n. sp. - Martini, p. 361, 362, pl. 4, figs. 18a, 18b, 19a, 19b.

Remarks: The observed specimens were smaller (7 μm) than those of the original description (8-16 μm).

Discoaster braarudii Bukry, 1971
Pl. 24, figs. 4-7, 12-14

1971b *Discoaster braarudii* n. sp. - Bukry, p. 45, pl. 2, fig. 10.

Discoaster deflandrei Bramlette & Riedel, 1954
Pl. 21, figs. 8, 12, 15, 18

1954 *Discoaster deflandrei* n. sp. - Bramlette & Riedel, p. 399, pl. 33, fig. 6, text-fig. 1.

Discoaster druggii Bramlette & Wilcoxon, 1967
Pl. 21, figs. 9-11

1967 *Discoaster druggii* n. sp. - Bramlette & Wilcoxon, p. 110, pl. 8, figs. 2-8.

Discoaster exilis Martini & Bramlette, 1963
Pl. 23, figs. 1-4, 13-15

1963 *Discoaster exilis* n. sp. - Martini & Bramlette, p. 852, pl. 104, figs. 1-3.

Discoaster formosus Martini & Worsley, 1971
Pl. 22, figs. 1, 13

1971 *Discoaster formosus* n. sp. - Martini & Worsley p. 1500, pl. 2, figs. 1-8.

Remarks: The observed specimens were smaller (6-12 μm) than those of the original description (15-19 μm).

Discoaster gemmeus Stradner, 1959
Pl. 21, fig. 4

1959 *Discoaster gemmeus* n. sp. - Stradner, p.1086, text-fig. 21.

Discoaster* aff. *kugleri Martini & Bramlette, 1963
Pl. 24, figs. 8, 16, 17

aff. 1963 Discoaster kugleri n. sp. - Martini & Bramlette, p. 853, pl. 102, figs.11-13.

Remarks: The observed specimens of *Discoaster* aff. *kugleri* are similar to those from the experimental Mohole drilling (Martini & Bramlette, 1963). They differ from the original description by the presence of a strong central knob with rather strong ridges extending along the rays. See also taxonomic notes in chapter 3.3.

Discoaster moorei Bukry, 1971
Pl. 24, figs. 1-3, 15

1971b *Discoaster moorei* n. sp. - Bukry, p. 46, pl. 2, figs. 11, 12, pl. 3, figs.1, 2.

Discoaster musicus Stradner, 1959
Pl. 22, figs. 2 (cf.), 3

1959 *Discoaster musicus* n. sp. - Stradner, p. 1088, text-fig. 28.

Discoaster obtusus Gartner, 1967
Pl. 22, fig. 8

1967 *Discoaster obtusus* n. sp. - Gartner, p. 2, pl. 3, figs. 1-4, 5a, 5b, 6a, 6b.

?*Discoaster* sp.
Pl. 21, figs. 1-3

Discoaster stellulus Gartner, 1967, emend. Jiang & Wise, 2006
Pl. 22, figs. 6, 7, 9, 11, 12, 14, 15

1967 *Discoaster stellulus* n. sp. – Gartner, 1967, p. 3, pl. 4, figs. 1-3.
2006 emended Jiang & Wise - Jiang & Wise, p. 83, pl. 1, figs. 1-22.

Discoaster tanii Bramlette & Riedel, 1954
Pl. 21, figs. 6, 7

1954 *Discoaster tani* n. sp. - Bramlette & Riedel, p. 397, pl. 39, figs. 19a, 19b.

Discoaster variabilis Martini & Bramlette, 1963
Pl. 23, figs. 5-12; cf. Pl. 24, figs. 9-11

1963 *Discoaster variabilis* n. sp. -Martini & Bramlette, p. 854, pl. 104, figs. 4-9.

Family: Sphenolithaceae Deflandre, 1952

Genus: *Sphenolithus* Deflandre, 1952

Sphenolithus abies Deflandre, 1954
Pl. 19, figs. 11-14; Pl. 20, figs. 1, 8, 9

1954 *Sphenolithus abies* n. sp. - Deflandre - Deflandre & Fert, p. 164, pl. 10, figs. 1-4.

Sphenolithus conicus Bukry, 1971
Pl. 19, figs. 5, 6

1971a *Sphenolithus conicus* n. sp. - Bukry, p. 320, pl. 5, figs. 10-12.

Sphenolithus* cf. *delphix Bukry, 1973
Pl. 19, figs. 15-18

cf.1973b *Sphenolithus delphix* n. sp. - Bukry, p. 679, pl. 3, figs. 19-22.

Sphenolithus heteromorphus Deflandre, 1953
Pl. 19, figs. 1-4, 7, 8; Pl. 20, figs. 7, 11

1953 *Sphenolithus heteromorphus* n. sp. - Deflandre, p. 1786, figs. 1, 2.

Sphenolithus moriformis (Brönniman & Stradner, 1960) Bramlette & Wilcoxon, 1967
Pl. 19, figs. 9, 10; Pl. 20, figs. 2-6

1960 *Nannoturbella moriformis* n. sp. - Brönnimann and Stradner, p. 368, figs. 11-16.
1967 *Sphenolithus moriformis* (Brönniman & Stradner, 1960) Bramlette & Wilcoxon - Bramlette & Wilcoxon, pp. 124-126, pl. 3, figs. 1-6.

Sphenolithus radians Deflandre, 1952
Pl. 19, figs. 19-21

1952 *Sphenolithus radians* n. sp. - Deflandre - Grassé, p. 466, figs. 343j-k, 363a-g.

Family: Microrhabdulaceae Deflandre, 1963

Genus: *Microrhabdulus* Deflandre, 1959

Microrhabdulus decoratus Deflandre, 1959
Pl. 18, figs. 4, 5

1959 *Microrhabdulus decoratus* n. sp. - Deflandre, p.141, pl. 4, figs. 6-8.

Family: Polycyclolithaceae Forchheimer, 1972 emend. Varol, 1992

Genus: *Micula* Vekshina, 1959

Micula concava (Stradner, 1960) Verbeek, 1976
Pl. 18, figs. 10, 11, 16

1960 *Nannotethraster concavus* n. sp. - Stradner - Martini & Stradner, p. 269, figs. 12, 18.
1985a *Micula concava* (Stradner, 1960) Verbeek, 1976; Perch-Nielsen, p. 391, fig. 58.30.

INCERTAE SEDIS

Genus: *Biantholithus* Bramlette & Martini, 1964

Biantholithus sparsus Bramlette & Martini, 1964
Pl. 18, figs. 17, 21, ?22, ?23

1964 *Biantholithus sparsus* n. sp. - Bramlette & Martini, p. 305, pl. 4, figs. 21-24.

Genus: *Tribrachiatus* Kamptner, 1958

Tribrachiatus orthostylus (Bramlette & Riedel, 1954) Shamrai, 1963
Pl. 18, fig. 20

1954 *Discoaster tribrachiatus* n. sp. – Bramlette & Riedl, p. 397, pl. 38
1963 *Tribrachiatus orthostylus* n. sp. Shamrai - Shamrai, p. 38, pl. 2, fig. 13, 14.

Tribrachiatus bramlettei (Bronimann & Stradner, 1960) Proto Decima et al., 1975
Pl. 18, fig. 15

1960 *Marthasterites bramlettei* n. sp. - Brönnimann & Stradner, p. 366, figs. 17-20, 23, 24.
1975 *Tribrachiatus bramlettei* (Broniman & Stradner, 1960) Proto Decima et al. - Proto Decima et al., p. 49, pl. 4, figs. 7, 8.

3.2. Calcareous dinoflagellates

Three species of calcareous dinoflagellates were determined, all belong to the genus *Thoracosphaera*. Some undetermined specimens were attributed to calcareous dinoflagellates as well, they are figured in Pl. 25, figs. 10, 12, 13, 15, 16.

Phylum: Pyrrophycophyta Bold, 1973
Class: Dinophyceae Fritsch, 1935
Order: Thoracosphaerales Tanger, 1982
Family: Thoracosphaeraceae Schiller, 1930

Genus: *Thoracosphaera* Kamptner, 1927

Thoracosphaera fossata Jafar, 1975
Pl. 25, figs. 4, 7, 9

1975 *Thoracosphaera fossata* n. sp. - Jafar, p. 83, pl. 11, figs. 1, 2.

Thoracosphaeraheimii (Lohmann, 1919) Kamptner, 1954
Pl. 25, figs. 1, 5, 8

1919 *Syracosphaera heimi* n. sp. - Lohmann, p. 117, fig. 29.
1954 *Thoracosphaera heimi* (Lohmann, 1919) Kamptner - Kamptner, pp. 40-42, figs. 41, 42.

Thoracosphaera saxea Stradner, 1961
Pl. 25, figs. 2, 3, 6, 11, 14

1961 *Thoracosphaera saxea* n. sp. - Stradner, 1961, p. 84, fig. 71.

3.3. Taxonomic notes

Discoaster adamantheus and some similar species are considered by Young (1998) to be preservational species or the product of intraspecific variability. This is surely a reasonable way to treat these forms as diagenetically-altered discoasters were clearly present in the studied material. Furthermore, species like *Discoaster adamantheus*, *D. stellulus*, *D. obtusus*, and *D. formosus* might in fact represent distinct morphotypes or unusual forms of other species. Despite the fact that the species status of these forms is debatable, in this work they were listed as separate species for two reasons: first, considering these forms as separate species enables a comprehensive representation morphological diversity of nannofossils found in the studied material and links it with existing work. Secondly, the presence of such forms might prove to have some palaeoecological significance (e.g., growth in suboptimal conditions).

The case is similar with the species (or form) *Coccolithus streckeri*, which, again, is interpreted by Young (1998) as an early growth-stage of large *C. pelagicus* with bar. This species/form is also listed separately, for the same reasons as stated above.

Some very rare specimens of *Discoaster* aff. *kugleri* (Pl. 24, figs. 8, 16, 17), similar to those from the experimental Mohole drilling (Martini & Bramlette, 1963), were found in the studied material. They differ from the original description of *D. kugleri* by the presence of a strong central knob with rather strong ridges extending along the rays. However, the specimens found did not show the characteristic lack of radial symmetry.

In some samples, some very rare atypical specimens of *Discoaster* cf. *variabilis* were found, with some characteristics of *Discoaster bollii* (Pl. 24, figs. 9-11). The (lack of) stratigraphic significance of both morphotypes mentioned above is discussed in chapter 4.2.

The occurrence of discoasters, similar to important stratigraphic markers, can be explained in terms of the intraspecific variability within the genus *Discoaster*. Stradner (1972) explains that this variability is particularly wide in the case of *D. variabilis*, *D. bollii*, and *D. kugleri*. These species can be interpreted as extreme morphotypes within a continuous spectre of slightly varying forms.

In accordance with Perch-Nielsen (1985), Young (1998), and Wise et al. (2002) *Calcidiscus macintyrei* is determined as a circular placolith with a diameter of 10 μm or more with a small central pore (or depression) with about 40 elements composing each shield. The diameter of the very few specimens observed in this study (Pl. 15, figs. 11, 12) measured between 11-12 μm. This is also in accord with the measurements used by Fornaciari et al. (1996), who ascribe to *C. macintyrei* specimens equal to or larger than 11 μm.

The nannoliths from Slovenske Gorice that have been assigned to the species *Sphenolithus* aff. *delphix* (Pl.19, figs. 15-18) can be distingushed from *S. heteromorphus* by the more elongate and sharpened apical spine and lateral elements giving it a triradiate outline. For this reason, the two species are listed separately. As the lateral elements of the specimens are not distinctly smaller than the elements of the proximal shield, it is possible that the nannoliths assigned to *S.* aff. *delphix* are in fact distinct morphotypes of *S. heteromorphus*.

3.4. Nannoplankton assemblage composition

Up to 38 species of calcareous nannoplankton were found in individual samples. *Coccolithus pelagicus*, *Helicosphaera carteri*, *Sphenolithus heteromorphus, Reticulofenestra minuta* and some other *Reticulofenestra* species dominate the assemblages. The genera *Helicosphaera*, *Reticulofenestra*, and *Discoaster* are represented by the highest number of species. The first two have common representative species in samples from all studied sections, *Discoaster* by contrast, is only common in short intervals of some sections.

Allochthonous species with documented last occurrences before the Middle Miocene are listed separately; they are always rare or very rare. It is very likely that specimens of some other species with longer ranges have been reworked as well. Their presence is considered negligible by the analogy with clearly reworked specimens, which never represent a significant proportion of the studied nannoplankton assemblages.

Nannoplankton assemblage composition of all examined samples is presented in the Appendix, Tabs. 1-13.

4. BIOSTRATIGRAPHY

4.1. Middle Miocene nannoplankton biozonations

Young (1998) divided the Neogene into 8 successive intervals on the basis of the most clearly observable biostratigraphic events. These intervals represent the minimal time resolution and can be determined even when the nannoplankton assemblages are poorly preserved. According to this division, the Middle Miocene (and the top of Lower Miocene) can be assigned to intervals C and D. Interval C can be correlated with standard nannoplankton biozones NN4 and NN5 and is characterized by large diversity of nannoplankton assemblages. Interval D (Young, 1998) can be correlated with the upper part of the Middle Miocene and the standard nannoplankton biozones NN6 and NN7. It is marked by lower diversity than interval C.

All but one of the measured sections were assigned to the interval C (Young, 1998), comprising the boundary between the Lower and the Middle Miocene. The upper part of the Lenart section was assigned to the interval D (Young, 1998).

The standard biozones of the Miocene have been further subdivided into shorter intervals. Theodoridis (1984) established a zonation, based on a wide array of samples from the Miocene deposits in Spain, Israel, the Mediterranean islands, Java and borehole cores from the Atlantic and the Indian Ocean, while Fornaciari et al. (1996) proposed an alternative biostratigraphic nannoplankton zonation, based exclusively on material from the north Mediterranean. Their work was recently emended by Di Stefano et al. (2008).

All zonations mentioned above are correlated in Fig. 4.1.

Most sections from Slovenske Gorice were relatively short. A combination of existing zonations enabled the stratigraphic correlation of individual sections. The samples were arranged in biostratigraphical order by using combined events used in previously established biozonations. This enabled the reconstruction of the local ranges of autochthonous species (Fig. 4.2) and the arranging of sections into a biostratigraphical order (Fig. 4.3). No single existing zonation was directly applicable to Slovenske

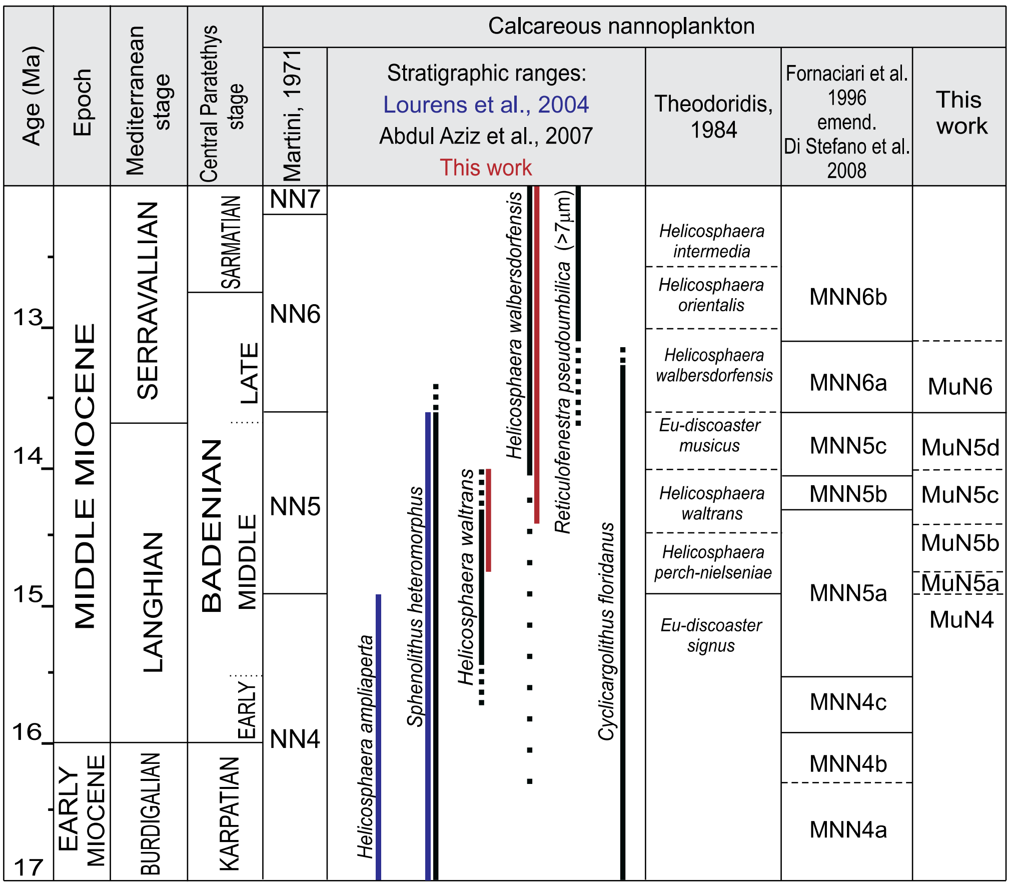
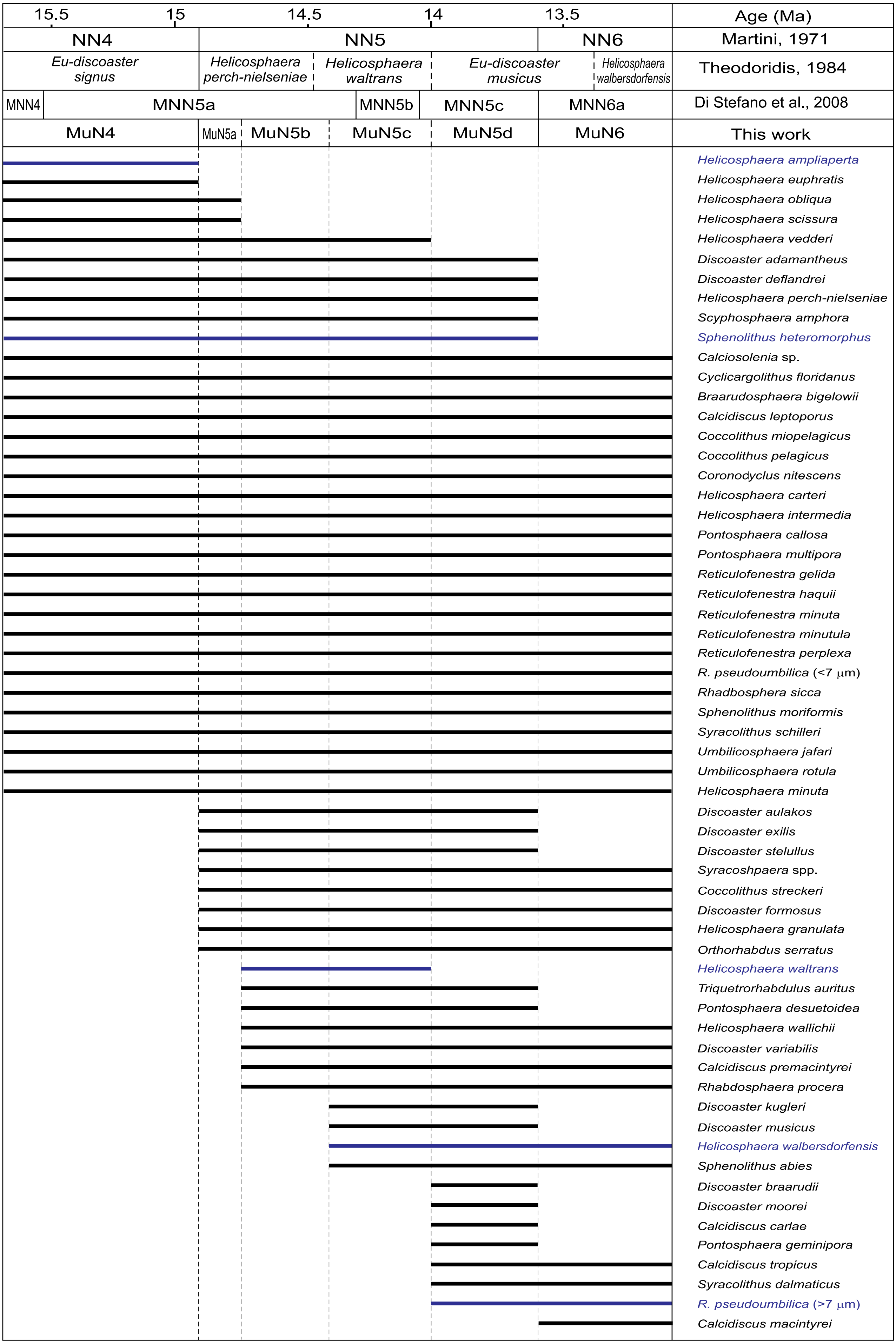


Fig. 4.1. The stratigraphic correlation of all nannoplankton biozonations used in this study, ploted against an absolute time scale. The dashed lines indicate boundaries of uncertain age.


15.5
15
14.5
14
13.5
Age (Ma)
NN4
NN5
NN6
Martini, 1971
Eu-discoaster signus
Helicosphaera perch-nielseniae
Helicosphaera waltrans
Eu-discoaster musicus
Helicosphaera walbersdorfensis
Theodoridis, 1984
MNN4
MNN5a
MNN5b
MNN5c
MNN6a
Di Stefano et al., 2008
MuN4
MuN5a
MuN5b
MuN5c
MuN5d
MuN6
This work
Helicosphaera ampliaperta
Helicosphaera euphratis
Helicosphaera obliqua
Helicosphaera scissura
Helicosphaera vedderi
Discoaster adamantheus
Discoaster deflandrei
Helicosphaera perch-nielseniae
Scyphosphaera amphora
Sphenolithus heteromorphus
Calciosolenia sp.
Cyclicargolithus floridanus
Braarudosphaera bigelowii
Calcidiscus leptoporus
Coccolithus miopelagicus
Coccolithus pelagicus
Coronocyclus nitescens
Helicosphaera carteri
Helicosphaera intermedia
Pontosphaera callosa
Pontosphaera multipora
Reticulofenestra gelida
Reticulofenestra haquii
Reticulofenestra minuta
Reticulofenestra minutula
Reticulofenestra perplexa
R. pseudoumbilica (<7 µm)
Rhadbosphera sicca
Sphenolithus moriformis
Syracolithus schilleri
Umbilicosphaera jafari
Umbilicosphaera rotula
Helicosphaera minuta
Discoaster aulakos
Discoaster exilis
Discoaster stelullus
Syracoshpaera spp.
Coccolithus streckeri
Discoaster formosus
Helicosphaera granulata
Orthorhabdus serratus
Helicosphaera waltrans
Triquetrorhabdulus auritus
Pontosphaera desuetoidea
Helicosphaera wallichii
Discoaster variabilis
Calcidiscus premacintyrei
Rhabdosphaera procera
Discoaster kugleri
Discoaster musicus
Helicosphaera walbersdorfensis
Sphenolithus abies
Discoaster braarudii
Discoaster moorei
Calcidiscus carlae
Pontosphaera geminipora
Calcidiscus tropicus
Syracolithus dalmaticus
R. pseudoumbilica (>7 µm)
Calcidiscus macintyrei

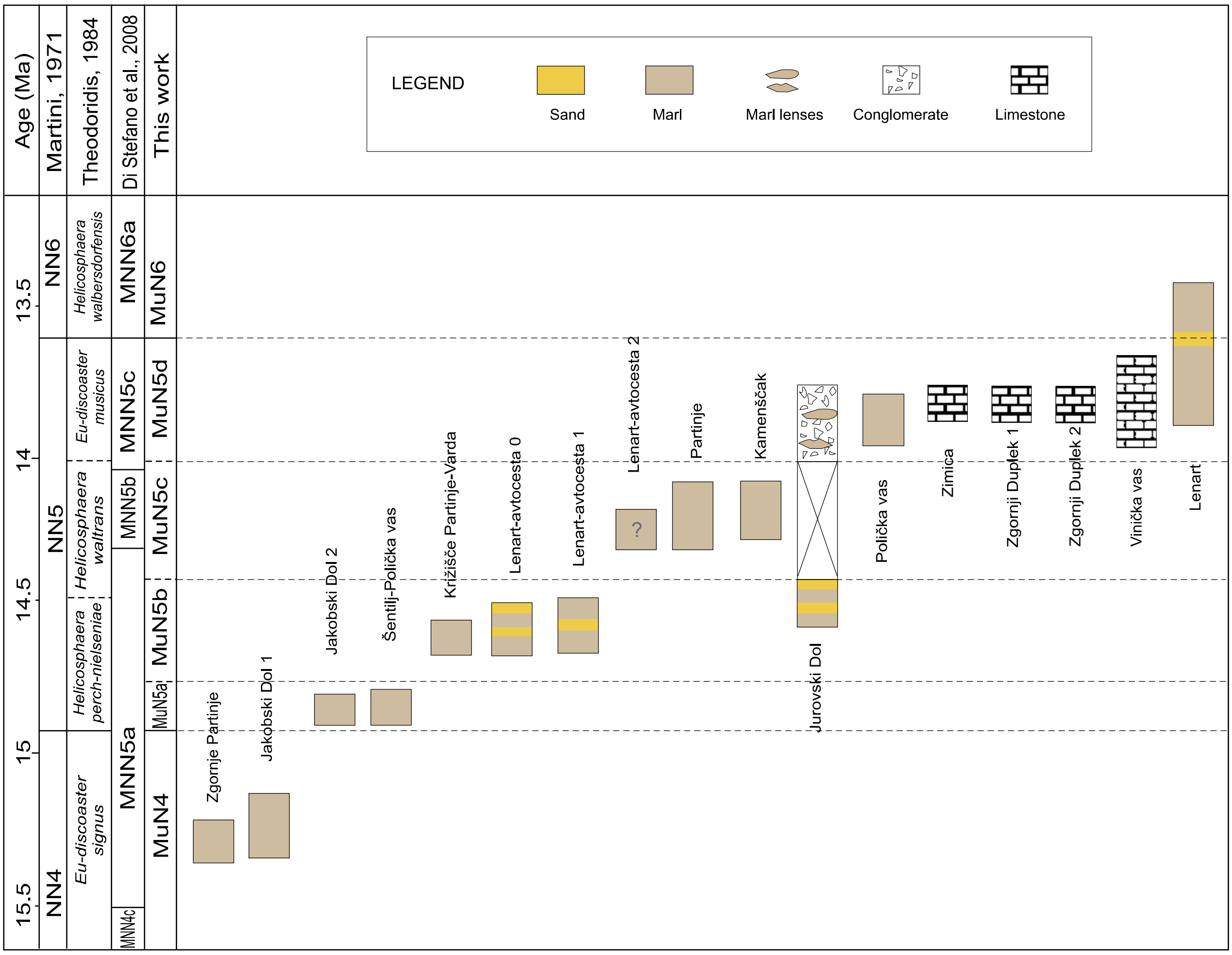


Fig. 4.3. The stratigraphic correlation of all studied sections. Position of the Lenart-avtocesta 2 section is inferred from the supperposition of deposits and could not be confirmed biostratigraphically.

Gorice, so 6 local biozones were defined (MuN4, MuN5a-d, MuN6).

4.2. Observed biostratigraphic events and the presence of marker species

4.2.1. The sections assigned to NN4

The stratigraphic marker species of NN4 were present in samples from several sections, yet the composition of the accompanying assemblage and their distribution pattern suggest that they are autochthonous only in two sections: Zgornje Partinje and Jakobski Dol 1 (Appendix, Tabs. 1, 2). Both sections consist of a lithologicaly uniform succession of marls. The marls from Zgornje Partinje are yellow and sandy while the ones from Jakobski Dol 1 are dark grey and silty (Fig. 1.5B). *Sphenolithus heteromorphus* was present in most samples from both sections, which indicates that they are not older than NN4. The FO of this species is an excellent biostratigraphic horizon (Fornaciari et al., 1993) and has been dated at 18.42 Ma in the equatorial Pacific (Olaffson, 1989). The presence of *Helicosphaera ampliaperta* in some samples from both sections indicates that the sampled beds are not younger than the top of NN4. This is further supported by the presence of *H. scissura* and *H. euphratis* in some samples from the section Jakobski Dol 1. Another indication of the age of the marls in the Jakobski Dol 1 section is the presence of a single discoaster species - *Discoaster deflandrei*. According to Fornaciari et al. (1993), this is the dominant discoaster species until the end of NN4; after the beginning of NN5 *D. deflandrei* represents less than 30% of all discoasters.

Helicosphaera scissura is also present in several samples from the Jakobski Dol 2 section (Appendix, Tab. 3), where it is considered autochtonous, while *Discoaster deflandrei* is the dominant discoaster species in the samples from the Šentilj – Polička vas section (Appendix, Tab 4). These two sections could therefore be assigned either to the top part of NN4 or the bottom part of NN5. The absence of *Helicosphaera ampliaperta* alone does not suffice to assign

Fig. 4.2. Compilation of observed ranges of autochthonous species in all examined sections. The stratigraphic marker species that were used to establish local biozones are marked in blue.

them to NN5 with certainty (the species is reportedly rare in the upper part of its range).

Fornaciari et al. (1996) assign the top of NN4 to subzones MNN4b and the bottom of MNN5a (MNN4c and MNN5a in Di Stefano et al., 2008) (Fig. 4.1). The MNN4b of Fornaciari et al., 1996 (MNN4c in Di Stefano et al., 2008) is characterized by the temporary disappearance (or extreme rarity) of *Sphenolithus heteromorphus* and a short acme of *Helicosphaera ampliaperta*, which is also observable in the equatorial Pacific (Shafik et al., 1998) and northeast Austria (Ćorić et al., 2004). The extreme rarity of *S. heteromorphus* is also observed in the northwestern Central Paratethys (Švabenická, 2000, 2002a) and in the Molasse Basin (Ćorić & Švabenická, 2004).

Theodoridis (1984) defines the upper part of NN4 as the *Eu-discoaster signus* subzone. As *Discoaster signus* was not found in any sample from Slovenske Gorice, no direct correlation with this interval zone was possible.

4.2.2. The sections assigned to NN5

Fornaciari et al. (1996) divide the standard nannoplankton biozone NN5 into intervals MNN5a and MNN5b on the basis of the presence of *Helicosphaera walbersdorfensis*. In the emended version of their stratigraphic division (Di Stefano et al., 2008), MNN5a is divided into two successive biozones by the LCO of *Helicosphaera waltrans*, which is not considered a good stratigraphic marker by Fornaciari et al. (1996).

Hohenegger et al. (2009) report the FO of *H. walbersdorfensis* in NN4, which is not the case in Slovenske Gorice, where the species was only observed in nannoplankton assemblages typical of NN5 and NN6.

The Jakobski Dol 2 (Appendix, Tab. 3), Šentilj-Polička vas (Appendix, Tab. 4), and Lenart–avtocesta 2 sections (Appendix, Tab. 7) could all be assigned to MNN5a (sensu Fornaciari et al., 1996), since they belong to NN5 and do not contain *H. walbersdorfensis*. The Partinje, Kamenščak, Polička vas and Lenart sections, as well as the limestone sections (Zimica, Zgornji Duplek 1 and 2 and Vinička vas) could all be assigned to MNN5b (sensu Fornaciari et al., 1996) as they contain *H. walbersdorfensis* and *Sphenolithus heteromorphus*.

Theodoridis (1984) divides NN5 into three successive intervals: *Helicosphaera perch-nielseniae* (between the LO of *H. ampliaperta* and the LO of *H. perch-nielseniae*), *Helicosphaera waltrans* (the entire range of *H. waltrans*) and *Eu-discoaster musicus* (between the LO of *H. waltrans* and the LO of *Sphenolithus heteromorphus*).

The presence of *Helicosphaera perch-nielseniae* was recorded in some samples from the Jakobski dol 1 and 2 sections (Appendix, Tabs. 2 and 3) and also in Jurovski dol, Lenart–avtocesta 1, and Križišče Partinje-Varda sections (Appendix, Tabs. 10, 6 and 5), where *H. waltrans* was found as well; this clearly indicates that Martini's subzones *H. perch-nielseniae* and *H. waltrans* partially overlap. Some very rare specimens of *H. perch-nielseniae* were found in individual samples from the Partinje (Appendix, Tab. 8A), Polička vas (Appendix, Tab. 11A) and Lenart sections (Appendix, Tab. 13A), where they are supposedly reworked.

Sections Polička vas (Appendix, Tab. 11), Zgornji Duplek 1 and 2, Zimica, Vinička vas (Appendix, Tab. 12), and the bottom part of the Lenart section (Appendix, Tabs. 13A-C) can all be assigned to the *Eu-discoaster musicus* subzone of Theodoridis (1984), as the assemblages from samples from these sections contain *H. walbersdorfensis* while *H. waltrans* is absent.

H. waltrans is certainly a stratigraphically useful species, as it only occurs in a short interval in the Middle Miocene (Theodoridis, 1984; Fornaciari et al., 1996; Di Stefano et al., 2008). According to Švabenická (2000, 2002a, 2002b) and Ćorić et al. (2007), the FO of the species is diachronous in the eastern (top of NN4) and western part of the Central Paratethys, as well as the Mediterranean (middle part of NN5). Fornaciari et al. (1996) report the FO of *H. waltrans* in the Mediterranean in NN5 (MNN5a), while Di Stefano et al. (2008) observe this event in NN4. Hohenegger et al. (2009) observe the FO of rare specimens of *H. waltrans* in the Styrian basin in NN4 (bottom of the Badenian), however, their results show that the species is very rare and easily overlooked in the lower part of its range, as it was only found in a single sample assigned to NN4.

For reasons stated above, any correlation based on the first occurrence of this species has to be approached with caution. Contrary to its FO, the LCO of *H. waltrans* is a reliable stratigraphic marker and was dated at 14.36 Ma by Abdul Aziz et al. (2008).

In the Mediterranean, the ranges of *H. ampliaperta* and *H. waltrans* overlap, but this is not the case in the Mura Depression, where a situation similar to the one described by Theodoridis (1984) was observed – the FO of *H. waltrans* occurs in NN5.

In several samples from the Partinje, Lenart, Zimica, Zgornji Duplek 1 and 2 and Vinička vas sections (Appendix, Tabs. 8, 12, 13), which belong to the upper part of NN5, rare specimens of *Sphenolithus abies* and/or *Discoaster braarudii* were found. The same species (though *D. braarudii* is determined as *Discoaster brouwerii*) are reported from the upper part of NN5 from the Transylvanian Basin (Chira & Vulc, 2003), East Carpathians (Mărunțeanu, 1999), and the Vienna Basin (Kováč et al., 2004).

Helicosphaera wallichii was found in some samples from the Križišče Partinje-Varda, Kamenščak, Partinje, Jurovski Dol, and Lenart sections (Appendix, Tabs. 5, 8, 9, 10 and 13). Its distribution pattern is somewhat puzzling, since these sections are attributed to the middle part of NN5.

Very rare specimens of *Syracolithus dalmaticus* holococcoliths (*Homozygosphaera wettsteinii* in Mihajlović & Knežević, 1989), were found in the upper part of the Lenart section (Appendix, Tab. 13D), assigned to the base of NN6. These holococcoliths are reportedly produced by the haploid generation of *Helicosphaera wallichii* (Geisen et al., 2004). Their occurrence corresponds to the reported range of *H. wallichii* (Mihajlović & Knežević, 1989; Chira, 2001; Chira & Vulc, 2003), while *H. wallichii* occurs somewhat earlier in Slovenske Gorice.

4.2.3. The sections assigned to NN6

Biozones NN6 and NN7 are very difficult to distinguish in the Central Paratethys realm (Stradner & Fuchs, 1979; Bajraktarević, 1983; Mihajlović & Knežević, 1989). NN6 begins with the last occurrence of *Sphenolithus heteromorphus*; this event is globally well-correlated and is observable in the middle of the Lenart section (Appendix, Tab. 13B). In the equatorial Pacific, it was dated at 13.51 Ma (Turco et al., 2002) and 13.2 (Backman & Raffi, 1997). Olaffson (1989) observes this event at 13.17 in the equatorial Atlantic, however, he reports a dramatic abundance drop well before this level. A similar situation is described in the western Mediterranean by Abdul Aziz et al. (2008), who calculate the LCO of the species at 13.54 Ma or 13.63 Ma, according to different age models, while the LO of the species occurs about 0.3 Ma later.

The FO of very rare specimens of *Reticulofenestra pseudoumbilica* (>7 μm) occurs at the very top of NN5. Perch-Nielsen (1985a), Fornaciari et al. (1990), and Young (1998) consider this event to be an alternative marker of the boundary between NN5 and NN6. The two events are simultaneous in the Mura Depression, which corresponds to the situation in low latitudes, while in higher latitudes the FO of *Reticulofenestra pseudoumbilica* (>7 μm) occurs considerably later (Raffi et al., 1995) than the LO of *Sphenolithus heteromorphus*.

Reticulofenestra pseudoumbilica (>7 μm) is very rare at the base of NN6 and becomes more common somewhat higher. The FCO of *Reticulofenestra pseudoumbilica* (>7 μm) was dated at 13.10 Ma (Abdul Aziz et al., 2008).

Near the FCO of *Reticulofenestra pseudoumbilica* (>7 μm), the FO of very rare specimens of *Calcidiscus macintyrei* was observed; this corresponds to the boundary of Mediterranean biozones MNN6a and MNN6b of Fornaciari et al. (1996). The FO of *Calcidiscus macintyrei* was dated at 13.16 Ma (Turco et al., 2002). Olaffson (1989) and Raffi & Flores (1995) do not consider the FO of *Calcidiscus macintyrei* to be a good stratigraphic marker as it is diachronous in different latitudes.

In the studied material, *Cyclicargolithus floridanus* becomes very rare near the LO of *Sphenolithus heteromorphus* (Appendix, Tab. 13) and gradually disappears at the base of NN6. Its LCO is very close to the FO of *Reticulofenestra pseudoumbilica* (>7 μm), while its LO is very near the FCO of this species. The LO of *Cyclicargolithus floridanus* is dated at 13.32 Ma in the equatorial Pacific (Turco et al., 2002), at 12.65 Ma in the equatorial Atlantic (Olaffson, 1989) and at around 13.3 Ma in the Mediterranean (Hilgen et al., 2003). In the North Atlantic, a dramatic drop in its abundance occurs at 13.2 Ma, but rare specimens of the species persists for as long as 11.9 Ma (Gartner, 1992). It appears that the LO of this species is diachronous in different latitudes (Marino & Flores, 2002; Turco et al., 2002) and different geographic regions.

4.2.4. The lack of evidence for NN7

The base of NN7 is defined at the FO of *Discoaster kugleri* (Martini, 1971). In a single sample from the Partinje section and in several samples from the Lenart section some very rare specimens of *Discoaster* aff. *kugleri* (Pl. 24, Figs. 8, 16, 17) were found. The specimens resemble the atypical morphotype of *D. kugleri* (Martini & Bramlette, 1963) from the Mohole experimental drilling, but they are not characterized by a lack of radial symmetry and are not considered to be reliable stratigraphic markers. In the case of Partinje section, the accompanying assemblage contained *Sphenolithus heteromorphus, Helicosphaera waltrans,* and *H. walbersdorfensis*, but no specimens of *Reticulofenestra pseudoumbilica* > 7μm (Appendix, Tab. 8), so the section was assigned to NN5 (MuN5c). In the case of Lenart section, the accompanying assemblage contained *Sphenolithus heteromorphus, H. walbersdorfensis,* and very rare specimens of *R. pseudoumbilica* >7 μm (Appendix, Tabs. 13A, B). The section was assigned to the top of NN5 (MuN5d). The occurrence of discoasters similar to *D. kugleri* before NN6 was also reported by von Salis (1982), who describes their occurence from the beginning of NN6 in the southeast Atlantic.

In the Lenart, Zimica, and Zgornji Duplek 2 sections, some atypical specimens of *Discoaster* cf. *variabilis* were found with some characteristics of *Discoaster bollii* (FO in the middle of NN7 according to Raffi et al., 1995). The specimens found are considered to represent an unusual morphotype of *D. variabilis*.

Some authors (Raffi et al., 1995; Marino & Flores, 2002; Chira in Vulc, 2003) use the FO of *Calcidiscus macintyrei* and the LO of *Cyclicargolithus floridanus* as approximations of the boundary of NN6 and NN7. Both events were noted in the Mura Depression in the upper part of the Lenart section (Appendix, Tab. 13C). The accompanying assemblage is characterized by high diversity, the presence of *Orthorhabdus serratus* (the single blade variety and the normal morphotype), *Coronocyclus nitescens* (elliptical variety), and *Calcidiscus premacintyrei*. All of these species have their LO before the end of NN6 (Young, 1998). This indicates that these assemblages can be assigned to NN6. The same events, occurring in a very similar manner and in precisely the same order of succession, can be observed in the Mediterranean (Fornaciari et al., 1996), where they are also assigned to NN6. Considering all of the above, none of the samples from Slovenske Gorice was assigned to NN7.

4.3. A local biostratigraphic zonation for the Mura Depression

4.3.1. A combination of existing zonations

Several events used in the biostratigraphic zonations of Theodoridis (1984) and Fornaciari et al. (1996) emended by Di Stefano et al. (2008) were observed in the studied material, however, none of these schemes accurately described the situation observed in Slovenske Gorice. The use of combined marker events from all three zonations above and the standard nannoplankton zonation of Martini (1971) made it possible to divide the studied interval into six successive interval zones. Their correlation with the zonations of Theodoridis (1984) and Fornaciari et al. (1996) emended by Di Stefano et al. (2008) is shown in Fig. 4.1.

Both Fornaciari et al. (1996) and Di Stefano et al. (2008) use several FCO and LCO of individual species as stratigraphic markers. Apart from the case of the FCO of *Reticulofenestra pseudoumbilica* (>7 μm), observed in a long continuous section, only the FO and LO (respectively the presence or absence of individual species) have been used in this particular case for the following reasons:

- abundance oscillations of individual species were not considered to represent reliable stratigraphic events as they could vary between different depositional environments due to ecological factors;
- some stratigraphic markers (e.g., *Helicosphaera waltrans*) were rare or very rare in most of their observed stratigraphic range;
- the shortness of sections in Slovenske Gorice restricted the possibility of tracking abundance changes through time and provided little room for comparison.

4.3.2. Definitions of local interval zones

Interval MuN4.— MuN4 is only limited upwards and ends with the LO of *Heliosphaera ampliaperta*. The base of this interval was not defined, as the material from this time interval was rather scarce and no stratigraphically useful events were observed.

The interval is marked by low species diversity and a scarcity of nannofossils. *Discoaster deflandrei* dominates among the discoasters. Very rare specimens of *H. ampliaperta, H. scissura* and *H. euphratis* are present.

This interval zone can be correlated with the upper part of the NN4 of Martini (1971) and the *Eu-discoaster signus* zone of Theodoridis (1984) (Fig. 4.1).

Interval MuN5a.— MuN5a is defined as the interval between the LO of *Heliosphaera ampliaperta* and the FO of *Helicosphaera waltrans*. The assemblage composition is similar to that in the interval MuN4, however, diversity and abundance of coccoliths are markedly higher in MuN5a. The LO of *Helicosphaera scissura* and the FO of *Discoaster exilis* and *Helicosphaera minuta* were observed in this interval. The latter seems to be a local event as *Helicosphaera minuta* is already present in the middle Karpathian in the Styrian Basin (Spezzaferri & Ćorić, 2001).

Interval MuN5a can be correlated with the lowermost part of NN5 and possibly with the top of NN4 (Fig. 4.1), as *Helicosphaera ampliaperta* is reportedly very rare in the upper part of its range. The interval can be partly correlated with the beginning of *Helicosphaera perch-nielseniae* biozone of Theodoridis (1984); this biozone, however, ends with the LO of *Helicosphaera perch-nielseniae* and the FO of *H. waltrans*, while in Slovenske Gorice the ranges of the two species overlap. This overlapping is also observed in the Mediterranean by Fornaciari et al. (1996).

In the Mediterranean (Di Stefano et al., 2008) and the eastern part of the Central Paratethys (Švabenická, 2002b), the ranges of *Helicosphaera ampliaperta* and *H. waltrans* overlap. This is not the case in the Mura Depression, where a situation similar to the one described by Theodoridis (1984) was observed, i.e. the FO of *H. waltrans* clearly occurs within NN5 (Fig. 4.1).

Interval MuN5b.— MuN5b is defined as the the interval between the FO of *Helicosphaera waltrans* and the FO of *Helicosphaera walbersdorfensis*; the nannoplankton assemblage is not particularly rich and nannofossils are moderately common with *Helicosphaera* and *Reticulofenestra* represented by several species. The FO of *Discoaster variabilis*, *Calcidiscus premacintyrei,* and the FO of *Rhabdosphaera procera* were observed in this interval.

H. waltrans is very rare in most of its range observed in the material from Slovenske Gorice, but the well-preserved state of the studied material and the sampling in high-resolution increased the probability of finding rare species (at least in some samples) and allowed its FO to be used as a stratigraphic marker.

Interval MuN5c.— MuN5c is defined as the interval between the FO of *Helicosphaera walbersdorfensis* and the LO of *Helicosphaera waltrans*. The nannofossils are abundant and nannoplankton assemblages are relatively diverse. The FO of *Sphenolithus abies* was observed in this interval. The interval corresponds to MNN5b biozone of Di Stefano et al (2008) during which *H. waltrans* and *H. walbersdorfensis* coexist in low abundances. The upper boundary of the interval can be correlated with the end of Theodoridis's *Helicosphaera waltrans* biozone (1984) (Fig. 4.1).

Interval MuN5d.— MuN5d is defined as the interval between the LO of *Helicosphaera waltrans* and the LO of *Sphenolithus heteromorphus*. The nannoplankton assemblages are very diverse, nannofossils are very abundant. *Syracolithus dalmaticus* has its FO in this interval, as does the elliptical morphotype of *Coronocyclus nitescens* and the single blade morphotype of *Orthorhabdus serratus*. Towards the top of the interval the FO of very rare specimens *Reticulofenestra pseudoumbilica* (>7 μm) can be observed. *Discoaster braarudii* and *D. moorei* were only observed in this interval, but this could be due to ecological factors.

This interval zone can be correlated with the top part of NN5 (Martini, 1971). It is identical to the *Discoaster musicus* biozone of Theodoridis (1984) and can also be roughly correlated with the MNN5c biozone of Di Stefano et al. (2008) (Fig. 4.1).

Interval MuN6.— MuN6 is defined as the interval between the LO of *Sphenolithus heteromorhus* and the FCO of *Reticulofenestra pseudoumbilica* (>7 μm). The nannofossils are very abundant and nannoplankton assemblages are very diverse. In the beginning of the interval, *Reticulofenestra pseudoumbilica* (>7 μm) becomes continuously present in all samples and gradually increases in abundance, while *Cyclicargolithus floridanus* gradually dissapears from the assemblage. The FO of very rare specimens of *Calcidiscus macintyrei* was observed in this interval.

The interval can be correlated with the bottom part of NN6 (Martini, 1971), the *Helicosphaera walbersdorfensis* biozone of Theodoridis (1984) and MNN6a biozone of Di Stefano et al. (2008) (Fig. 4.1).

5. FACIES, STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

5.1. Lithofacies of sampled Badenian deposits

The sections sampled in the scope of this study consisted of marls, sands, and lithothamnium limestone; most often an entire section consisted of a single lithofacies.

Marls represent the dominant lithological component in the studied sections. They are typically deposited in offshore environments The marls sampled in Slovenske Gorice contained relatively diverse nannoplankton assemblages (except in the case of laminated marls in the Jablance section), which is consistent with an offshore depositional environment and indicates that Badenian marl successions were formed in deeper water environments within the Mura Depression. Marls in some of the sampled Badenian successions might have originated from redeposition. This could explain the faint normal grading observed in marls in the Lenart–avtocesta 0 and 1 sections (Figs. 1.7, 1.8). The nannoplankton assemblages found in individual sections exhibit specific character and with very few exceptions (see chapter 4.1.2) stratigraphic markers of specific interval zones do not occur together with the stratigraphic markers of other interval zones as would be expected in the case of any significant redeposition. If redeposition did in fact occur, it probably happened shortly after the primary deposition.

Sands are more characteristic of nearshore shallow water environments; an example of this is the Jablance section, consisting mostly of sand. A shallow to intertidal depositional environment of the deposits sampled in this section is further demonstrated by the presence of wave-formed ripple marks on the upper surface of a 20 cm sandstone bed (Fig. 1.17A).

The limestone sections Zgornji Duplek 1, Zgornji Duplek 2, Zimica, and Vinička vas are situated within a continuous patch of lithothamnium limestone between Hrastovec and Kamenščak (Fig. 1.4). The structure of this large carbonate body is not uniform – near Kamenščak in the south-west, the lithotamnium limestone is bindstone rich in macrofossils (Horvat, oral communication), while in Vinička vas, in the centre of this area, lithothamnium limestone occurs in the form of abundant spheroid concentric rhodoliths bound together with hard marl to form rudstone (Fig. 1.6). Rhodoliths were also found in the top part of the Lenart section, where they were incased in marl.

Lithothamnium limestone was formed in shallow coastal environments at a depth less then 50 m, but usually no deeper than 15 m (Ranazzo et al., 2002). It accumulated throughout the entire Central Paratethys region during the entire span of the Badenian and was often deposited on shallow carbonate platforms or ramps rather than reefs (Riegl & Piller, 2000). The limestone is composed mostly of the remains of corallinacean algae and contains the remains of other organisms like corals, molluscs, echinoderms, and other fossils.

Rhodoliths are formed in a wide range of marine environments down to depths of about 90 m. They require clear waters that are sheltered from excessive wave and tidal currents (Bosence, 1983) but have a certain level of energy in their environment, as their formation requires frequent movement. This is particularly so in the case in the spheroidal laminated rhodoliths, which usually form under the influence of strong currents (Burgess & Anderson, 1983). Rhodolits can also be associated with transgressions, sea-level fluctuations, and intensive tectonic activity, which causes the development of complex sea floor topography (Randazzo et al., 1999).

The Jurovski Dol section lies outside the extensive lithothamnium limestone area between Hrastovec and Kamenščak (Fig. 1.4). The upper part of the Jurovski Dol section (Figs. 1.9; 1.13) consists mostly of lithothamnium limestone conglomerate containing fossil fragments of various kinds. It also contains chert pebbles, ranging in size from a few milimeters to several centimetres (Fig. 1.14), and marl lenses (Fig. 1.15), which probably represent the remains of deformed marl interbeds. The presence of marl lenses and pebbles in lithothamnium limestone conglomerate suggests that these deposits are the product of redeposition and mixing of material from various sources. Lithothamnium limestone presumably originates from a carbonate ramp or a platform, while the pebbles suggest a near-shore environment. Their occurrence in combination with marl, containing a diverse nannoplankton assemblage including several pelagic species, suggests their redeposition in a deeper marine environment.

5.2. Sequence stratigraphic correlation

As stated above, most sampled sections consisted of a single lithofacies. Recording the development of somewhat thicker and more diverse sedimentological sucessions was only possible in a few cases (Figs. 1.7 – 1.11). The arrangement of sections into a stratigraphical order on the grounds of the presence of nannoplankton marker species (Fig. 4.3) provided some further insight into the stratigraphical distribution of lithofacies in the Mura Depression.

Sand and sandstone were barren of nannofossils and could only be dated biostratigraphically in the case of interbeds within predominantly marl successions. In all such cases except the upper part of the Lenart section (Fig. 4.3), they were assigned to the interval zone MuN5a. This interval was correlated with the lower part of NN5 and probably corresponds to the sea-level lowstand at the transition of global 3rd order eustatic cycles TB2.3 and TB2.4 (Fig. 1.2) and the transition between the Lower and the Middle Badenian. The pattern of lithological succession of interbedded marl and sand beds is difficult to correlate with a single eustatic event and suggests several short lived sea-level changes, possibly resulting (at least in part) from tectonic activity. This is in accordance with the findings of Kováč et al. (2007), who find the correlation of 3rd order eustatic changes and Central Paratethys sedimentary sequences is not simple because of interference from regional factors and describe several different possible correlations (Fig. 1.2).

Sand beds in the Lenart section were correlated with interval MuN6, corresponding to the base of NN6 (Figs. 4.1, 4.3), and probably indicate a sea-level drop at the transition of global eustatic cycles TB2.4 and TB2.5 or the Middle and the Upper Badenian.

The palaeogeographic maps created by Goncharova et al. (2004) and Ilyina et al. (2004) show carbonate bioherms and platforms existing in the entire Central Paratethys realm throughout the entire Badenian (Fig. 5.1). Nannoplankton assemblages found in all marl samples from the lithothamnium limestone sections (Zimica, Zgornji Duplek 1 and 2, Vinička vas) belong to the interval MuN5d (top of NN5), but the duration of the time interval during which the limestone was deposited is uncertain. The borehole in Lormanje, approximately 1 km southeast of Lenart (Novak et al., 1974a; b), that passes through over 100 m of lithothamnium limestone, indicates that lithothamnium limestone was accumulating in the Mura Depression as early as in the Early Badenian.

In the top part of the Lenart section, some rhodoliths were found embedded in marl (Figs. 1.10, 1.16); they are incased in predominantly terrigenous sediment, which suggests that they are most probably allochthonous (Burgess & Anderson, 1983). Their redeposition was synchronous with their formation, or it occurred as a consequence of a regression that caused the increase in the energy level in the shallow carbonate platforms or even their emergence from the sea. Their redeposition seems more likely as rhodoliths themselves bear some characteristics of deeper water (over 50 m) origin according to Bosence (1983), like concentric layers of crustose corallines together with foraminifers and bryozoa and borings of various organisms (Fig. 1.16). According to the stratigraphic position of their occurrence, the inferred shallowing could occur during the regression at the transition of global eustatic cycles TB2.4 and TB2.5 (corresponding roughly to the transition of NN5 and

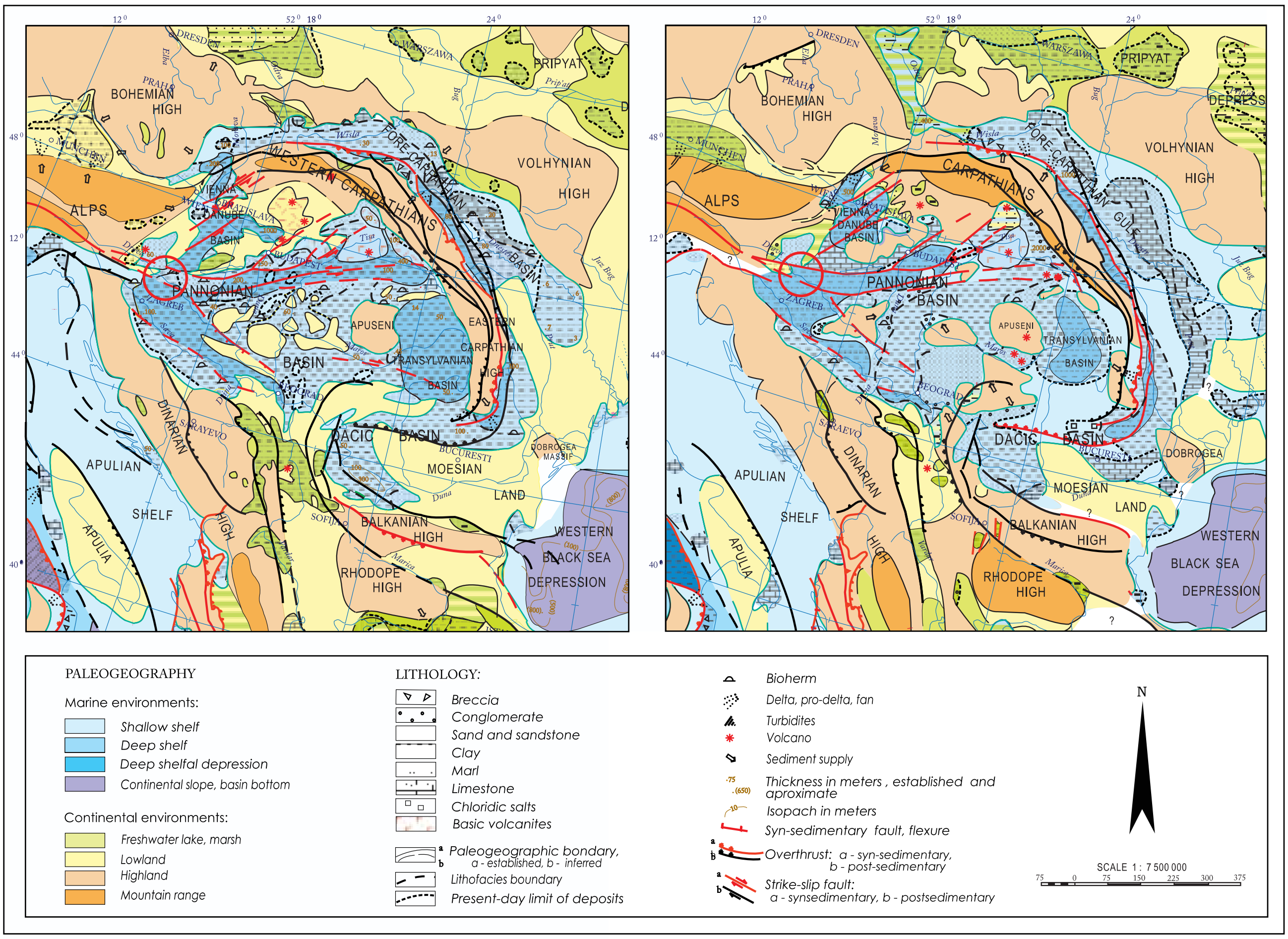


Fig. 5.1. Maps of the palaeogeographical situation of the studied area during the. Early Badenian - left (Goncharova et al., 2004), Late Badenian - right (Ilyna et al., 2004). The location of the Mura Depression is marked with a red circle.

NN6). Another argument in favour of the inferred shallowing is the disappearance of discoasters and the rise in abundance of sphenoliths in the upper part of the Lenart section indicating a rise in nutrient levels (Bartol & Pavšič, 2005).

The lithostratigraphical correlation of Badenian deposits from this marginal part of the Central Paratethys is highly unreliable, as very different facies occur simultaneously in different localities. The striped sands and laminated marls might represent an exception in this respect as they are not very common in Badenian successions, but they mark the Badenian/Sarmatian transition in several localities throughout the Central Paratethys, including the vicinity of Lenart in Slovenske Gorice (Novak et al., 1974b, Rijavec, 1973), the central Pannonian Basin (Báldi, 2006), and Karaburma near Belgrade (Mihajlović & Knežević, 1989). Striped sands and marls with alternating light grey and dark yellow-brown laminae (Fig. 1.18) make up a considerable portion of the Jablance section. This might bear some stratigraphical importance and allow a tentative correlation of the Jablance section with the Badenian/Sarmatian transition.

There is another clue about the age of the deposits from Jablance section. The age of the sediments in Slovenske Gorice is growing in the east-west direction (Rijavec, 1976; Žnidarčič & Mioč, 1989). The Jablance section is situated about 1 kilometre west of the Vinička vas section, which implies that deposits from the Jablance section are younger than the ones sampled in Vinička vas. The dip angle of bedding planes recorded during field observations further suggests the superposition of deposits sampled in Jablance over those from Vinička vas. Since the Vinička vas section is biostatigraphically assigned to MuN5d (top of NN5), the deposits sampled in Jablance section are younger than NN5.

5.3. The lateral distribution of facies

The studied sections, which belong to the same interval zone, often reflect different depositional environments. The most prominent example of this are the sections assigned to the interval MuN5d. On one hand there are the thick marl beds from the Polička vas and Lenart sections (bottom part) with diverse nannoplankton assemblages suggesting an offshore depositional environment. On the other hand there are Zimica, Zgornji Duplek 1 and 2, and Vinička vas sections (Appendix, Tab. 12), which are composed of lithothamnium limestone and were assigned to the same interval zone. Sections with distinctly different lithologies of very similar age were found only a few kilometres apart (Figs. 1.4, 4.3). This is a clear indication that in the Mura Depression during the MuN5d interval (top of NN5) deeper basins existed in close proximity of shallow carbonate platforms.

The diversity of depositional environments in the Central Paratethys region during the Badenian is also referred to by several other authors (e.g., Randazzo et al., 1999; Vrsaljko et al., 2005) and is figured on the palaeogeographical maps in Fig. 5.1, where the complexity of the Mura Depression in space and time is clearly observable.

The existence of a carbonate platform in the southeastern part of the study area seems highly probable, considering there is a large limestone patch between Hrastovec and Kamenščak with Zgornji Duplek 1 and 2, Zimica and Vinička vas sections (Fig. 1.4).

The existence of a carbonate platform bordering on the deeper marine environment is also reflected in the presence of rhodoliths encased in marl in the upper part of the Lenart section (MuN6, lower part of NN6); they were supposedly redeposited in the deeper peri-platform environment near a carbonate platform.

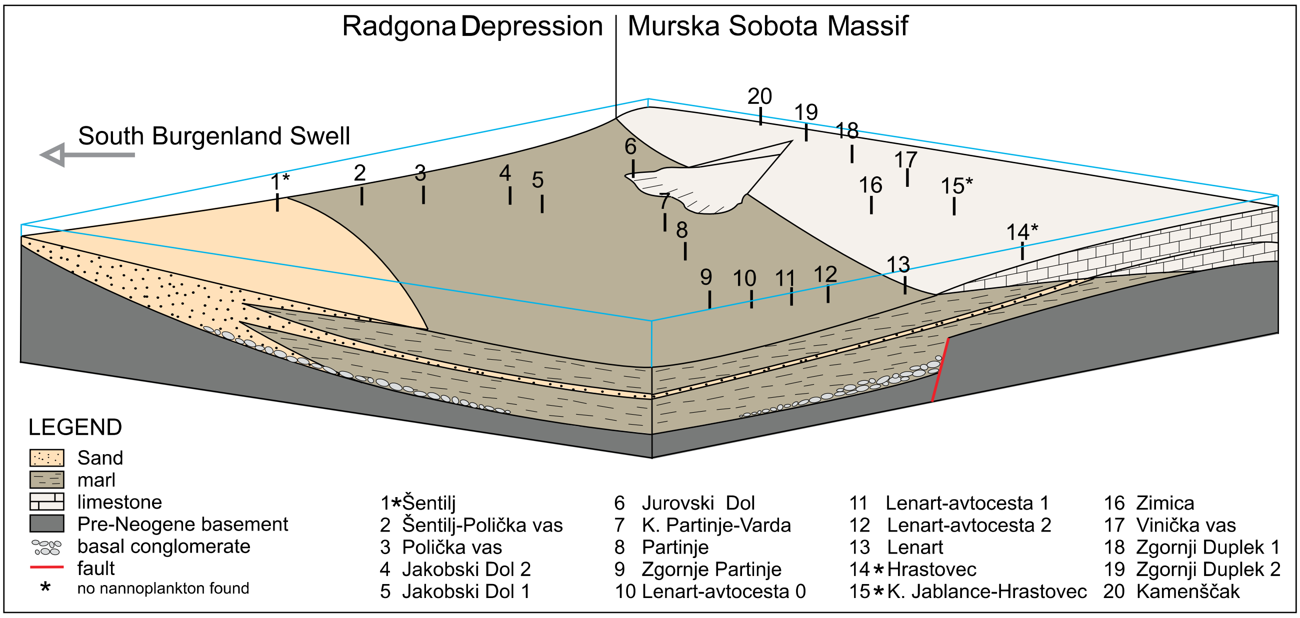


Fig. 5.2. A depositional model of the south-western part of the Mura Depression in the Late Badenian with positions of studied sections.

The observed differences between the depositional environments in the Mura Depression during the upper part of NN5 could be attributed to the position of sections on two different tectonic blocks (Fig. 5.2). The varying thickness of Neogene deposits on the pre-Tertiary basement (Mioč & Žnidarčič, 1996; Gosar, 2005) confirms that the tectonic subunits constituting the Mura Depression had subsided to different depths. Therefore it seems likely that the deposits sampled in the Lenart, Jurovski Dol, and Polička vas sections were deposited on a deeply subsided tectonic block, while the ones from the Vinička vas, Zgornji Duplek 1 and 2 and Zimica sections were deposited on another tectonic block, which provided a shallower marine environment.

The studied area lies on two different tectonic blocks: the Radgona Depression, where the depth of the Pre-Neogene basement reaches 2000 m, and the Murska Sobota Massif, where the Pre-Neogene basement is only 500 to 1000 m deep (Figs. 1.2, 5.2). Mioč & Žnidarčič (1996) position the boundary between the Radgona Depression and Murska Sobota Massif as it is shown in Figs. 1.3 and 1.4. The boundary between Radgona Depression and Murska Sobota Massif can also be inferred from the thickness of Neogene deposits (Gosar, 2005) (Fig. 1.3).

Our data indicate that the inferred boundary between the Radgona Depression and Murska Sobota Massif (Mioč & Žnidarčič, 1996) should be shifted towards the south to include the site of the Lenart section into the Radgona Depression, while the lithothamnium limestone sections between Hrastovec and Zgornji Duplek belong to the Murska Sobota Massif as proposed on the sketch of Mioč & Žnidarčič (1996).

The boundary between deep water facies and shallow water facies corresponds to the Pesnica fault, which separates the Jarenina and Lenart tectonic blocks from the Maribor and Pesnica tectonic blocks of Slovenske Gorice (Fig. 1.4). Perhaps the correspondence is coincidental or perhaps the Pesnica fault is, in fact, much older than previously suggested and represents one of the boundaries of the tectonic subunits of the Mura Depression.

6. NANNOPLANKTON AND PALAEOECOLOGY

6.1. Nannoplankton assemblage composition

The composition of fossil nannoplankton assemblages depends on the palaeoecological conditions at the time of deposition and diagenetic changes. Through diagenesis, nannofossils can dissolve and thus disappear from the assemblage or they can be modified to a point where they become unrecognizable. Some species of coccoliths are more susceptible to diagenetic changes then others. Bukry (1981a) composed a scale of sensitivity of different heterococcoliths to dissolution; selected groups from this scale, which were also found in the studied material, are listed in Fig. 6.1. The higher the position of a certain form in the list, the more resistant it is to dissolution. At the bottom of the list, holococcoliths have been added as they are generally more sensitive to dissolution than heterococcoliths.

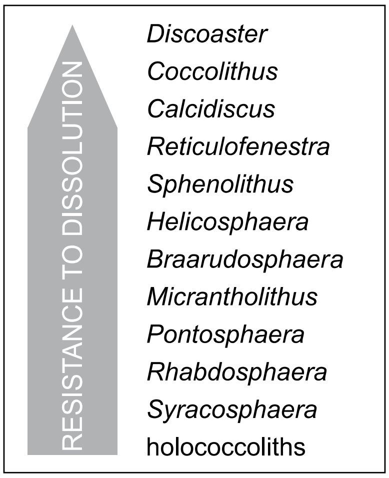


Fig. 6.1. Selected groups of nannofossils arranged with respect to their resistance to dissolution (modified after Bukry, 1981a). The higher in the list a certain group is positioned, the more resistant it is to dissolution.

The samples from the Lenart and Polička vas sections contain the most diverse nannoplankton assemblages, which enabled their correlation with the top part of NN5 and the bottom part of NN6 (MuN5d and MuN6). The poorest nannoplankton assemblages were found in samples from the Zgornje Partinje and Jakobski Dol 1 sections.

The state of preservation and nannoplankton diversity are obviously correlated. The samples with the poorest preservation of nannofossils contained the least diverse nannoplankton assemblages. This could have a significant effect on the recorded composition of nannoplankton assemblages. To avoid this effect, samples were collected in short intervals (10 cm), which increased the possibility of reconstructing realistic representations of original taphocoenosis, as we were able to choose among several different samples, among which at least some would be in a satisfactory state of preservation. This enabled the reconstruction of relatively diverse nannoplankton assemblages even in sections where most samples were poorly preserved. At least some samples from all sampled sections, except the upper part of the Jurovski Dol section, contained recognizable sensitive forms of coccoliths, including holococcoliths, *Syracosphaera* spp., *Rhabdosphaera* spp., *Pontosphaera* spp., and *Braarudosphaera bigelowii*. This indicates that they are realistic representations of the original taphocoenoses.

The number of autochthonous species found in an individual sample depends strongly on the state of its preservation, and the average number of species in a sample from a single section is therefore not a very good measure of species diversity. In spite of large differences between the number of analysed samples and the state of preservation of nannofossils, most of the studied sections contained between 30 and 40 autochthonous species. Only two sections stand out in this respect:

- the Zgornje Partinje section, with a total of only 13 species
- part of the Lenart section, with a total of 58 species.

All nannoplankton assemblages from Slovenske Gorice are rather diverse, and this might indicate warm surface waters. The number of all autochthonous species in all examined samples is shown in Fig. 6.2. Within individual interval zones, the species diversity is comparable, except in the following cases:

- The nannoplankton assemblage in the sections assigned to interval MuN4 (NN4), are considerably poorer than other sections, particularly in the case of Zgornje Partinje. Though most of the material in the Zgornje Partinje section is poorly preserved, the presence of dissolution-sensitive species in some samples indicates that this is not entirely a consequence of diagenetic alteration. The low diversity could be explained by low water temperatures; yet the continuous presence of *Sphenolithus heteromorphus* indicates that this is not the case. The low diversity may reflect the sea-level lowstand at the beginning of the Badenian, as nannoplankton assemblages are generally more diverse in pelagic environments.
- The nannoplankton assemblage in the upper part of the Jurovski Dol section is much less diverse than the assemblages from the other two sections assigned to the interval MuN5d. The material from this section was probably subjected to stronger diagenetic overprint, due to the contact of two different lithologies (marl lenses within lithothamnium limestone, see Figs. 1.9 and 1.15). This would also explain the absence of forms sensitive to diagenetic alteration.

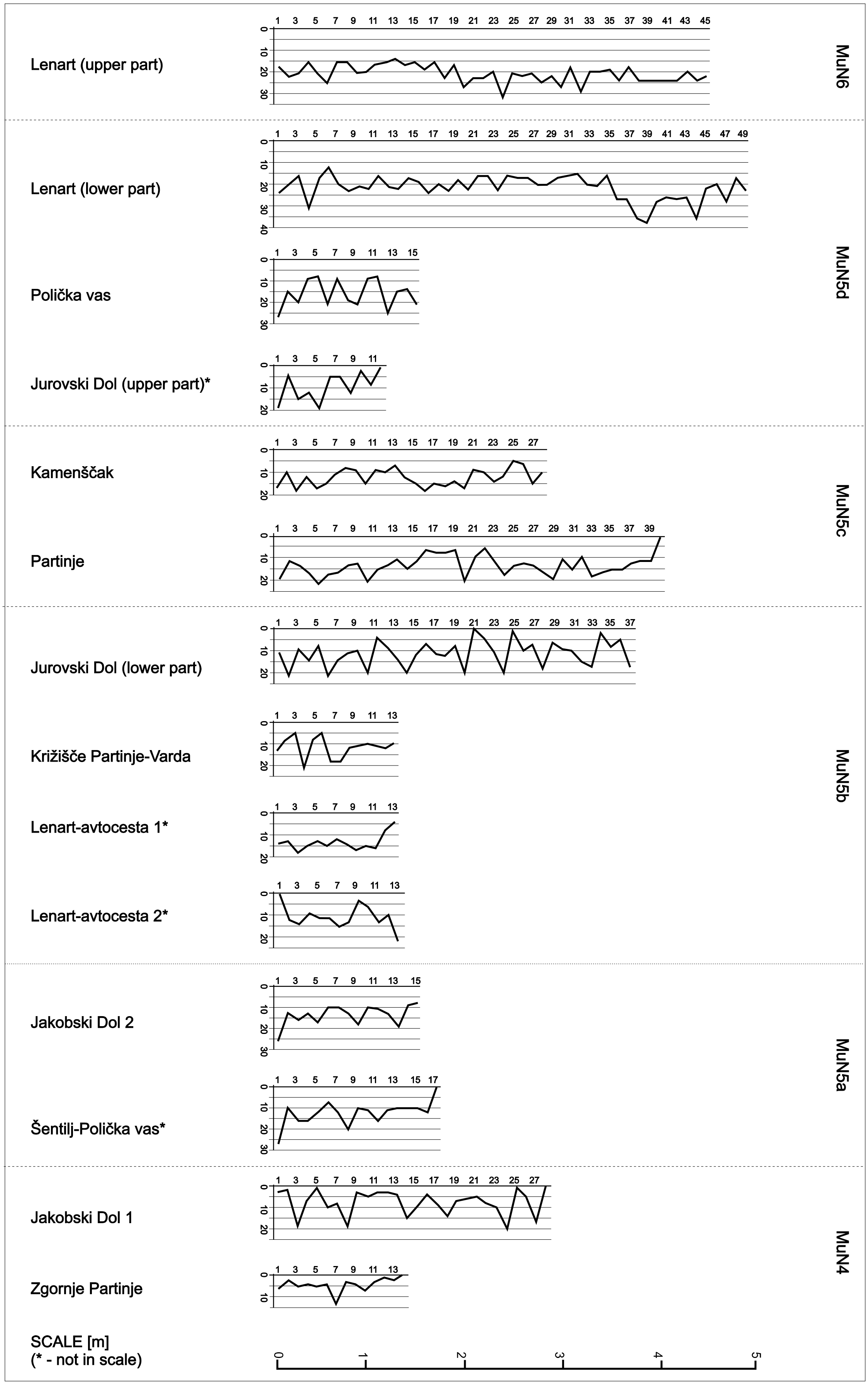


Fig. 6.2. The number of autochthonous species in all examined samples.

- The middle part of the Lenart section assigned to the transition of MuN5d and MuN6 (NN5 and NN6) is characterized by exceptionally diverse nannoplankton assemblages rich in discoasters and sphenoliths. This is interpreted as a result of high temperatures creating an environment suitable for the thriving of various nannoplankton species.

Samples from all studied sections contain allochthonous Paleogene species and also some Mesozoic species. The redeposited species originate from older sediments and rocks that can also be found in the Pre-Neogene basement of the Mura Depression. They were probably transported into the sedimentary basin by rivers. During the phase of intensive tectonic activity during the Lower and Middle Badenian (Styrian phase) some parts of the Mura Depression emerged from the sea – as indicated by the borehole in the centre of the Murska Sobota Massif, in which the Lower Badenian sandy marls are directly overlain by Upper Badenian clayey and sandy marls (Novak et al., 1976). Emerged areas like these represent another likely source of redeposited Paleogene species. The number of allochthonous species in all examined samples is presented in Fig. 6.3.

The number of allochthonous species per sample varies between 0 and 11, though only a handful of samples contain more than 4 (Fig. 6.3). No particular differences among different sections were observed in this respect, with the exception of the assemblage from the Jakobski Dol 1 section, where only one sample contained an allochthonous species. The near absence of allochtonous species could be attributed to poor preservation of the material, but it might also reflect less intensive redeposition of older nannofossils, associated with the Lower Badenian transgression.

6.2. The nature and number of dominant species

The dominant species in all recorded nannoplankton assemblages include *Coccolithus pelagicus*, *Helicosphaera carteri, Reticulofenestra* spp. and *Sphenolithus heteromorphus*.

Coccolithus pelagicus of modern oceans is a typical subarctic species (Baumann et al., 2000). It thrives in water temperatures below 10°C, and, as such, it is considered to be an indicator of cold water (Ćorić & Rögl, 2004; Krammer et al., 2006). At the same time, the bigger morphotype of *Coccolithus pelagicus* (a sibling species) is known to thrive in considerably warmer (18°C) waters along the coasts of Portugal (Cachão & Moita, 2000), South Africa (Baumann et al., 2004), and New Zealand (Ziveri et al., 2004). This means that only the smaller morphotype is useful as a cold water indicator. *Coccolithus pelagicus* is also considered to be an r-strategist (Ćorić & Rögl, 2004), as it thrives in high nutrient waters and can form very large populations in upwelling regions (Baumann et al., 2000). The opportunistic nature of the species is also indicated by its unusually long stratigraphic range, from the early Paleogene to this day (Sato et al., 2004).

The species of the cosmopolitan genus *Reticulofenestra* are often subject to substantial – and sometimes difficult to interpret (e.g., Kameo & Takayama, 1999) – oscillations in the abundance and size of coccoliths. Negri & Villa (2000), Flores et al. (2005), and Krammer et al. (2006) interpret small reticulofenestrids as typical r-strategists that are able to withstand oligotrophic conditions, but only thrive in high-nutrient environments. Nagimarosy (2000) points out the opportunistic character of the *Reticulofenestra* species and reports that some species tolerate fluctuations in salinity rather well. An abundance of reticulofenestrids in Lower Miocene beds from southeast Slovenia, enriched with pentaliths (Bartol et al., 2008), corresponds to the latter observation rather well.

The recent *Helicosphaera* species are common in warm surface waters with a medium to high content of nutrients (Negri & Villa, 2000; Melinte, 2005). The recent *Helicosphaera carteri* is most abundant in warm tropical marine environments; however, it is also present in temperate and cold environments (Edwards, 1968) and prefers high-nutrient waters (Perch-Nielsen, 1985a, Baumann et al., 2005). Nagimarosy (2000) presumes that *Helicosphaera* species indicate shallow water, while Švabenická (2002a) interprets the abundance of *Helicosphaera* species as an indication of unstable environmental conditions and links their dominance to shallow epicontinental seas and possibly to the beginning of a transgression.

In most of the analysed nannoplankton assemblages assigned the Middle and the Upper Badenian, more than one nannoplankton species is abundant. Baumann et al. (2005) compared the species composition of living assemblages and the assemblages found in taphocoenosis in the sediment, and found that a single assemblage in the sediment consists of several living assemblages. The seasonal changes of living assemblages could not be observed in the taphocoenosis; however, longer-term climatic and oceanographic changes were clearly recorded. The presence of several dominant species in the Badenian assemblages from the Mura Depression is probably a consequence of cyclical short-term (seasonal) changes in the composition of the living assemblage reflecting the seasonal character of the climate.

The presence of dominant taxa in all sections containing nannofossils is shown in Fig. 6.4.

6.3. The temporal pattern of changes in nannoplankton assemblage composition

Several other aspects of nannoplankton assemblage composition bearing potential palaeoecological relevance were considered. Apart from the number and nature of dominant species discussed in the previous chapter, special attention was paid to the presence and abundance oscillations of several taxa, which were indicative of certain environments. The presence and abundance of these taxa is presented in Fig. 6.4.

6.3.1. Interval zone MuN4

Samples from the Zgornje Partinje and Jakobski Dol 1 sections, assigned to the interval MuN4, contain coccoliths in relatively low abundances (Fig. 6.4). The assemblage in the Zgornje Partinje section is dominated by *Helicosphaera car-*

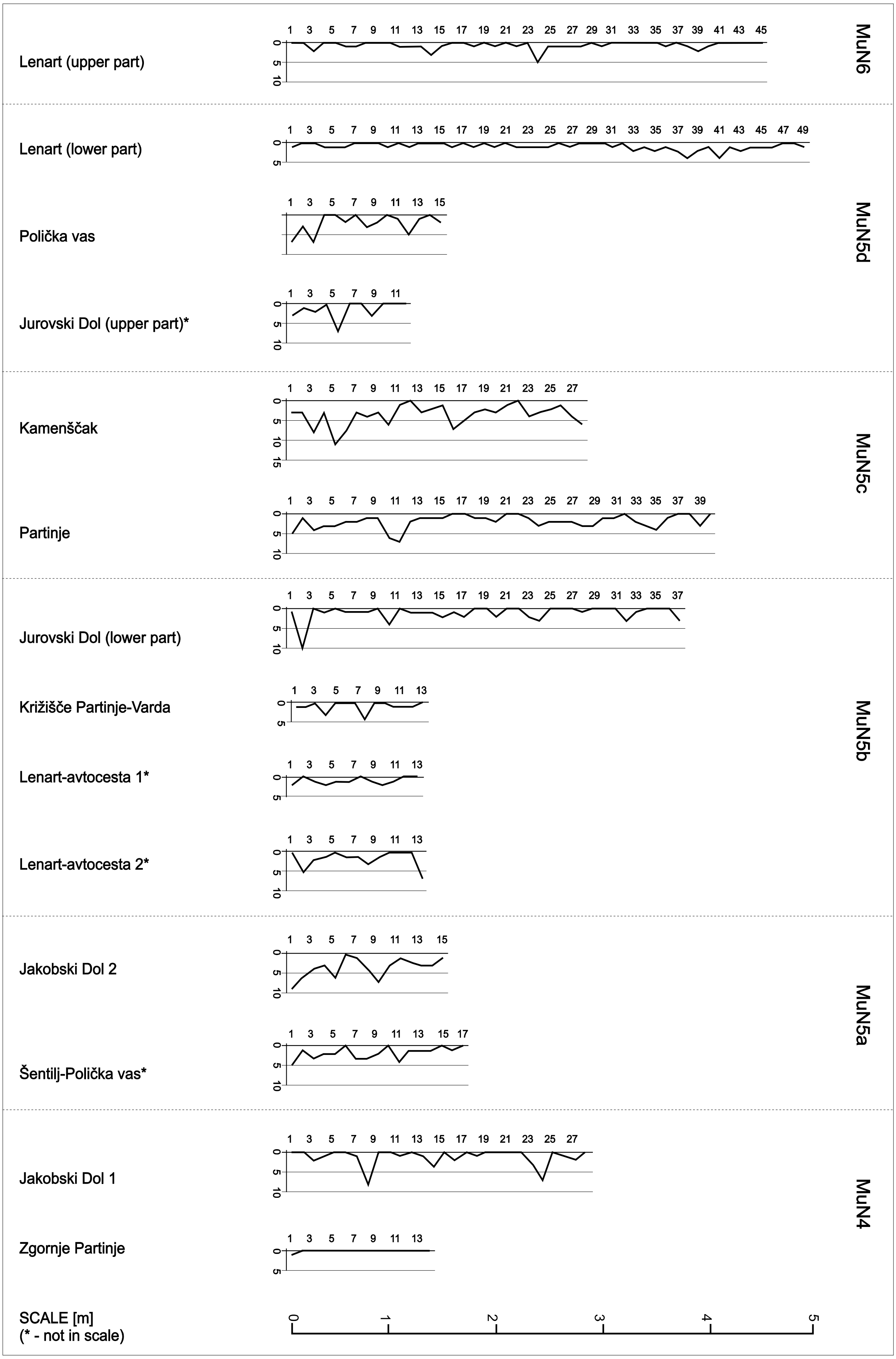
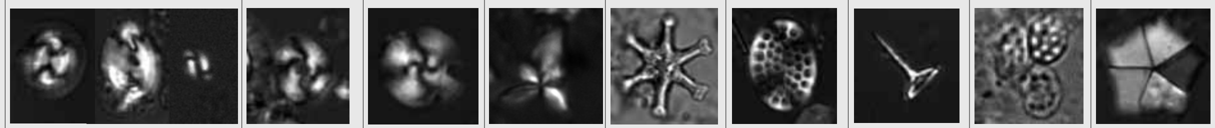


Fig. 6.3. The number of allochthonous species in all examined samples.



Interval zone	Section	Coccolith abundance	Dominant species (SEASONALITY)	R. gelida (SEASONALITY)	C.floridanus (RICH IN NUTRIENTS)	Sphenolithus spp. (WARM WATER)	Discoaster spp. (WARM WATER)	Pontosphaera spp. (OLIGOTROPHIC, DEEP)	Rhabdosphaera spp. (OLIGOTROPHIC, DEEP)	S. schilleri (OLIGOTROPHIC, DEEP)	B.bigelowii (REDUCED SALINITY?)	General observations
MuN6	Lenart (upper part)	+++	C. pelagicus H. carteri R. minuta R. haquii S. heteromorphus	+++	+	+++	+	+++	+++	+++	++	-pronounced warm water character -rich in nutrients -strong seasonality
MuN5d	Lenart (lower part)	+++	C. pelagicus H. carteri R. minuta	+++	+++	++	+++	++	++	+++	+	-pronounced warm water character -strong seasonality
	Polička vas	+++	C. pelagicus H. carteri R. minuta	+++	+++	++	+	++	++	+	+	
	Jurovski Dol (upper part)	++	C. pelagicus H. carteri R. minuta	+++	++	++	+++	+	/	/	/	
	Vinička vas	++	R. minuta	/	/	++	/	+	/	/	/	
	Zimica	++	C. pelagicus R. minuta	+	/	+	+	/	/	/	/	
	Zgornji Duplek 1	++	R. minuta	/	/	++	+	/	+	/	/	
	Zgornji Duplek 2	+++	C. pelagicus R. minuta	+	+	++	/	+	/	/	/	
MuN5c	Kamenščak	++	C. pelagicus (H. carteri) (R. minuta)	++	+++	++	+	++	+	/	+++	-warm water, rich in nutrients -seasonality -occasional freshwater influences
	Partinje	+++	R. minuta (C. pelagicus) (H. carteri) (S. heteromorphus) (R. pseudoumbilica)	++	++	+++	+	+	++	+	+	
MuN5b	Jurovski Dol (lower part)	++	C. pelagicus H. carteri R. minuta	++	+	++	+	++	+	/	/	-warm water -seasonality
	Lenart-avtocesta 1	++	C. pelagicus H. carteri R. minuta	++	+	+	+	+	+	/	/	
	Križišče Partinje-Varda	++	C. pelagicus H. carteri R. minuta	++	++	+	+	+	+	+	+	
MuN5a	Šentilj-Polička vas	++	C. pelagicus H. carteri	++	+++	++	+	+	+	/	++	-warm water, rich in nutrients -weak seasonality -freshwater influences
	Jakobski Dol 2	++	R. minuta (C. pelagicus)	+	+++	+	+	+	/	+	+	
MuN4	Jakobski Dol 1	+	C. pelagicus	+	+	+	+	+	+	+	+	-low diversity -deepening upwards trend ?
	Zgornje Partinje	+	H. carteri	/	+	+	/	/	/	/	+	

Fig. 6.4. The nannofossil abundance, number and identity of dominant species, and the presence of palaeoecological indicator taxa in all sections containing calcareous nannoplankton. For explanation see text and chapter 2.3.

teri, which might indicate the beginning of a transgression (according to Švabenická, 2002a), since species diversity is relatively low and typical pelagic species are missing (Appendix, Tab. 1). In the Jakobski Dol 1 section, *Coccolithus pelagicus* dominates the assemblage, while *Helicosphaera carteri* and *Reticulofenestra minuta* are common (Appendix, Tab. 2). A few discoasters in samples from this section might reflect a deepening of the depositional environment (Chapman & Chepstow-Lusty, 1997), as could the continuous presence of rare or few specimens of *Pontosphaera* spp. (a pelagical genus according to Melinte, 2005). The continuous presence of rare specimens of *Sphenolithus* spp., an indicator of warm water (according to Perch-Nielsen, 1985a; Nagymarosy, 2000; Krammer et al., 2006), characterises both sections.

6.3.2. Interval zone MuN5a

The nannoplankton assemblage from both sections belonging to the interval zone MuN5a (Šentilj-Polička vas and Jakobski Dol 2) resembles the assemblage from the sections belonging to MuN4 (Appendix, Tabs. 3, 4). The two assemblages assigned to this time interval are also rather similar to one another, except for the obvious distinction in the abundance of *Reticulofenestra minuta* that dominates the assemblages in the Jakobski Dol 2 section and is rare in the assemblages from the Šentilj-Polička vas section (dominated by *Coccolithus pelagicus*) (Fig. 6.4). Ćorić & Rögl (2004) describe alternating assemblages, where either *Coccolithus pelagicus* or *Reticulofenestra minuta* dominate; the dominance of the latter supposedly occurs when there is a rise in temperatures and a drop in the amount of nutrients. This could also be the case in the assemblages from Slovenske Gorice, as the dominance of *Reticulofenestra minuta* coincides with a slight increase in the abundance of discoasters, possibly indicating a moderate deepening (and a drop in the nutrient levels) of the depositional environment.

Both assemblages contain rare sphenoliths and rare or few discoasters, which normally indicate warm water. Discoasters are never abundant in shallow water (Bukry, 1981a), so their rarity is probably linked to shallow water, rather than low temperatures.

Braarudosphaera bigelowi is able to thrive in low salinity marine environments (Bartol et al., 2008 and the references therein), while the genus *Pontosphaera* is an indicator of stable marine environments with only slight salinity fluctuations (Melinte, 2005). The presence of *B. bigelowii* pentaliths in several consequent samples from the middle part of the Šentilj–Polička vas section might indicate environments with lowered salinity. The species *Pontosphaera multipora* is continuously present and is only absent in a single sample (ŠP-11), where there *B. bigelowii* reaches its maximum abundance. This corresponds well to the presumed palaeoecological preferences of both species and implies a short term episode of slight fresh water influences, perhaps indicating the proximity of land.

6.3.3. Interval zone MuN5b

The nannoplankton assemblages from the sections assigned to this interval zone are quite similar to one another. *Coccolithus pelagicus*, *Helicosphaera carteri,* and *Reticulofenestra minuta* are commonly abundant in the same sample, implying the seasonal character of climate (see chapter 6.2). Very rare specimens of typical pelagic species (*Pontosphaera multipora*, *Rhabdosphaera sicca*, *Discoaster* sp.) are present, but no holococcoliths were found. The presence of a few discoasters and few to rare sphenoliths indicates warm water (Fig. 6.4).

Reticulofenestra gelida is believed to represent a cold water morphotype of *Reticulofenestra pseudoumbilica* (Wei & Thierstein, 1991). Where both species occur in the same sample, the seasonal character of a climate with distinct cold periods can be inferred (Spaulding, 1991). A few *Reticulofenestra gelida* specimens were found in samples from the Lenart–avtocesta 1 and Križišče Partinje-Varda sections; they were very rare to rare in the former, while only a few specimens were found in the latter. This is another indication of the seasonal character of the climate during interval MuN5b.

6.3.4. Interval zone MuN5c

Some samples from the Partinje and Kamenščak sections contained few to rare *Braarudosphaera bigelowii* pentaliths, which perhaps indicate fresh water influences or the proximity of a brackish environment. The assemblages from the two sections are quite different from one another; in the assemblage from the Kamenščak section *Coccolithus pelagicus* is the dominant species and holococcoliths are absent, which could reflect a high concentration of nutrients in the water, perhaps associated with shallow water. The most abundant species in the samples from the Partinje section is *Reticulofenestra minuta*, with large oscillations in abundance. *Coccolithus pelagicus* and *Helicosphaera carteri* are common and a few holococcoliths were found. This assemblage is also marked by an increase in *Sphenolithus* spp. abundance, denoting very warm water (Fig. 6.4).

Both assemblages contain *Reticulofenestra pseudoumbilica* and *R. gelida*; along with the simultaneous occurrence of several dominant species in the assemblage, implying the seasonal character of the climate.

6.3.5. Interval zone MuN5d

The nannoplankton assemblages from this time interval are characterized by very high species-diversity, implying very warm water (Perch-Nielsen, 1985a), which is, then, further suggested by the continuous presence of discoasters and sphenoliths (Fig. 6.4). Near the top of the lower part of the Lenart section there is an interval enriched with several species of discoasters (Appendix, Tab. 13B); similar – though less pronounced – enrichments can be observed in the upper part of the Jurovski Dol section and the Zgornji Duplek 1 section (Appendix, Tabs. 10, 12). Discoasters indicate warm water (Perch-Nielsen, 1985a; Nagymarosy, 2000; Melinte, 2005; Krammer et al., 2006), and their increased abundance suggests a rather deep depositional environment with a low concentration of nutrients (Chapman & Chepstow-Lusty, 1997); this could coincide with a sea-level highstand at the end of a transgression or at the beginning of a regression. The warm water character of the assemblage is further demonstrated by the abundance of *Cyclicargolithus floridanus*, a species which reaches its maximum abundance in this time interval; the peak in its abundance is followed by a peak in the abundance of discoasters. Since *Cyclicargolithus floridanus* prefers a higher concentration of nutrients (Melinte, 2005) while discoasters prefer oligotrophic environment, this probably reflects a drop in the concentration of nutrients, possibly linked to the sea level rise. The decrease in the abundance of *Helicosphaera carteri* during a peak in the abundance of discoasters suggests a drop in nutrient concentrations as well.

The co-occurrence of several dominant species and the presence of *Reticulofenestra pseudoumbilica* and *Reticulofenestra gelida* (a summer and winter variety of the same species according to Wei & Thierstein, 1991) in the samples from all sections assigned to this time interval indicates the seasonal character of climate.

The Lenart and Polička vas sections contain relatively common specimens of *Pontosphaera* spp. (an indicator of zero or slight salinity fluctuations according to Melinte, 2005), *Rhabdosphaera* spp. (indicator of oligotrophy, according to Negri & Villa, 2000; rhabdoliths contribute to the buoyancy of coccolithophores and are characteristic of environments with low turbulence, according to Edwards, 1968 and Baumann et al., 2005) and holococcoliths (indicating oligotrophic environments according to Cros et al., 2000; Baumann et al., 2005; Cros et al., 2000; Cros & Estrada, 2008). This presumably reflects relatively deep water oligotrophic depositional environment in this part of the Mura Depression at the top of NN5.

The assemblages from the sections of lithothamnium limestone (Zgornji Duplek 1 and 2, Zimica and Vinička vas) are considerably poorer than the assemblages from the other sections assigned to MuN5d. This is attributed to a much lower number of samples and different depositional environments and/or stronger diagenetic influences operating at the contact of two different lithologies.

Discoasters are very rare in most of the nannoplankton assemblages found in Slovenske Gorice; they only become abundant in a short time interval at the top of NN5. The temperature threshold for discoasters is 14°C (Chapman & Chepstow-Lusty, 1997). Their abundance would imply favourable conditions for their development, though some species (*Discoaster aulacos, D. variabilis*, *D. formosus*) are smaller than stated in their original descriptions. This might reflect suboptimal conditions for their development, perhaps linked to temperatures close to their tolerance threshold.

6.3.6. Interval zone MuN6

Only the upper part of the Lenart section was assigned to this time interval corresponding to the lower part of NN6; the nannoplankton assemblage is rich and diverse, and – apart from a few isolated specimens – discoasters are absent. Still, the warm-water character of the assemblage is apparent as sphenoliths are abundant, while the species linked to a deep oligotrophic environment (*Pontosphaera* spp., *Rhabdosphaera* spp., *Syracolithus schilleri*) continue to be present in relatively high numbers (Fig. 6.4).

Discoasters and sphenoliths are both reliable warm-water indicators and are presumably linked to relatively deep water. The samples from the Lenart section display an interesting pattern; though both genera were supposed to be K-strategists, discoasters become abundant in one part of the section (top of NN5) and practically vanish from the next, whereas sphenoliths become abundant. This clearly demonstrates that the palaeoecological preferences of both groups are at least slightly different. Sphenoliths presumably prefer water that is somewhat richer in nutrients than discoasters (Bartol & Pavšič, 2005).

Occasional rises in abundance of *Braarudosphaera bigelowii* might reflect fresh water influences. This represents an argument in favour of the shallowing in this interval zone.

6.4. Calcareous dinoflagellates

Specimens of calacareous dinoflagellates were rarely present in samples from all sections examined except Zgornje Partinje; this could perhaps be interpreted as a vague indication of water depths, as calcareous cysts are only common in pelagic populations and are strongly subordinate to naked forms in the neritic (Janofske & Karwath, 2000).

The most common of all calcareous dinoflagellate taxa found was *Thoracosphaera saxea*. It was present in samples from all sections except Zgornje Partinje and Jakobski Dol 1 (MuN4). *Thoracosphaera tuberosa* and *Thoracosphaera heimii* were also found in samples from most studied sections (Appendix, Tabs. 1-13).

Calcareous dinoflagellates thrive in low-nutrient waters. Several species demonstrate a preference for warm waters. Still, the ecological preferences of individual species are very specific, and it is not possible to use the entire group as an indicator of oligotrophic or warm waters (Höll et al., 1998).

The distribution patterns of the three determined species are markedly different from one another; this indicates the distinct ecological preferences of different species. It is impossible to give a more precise description of these preferences based only on the presence of a few specimens, particularly as their distribution patterns are obscure and do not seem to correspond with any of the observed changes in the composition of calcareous nannoplankton assemblages.

7. UPPER BADENIAN PALAEOCLIMATE AND PALAEOGEOGRAPHY

7.1. Palaeoclimate

Notable changes in nannoplankton assemblage composition, relative abundances, and number of taxa were observed in the studied material. They reflect considerable environmental fluctuations, particularly nutrient availability (perhaps associated with water depth), temperatures, and seasonal changes. High diversity, the continuous presence of rare discoasters and sphenoliths, and the abundance of *Helicosphaera* spp. indicate relatively warm water throughout the entire interval studied.

An interesting interval, enriched with several species of the warm water genera *Discoaster* and *Sphenolithus*, was observed at the transition of MuN5d and MuN6 (in the Lenart section, and part of the Jurovski Dol and Zgornji Duplek 1 sections) (Appendix, Tabs. 10, 12, 13B-D). The discoaster-enriched beds are also marked by very diverse nannoplankton assemblages, and both of these characteristics indicate high surface water temperatures; the warm water character of the assemblage is not as pronounced during any other interval. On the basis of the LO of *Sphenolithus heteromorphus*, which is a globally well-correlated event, we can estimate the absolute age of these beds at 13.53 Ma (Lourens et al., 2004).

In the Lenart section, the discoasters virtually disappear after the beginning of NN6. However, their disappearance does not reflect a drop in temperatures, as they are replaced by an abundance of sphenoliths, which are considered to be warm water indicators as well (Appendix, Tab. 13B-D). The most probable reason for this switch seems to be the shallowing of the depositional environment coupled with a rise in nutrient availability (Bartol & Pavšič, 2005). Shallowing is also indicated by the presence of individual rhodoliths within the marl matrix towards the top of the Lenart section (Figs. 1.10, 1.16).

As far as the calcareous nannoplankton assemblages of the Mura Depression are concerned, the rise in $\delta^{18}O$ which coincides with the boundary of the Middle and the Upper Badenian – known as the Mi3 event of Miller et al. (1991) – goes unnoticed. As a matter of fact, the youngest assemblages considered in this study (the bottom of NN6) display a distinct warm water character. However, the presence of several dominant species and *Reticulofenestra gelida* can be observed from the beginning of NN5 on and increases upwards (Fig. 6.4); this suggests the increasingly seasonal character of the climate and reflects the changing of dominant species within different seasons.

The enrichment in warm water taxa at the time of the Mi3 event, when the MCO was coming to an end, is quite surprising. Nevertheless, the presence of warm water taxa in deposits of this age is not an isolated event. The nannoplankton assemblages found in Višnjica and Karaburma near Belgrade (Pavšič & Mihajlović, 1981) are very similar to those from the Lenart section. At the very bottom of NN6, there is a short interval of enrichment with several species of discoasters that, in turn, are replaced by sphenoliths (Mihajlović & Knežević, 1989). The nannoplankton assemblages from Turda and Ocna Dej in Romania, which are assigned to the transition of NN5 and NN6 (Chira, 2001) are also rich in discoasters and could be considered to indicate warm water as well.

The termination of MCO in the Central Paratethys was diachronous; climatic oscillations which lead to the end of MCO in the Central Paratethys realm started to occur in the Middle Badenian and appear to be regionally specific (see chapter 1.2.2). Temperatures in different regions of the Central Paratethys realm were rather variable (Kroh, 2007; Utescher, 2007b), with the western and southwestern part of this region appearing to be warmer than the north and northeast. This might reflect better communication within the western part of the Paratethys realm. Though the cooling at the end of the Middle Badenian had already affected the deeper benthic environments (as indicated by the $\delta^{18}O$ content of pectinid and brachiopod shells from the Styrian Basin discussed by Bojar et al., 2004), the surface waters obviously remained warm enough to sustain a distinctly warm water nannoplankton assemblage at least in the southwest part of the Central Paratethys.

7.2. Palaeogeography

The most intriguing palaeogeographical problem in the study area is the time of the final closure of the Slovenian Corridor, the link between the Central Paratethys, and the Mediterranean (Figs. 1.1, 5.1). Horvat (2004) reports that the Slovenian Corridor remained open until the end of NN5 at 13.53 Ma, according to Lourens et al. (2004), or 13.37 Ma, according to Abdul Aziz et al. (2008). At the end of the Badenian, bryozoans (Moisette et al., 2006) and other stenohaline organisms (Kroh, 2007) disappeared from the Central Paratethys, and in the Sarmatian, the first endemic gastropods appeared (Harzhauser et al., 2002); this is evidence that the Slovenian Corridor was closed by the beginning of the Sarmatian. The Slovenian Corridor therefore closed at some point in the Late Badenian (between the NN5/NN6 boundary at 13.53 Ma and the beginning of the Sarmatian at 12.7 Ma).

The deposits sampled in the Lenart section, where the boundary of the Middle and Late Badenian can be observed, show some indications of a regression, but no evidence of any major change that could be associated with the closure of the Slovenian Corridor or a change in circulation type from anti-estuarine to estuarine as suggested by Báldi (2006). Perhaps a change of such magnitude could explain why the deposits sampled in the Jablance section (tentatively correlated with Late Badenian or Early Sarmatian) are so distinctly different from all other sampled deposits.

Badenian nannoplankton assemblages from the Mura Depression closely resemble those from the Mediterranean (Fornaciari et al., 1996; Di Stefano et al., 2008), and apart from the very similar species composition, the same biostratigraphic events can also be observed in the same succession. This parallelism is particularly distinct in the youngest deposits studied in Slovenske Gorice, assigned to MuN6 (lower part of NN6). The last common events between the two realms observed in the scope of this study are the FO of *Reticulofenestra pseudoumbilica* (>7 μm), the LO of *Sphenolithus heteromorphus*, the LO of *Cyclicargolithus floridanus*, the FCO of *Reticulofenestra pseudoumbilica* (> 7μm), and the FO of *Calcidiscus macintyrei*; all of these events take place in a short interval around the NN5/NN6 boundary. While the LO of *Sphenolithus heteromorphus* is a globally well-correlated event, the other events mentioned above are reportedly diachronous in different regions. The close resemblance in nature and the succession of the events mentioned above suggests the persistence of a seaway connecting the Mediterranean and the Central Paratethys realm in the bottom part of NN6.

The Late Badenian regression at the end of the eustatic cycle TB2.5 increased the palaeogeographic complexity of the Central Paratethys realm. It is possible that the connection between the Central Paratethys and the Mediterranean terminated in a gradual manner, so that the Mediterranean influences ceased in the eastern and northern part of the Central Paratethys sooner than they did in its western and southern part. The present study suggests that the communication between the two realms was still active at least in the lower part of NN6 and the TB2.5 global eustatic cycle. The parallelism between the changes in nannoplankton assemblages in the Mura Depression and the Mediterranean is still present in the youngest Badenian deposits considered in this study (top of Lenart section). The last events observed in both realms are the FO of *Calcidiscus macintyrei* and the FCO of *Reticulofenestra pseudoumbilica* (>7 μm); the latter event was recently dated by Abdul Aziz et al. (2008) at 13.1 Ma. Though the exact time of closure of the Slovenian Corridor cannot be determined, this allows the time interval within which the seaway closed, to be narrowed down to a 400 ky period between 13.1 Ma and 12.7 Ma.

8. CONCLUSIONS

Twenty-two sections of Badenian deposits in Slovenske Gorice were studied. The lithology of most sections was rather uniform - consisting exclusively of marl or lithothamnium limestone - while a few sections consisted of marls with interbedded sands.

109 species and forms of calcareous nannoplankton were found in samples from 17 sections. *Coccolithus pelagicus*, *Helicosphaera carteri*, *Reticulofenestra* spp., and *Sphenolithus heteromorphus* dominated the assemblages. The genera *Helicosphaera, Reticulofenestra* and *Discoaster* are represented by the highest number of species. The presence of dissolution-sensitive forms in samples from all studied sections indicates that the composition of nannofossil assemblages was not significantly altered by diagenesis. The sampling in high resolution and the use of semi-quantitative estimations of relative species abundances enabled the tracking of changes in the composition of nannoplankton assemblages through time.

None of the existing calcareous nannoplankton biozonations for the Middle Miocene could be directly applied to the studied material. The use of combined marker events, however, made it possible to divide the studied time interval between the upper part of NN4 and the lower part of NN6 into 6 interval zones (MuN4, MuN5a-d, and MuN6) defined on the basis of the LO of *Heliosphaera ampliaperta*, the FO and LO of *Helicosphaera waltrans*, the FO of *Helicosphaera walbersdorfensis*, the LO of *Sphenolithus heteromorphus*, and the FCO of *Reticulofenestra pseudoumbilica* (>7 µm).

Various studied sections that were assigned to the same interval zone reflected different depositional environments. These findings indicate that shallow marine environments existed in close proximity of deeper basins in the Mura Depression. During the Late Badenian a shallow carbonate platform existed in the southeast of the study area and was replaced by deeper marine environment in the northwest.

Changes in the facies and the composition of the nannoplankton assemblages reflected sea-level oscillations associated with global eustatic cycles TB2.3, TB2.4, and TB2.5. A transgression at the beginning of the Badenian (beginning of TB2.3) is reflected in the composition of the nannoplankton assemblages. The regressions at the transition of 3rd order cycles TB2.3/TB2.4 and TB2.4/TB2.5 are reflected in the sand interbeds in predominantly marl successions. The appearance of rhodoliths within the marl succession and a change in the nannoplankton assemblage composition mark the beginning of the regression at the end of TB2.5.

The presence of warm water taxa indicated warm water throughout the entire studied interval. The presence of several dominant species in nannoplankton assemblages along with the increasing abundance of *Reticulofenestra gelida* pointed to gradually increasing seasonality from the beginning of NN5 onwards.

The nannoplankton assemblages from the uppermost part of NN5 and the lower part of NN6 were very diverse and rich in discoasters (MuN5d) and sphenoliths (MuN6), which indicates high water temperatures at the NN5/NN6 boundary, which was correlated with the Mi3 isotopic event marking the start of a global cooling. This controversy can be explained by the cooling affecting deeper benthic environments while having little or no effect on the temperature of surface waters.

The changes in the nannoplankton assemblage composition observed in the Mura Depression closely resemble those described in the Mediterranean. This parallelism is still present in the youngest sediment samples from Slovenske Gorice, which were assigned to the NN5/NN6 boundary and the lower part of NN6. From these findings it can be concluded, that the Slovenian Corridor was still open at the beginning of the Late Badenian. The time interval during which the final closure of the Slovenian Corridor occurred can be narrowed down to the time interval between the FCO of *Reticulofenestra pseudoumbilica* (>7 µm) at 13.1 Ma and the beginning of the Sarmatian at 12.7 Ma.

ACKNOWLEDGEMENTS

I would like sincerely to thank Stjepan Ćorić and Aleksander Horvat for reviewing the manuscript and providing many helpful suggestions and remarks, to Špela Goričan and Adrijan Košir for critical reading of the manuscript and for their comments, and to Jernej Pavšič for helping me with the field work and for supervising the making of the dissertation, which served as the basis for this work. I am grateful to Ines Galović for taxonomic remarks and a discussion on systematic palaeontology, Fred Rögl, Lubov Borisovna Ilyna and Irina Alexandrovna Goncharova for the permission to reproduce their palaeogeographical maps, and Sergej Valentinovich Popov for sending me the original documents. I would also like to thank Špela Goričan, Adrijan Košir, and Franci Cimerman for helping me with the work on the SEM and to Tomislav Popit for sharing his field notes from the sections in highway construction sites and the sample Lat-1. I am also grateful to Boštjan Bugarič for designing the cover and to Adrijan Košir for preparing the final graphic design and page setting of this book.

I would like to acknowledge the Department of Geology (Faculty of Natural Sciences) Ljubljana for providing the basic work materials and enabling the use of their light microsope and camera, the Geological Survey of Slovenia, particularly Staša Čertalič, Miloš Bavec and Andrej Lapanje, for providing some research reports and detailed geological maps from their archives, and the Schweizerbart'she Verlagsbuchhandlung (http://www.schweizerbart.de) for allowing the reproduction of palaeogeographical maps as copyright holder.

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PLATES 1–25

Plate 1

Figure 1: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample KAM-23.
Figure 2: *Helicosphaera carteri* Kamptner, 1954, distal view, sample LR-37.
Figure 3: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample Lac-15.
Figure 4: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample LT-31.
Figure 5: *Helicosphaera carteri* Kamptner, 1954, distal view, sample LR-40.
Figure 6: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample LR-40.
Figure 7: *Helicosphaera carteri* Kamptner, 1954, distal view, sample LR-24.
Figure 8: *Helicosphaera carteri* Kamptner, 1954, distal view, sample LT-96.
Figure 9, 10: *Helicosphaera granulata*, (Bukry & Percival, 1971) Jafar & Martini, 1975, distal view, sample LT-11.
Figure 11: *Helicosphaera granulata* (Bukry & Percival, 1971) Jafar & Martini, 1975, distal view, sample LT-96.
Figure 12: *Helicosphaera granulata* (Bukry & Percival, 1971) Jafar & Martini, 1975, distal view, sample Lac-14.
Figure 13: *Helicosphaera granulata* (Bukry & Percival, 1971) Jafar & Martini, 1975, distal view, sample JU-43.
Figure 14: *Helicosphaera carteri* Kamptner, 1954, distal view, sample LR-35.
Figure 15: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample LR-38.
Figure 16: *Helicosphaera granulata* (Bukry & Percival, 1971) Jafar & Martini, 1975, proximal view, sample LR-34.
Figure 17: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample PV-1.
Figure 18: *Helicosphaera carteri* Kamptner, 1954, proximal view, sample LT-51.
Figure 19: *Helicosphaera carteri* Kamptner, 1954, distal view, sample LR-38.

Figures 1-13: LM, 1000x, scale bar 5 µm. Figures 1, 10, 11 and 12 PPL, others XPL.
Figures 14-19: SEM, scale bar in each figure.

Plate 1

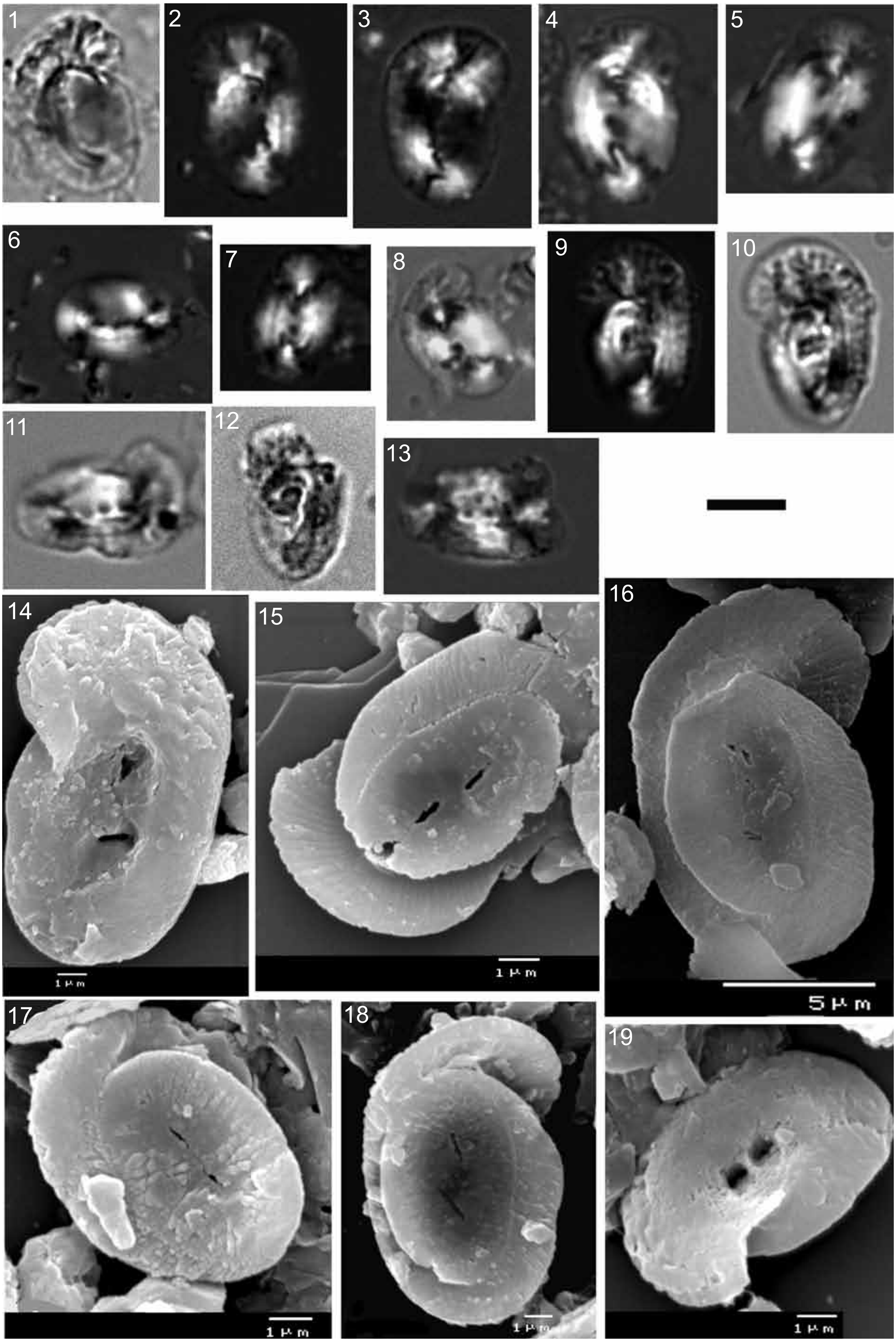

Plate 2

Figure 1: *Helicosphaera* cf. *truempyi* Biolzi & Perch-Nielsen, 1982, distal view, sample LT-96.
Figure 2*: *Helicosphaera* cf. *truempyi* Biolzi & Perch-Nielsen, 1982, sample JU-16.
Figure 3*: *Helicosphaera euphratis* Haq, 1966, sample JU-10.
Figure 4: *Helicosphaera euphratis* Haq, 1966, sample JA-3.
Figure 5: *Helicosphaera intermedia* Martini, 1965, distal view, sample LR-31.
Figure 6: *Helicosphaera intermedia* Martini, 1965, proximal view, sample LE-19.
Figure 7: *Helicosphaera intermedia* Martini, 1965, proximal view, sample LR-35.
Figure 8*: *Helicosphaera euphratis* Haq, 1966, proximal view, sample LR-38.
Figure 9: *Helicosphaera intermedia* Martini, 1965, proximal view, sample LT-31.
Figure 10: *Helicosphaera intermedia* Martini, 1965, proximal view, sample LT-51.
Figure 11: *Helicosphaera intermedia* Martini, 1965, proximal view, sample KAM-5.
Figure 12: *Helicosphaera intermedia* Martini, 1965, distal view, sample LT-61.
Figure 13: *Helicosphaera intermedia* Martini, 1965, distal view, sample LR-36.
Figure 14: *Helicosphaera intermedia* Martini, 1965, proximal view, sample LR-35.
Figure 15: *Helicosphaera intermedia* Martini, 1965, distal view, sample LR-38.

Figures 1-13: LM, 1000x, XPL, scale bar 5 µm.
Figures 14, 15: SEM, scale bar in each figure.
* film camera, scale approximate.

Plate 2

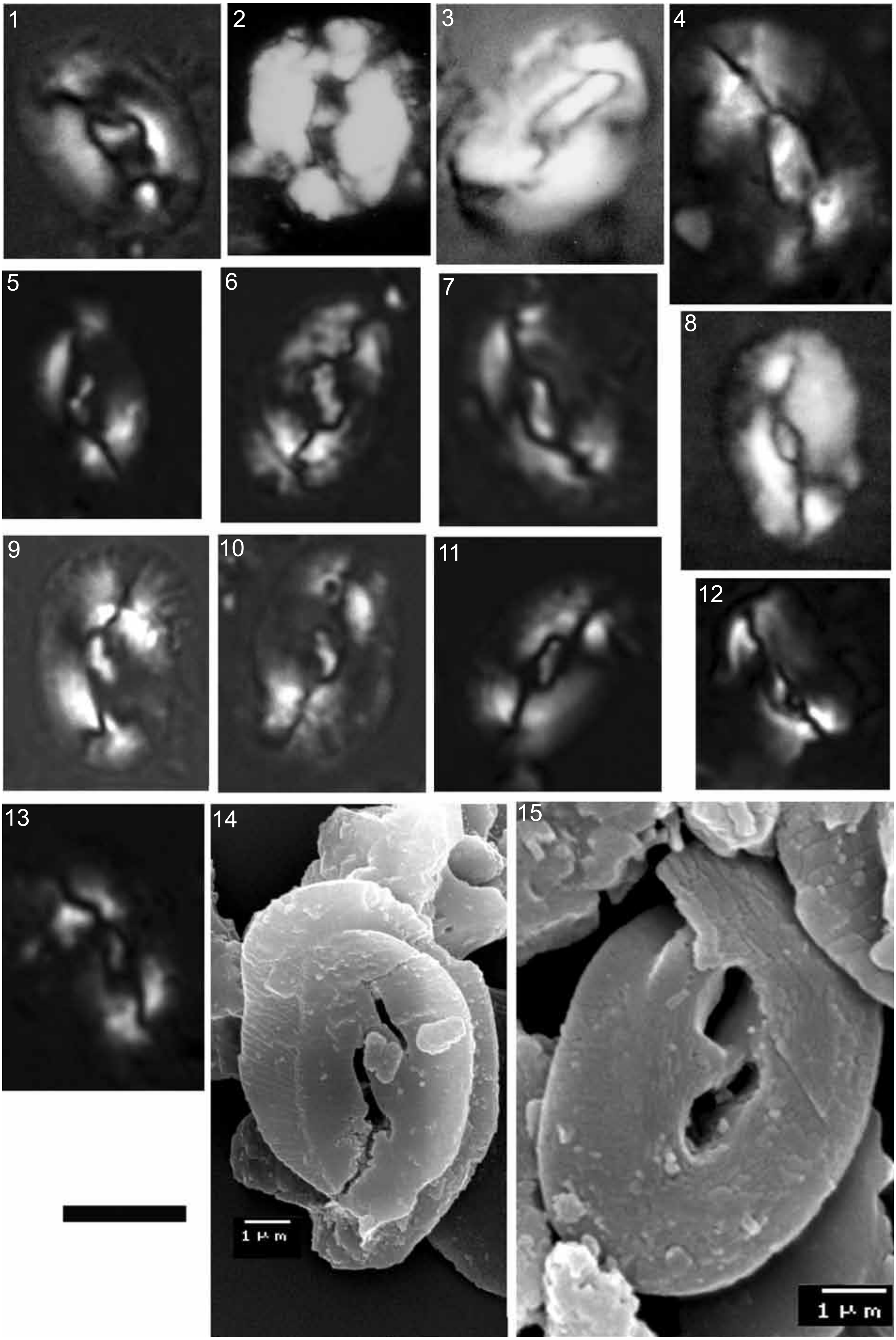

Plate 3

Figure 1, 2: *Helicosphaera minuta* Müller, 1981, proximal view, sample ŠP-16.
Figure 3, 4: *Helicosphaera minuta* Müller, 1981, distal view, sample Lac-5.
Figure 5: *Helicosphaera minuta* Müller, 1981, sample KAM-19.
Figure 6: *Helicosphaera walbersdorfensis* Müller, 1974, proximal view, sample PO-20.
Figure 7, 8 : *Helicosphaera walbersdorfensis* Müller, 1974, proximal view, sample LR-13.
Figure 9: *Helicosphaera walbersdorfensis* Müller, 1974, proximal view, sample LT-51.
Figure 10: *Helicosphaera walbersdorfensis* Müller, 1974, proximal view, sample Lac-14.
Figure 11, 12: *Helicosphaera vedderi* Bukry, 1981, proximal view, sample PO-1.
Figure 13: *Helicosphaera wallichii* Okada & McIntyre, 1977, distal view, sample PO-23.
Figure 14: *Helicosphaera wallichii* Okada & McIntyre, 1977, proximal view, sample JU-6.
Figure 15: *Helicosphaera wallichii* Okada & McIntyre, 1977, proximal view, sample PO-20.
Figure 16: *Helicosphaera minuta* Müller, 1981, proximal view, sample LT-51.
Figure 17: *Helicosphaera minuta* Müller, 1981, proximal view, sample LT-51.
Figure 18: *Helicosphaera wallichii* Okada & McIntyre, 1977, proximal view, sample KPV-8.
Figure 19: *Helicosphaera wallichii* Okada & McIntyre, 1977, proximal view, sample PO-11.
Figure 20: *Helicosphaera walbersdorfensis* Müller, 1974, proximal view, sample LR-35.
Figure 21: *Helicosphaera wallichii* Okada & McIntyre, 1977, proximal view, sample LR-34.

Figures 1-15, 18, 19: LM, 1000x, scale bar 5 μm. Figures 2, 4, 5, 6, 7, 9, 10 and 12 PPL, others XPL.
Figures 16, 17, 20, 21: SEM, scale bar in each figure.

Plate 3

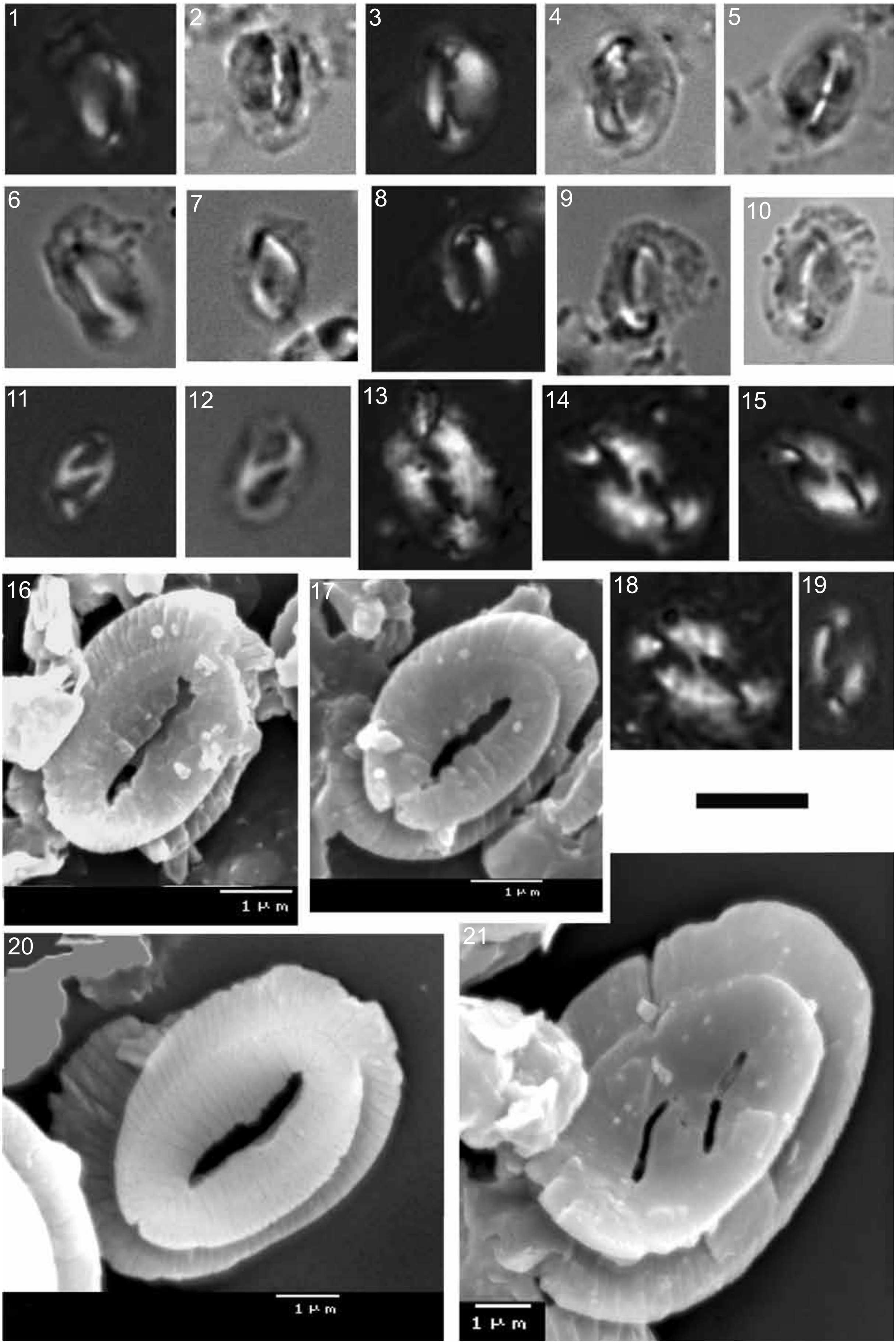

Plate 4

Figure 1: *Helicosphaera mediterranea* Müller, 1981, proximal view, sample JAK-10.
Figure 2: *Helicosphaera mediterranea* Müller, 1981, proximal view, sample JU-10.
Figure 3: *Helicosphaera mediterranea* Müller, 1981, sample KAM-16.
Figure 4: *Helicosphaera mediterranea* Müller, 1981, sample PO-20.
Figure 5: *Helicosphaera waltrans* Theodoridis, 1984, distal view, sample JU-4.
Figure 6: *Helicosphaera waltrans* Theodoridis, 1984, distal view, sample Lc-3.
Figure 7: *Helicosphaera waltrans* Theodoridis, 1984, proximal view, sample JU-6.
Figure 8: *Helicosphaera waltrans* Theodoridis, 1984, distal view, sample JU-6.
Figure 9: *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini, 1975, proximal view, sample KPV-4.
Figure 10: *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini, 1975, distal view, sample PO-11.
Figure 11, 12: *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini, 1975, distal view, sample JA-30.
Figure 13: *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini, 1975, proximal view, sample PV-1.
Figure 14: *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini, 1975, proximal view, sample PV-1.
Figure 15: *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar & Martini, 1975, proximal view, sample LR-34.

Figures 1-12: LM, 1000x, scale bar 5 µm. Figures 10 and 12 PPL, others XPL.
Figures 13-15: SEM, scale bar in each figure.

Plate 4

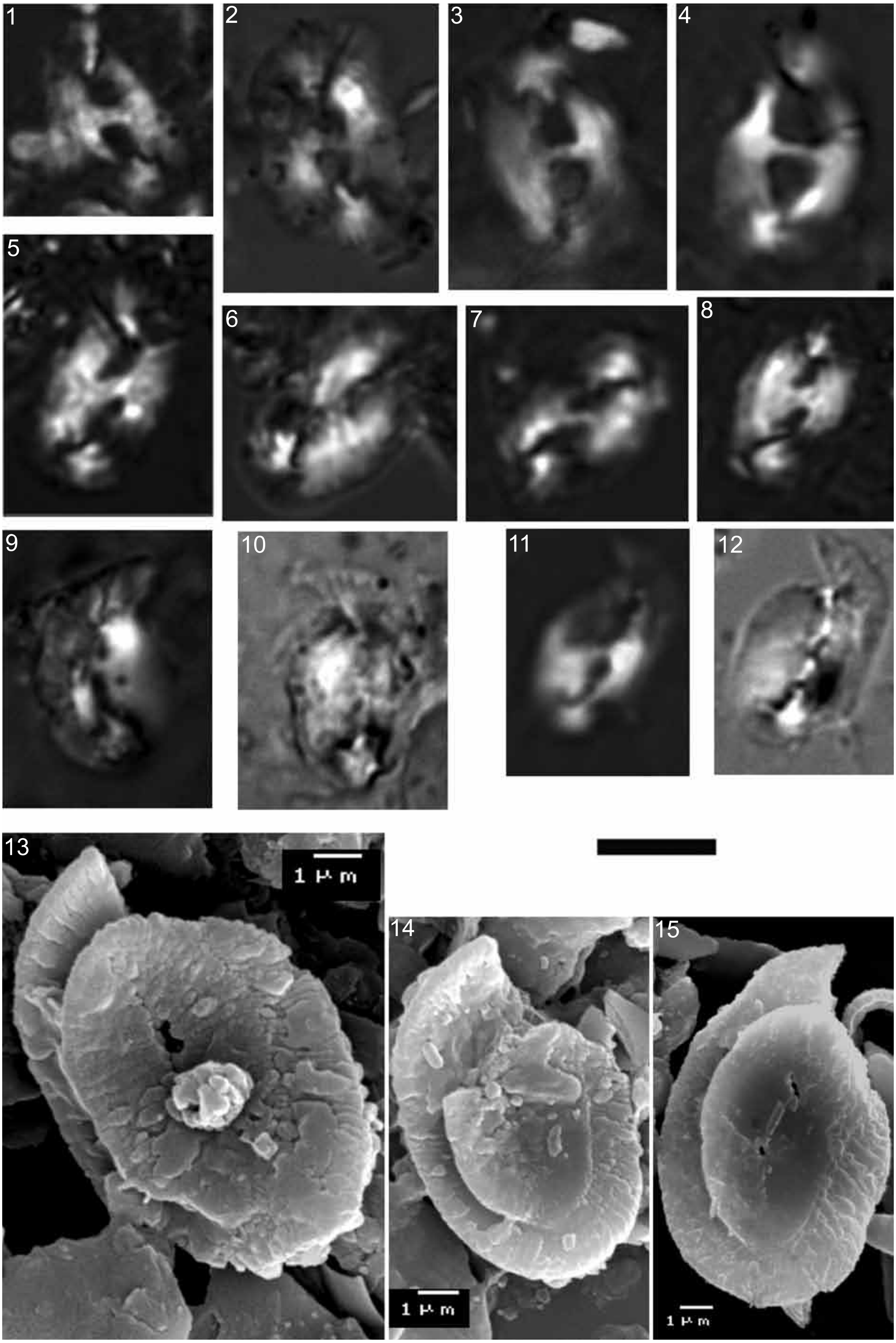

Plate 5

Figure 1: *Helicosphaera compacta* Bramlette & Wilcoxon, 1967, sample JAK-3.
Figure 2: *Helicosphaera recta* (Haq, 1966) Jafar & Martini, 1975, distal view, sample LR-17.
Figure 3: *Helicosphaera recta* (Haq, 1966) Jafar & Martini, 1975, distal view, sample PO-11.
Figure 4: *Helicosphaera recta* (Haq, 1966) Jafar & Martini, 1975, distal view, sample PO-6.
Figure 5: *Helicosphaera recta* (Haq, 1966) Jafar & Martini, 1975, proximal view, sample JAK-13.
Figure 6, 7: *Helicosphaera obliqua* Bramlette & Wilcoxon, 1967, distal view, sample JAK-3.
Figure 8, 11: *Helicosphaera ampliaperta* Bramlette & Wilcoxon, 1967, sample JA-24.
Figure 9, 10: *Helicosphaera ampliaperta* Bramlette & Wilcoxon, 1967, sample JA-14.
Figure 12, 15: *Helicosphaera ampliaperta* Bramlette & Wilcoxon, 1967, distal view, sample KAM-16.
Figure 13, 14: *Helicosphaera scissura* Müller, 1974, distal view, sample JA-24.
Figure 16, 17: *Helicosphaera scissura* Müller, 1974, distal view, sample ŠP-1.
Figure 18: *Helicosphaera compacta* Bramlette & Wilcoxon, 1967, proximal view, sample PV-1.

Figures 1-17: LM, 1000x, scale bar 5 μm. Figures 10, 11 and 17 PPL, others XPL.
Figure 18: SEM, scale bar in figure.
* film camera, scale approximate.

Plate 5

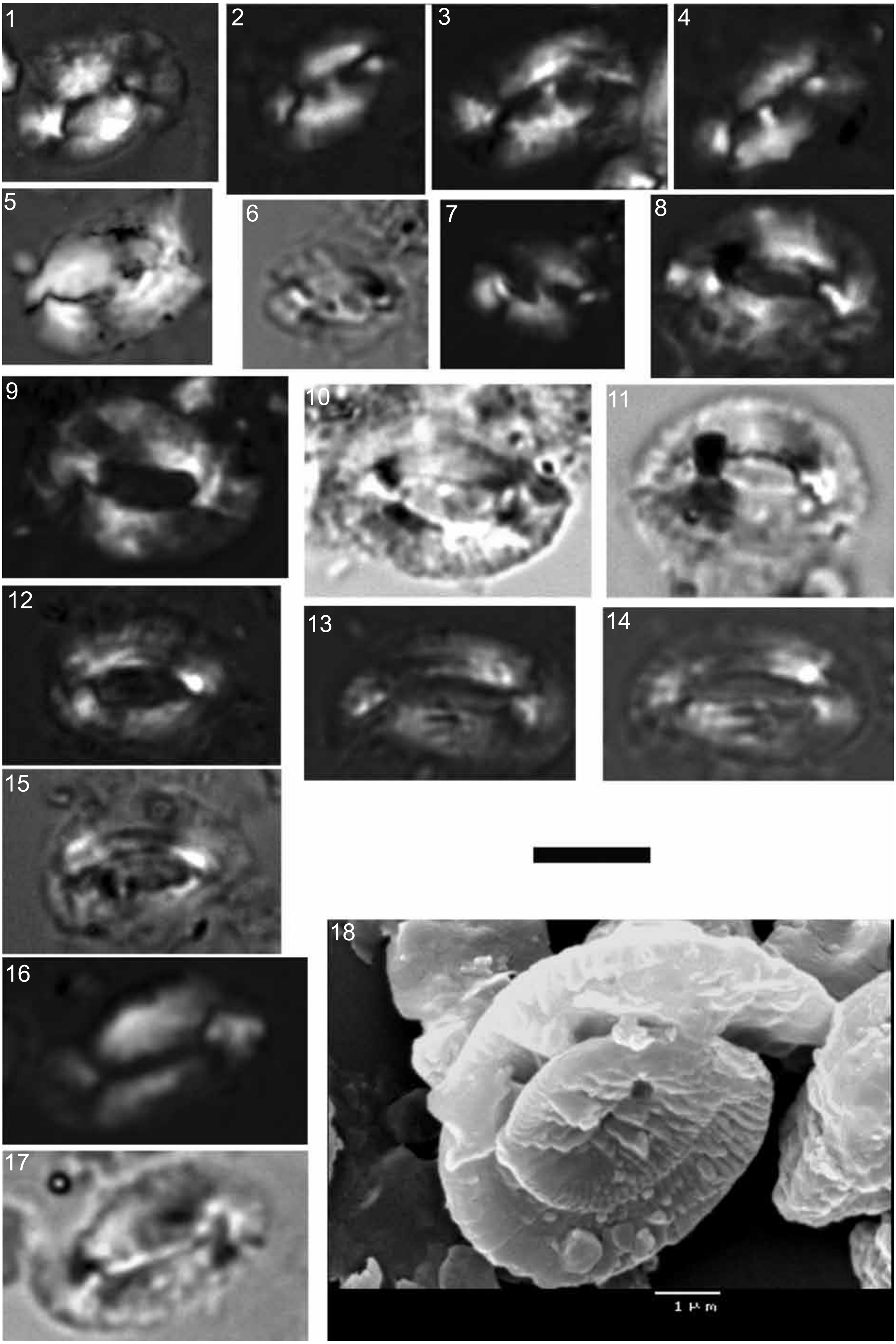

Plate 6

Figure 1: *Pontosphaera multipora* (Kamptner, 1948) Roth, 1970 emend. Burns, 1973, sample LR-38.
Figure 2: *Pontosphaera multipora* (Kamptner, 1948) Roth, 1970 emend. Burns, 1973, sample LR-37.
Figure 3: *Pontosphaera multipora* (Kamptner, 1948) Roth, 1970 emend. Burns, 1973, sample JAK-14.
Figure 4: *Pontosphaera desuetoidea* Bartol, 2009, sample JU-6.
Figure 5: *Pontosphaera plana* (Bramlette & Sullivan, 1961) Haq, 1971, sample JAK-14.
Figure 6: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, sample LR-36.
Figure 7: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, sample LR-38.
Figure 8: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, sample LR-38.
Figure 9: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, sample LR-36.
Figure 10: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, sample LE-19.
Figure 11: *Pontosphaera desueta* (Müller, 1970) Perch-Nielsen, 1984, sample LT-21.
Figure 12: *Pontosphaera desueta* (Müller, 1970) Perch-Nielsen, 1984, sample Lc-8.
Figure 13: *Pontosphaera desueta* (Müller, 1970) Perch-Nielsen, 1984, sample KAM-27.
Figure 14: *Pontosphaera latelliptica* (Báldi-Beke & Báldi, 1974) Perch-Nielsen, 1984, sample KAM-5.
Figure 15: *Pontosphaera latelliptica* (Báldi-Beke & Báldi, 1974) Perch-Nielsen, 1984, sample KAM-6.
Figure 16: *Pontosphaera multipora* (Kamptner, 1948) Roth, 1970 emend. Burns, 1973, distal view, sample LR-34.
Figure 17: *Pontosphaera multipora* (Kamptner, 1948) Roth, 1970 emend. Burns, 1973, distal view, sample LR-35.
Figure 18: *Pontosphaera geminipora* Bartol, 2009, proximal view, sample LR-35.
Figure 19: *Pontosphaera geminipora* Bartol, 2009, holotype, distal view, sample LR-35.
Figure 20:*Pontosphaera geminipora* Bartol, 2009, distal view, sample LR-34.
Figure 21: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, proximal view, sample LR-35.
Figure 22: *Pontosphaera callosa* (Martini, 1969) Varol, 1982, proximal view, sample LR-35.
Figure 23: *Pontosphaera desuetoidea* Bartol, 2009, holotype, distal view, sample LR-38.

Figures 1-15: LM, 1000x, scale bar 5 µm. Figure 9 PPL, others XPL.
Figures 16-23: SEM, scale bar in each figure.

Plate 6

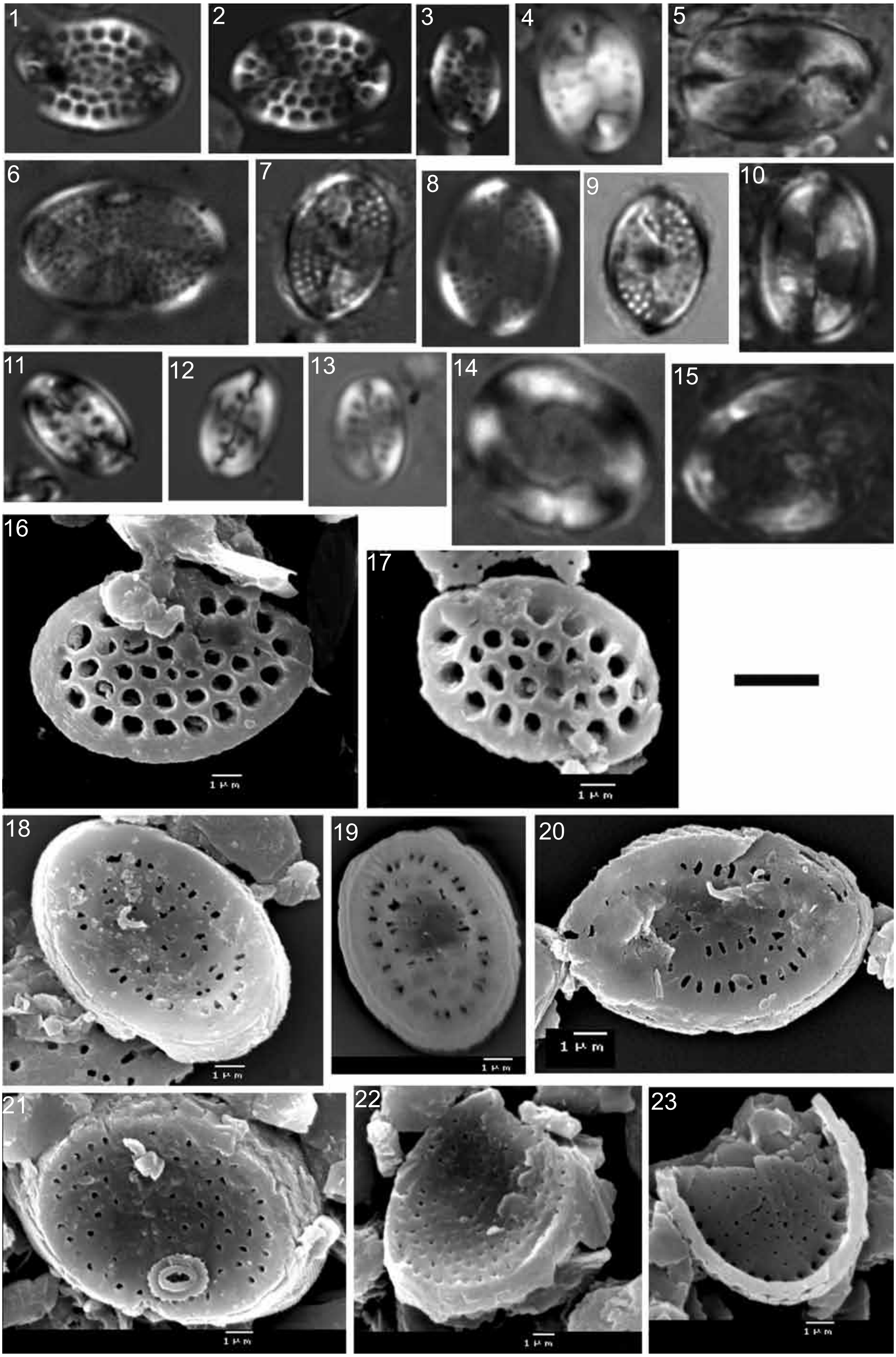
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Plate 7

Figure 1: *Transversopontis exilis* (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971, sample JAK-14.
Figure 2: *Transversopontis exilis* (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971, sample PV-3.
Figure 3: *Transversopontis sigmoidalis* Locker, 1967, sample JU-26.
Figure 4: *Transversopontis pulcher* Perch-Neilsen, 1967, sample LR-2.
Figure 5*: *Scyphosphaera amphora* Deflandre, 1942, sample KPV-4.
Figure 6: *Transversopontis pulcheroides* (Sullivan, 1964) Báldi-Beke, 1971, sample Lac-5.
Figure 7*: *Transversopontis pulcheroides* (Sullivan, 1964) Báldi-Beke, sample PO-4.
Figure 8: *Rhadbosphaera vitrea* (Deflandre, 1954) Bramlette & Sullivan, 1961, sample LR-24.
Figure 9: *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner, 1977, sample LR-17.
Figure 10: *Rhabdosphaera sicca*, (Stradner, 1963) Fuchs & Stradner, 1977, sample Lc-10.
Figure 11: *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner, 1977, sample KPV-7.
Figure 12, 16: *Rhabdosphaera crebra* (Deflandre, 1954) Bramlette & Sullivan, 1961, sample JU-40.
Figure 13: *Rhadbosphaera procera* Martini 1969, sample Lc-10.
Figure 14: *Rhadbosphaera procera* Martini 1969 sample LT-61.
Figure 15: *Rhadbosphaera procera* Martini 1969, sample LT-51.
Figure 17: *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner, 1977, sample LT-51.
Figure 18: *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner, 1977, sample LT-51.
Figure 19: *Blackites trochos* Bybell, 1975, sample LR-37.
Figure 20: *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner, 1977, sample LT-38.
Figure 21: *Rhabdosphaera sicca* (Stradner, 1963) Fuchs & Stradner, 1977, sample LR-35.
Figure 22: *Scyphosphaera amphora* Deflandre, 1942, sample LR-34.

Figures 1-16, 19: LM, 1000x, scale bar 5 µm. Figures 9, 12 and 13 PPL, others XPL.
Figures 17, 18, 20-22: SEM, scale bar in each figure.
* film camera, scale approximate.

Plate 7

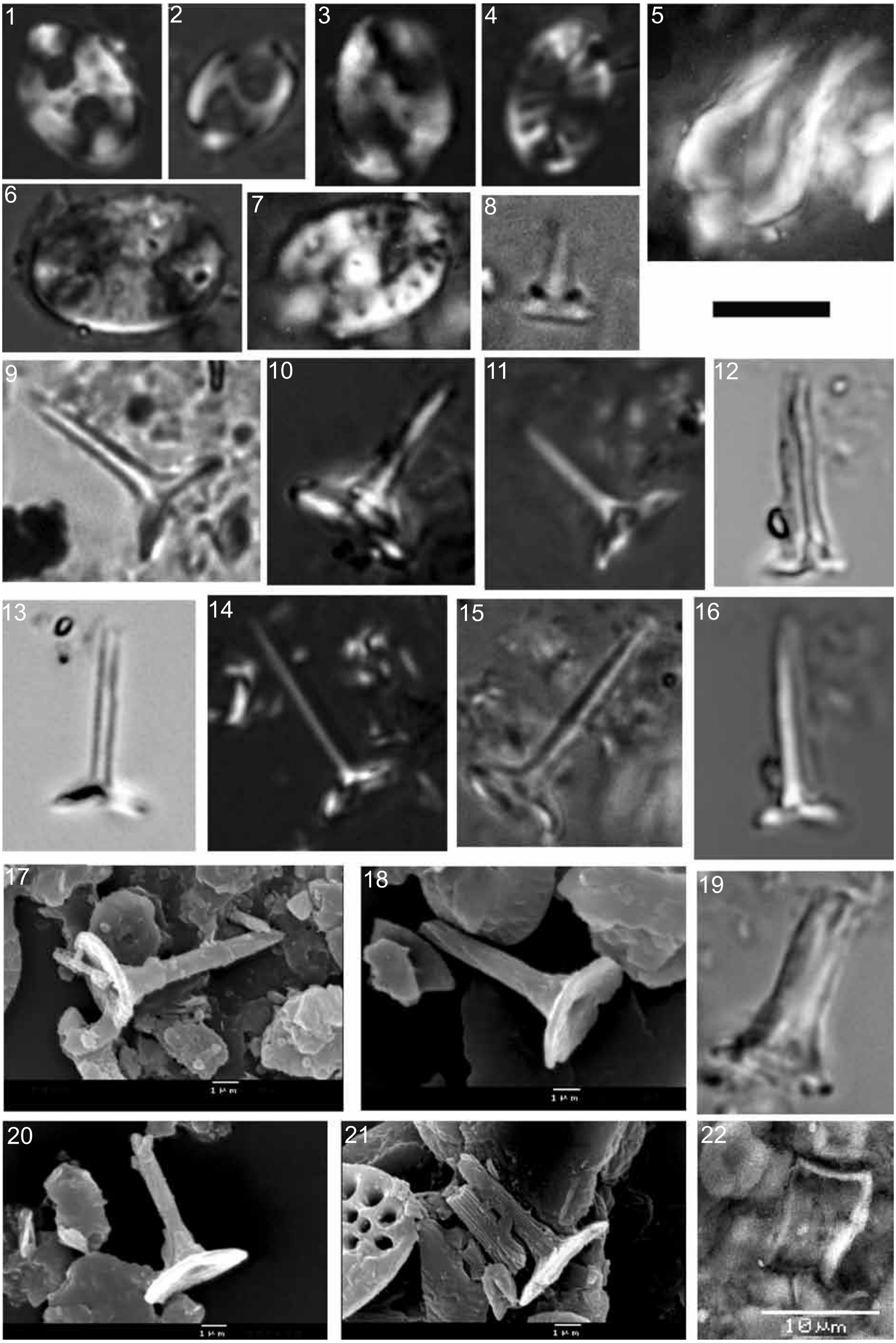
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Plate 8

Figure 1: *Syracosphaera pulchra* Lohman, 1902, sample LR-39.
Figure 2: *Syracosphaera pulchra* Lohman, 1902, sample LR-38.
Figure 3: *Syracosphaera pulchra* Lohman, 1902, sample LE-19.
Figure 4: *Syracosphaera clathrata* Roth & Hay 1967, sample JU-26.
Figure 5: *Syracosphaera pulchra* Lohman, 1902, sample ŠP-1.
Figure 6: *Calciosolenia* sp., sample LR-17.
Figure 7, 8: *Calciosolenia* sp., sample LE-25.
Figure 9: *Calciosolenia* sp., sample LT-81.
Figure 10: *Calciosolenia* sp., sample Lac-5.
Figure 11: *Syracosphaera clathrata* Roth & Hay 1967, sample PV-1.
Figure 12: *Syracosphaera clathrata* Roth & Hay 1967, sample LT-51.
Figure 13: *Syracosphaera clathrata* Roth & Hay 1967, sample LT-51.
Figure 14: *Syracosphaera pulchra* Lohman, 1902, sample LT-51.
Figure 15: *Syracosphaera clathrata* Roth & Hay 1967, sample LT-51.
Figure 16: *Calciosolenia brasiliensis* (Lohman) Young 2003, sample LT-51.
Figure 17: *Calciosolenia brasiliensis* (Lohman) Young 2003, sample LT-51.
Figure 18: *Calciosolenia brasiliensis* (Lohman) Young 2003, sample LT-51.

Figures 1-10: LM, 1000x, scale bar 5 µm. Figures 6, 8 and 10 PPL, others XPL.
Figures 11-18: SEM, scale bar in each figure.

Plate 8

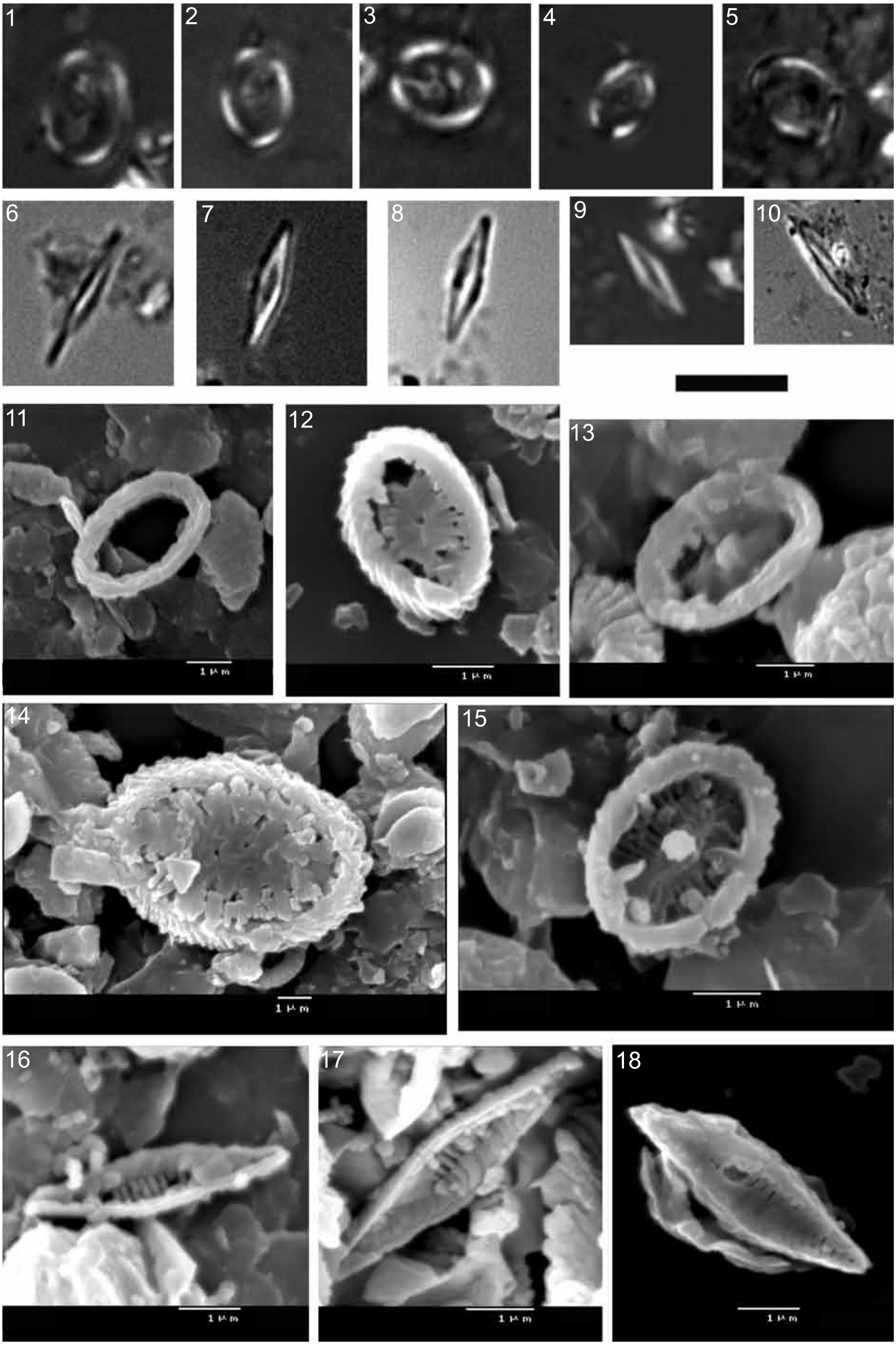

Plate 9

Figure 1, 2: *Cribrocentrum reticulatum* Roth & Thierstein, 1972, sample PV-12.
Figure 3, 4: *Watznaueria barnesiae* (Black, 1959) Perch-Nielsen, 1968, sample JAK-2.
Figure 5: *Watznaueria barnesiae* (Black, 1959) Perch-Nielsen, 1968, sample JU-45.
Figure 6: *Cribrocentrum reticulatum* Roth & Thierstein, 1972, sample Lc-10.
Figure 7, 8: *Cyclicargolithus floridanus* (Hay et al., 1967) Bukry, 1971, sample LR-39.
Figure 9: *Watznaueria barnesiae* (Black, 1959) Perch-Nielsen, 1968, sample JA-14.
Figure 10: *Cyclicargolithus abisectus* (Müller, 1970) Bukry, 1973, sample LR-30.
Figure 11: *Coronocyclus nitescens* (Kamptner, 1963) Bramlette & Wilcoxon, 1967, sample LT-61.
Figure 12: *Cyclicargolithus floridanus* (Hay et al., 1967) Bukry, 1971, sample ŠP-8.
Figure 13, 16: *Cyclicargolithus floridanus* (Hay et al., 1967) Bukry, 1971, sample JAK-9.
Figure 14: *Coronocyclus nitescens* (Kamptner, 1963) Bramlette & Wilcoxon, 1967, sample LE-3.
Figure 15: *Coronocyclus nitescens* (Kamptner, 1963) Bramlette & Wilcoxon, 1967, sample LR-1.
Figure 17: *Cyclicargolithus abisectus* (Müller, 1970) Bukry, 1973, sample JA-14.
Figure 18: *Cyclicargolithus abisectus* (Müller, 1970) Bukry, 1973, sample PV-15.
Figure 19: *Coronocyclus nitescens* (Kamptner, 1963) Bramlette & Wilcoxon, 1967, sample JU-40.
Figure 20, 21: *Broinsonia parca* (Stradner, 1963) Bukry, 1969, sample LR-38.
Figure 22*: *Retecapsa* sp., sample LR-38.

All figures: LM, 1000x, scale bar 5 μm. Figures 2, 4, 8, 11, 14, 15, 16, 19, 20 PPL, others XPL.
* film camera, scale approximate.

Plate 9

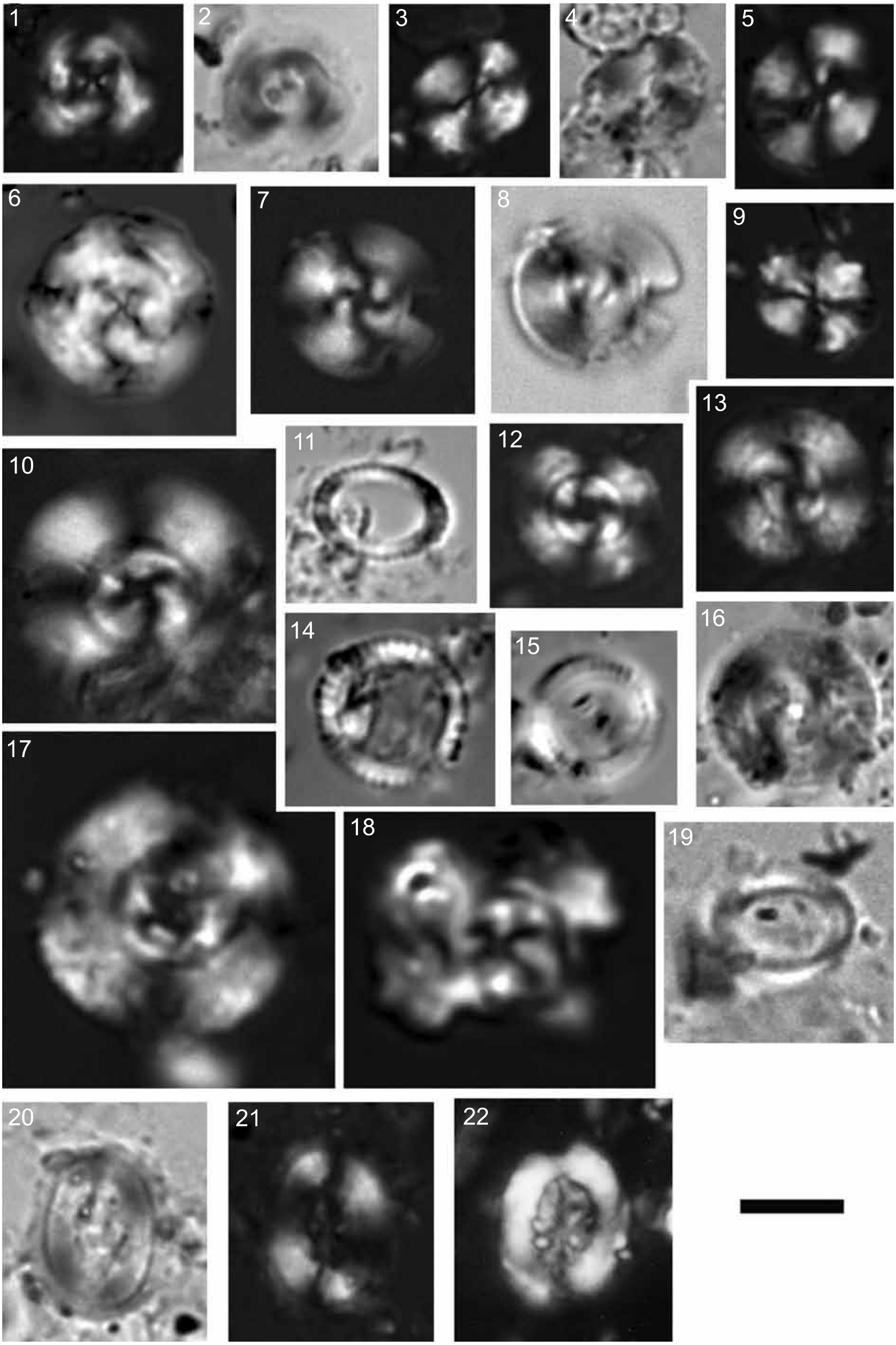

Plate 10

Figure 1, 2: *Reticulofenestra callida* (Perch-Nielsen, 1971) Bybell, 1975, sample KAM-18.
Figure 3: *Reticulofenestra callida* (Perch-Nielsen, 1971) Bybell, 1975, sample KAM-17.
Figure 4: *Reticulofenestra callida* (Perch-Nielsen, 1971) Bybell, 1975, sample JA-23.
Figure 5, 6: *Reticulofenestra dictyoda* (Levin, 1965) Martini & Rizkowski, 1968, sample JAK-5.
Figure 7, 8: *Reticulofenestra dictyoda* (Levin, 1965) Martini & Rizkowski, 1968, sample JAK-8.
Figure 9: *Reticulofenestra lockeri* Müller, 1970, sample PO-3.
Figure 10: *Reticulofenestra lockeri* Müller, 1970, sample JAK-2.
Figure 11: *Reticulofenestra dictyoda* (Levin, 1965) Martini & Rizkowski, 1968, sample ŠP-11.
Figure 12*: *Reticulofenestra hillae* Bukry & Percival, 1971, sample JU-36.
Figure 13: *Reticulofenestra bisecta* (Hay, Mohler & Wade, 1966) Roth, 1970, sample JU-40.
Figure 14: *Reticulofenestra lockeri* Müller, 1970, sample JA-23.
Figure 15: *Reticulofenestra scrippsae* (Bukry & Percival, 1971) Roth, 1973, sample PO-6.
Figure 16: *Reticulofenestra scrippsae* (Bukry & Percival, 1971) Roth, 1973, sample Lac-15.
Figure 17: *Reticulofenestra bisecta* (Hay, Mohler & Wade, 1966) Roth, 1970, sample JU-41.
Figure 18: *Reticulofenestra scrippsae* (Bukry & Percival, 1971) Roth, 1973, sample JU-41.
Figure 19: *Reticulofenestra callida* (Perch-Nielsen, 1971) Bybell, 1975, sample LR-35.
Figure 20: *Reticulofenestra perplexa* (Burns, 1975) Wise, 1983, sample LT-71.
Figure 21: *Reticulofenestra perplexa* (Burns, 1975) Wise, 1983, sample ŠP-1.
Figure 22: *Reticulofenestra perplexa* (Burns, 1975) Wise, 1983, sample ŠP-8.
Figure 23: *Reticulofenestra perplexa* (Burns, 1975) Wise, 1983, sample LE-19.
Figure 24: *Reticulofenestra perplexa* (Burns, 1975) Wise, 1983, sample LE-7.

Figures 1-18, 20-24: LM, 1000x, scale bar 5 μm. Figures 2, 6, and 8 PPL, others XPL.
Figure 19: SEM, scale bar in each figure.
* film camera, scale approximate.

Plate 10

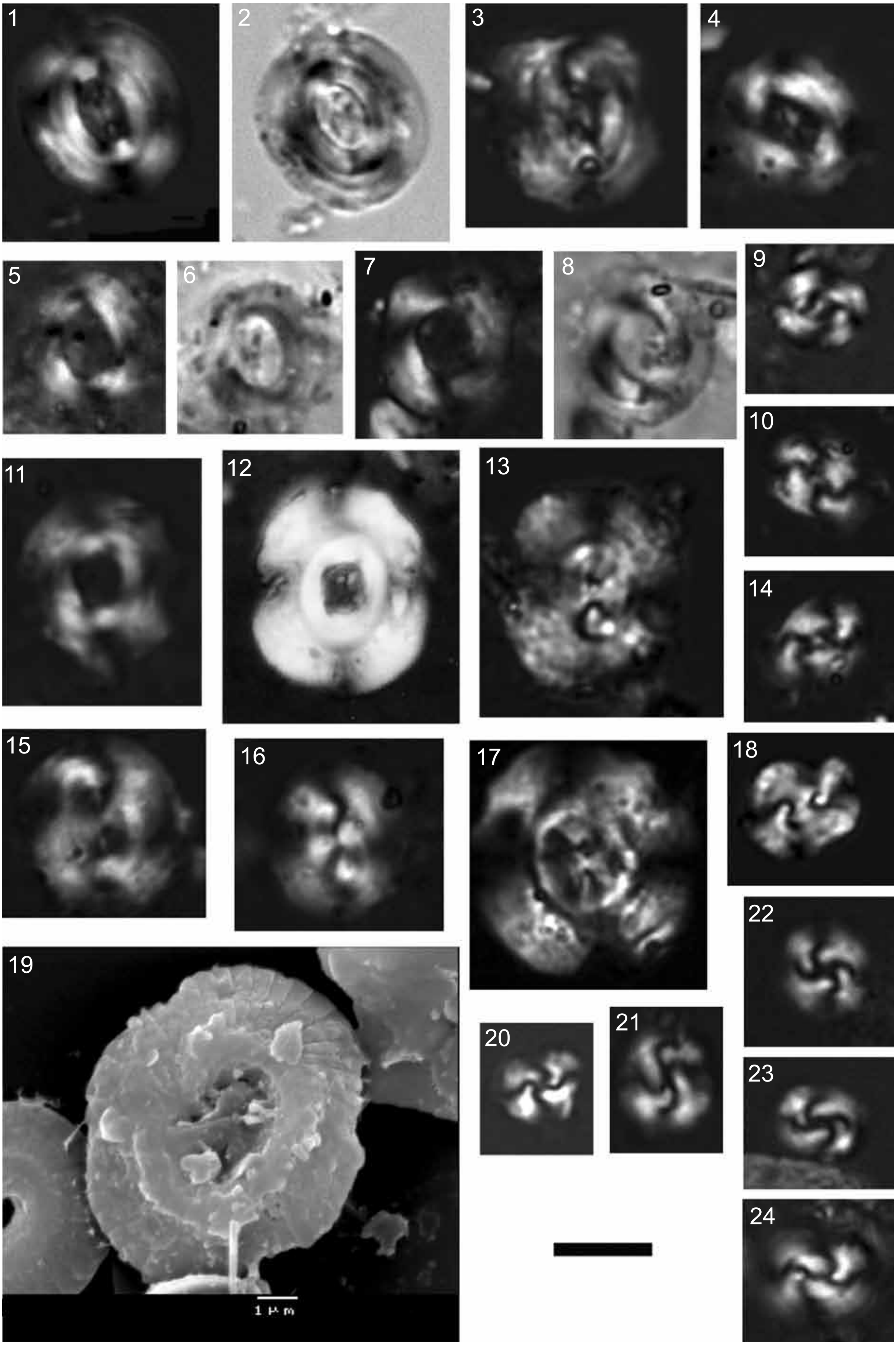

Plate 11

Figure 1: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), sample LR-40.
Figure 2: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), sample LT-71.
Figure 3: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), sample JU-45.
Figure 4, 5: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), sample LT-51.
Figure 6: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), sample PO-3.
Figure 7: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), sample LR-40.
Figure 8: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), sample LR-29.
Figure 9: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), sample LT-51.
Figure 10: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), sample LT-31.
Figure 11: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), sample LE-25.
Figure 12, 13: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, sample PV-1.
Figure 14: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, sample LR-35.
Figure 15: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, sample LT-31.
Figure 16: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, sample LE-25.
Figure 17: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, proximal view, sample LR-35.
Figure 18: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, distal view, sample LR-35.
Figure 19: *Reticulofenestra gelida* (Geitzenauer, 1972) Backman, 1978, distal view, sample LR-38.
Figure 20: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), proximal view.
Figure 21: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), distal view, sample LR-35.
Figure 22: *Reticulofenestra pseudoumbilica* Gartner, 1969, (<7 µm), proximal view, sample LR-34.
Figure 23: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), proximal view, sample LR-38.
Figure 24: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), distal view, sample LT-51.
Figure 25: *Reticulofenestra pseudoumbilica* Gartner, 1969, (>7 µm), proximal view, sample LT-51.

Figures 1-16: LM, 1000x, scale bar 5 µm. Figures 5, 9 and 13 PPL, others XPL.
Figures 17-25: SEM, scale bar in each figure.

Plate 11

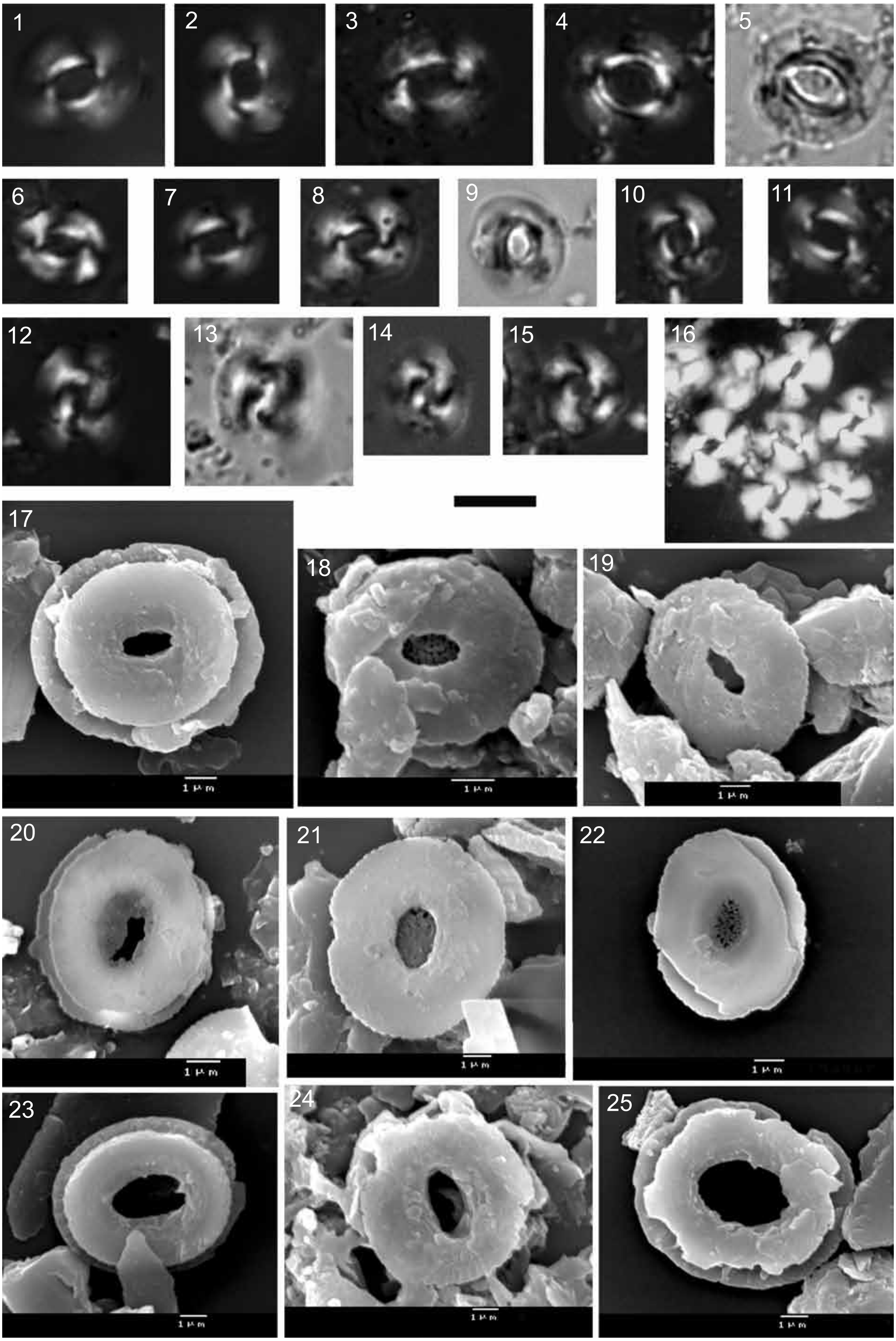

Plate 12

Figure 1: *Reticulofenestra haqii* Backman, 1978, sample ZP-7.
Figure 2: *Reticulofenestra haqii* Backman, 1978, sample LR-40.
Figure 3: *Reticulofenestra haqii* Backman, 1978, sample KPV-7.
Figure 4: *Reticulofenestra haqii* Backman, 1978, sample KPV-1.
Figure 5: *Reticulofenestra haqii* Backman, 1978, sample JAK-3.
Figure 6: *Reticulofenestra haqii* Backman, 1978, sample LT-11.
Figure 7: *Reticulofenestra minutula* (Gartner, 1967) Haq & Bergren, 1978, coccosphere, sample LT-51.
Figure 8: *Reticulofenestra minutula* (Gartner, 1967) Haq & Bergren, 1978, sample LT-16.
Figure 9: *Reticulofenestra minutula* (Gartner, 1967) Haq & Bergren, 1978, sample LR-1.
Figure 10: *Reticulofenestra haqii* Backman, 1978, coccosphere fragment, sample Lc-10.
Figure 11: *Reticulofenestra minuta* Roth, 1970, sample KPV-1.
Figure 12: *Reticulofenestra minuta* Roth, 1970, sample KPV-1.
Figure 13: *Reticulofenestra minuta* Roth, 1970, sample JU-41.
Figure 14: *Reticulofenestra minuta* Roth, 1970, sample JU-41.
Figure 15: *Reticulofenestra haqii* Backman, 1978, coccosphere, sample LT-51.
Figure 16: *Reticulofenestra haqii* Backman, 1978, distal view, sample PV-1.
Figure 17: *Reticulofenestra haqii* Backman, 1978, sample PV-1.
Figure 18: *Reticulofenestra minutula* (Gartner, 1967) Haq & Bergren, 1978, coccosphere, sample lT-51.
Figure 19: *Reticulofenestra minutula* (Gartner, 1967) Haq & Bergren, 1978, distal view, sample LT-51.
Figure 20: *Reticulofenestra minutula* (Gartner, 1967) Haq & Bergren, 1978, distal view, sample LT-51.
Figure 21: *Reticulofenestra minuta* Roth, 1970, distal view, sample PV-1.
Figure 22: *Reticulofenestra minuta* Roth, 1970, distal view, sample LT-51.
Figure 23: *Reticulofenestra minuta* Roth, 1970, distal view, sample LR-34.

Figures 1-14: LM, 1000x, XPL, scale bar 5 μm.
Figures 15-23: SEM, scale bar in each figure.

Plate 12

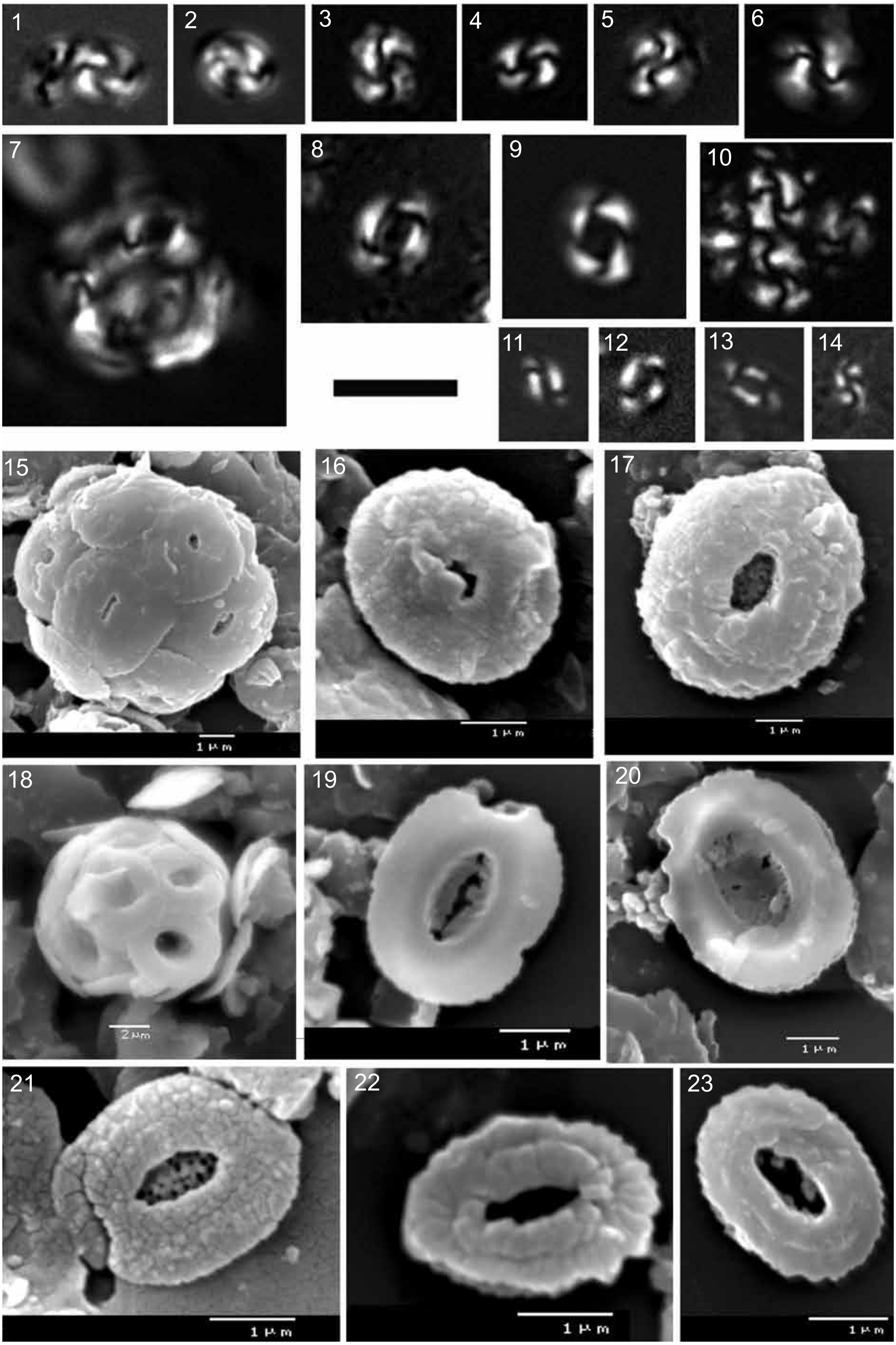
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Plate 13

Figure 1, 2: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, sample LE-19.
Figure 3: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with bridge, sample Lac-15.
Figure 4: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with bridge, sample PO-15.
Figure 5: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with bridge, sample KAM-15.
Figure 6: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, coccosphere, sample LR-37.
Figure 7: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, coccosphere, sample LT-11.
Figure 8: *Coccolithus miopelagicus* Bukry, 1971 emend. Wise, 1973, sample JU-15.
Figure 9, 10: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, sample KAM-18.
Figure 11: *Coccolithus miopelagicus* Bukry, 1971 emend. Wise, 1973, sample PV-3.
Figure 12: *Coccolithus miopelagicus* Bukry, 1971 emend. Wise, 1973, sample Lac-15.
Figure 13: *Coccolithus miopelagicus* Bukry, 1971 emend. Wise, 1973, sample Ju-45.
Figure 14: *Coccolithus formosus* (Kamptner, 1963), Wise, 1973 sample JAK-4.
Figure 15: *Coccolithus formosus* (Kamptner, 1963), Wise, 1973, sample JA-3.
Figure 16: *Coccolithus formosus* (Kamptner, 1963), Wise, 1973, sample JAK-4.
Figure 17, 18: *Coccolithus streckeri* Takyama & Sato, 1987, sample LT-56.
Figure 19, 20: *Coccolithus formosus* (Kamptner, 1963), Wise, 1973, sample KAM-6.
Figure 21, 22: *Coccolithus streckeri* Takyama & Sato, 1987, sample LR-35.

All figures LM, 1000x, scale bar 5 µm. Figures 2, 9, 18, 19 and 22 PPL, others XPL.

Plate 13

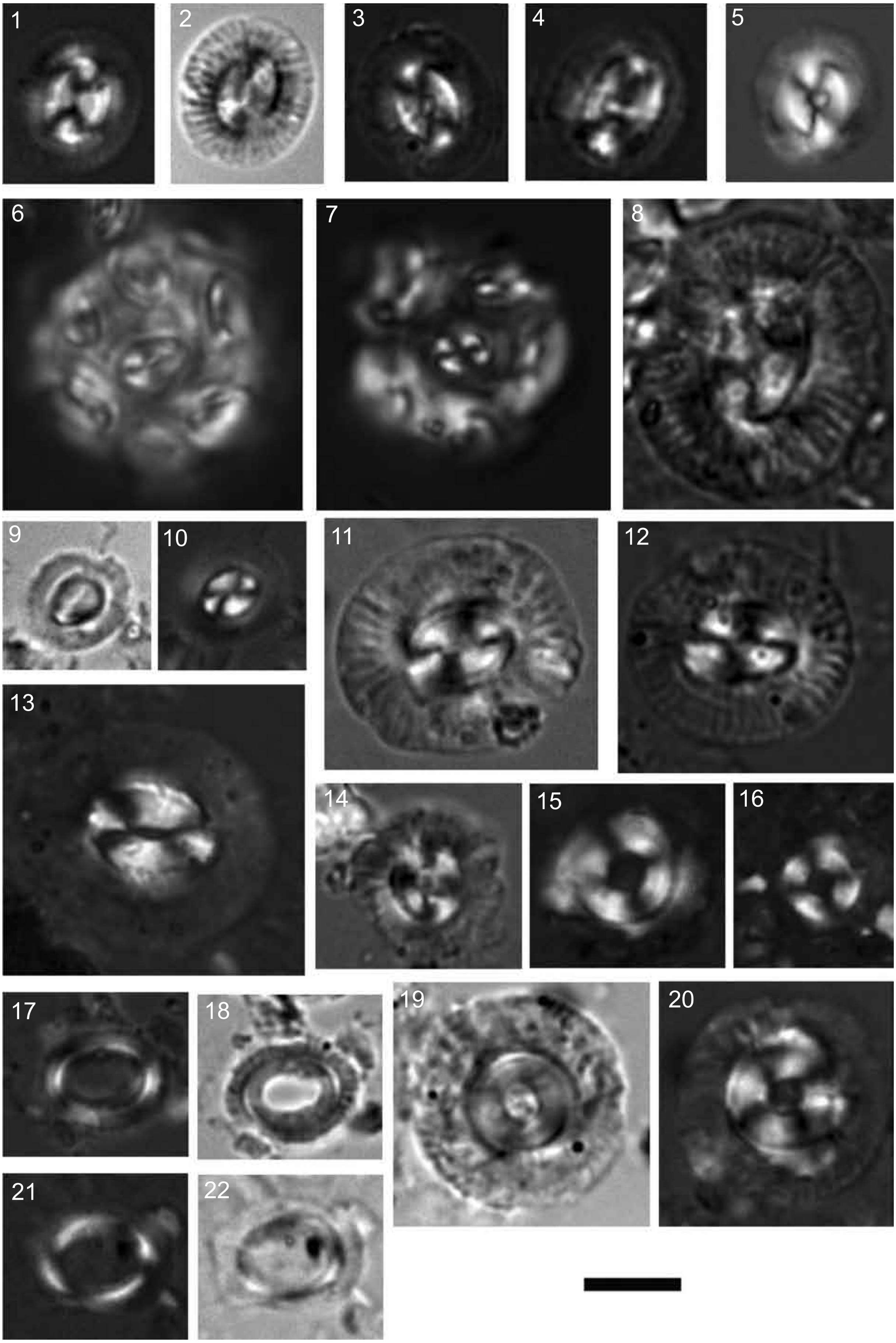

Plate 14

Figure 1: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, distal view, sample LT-51.
Figure 2: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, distal view, sample LT-51.
Figure 3: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, coccosphere, sample LR-35.
Figure 4: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with central bar, distal view, sample LR-38.
Figure 5: *Coccolithus miopelagicus* Bukry, 1971 emend. Wise, 1973, distal view, sample LR-34.
Figure 6: *Coccolithus miopelagicus* Bukry, 1971 emend. Wise, 1973, distal view, sample LT-51.
Figure 7: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, left with central cross, both distal view, sample PV-1.
Figure 8: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with central cross, proximal view, sample LR-35.
Figure 9: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with central cross, distal view, sample LR-35.
Figure 10: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with central cross, proximal view, sample LR-38.
Figure 11: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with central cross, proximal view, sample LR-38.
Figure 12: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930, with central cross, proximal view, sample LR-38.

All figures SEM, scale in each figure.

Plate 14

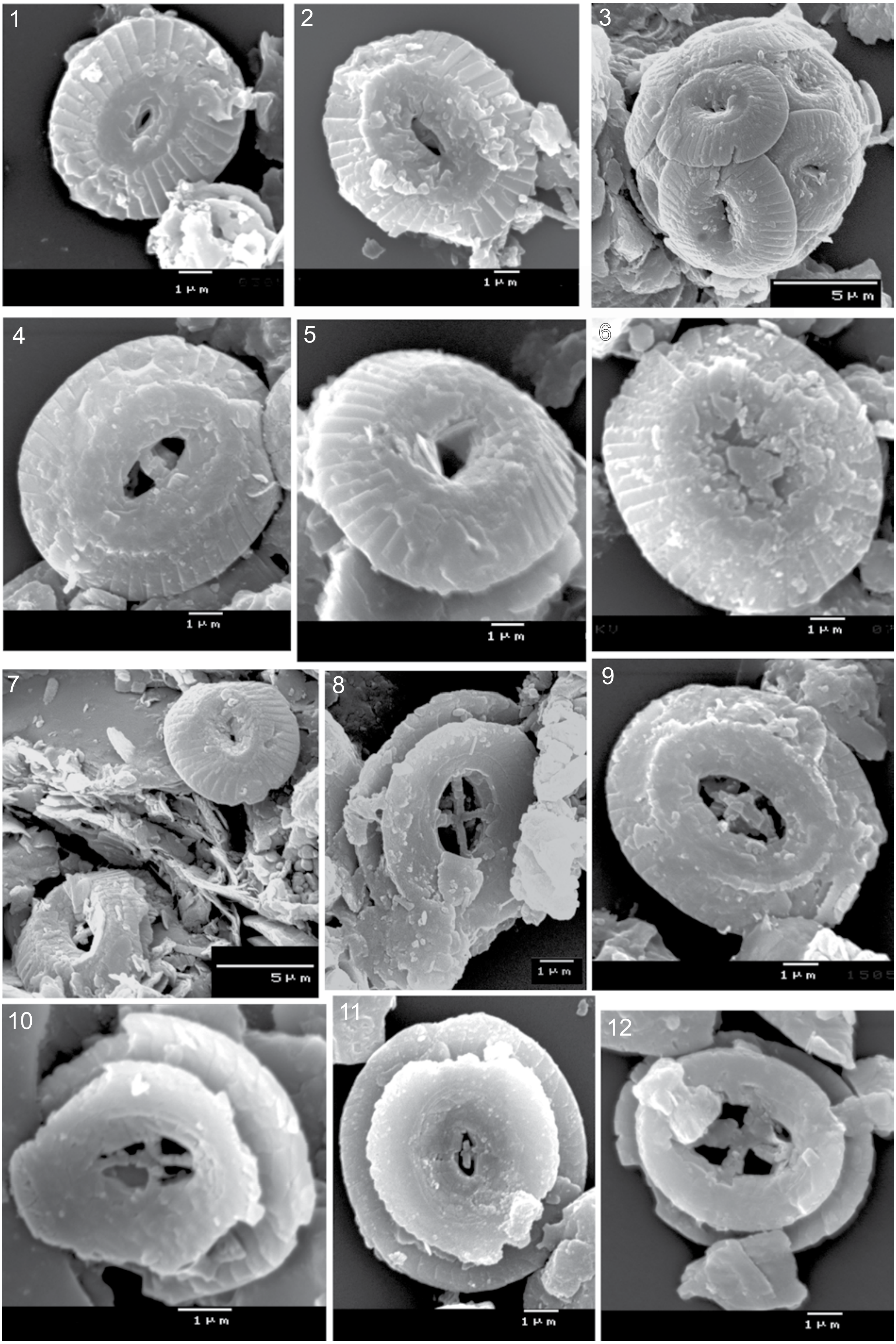
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Plate 15

Figure 1: *Calcidiscus premacintyrei* Theodoridis, 1984, sample LT-51.
Figure 2: *Calcidiscus premacintyrei* Theodoridis, 1984, sample LR-7.
Figure 3: *Calcidiscus premacintyrei* Theodoridis, 1984, sample LE-45.
Figure 4: *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loebelich & Tappan, 1978, sample LT-91.
Figure 5: *Calcidiscus tropicus* Kamptner, 1956, sample LT-21.
Figure 6: *Calcidiscus tropicus* Kamptner, 1956, sample LR-8.
Figure 7: *Calcidiscus tropicus* Kamptner, 1956, sample LR-35.
Figure 8: *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loebelich & Tappan, 1978, sample LT-96.
Figure 9: *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loebelich & Tappan, 1978, sample LT-11.
Figure 10: *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loebelich & Tappan, 1978, distal view, sample, LR-34.
Figure 11: *Calcidiscus macintyrei* (Bukry & Bramlette, 1969) Loebelich & Tappan, 1978, sample LT-21.
Figure 12: *Calcidiscus macintyrei* (Bukry & Bramlette, 1969) Loebelich & Tappan, 1978, sample LT-96.
Figure 13: *Calcidiscus premacintyrei* Theodoridis, 1984, distal view, sample LR-35.
Figure 14: *Calcidiscus premacintyrei* Theodoridis, 1984, distal view, sample LR-35.
Figure 15: *Calcidiscus premacintyrei* Theodoridis, 1984, proximal view, sample LR-38.
Figure 16: *Calcidiscus carlae* (Lehotayova & Priewalder, 1978) Janin, 1992, distal vew, sample LR-35.
Figure 17: *Calcidiscus carlae* (Lehotayova & Priewalder, 1978) Janin, 1992, proximal view, sample LR-35.
Figure 18: *Calcidiscus carlae* (Lehotayova & Priewalder, 1978) Janin, 1992, distal view, sample LR-35.

Figures 1-9, 11, 12: LM, 1000x, scale bar 5 μm. Figures 6, 9, 11, 12 XPL, others PPL.
Figures 10, 13-18: SEM, scale in each figure.

Plate 15

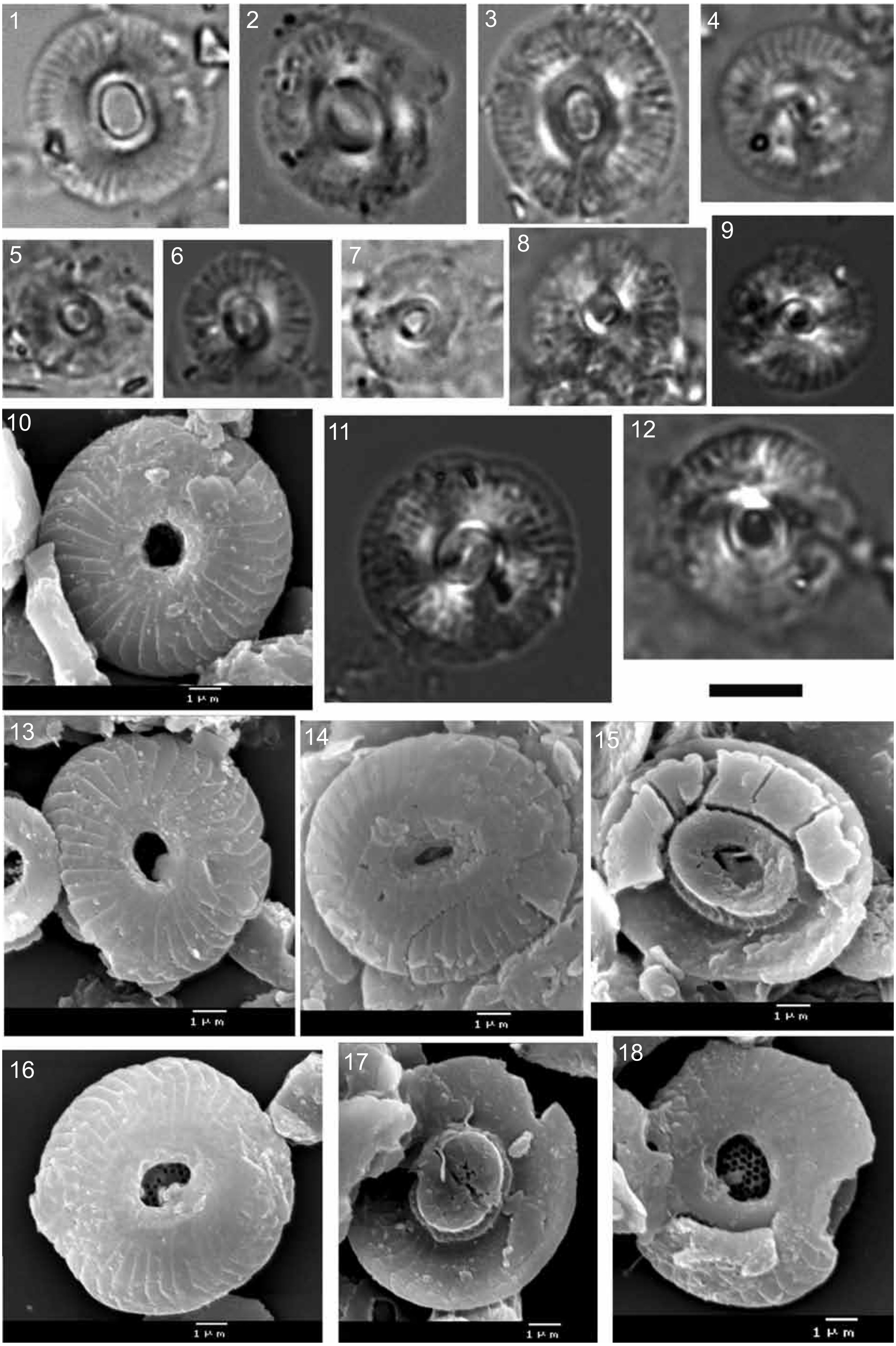

Plate 16

Figure 1: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, sample LR-40.
Figure 2: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, sample LR-38.
Figure 3, 4: *Umbilicosphaera jafari* Müller, 1974, sample PO-2.
Figure 5, 6: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, sample LT-51.
Figure 7, 8: *Umbilicosphaera jafari* Müller, 1974, sample LR-36.
Figure 9: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, sample LE-25.
Figure 10: *Umbilicosphaera jafari* Müller, 1974, sample LR-36.
Figure 11: *Umbilicosphaera jafari* Müller, 1974, sample LR-25.
Figure 12: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, distal view, sample LT-51.
Figure 13: *Umbilicosphaera jafari* Müller, 1974, proximal view, sample PV-1.
Figure 14: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, distal view, sample LR-38.
Figure 15: *Umbilicosphaera jafari* Müller, 1974, skupina, proximal view, sample PV-1.
Figure 16: *Umbilicosphaera jafari* Müller, 1974, distal view, sample LT-51.
Figure 17: *Umbilicosphaera rotula* (Kamptner, 1956) Varol, 1982, distal view, sample LR-38.
Figure 18: *Umbilicosphaera jafari* Müller, 1974, distal view, sample LT-51.
Figure 19: *Umbilicosphaera jafari* Müller, 1974, proximal view, sample PV-1.

Figures 1-11: LM, 1000x, scale bar 5 μm. Figures 4, 6 and 7 XPL, others PPL.
Figures 12-19: SEM, scale in each figure.

Plate16

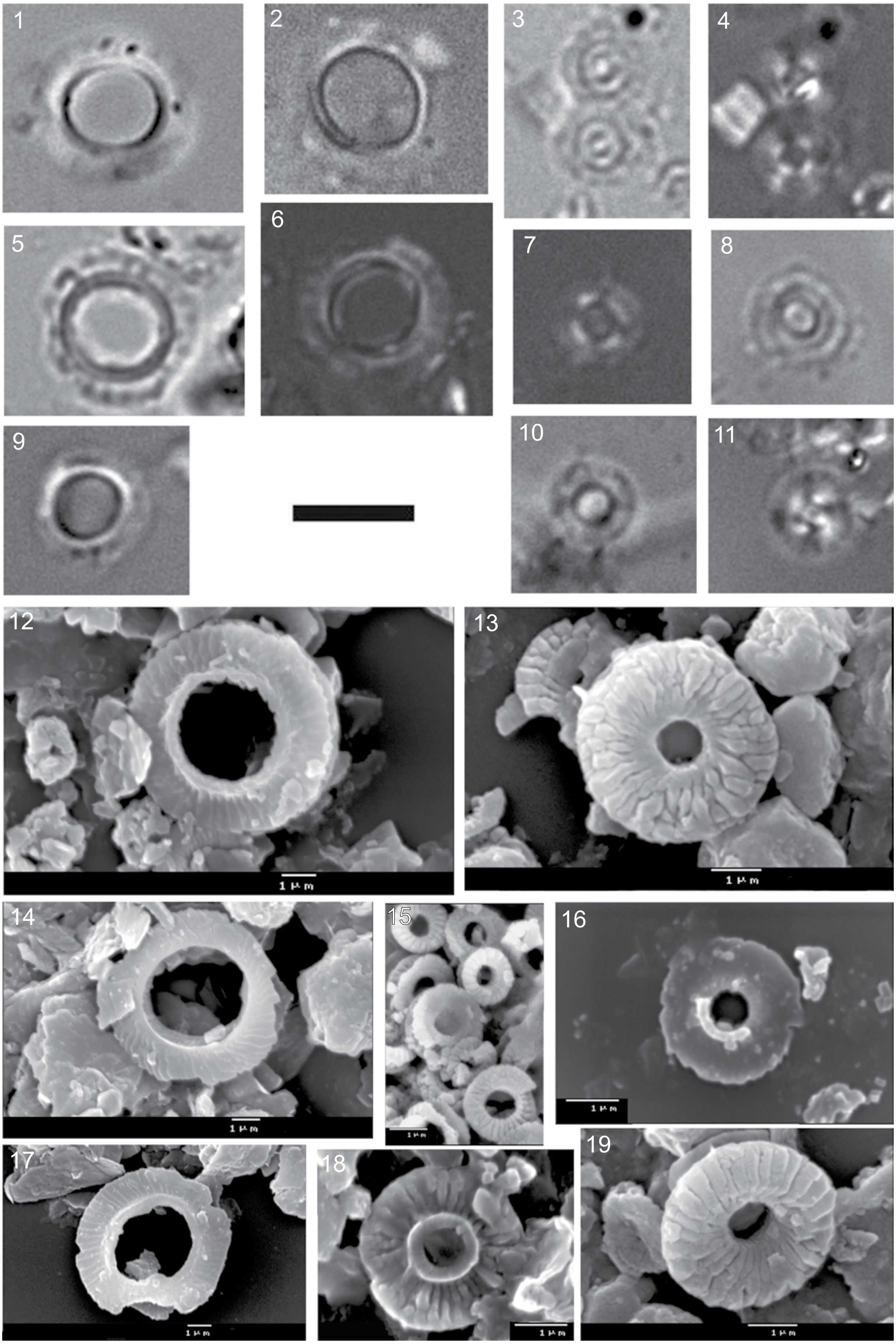
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Plate 17

Figure 1: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, sample LE-45.
Figure 2: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, sample LT-81.
Figure 3, 4: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, sample LT-31.
Figure 5: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, side view, sample LR-35.
Figure 6: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, 1970, side view, sample LR-35.
Figure 7: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, side view, sample LR-34.
Figure 8: *Zyghrablithus bijugatus* (Deflandre, 1954) Deflandre, 1959, sample JAK-2.
Figure 9: *Zygrhablithus bijugatus* (Deflandre, 1954) Deflandre, 1959, sample JAK-12.
Figure 10: *Syracolithus dalmaticus* (Kamptner) Loeblich & Tappan, 1966, sample LT-11.
Figure 11: *Syracolithus dalmaticus* (Kamptner) Loeblich & Tappan, 1966, sample LT-61.
Figure 12: *Syracolithus dalmaticus* (Kamptner) Loeblich & Tappan, 1966, sample LT-71.
Figure 13: *Zygrhablithus bijugatus* (Deflandre, 1954) Deflandre, 1959, sample PO-5.
Figure 14: *Zygrhablithus bijugatus* (Deflandre, 1954) Deflandre, 1959, sample JAK-5.
Figure 15: ?*Clathrolithus spinosus* Martini, 1961, fragment, sample LT-51.
Figure 16: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, sample LT-51.
Figure 17: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, sample LT-51.
Figure 18: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, overgrown, sample LT-51.
Figure 19: *Syracolithus schilleri* (Kamptner 1927) Loeblich & Tappan 1963, sample LT-51.
Figure 20: *Syracolithus dalmaticus* (Kamptner) Loeblich & Tappan, 1966, sample LT-51.

Figures 1-15: LM, 1000x, scale bar 5 µm. Figures 6, 7, 10 and 15 PPL, others XPL.
Figures 16-20: SEM, scale bar in each figure.

Plate 17

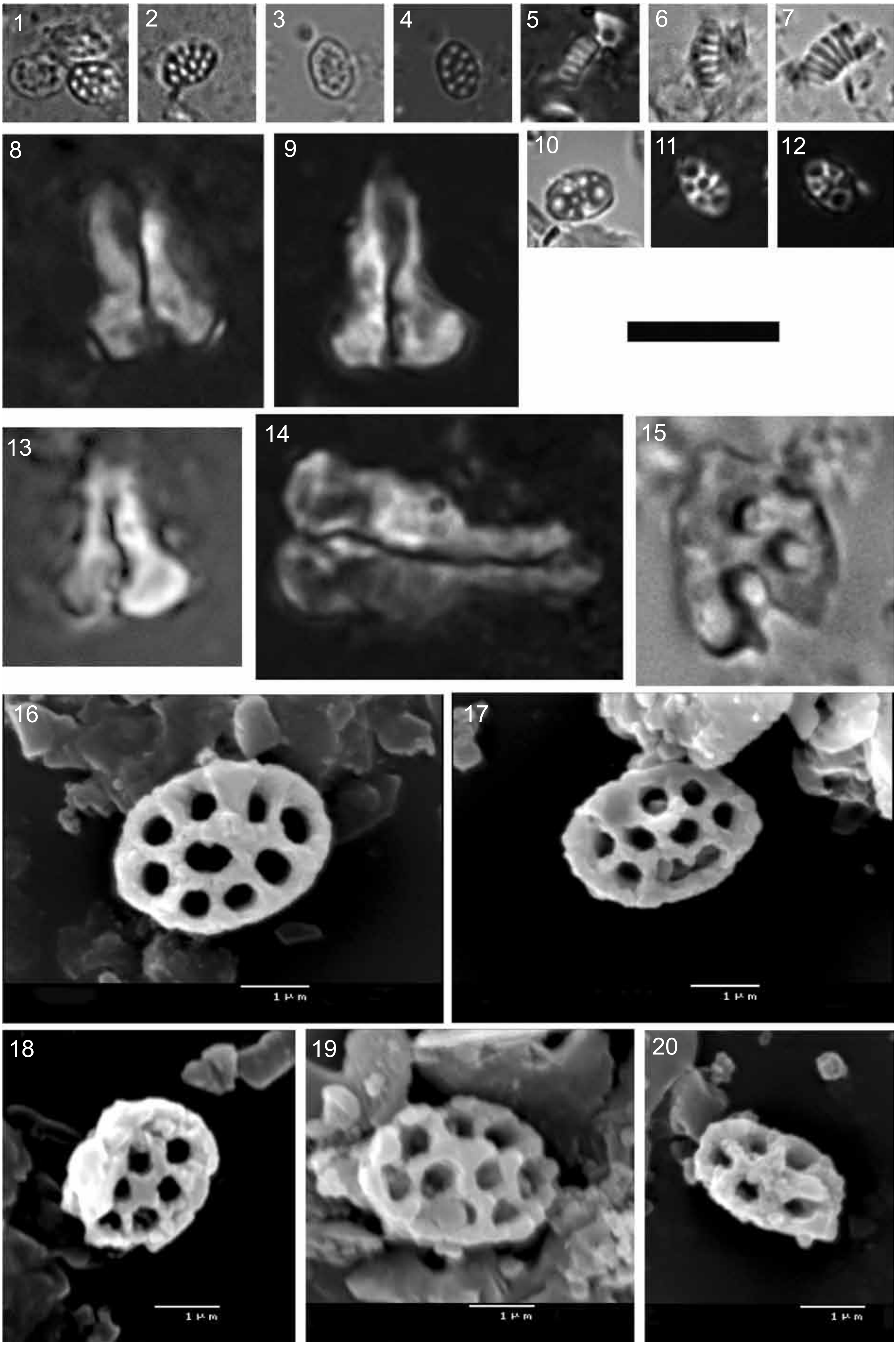

Plate 18

Figure 1: *Lithostromation perdurum* Deflandre, 1942, sample LR-38.
Figure 2: *Lithostromation perdurum* Deflandre, 1942, sample LR-38.
Figure 3: *Lithostromation perdurum* Deflandre, 1942, sample LR-37.
Figure 4, 5: *Microrhabdulus decoratus* Deflandre, 1959, sample JAK-2, different orientation of sample.
Figure 6: *Orthorhabdus serratus* Bramlette & Wilcoxon, 1967, sample JU-14.
Figure 7: *Orthorhabdus serratus* Bramlette & Wilcoxon, 1967, sample LT-61.
Figure 8: *Triquetrorhabdulus auritus* Stradner & Allram, 1982, sample JU-14.
Figure 9*: *Triquetrorhabdulus auritus* Stradner & Allram, 1982, JU-14.
Figure 10: *Micula concava* (Stradner, 1960) Verbeek, 1996, sample JAK-1.
Figure 11, 16: *Micula concava* (Stradner, 1960) Verbeek, 1996, sample PV-12.
Figure 12: *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947, sample LT-96.
Figure 13: *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947, sample LT-6.
Figure 14: *Micrantholithus* sp., sample JU-43.
Figure 15: *Tribrachiatus bramlettei* (Broniman & Stradner, 1960) Proto Decima et al., 1975, sample L-16(1).
Figure 17: *Biantholithus sparsus* Bramlette & Martini, 1964, sample JAK-2.
Figure 18: *Micrantholithus flos* (Deflandre, 1950) Deflandre & Fert, 1954, sample LT-21.
Figure 19: *Micrantholithus* sp., sample JU-48.
Figure 20: *Tribrachiatus orthostylus* (Bramlette & Reidel, 1954) Shamrai, 1963, sample PO-7.
Figure 21: *Biantholithus sparsus* Bramlette & Martini, 1964, sample PO-27.
Figure 22, 23: ?*Biantholithus sparsus* Bramlette & Martini, 1964, sample Lac-15, different orientation of sample.
Figure 24: *Lithostromation perdurum* Deflandre, 1942, sample LR-35.
Figure 25: *Lithostromation perdurum* Deflandre, 1942, sample LR-35.

Figures 1-23: LM, 1000x, scale bar 5 μm. Figure 2 PPL, others XPL.
Figures 24, 25: SEM, scale bar in each figure.

Plate 18

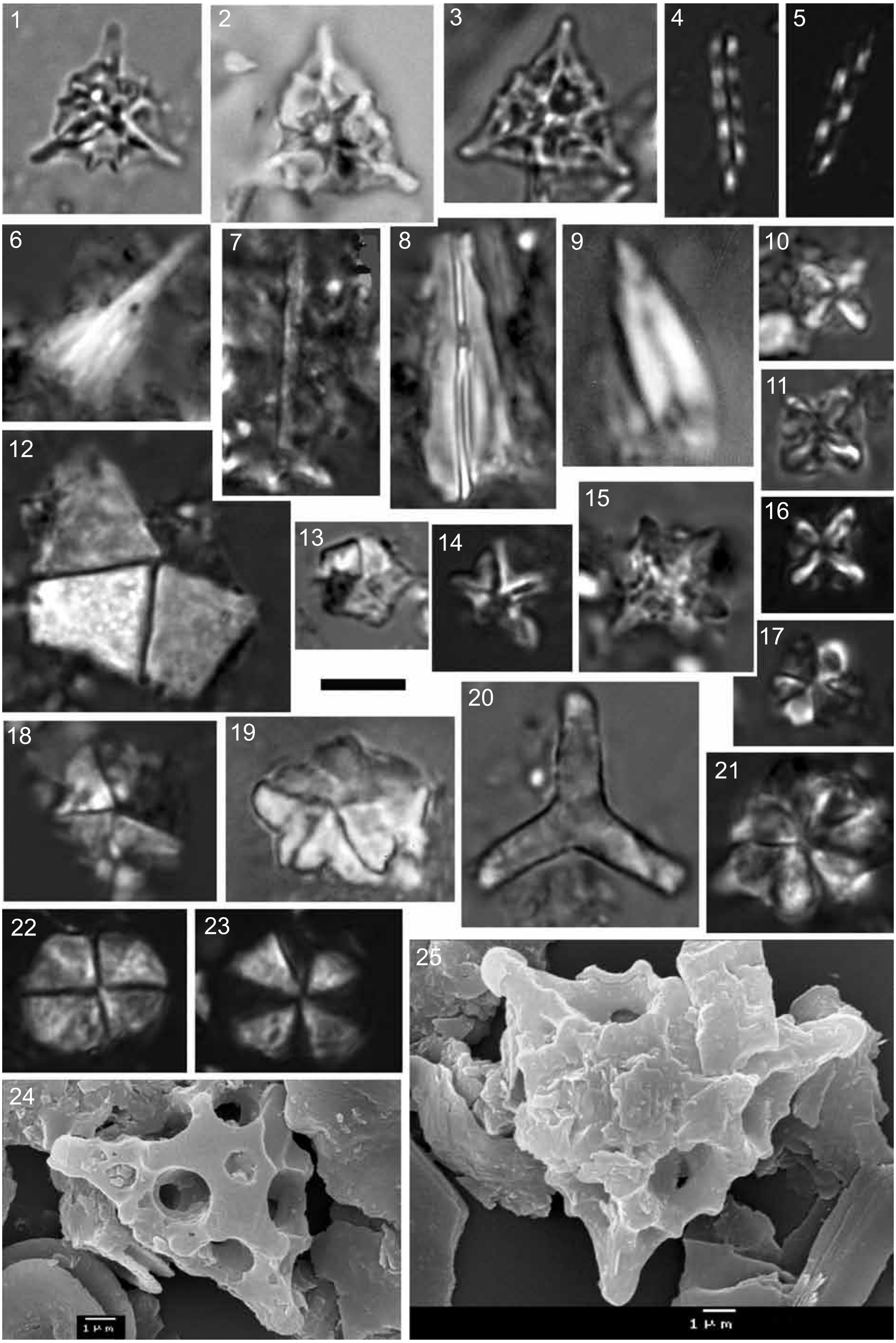

Plate 19

Figure 1, 2: *Sphenolithus heteromorphus* Deflandre, 1953, sample JA-30.
Figure 3, 4: *Sphenolithus heteromorphus* Deflandre, 1953, sample Lac-5, different orientation of sample.
Figure 5: *Sphenolithus conicus* Bukry, 1971, sample PV-2.
Figure 6: *Sphenolithus conicus* Bukry, 1971, sample JA-7.
Figure 7, 8: *Sphenolithus heteromorphus* Deflandre, 1953, sample KPV-8.
Figure 9, 10: *Sphenolithus moriformis* Bramlette & Wilcoxon, 1967, sample LR-1.
Figure 11, 12: *Sphenolithus abies* Deflandre, 1954, sample LE-25, different orientation of sample.
Figure 13: *Sphenolithus abies* Deflandre, 1954, sample LT-71
Figure 14: *Sphenolithus abies* Deflandre, 1954, sample LE-45.
Figure 15, 16: *Sphenolithus* cf. *delphix* Bukry, 1973, sample PO-11, different orientation of sample.
Figure 17: *Sphenolithus* cf. *delphix* Bukry, 1973, sample Lac-15.
Figure 18: *Sphenolithus* cf. *delphix* Bukry, 1973, sample JU-43.
Figure 19: *Sphenolithus radians* Deflandre, 1952, sample JU-8.
Figure 20: *Sphenolithus radians* Deflandre, 1952, sample JA-7.
Figure 21: *Sphenolithus radians* Deflandre, 1952, sample PV-1.

All figures LM, 1000x, scale bar 5 µm. Figures 2, 8 and 10 PPL, others XPL.

Plate 19

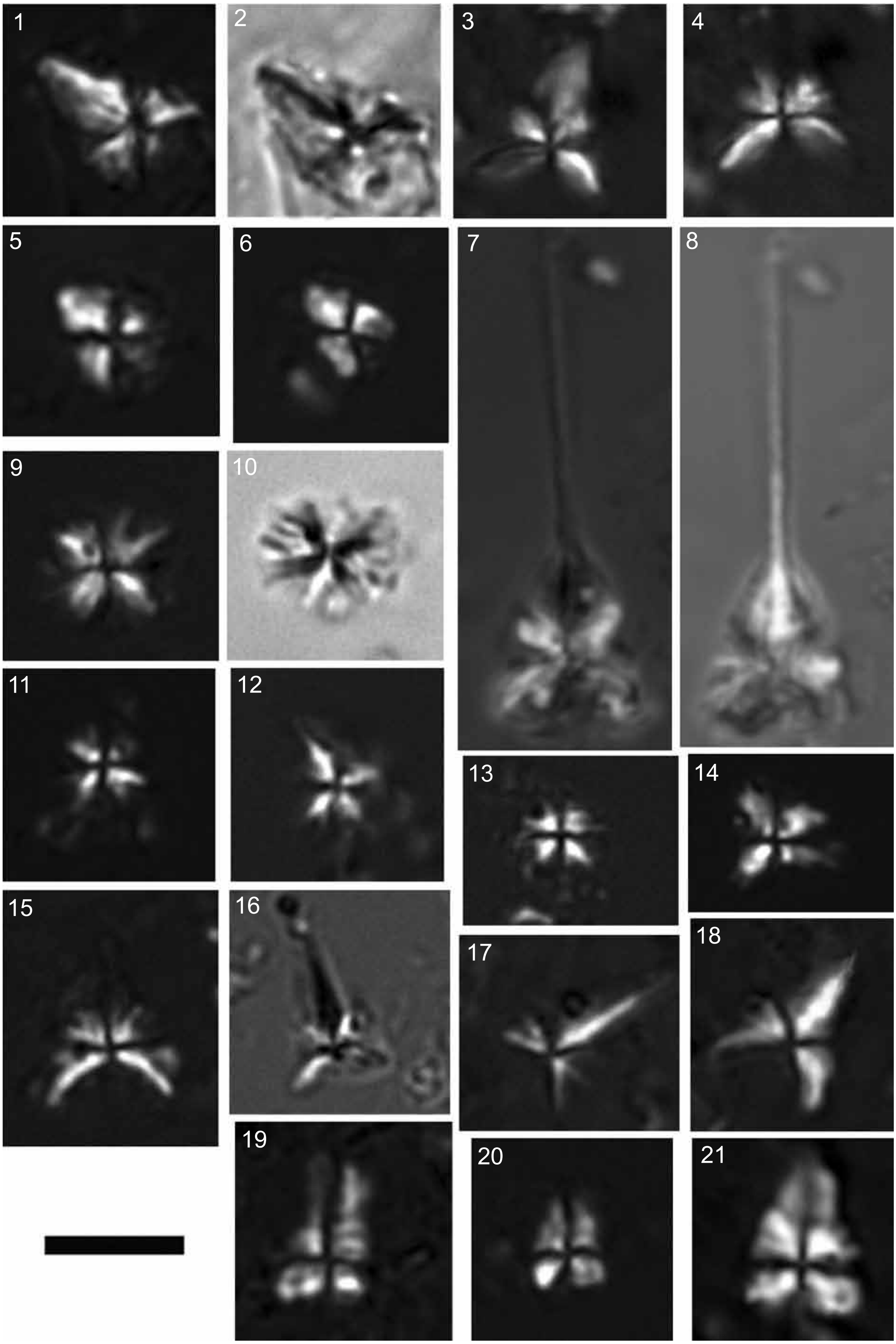

Plate 20

Figure 1: *Sphenolithus abies* Deflandre, 1954, sample LR-34.
Figure 2: *Sphenolithus moriformis* Bramlette & Wilcoxon, 1967, sample LR-34.
Figure 3: *Sphenolithus moriformis* Bramlette & Wilcoxon, 1967, sample LR-34.
Figure 4: *Sphenolithus moriformis* Bramlette & Wilcoxon, 1967, sample LR-34.
Figure 5: *Sphenolithus moriformis* Bramlette & Wilcoxon, 1967, sample LR-34.
Figure 6: *Sphenolithus moriformis* Bramlette & Wilcoxon, 1967, sample LR-34.
Figure 7: *Sphenolithus heteromorphus* Deflandre, 1953, sample PV-1.
Figure 8: *Sphenolithus abies* Deflandre, 1954, sample LR-34.
Figure 9: *Sphenolithus abies* Deflandre, 1954, sample LR-34.
Figure 10 *Orthorhabdulus serratus* Bramlette & Wilcoxon, 1967, sample PV-1.
Figure 11: *Sphenolithus heteromorphus* Deflandre, 1953, sample PV-1.
Figure 12 ?*Triquetrorhabdulus auritus* Stradner et allram, 1982, sample LR-34.
Figure 13: *Orthorhabdulus serratus* Bramlette & Wilcoxon, 1967, single blade morphotype, sample PV-1.
Figure 14: *Orthorhabdulus serratus* Bramlette & Wilcoxon, 1967, single blade morphotype, sample PV-1.
Figure 15: *Orthorhabdulus serratus* Bramlette & Wilcoxon, 1967, overgrown, sample PV-1.

All figures SEM, scale in each figure.

Plate 20

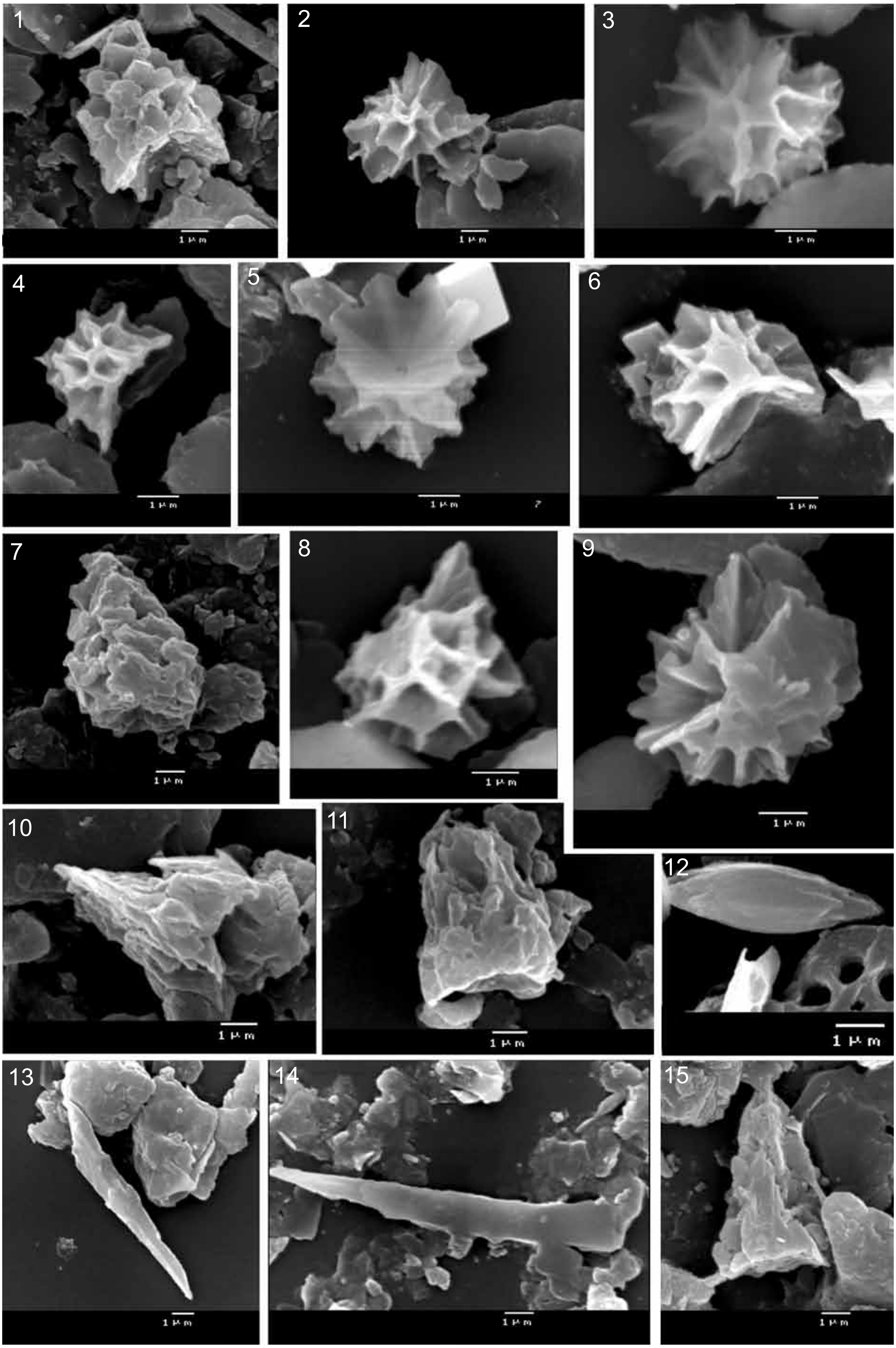

Plate 21

Figure 1*: ?*Discoaster* sp., sample JA-16.
Figure 2*: ?*Discoaster* sp., sample LR-35.
Figure 3: ?*Discoaster* sp., sample JU-45.
Figure 4: *Discoaster gemmeus* Stradner, 1959, sample JU-2.
Figure 5: *Discoaster binodosus* Martini, 1958, sample JU-41.
Figure 6*: *Discoaster tanii* Bramlette & Riedel, 1954, sample LR-35.
Figure 7: *Discoaster tanii* Bramlette & Riedel, 1954, sample JU-43.
Figure 8: *Discoaster deflandrei* Bramlette & Riedel, 1954, sample Lc-10.
Figure 9: *Discoaster druggii* Bramlette & Wilcoxon, 1967, sample JU-26.
Figure 10: *Discoaster druggii* Bramlette & Wilcoxon, 1967, sample PO-24.
Figure 11*: *Discoaster druggii* Bramlette & Wilcoxon, 1967, sample LR-35.
Figure 12: *Discoaster deflandrei* Bramlette & Riedel, 1954, sample JU-45.
Figure 13: *Discoaster aulakos* Gartner, 1967, sample ŠP-11.
Figure 14: *Discoaster aulakos* Gartner, 1967, sample PV-8.
Figure 15: *Discoaster deflandrei* Bramlette & Riedel, 1954, sample PO-20.
Figure 16: *Discoaster aulakos* Gartner, 1967, sample JU-43.
Figure 17: *Discoaster aulakos* Gartner, 1967, sample LR-34.
Figure 18: *Discoaster deflandrei* Bramlette & Riedel, 1954, sample LR-34.

Figures 1-16: LM, 1000x, scale bar 5 µm. Figures 1, 2, 3 and 11 XPL, others PPL.
Figures 17, 18: SEM, scale bar in each figure.
* film camera, scale approximate.

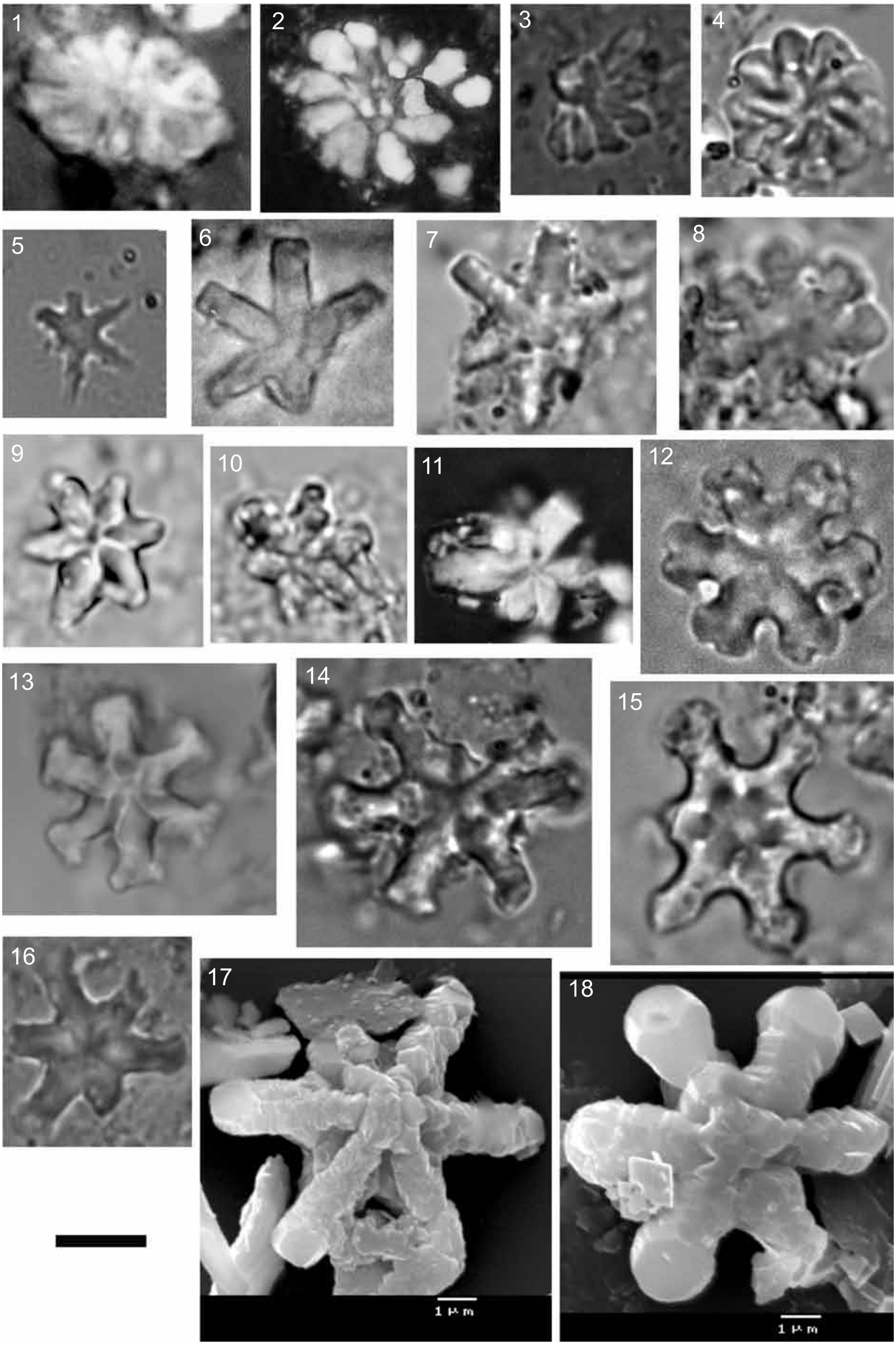
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Plate 22

Figure 1 *Discoaster formosus* Martini & Worsley, 1971, sample LR-38.
Figure 2 *Discoaster* cf. *musicus* Stradner, 1959, sample PO-15.
Figure 3 *Discoaster musicus* Stradner, 1959, sample LR-40.
Figure 4: *Discoaster adamanteus* Bramlette & Wilcoxon, 1967, sample LR-38.
Figure 5: *Discoaster adamanteus* Bramlette & Wilcoxon, 1967, sample JU-43.
Figure 6: *Discoaster stelullus* Gartner, 1967 emend. Jiang & Wise, 2006, proximal view, sample LR-39.
Figure 7: *Discoaster stelullus* Gartner, 1967 emend Jiang & Wise, 2006, proximal view, sample LR-37.
Figure 8: *Discoaster obtusus* Gartner, 1967, sample PO-35.
Figure 9*: *Discoaster stelullus* Gartner, 1967 emend. Jiang & Wise, 2006, proximal view, sample LR-33.
Figure 10: *Discoaster adamanteus* Bramlette & Wilcoxon, 1967, sample LR-34.
Figure 11: *Discoaster stelullus* Gartner, 1967 emend. Jiang & Wise, 2006, proximal view, sample LR-34.
Figure 12: *Discoaster stelullus* Gartner, 1967 emend. Jiang & Wise, 2006, distal view, sample LR-34.
Figure 13: *Discoaster formosus* Martini & Worsley, 1971, sample LR-35.
Figure 14: *Discoaster stelullus* Gartner, 1967 emend. Jiang & Wise, 2006, distal view, sample LR-35.
Figure 15: *Discoaster stelullus* Gartner, 1967 emend. Jiang & Wise, 2006, distal view, sample LR-35.

Figures 1-9: LM, 1000x, scale bar 5 µm. Figure 9 XPL, others PPL.
Figures 10-15: SEM, scale bar in each figure.
* film camera, scale approximate.

Plate 22

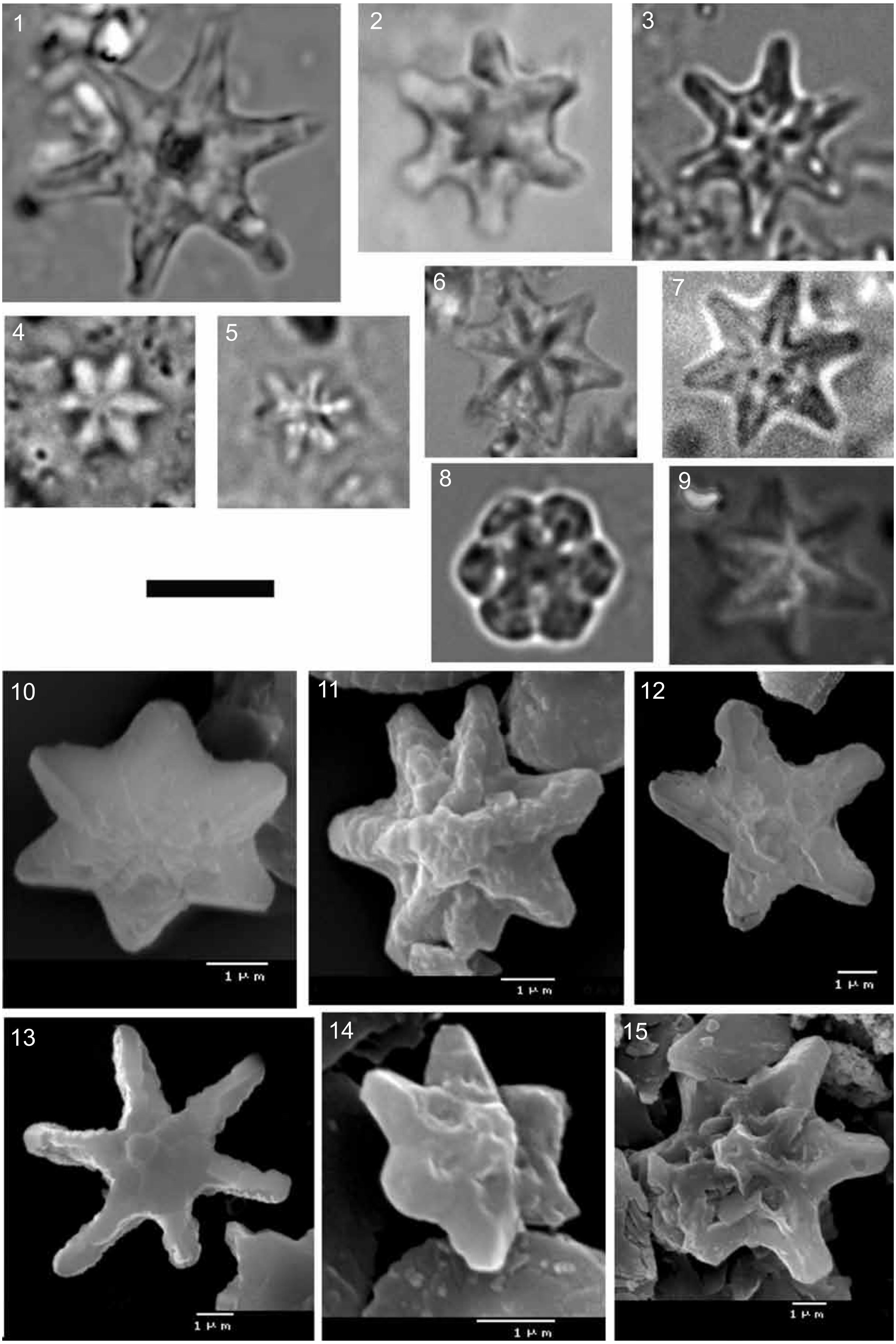


Plate 23

Figure 1: *Discoaster exilis* Martini & Bramlette, 1963, proximal view, sample LR-40.
Figure 2*: *Discoaster exilis* Martini & Bramlette, 1963, proximal view, sample LR-35.
Figure 3*: *Discoaster exilis* Martini & Bramlette, 1963, distal view, sample LR-35.
Figure 4: *Discoaster exilis* Martini & Bramlette, 1963, distal view (both specimens), sample LR-40.
Figure 5: *Discoaster variabilis* Martini & Bramlette, 1963, distal view, sample LR-38.
Figure 6: *Discoaster variabilis* Martini & Bramlette, 1963, distal view, sample LR-35.
Figure 7: *Discoaster variabilis* Martini & Bramlette, 1963, distal view, sample LR-1.
Figure 8: *Discoaster variabilis* Martini & Bramlette, 1963, distal view, sample JU-43.
Figure 9*: *Discoaster variabilis* Martini & Bramlette, 1963, proximal view, sample LR- 36.
Figure 10: *Discoaster variabilis* Martini & Bramlette, 1963, distal view, sample LR-34.
Figure 11: *Discoaster variabilis* Martini & Bramlette, 1963, proximal view, sample LR-35.
Figure 12: *Discoaster variabilis* Martini & Bramlette, 1963, distal view, sample LR-35.
Figure 13: *Discoaster exilis* Martini & Bramlette, 1963, distal view, sample LR-34.
Figure 14: *Discoaster exilis* Martini & Bramlette, 1963, distal view, sample LR-34.
Figure 15: *Discoaster exilis* Martini & Bramlette, 1963, distal view, sample LR-34.

Figures 1-9: LM, 1000x, PPL, scale bar 5 μm.
Figures 10-15: SEM, scale bar in each figure.
* film camera, scale approximate.

Plate 23

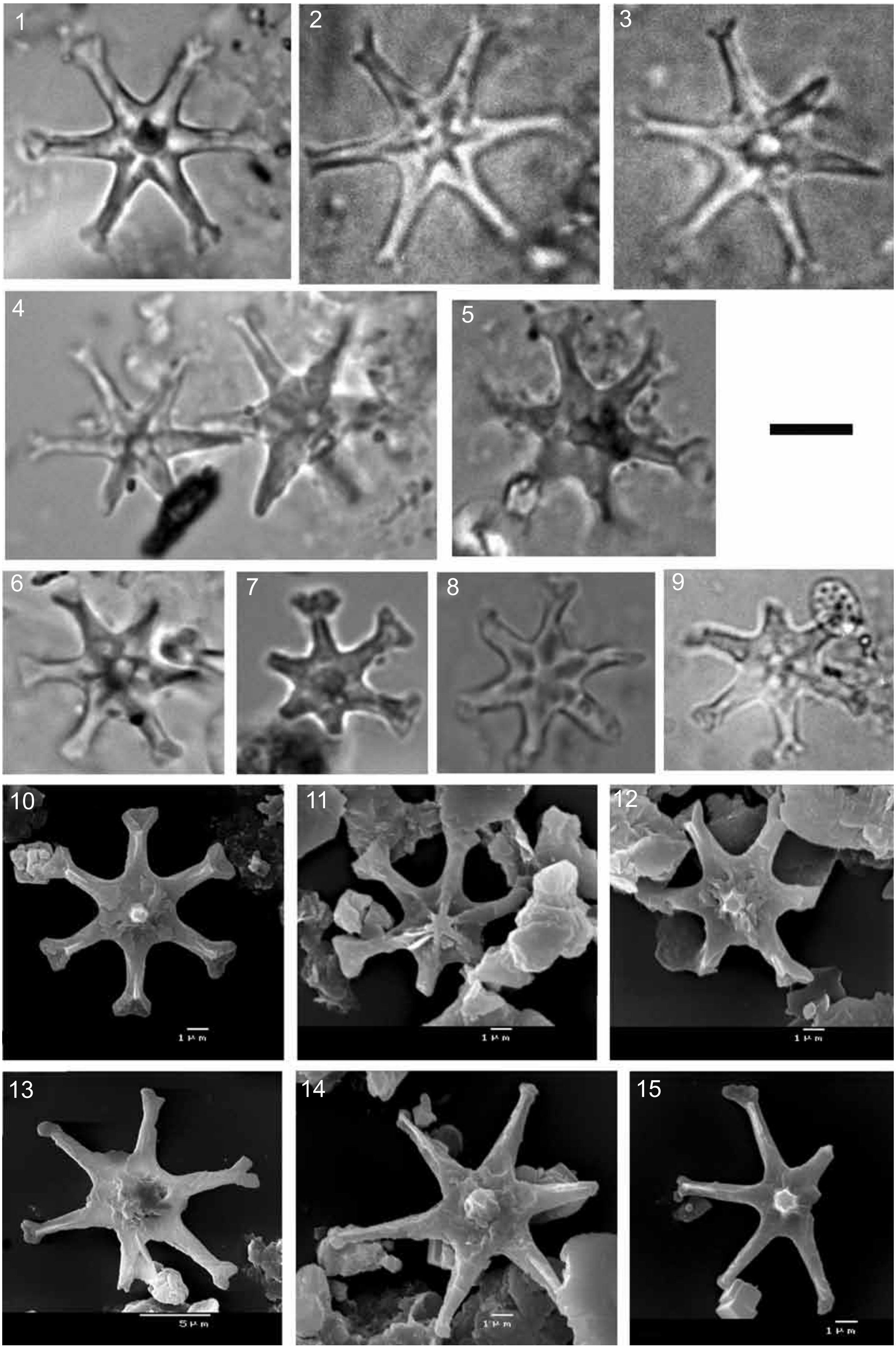


Plate 24

Figure 1*: *Discoaster moorei* Bukry, 1971, sample LR-34.
Figure 2*: *Discoaster moorei* Bukry, 1971, sample PV-15.
Figure 3: *Discoaster moorei* Bukry, 1971, sample LR-40.
Figure 4: *Discoaster braarudii* Bukry, 1971, sample LR-34.
Figure 5: *Discoaster braarudii* Bukry, 1971, sample LR-37.
Figure 6*: *Discoaster braarudii* Bukry, 1971, sample LR-34.
Figure 7: *Discoaster braarudii* Bukry, 1971, sample LR-38.
Figure 8: *Discoaster* aff. *kuglerii* Martini & Bramlette, 1963, sample LR-9.
Figure 9: *Discoaster* cf. *variabilis* Martini & Bramlette, 1963, sample LR-38.
Figure 10: *Discoaster* cf. *variabilis* Martini & Bramlette, 1963, sample LR-35.
Figure 11: *Discoaster* cf. *variabilis* Martini & Bramlette, 1963, sample LR-34.
Figure 12: *Discoaster braarudii* Bukry, 1971, sample LR-35.
Figure 13: *Discoaster braarudii* Bukry, 1971, sample LR-35.
Figure 14: *Discoaster braarudii* Bukry, 1971, sample LR-35.
Figure 15: *Discoaster moorei* Bukry, 1971, sample LR-34.
Figure 16: *Discoaster* aff. *kugleri* Martini & Bramlette, 1963, sample LR-35.
Figure 17: *Discoaster* aff. *kugleri* Martini & Bramlette, 1963, sample LR-35.

Figures 1-11: LM, 1000x, PPL, scale bar 5 µm.
Figures 12-17: SEM, scale bar in each figure.
* film camera, scale approximate.

Plate 24

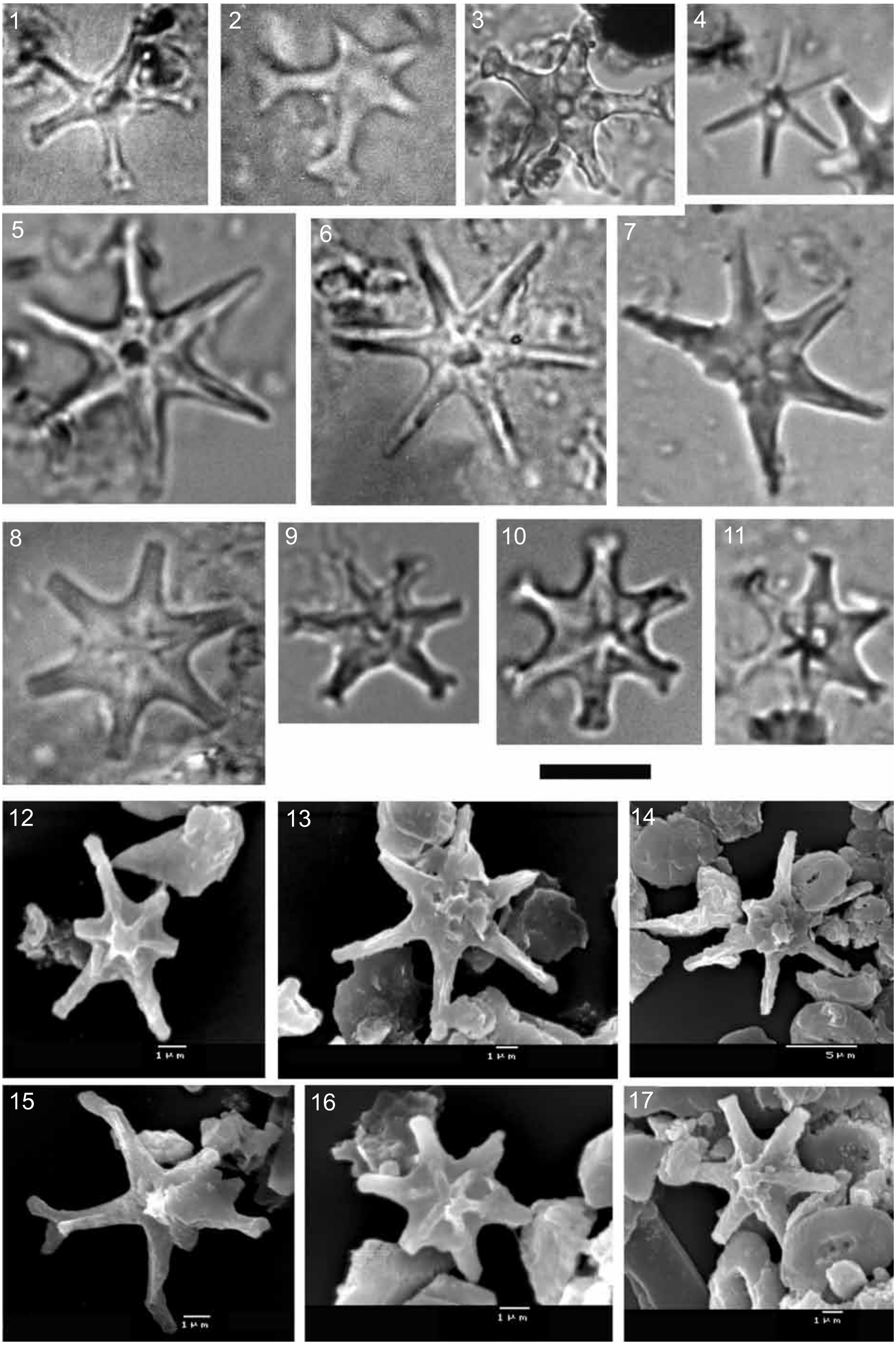
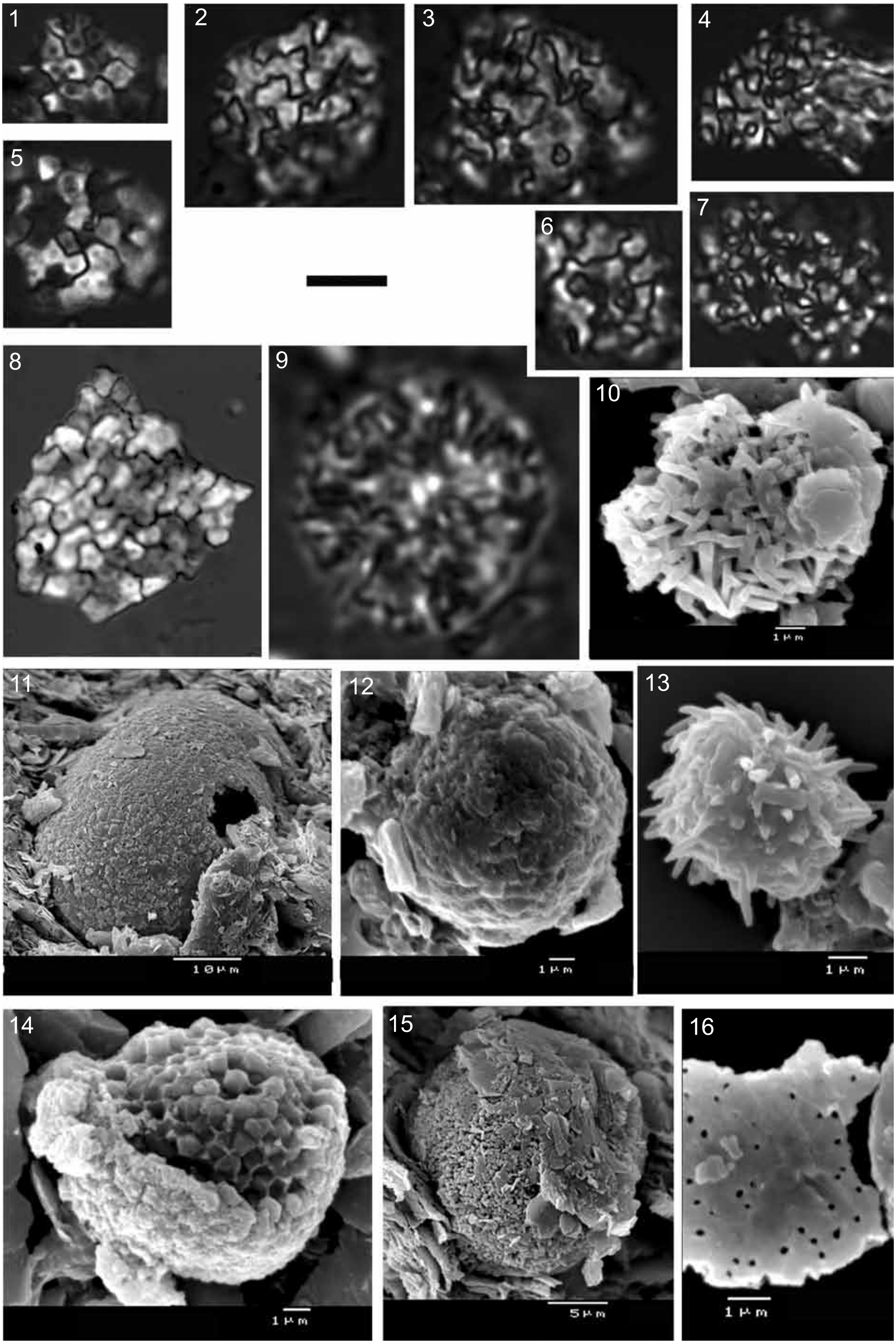


Plate 25

Figure 1: *Thoracosphaera heimii* (Lohman, 1919) Kamptner, 1954, sample LR-4.
Figure 2: *Thoracosphaera saxea* Jafar, 1975, sample PV-2.
Figure 3: *Thoracosphaera saxea* Stradner, 1961, sample PV-10.
Figure 4: *Thoracosphaera fossata* Jafar, 1975, sample JA-16.
Figure 5: *Thoracosphaera heimii* (Lohman, 1919) Kamptner, 1954, sample PV-15.
Figure 6: *Thoracosphaera saxea* Stradner, 1961, sample PV-10.
Figure 7: *Thoracosphaera fossata* Jafar, 1975, sample LE-7.
Figure 8: *Thoracosphaera heimii* (Lohman, 1919) Kamptner, 1954, sample Lc-10.
Figure 9: *Thoracosphaera fossata* Jafar, 1975, calcisphere, sample PO-10.
Figure 10: *Peridinium* sp., calcisphere - part, sample LR-35.
Figure 11: *Thoracosphaera saxea* Stradner, 1961, calcisphere, sample PV-1.
Figure 12: Calcisphere, sample LR-35.
Figure 13: ?Calcisphere, sample LR-35.
Figure 14: *Thoracosphaera saxea* Stradner, 1961, calcisphere filled up with pyrite crystals, sample LR-35.
Figure 15: Calcisphere, sample LR-35.
Figure 16: Calcisphere, fragment, sample PV-1.

Figures 1-9: LM, 1000x, XPL, scale bar 5 μm.
Figures 10-16: SEM, scale bar in each figure.

Plate 25



APPENDIX: NANNOPLANKTON ASSEMBLAGE COMPOSITION

Tables 1-13 show nannoplankton assemblages from all examined samples and the semi-quantitative abundance estimations for all species. The latter are represented by black dots of 4 different sizes, depending on their realative abundance (see legend). For further explanation see chapter 2.3.

The preservation of nannofossils in each sample is described with one of the following categories:

good: well preserved material without obvious signs of overgrowth or dissolution,

moderate: moderately well preserved material showing signs of overgrowth or dissolution,

poor: poorly preserved material. Most specimens badly damaged,

barren: sample barren of nannofossils.

The species are listed in alphabetical order. Allochthonous species are separated from the autochthonous species which constitute Badenian nannoplankton assemblages. The number of autochthonous and allochthonous species in each sample is given as well.

During the original examination *Reticulofenestra gelida* in *Reticulofenestra minutula* were considered as morphotypes of *R. pseudoumbilica* in *R. haquii* respectively, and their presence was not recorded. Because of their potential palaeoecological significance, some samples were re-examined to determine their presence. In the case of some sections (Lenart–avtocesta 0 and 1, Lenart – lower part, Zimica, Zgornji Duplek 1 and 2, Vinička vas) all samples were re-examined in this respect, while in the case of other sections only some samples were selected (and are marked with asterisks – like ZP-1*).

Legend to tables 1-13

ABUNDANCE		PRESERVATION	
·	few	**G**	good
•	rare	**M**	medium
●	common	**P**	poor
⬤	abundant	**B**	barren

Table 1: Zgornje Partinje section

SAMPLE	ZP-1*	ZP-2	ZP-3	ZP-4	ZP-5	ZP-6	ZP-7*	ZP-8	ZP-9	ZP-10	ZP-11	ZP-12*	ZP-13	ZP-14-18
SPECIES \ PRESERVATION	M	P	P	P	P	P	M	P	P	P	P	P	P	B
Braarudisphaera bigelowii							•							
Calciosolenia sp.							•							
Coccolithus pelagicus			•	•	•	•	●	•	•	•	•		•	
Cyclicargolithus floridanus	•		•		•	•	•			•	•			
Helicosphaera ampliaperta	•						•							
Helicosphaera carteri	●	●	●	•	●	●	●	●	●	•	●	•	•	
Helicosphaera obliqua							•							
Helicosphaera vedderi							•							
Reticulofenestra haqii			•		•	•	•			•				
Reticulofenestra minutula							•							
R. pseudoumbilica (<7µm)	•			•			•			•				
Sphenolithus heteromorphus		•	•	•	•		•	•	•	•				
Sphenolithus moriformis	•						•		•	•				
Autochtonous species (No.)	6	2	5	4	5	4	13	3	4	7	3	1	2	0
Coccolithus formosus	•													
Redeposited species (No.)	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2: Jakobski Dol 1 section

SAMPLE	JA-1	JA-2	JA-3*	JA-4	JA-5	JA-6	JA-7	JA-8*	JA-9	JA-10	JA-11	JA-12	JA-13	JA-14*	JA-15	JA-16	JA-17	JA-18*	JA-19	JA-20	JA-21	JA-22	JA-23	JA-24*	JA-25	JA-27	JA-30*	JA 26, 28, 29, 31-36
SPECIES \ PRESERVATION	P	P	M	P	P	P	P	M	P	P	P	P	P	M	M	P	P	M	P	P	P	P	M	M	P	P	M	B
Braarudosphaera bigelowii			.																									
Calcidiscus leptoporus			.																									
Coccolithus miopelagicus			.			.		.						.				.				.	.	•			•	
Coccolithus pelagicus	•	•	●	•	•	•	•	●	•	•	•	.	•	●	●	•	•	•	•	•	•	•	•	●	.	.	●	
Coronocyclus nitescens			.					.							.								.					
Cyclicargolithus floridanus			•	.		•	.	•		.			.	.	•	.	.	•	.	•	•	.	•	•		.	•	
Discoaster adamantheus		.																										
Discoaster deflandrei								.		.	.			.				.						.		.		
Helicosphaera ampliaperta			.					.						.	.			.						.				
Helicosphaera carteri	.		•	.		•	•	•	.			.	.	•	•		•	•		.	.	.	•	●		.	●	
Helicosphaera euphratis			.																									
Helicosphaera intermedia								.																				
Helicosphaera minuta																											.	
H. perch-nielseniae																								.			.	
Helicosphaera scissura			.			.		.							.									.				
Pontosphaera callosa								.																				
Pontosphaera multipora			.			.		.				.		•	.			.	.	.		.	.	.			•	
Reticulofenestra gelida														.				.						.			.	
Reticulofenestra haqii	.		.	•		•	.	.					.	.			.	.	.			.	.	•			•	
Reticulofenestra minuta			●	•		.		•		.				.			.	●	.		.		.	•		.	●	
Reticulofenestra minutula			.											.										.			•	
Reticulofenestra perplexa																		.						.				
R. pseudoumbilica (<7 µm)								.																			.	
Rhabdosphaera sicca														.													.	
Scyphosphaera amphora								.							.													
Sphenolithus heteromorphus			.	.		.	.	•			.			.	.	•	.	.		.	.	.	.	.			.	
Sphenolithus moriformis			.	.			.	.						.	.		.	.	.					•			.	
Syracolithus schilleri			.																									
Thoracosphaera fossata			.			.	.	.	.	.				•		.	.	.	.	.		.	.	.			.	
Thoracosphaera heimii																								.				
Umbilicosphaera jafari																								.				
Umbilicosphaera rotula							.	.																.			.	
Autochtonous species (No.)	3	2	18	7	1	10	8	19	3	5	3	3	4	15	10	4	8	14	7	6	5	8	10	20	1	5	17	0
Biantholithus sparsus								.								.												
Coccolithus formosus			.																					.				
Cribrocentrum reticulatum																								.				
Cyclicargolithus abisectus														.														
Discoaster sp.								.								.												
Discoaster obtusus								.																.				
Pontosphaera desueta																											.	
Pontosphaera plana											.																	
Reticulofenestra bisecta								.						.									.	.		.	.	
Reticulofenestra lockeri								.															.					
Reticulofenestra scrippsae			.					•					.	.				.						.				
Reticulofenestra umbilica								.																				
Sphenolithus radians							.																					
Watznaueria barnesae								.						.									.	.				
Transversopontis pulcher				.																				.				
Redeposited species (No.)	0	0	2	1	0	0	1	8	0	0	1	0	1	4	0	2	0	1	0	0	0	0	3	7	0	1	2	0

Table 3: Jakobski Dol 2 section

SAMPLE	JAK-1*	JAK-2	JAK-3	JAK-4	JAK-5*	JAK-6	JAK-7	JAK-8	JAK-9*	JAK-10	JAK-11	JAK-12	JAK-13*	JAK-14	JAK-15
SPECIES \ PRESERVATION	G	M	G	M	M	M	M	M	M	M	M	M	G	M	P
Braarudosphaera bigelowii					.										
Calcidiscus leptoporus					.										
Calciosolenia sp.	.														
Coccolithus miopelagicus	.	.	•	.	.	.	.	•	.	•		.	•	.	
Coccolithus pelagicus	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Coccolithus streckeri	.												.		
Cyclicargolithus floridanus	•	•	.	.	•	•	•	•	•	●	•	●	•	•	•
Discoaster deflandrei	.														
Discoaster exilis	.										.				
Discoaster formosus		.													
Discoaster spp.	.	.	.		.					.		.			
H. perch-nielseniae													.		
Helicosphaera carteri	●	●	•	•	•	•	●	•	•	•	•	•	●	•	
Helicosphaera granulata										.					
Helicosphaera minuta	•	•	.	.	•	.	.	•	•	.	•	.	•	.	.
Helicosphaera obliqua			.												
Helicosphaera scissura	.		.	.	.				.			.	.		
Helicosphaera vedderi	.				.										
Orthorhabdus serratus													.		
Pontosphaera callosa	.		.										.		
Pontosphaera multipora	.	.		.			.	.	.		.	.	.		•
Reticulofenestra gelida	.								.						
Reticulofenestra haqii	•	•	•	.	.	•	●	●	•	•	•	●	•	•	•
Reticulofenestra minuta	●	⬤	⬤	●	●	⬤	⬤	⬤	●	⬤	●	●	•	●	●
Reticulofenestra minutula	.								.				.		
Reticulofenestra perplexa	•				.				•				.		
R. pseudoumbilica (<7µm)	•	•	•	.	.	.	.	.	•	.	.		.		.
Sphenolithus heteromorphus	.		.	.	.			.	.		.	•	.		•
Sphenolithus moriformis	.	.	.	•	.	.	.	.			.		.	•	.
Syracolithus schilleri	.														
Syracosphaera sp.	.		.		.			.	.			.	.		
Thoracosphaera heimii									.						
Thoracosphaera tuberosa	.	.										.		.	
Umbilicosphaera jafari	•					.			.						
Umbilicosphaera rotula			.	.				.	.						
Autochtonous species (No.)	26	13	16	13	17	10	10	13	18	10	11	13	19	9	8
Biantholithus sparsus		.													
Coccolithus formosus	.			.									.		
Cribrocentrum reticulatum			.												
Cyclicargolithus abisectus	.				.										
Discoaster gemmeus									.						
Helicosphaera compacta			.						.						
Helicosphaera mediterranea										.					
Helicosphaera recta													.		
Micrantholithus flos	.														
Microrhabdulus decoratus		.													
Micula concava	.														
Pontosphaera plana							.				.			.	
Reticulofenestra bisecta	.	.		•	.			.	.	.			.	.	
Reticulofenestra callida					.			.	.						
Reticulofenestra lockeri		.	.												
Reticulofenestra scrippsae	.								.						
Reticulofenestra umbilica	.				.			.							
Watznaueria barnesae	.	.	.	.	.			.	.	.		.			.
Transversopontis exilis														.	
Zygrhablithus bijugatus	.	.			.				.			.			
Redeposited species (No.)	9	6	4	3	6	0	1	4	7	3	1	2	3	3	1

Table 4: Šentilj-Polička vas section

SAMPLE	ŠP-1*	ŠP-2	ŠP-3	ŠP-4*	ŠP-5	ŠP-6	ŠP-7	ŠP-8*	ŠP-9	ŠP-10	ŠP-11*	ŠP-12	ŠP-13	ŠP-14*	ŠP-15	ŠP-16	ŠP-17-23
SPECIES \PRESERVATION	M	M	M	M	M	M	M	G	P	P	M	M	M	M	P	M	B
Braarudosphaera bigelowii									·	·	•	·				·	
Calcidiscus leptoporus		·															
Calciosolenia sp.	•			·				·									
Coccolithus miopelagicus	•	·	·				·	·	·		·		·		·		
Coccolithus pelagicus	●	●	●	●	●	●	●	●	●	•	●	●	●	●	●	●	
Coccolithus streckeri								·									
Coronocyclus nitescens	·		·														
Cyclicargolithus floridanus	•		•	·	•	•	·	·	•	·	·	•	•	·	•	•	
Discoaster adamantheus	·															·	
Discoaster aulacos											·						
Discoaster deflandrei	·	·	·		·	·										·	
Discoaster exilis	·																
Discoaster sp.			·	·				·	•	·	·	·	•	·	·		
Discoaster stellulus	·							·									
Helicosphaera carteri	•	•	●	●	●	●	●	•	·	·	●	•	•	•	•	•	
Helicosphaera intermedia	·		·		·			·		·	·	·					
Helicosphaera minuta	·	·	·		·	·		·	·		·	·	·	·	·	•	
Helicosphaera scissura	·																
Orthorhabdus serratus	•			·				·									
Pontosphaera callosa								·			·						
Pontosphaera multipora	·	·	·	·	·	·	·	•	·	·		·	·				
Reticulofenestra gelida	·			•				·			•			•			
Reticulofenestra haqii	•	•	·	·	·			•						·			
Reticulofenestra minuta	·		·	·	·									·		·	
Reticulofenestra minutula	·			·													
Reticulofenestra perplexa	·							·			·						
R. pseudoumbilica (<7μm)	·		·	·			·							·			
Rhabdosphaera sicca	·						·										
Sphenolithus heteromorphus	·	·		·	·		·			·	•	•	·		·	·	
Sphenolithus moriformis	•	·	•	·	•		·	•	·	·	•	·	·	·	·	·	
Syracosphaera sp.	·						·	·									
Thoracosphaera fossata	·																
Thoracosphaera heimii	·			·			·		·	·	·	·				·	
Thoracosphaera saxea			·	·	·	·	·	·		·	·		·		·	·	
Umbilicosphaera rotula			·					·							·		
Autochtonous species (No.)	27	10	16	16	12	7	12	20	10	11	16	11	10	10	10	12	0
Coccolithus formosus	·				·		·				·		·				
Cribrocentrum reticulatum								·			·						
Discoaster gemmeus	·								·								
Pontosphaera plana							·										
Reticulofenestra bisecta	·	·	·	·	·		·	·			·			·		·	
Reticulofenestra callida	·																
Reticulofenestra scrippsae				·					·			·					
Reticulofenestra umbilica											·						
Sphenolithus conicus	·		·					·									
Zygrhablithus bijugatus			·														
Redeposited species (No.)	5	1	3	2	2	0	3	3	2	0	4	1	1	1	0	1	0

Table 5: Križišče Partinje-Varda section

SAMPLE	KPV-1*	KPV-2	KPV-3	KPV-4*	KPV-5	KPV-6	KPV-7	KPV-8*	KPV-9	KPV-10	KPV-11	KPV-12*	KPV-13	KPV-14
SPECIES \ PRESERVATION	M	M	P	M	M	P	M	M	P	P	P	M	P	P
Braarudosphaera bigelowii							.							
Calcidiscus leptoporus								.				.		
Calcidiscus premacintyrei	.													.
Calciosolenia sp.	.													
Coccolithus miopelagicus				.			.	.		.	.		.	.
Coccolithus pelagicus	•	•	•	●	•	•	●	•	•	●	•	•	•	•
Cyclicargolithus floridanus	.		•	.	•		.		.	.	.	.	.	.
Discoaster variabilis				.					.					
Discoaster sp.		.					.							
Helicosphaera carteri	•	•	•	●	•	•	•	●	•	•	•	•	•	•
H. perch-nielseniae		.		•				.						
Helicosphaera granulata						.								
Helicosphaera intermedia							.							
Helicosphaera minuta	.			.	.				.					
Helicosphaera wallichii							.	.				.	.	
Helicosphaera vedderi				.										
Helicosphaera waltrans	.	.		•			.	•		.	.	.	.	
Pontosphaera multipora							.							
Reticulofenestra gelida								.						
Reticulofenestra haqii	.			•			●	•	•	.	.			.
Reticulofenestra minuta	•	•	•	●	•	●	●	●	•	•	•	•	•	•
Reticulofenestra minutula	.			.				.				.		
Reticulofenestra perplexa				•				.						
R. pseudoumbilica (<7μm)				.				.					.	
Rhabdosphaera sicca				.	.		.		.				.	
Scyphosphaera amphora				.				.						
Sphenolithus heteromorphus	.	.		•	.	.	.	.		.	.	.	.	.
Sphenolithus moriformis	.		.	.	.		.	.	.	.	.		.	.
Syracolithus schilleri									.					
Thoracosphaera fossata		.		.				.	.	.	.	.	.	.
Thoracosphaera heimii							.			.				
Thoracosphaera saxea	.			.			.	.						
Umbilicosphaera jafari												.		
Umbilicosphaera rotula				.			.		.					
Autochtonous species (No.)	13	8	5	21	8	5	18	18	12	11	10	11	12	10
Coccolithus formosus								.						
Cribrocentrun reticulatum	.													
Cyclicargolithus abisectus		.												
Pontosphaera plana				.										
Reticulofenestra bisecta				.				.						
Reticulofenestra scrippsae												.	.	
Sphenolithus conicus				.				.						
Sphenolithus radians											.			
Watznaueria barnesae								.						
Redeposited species (No.)	1	1	0	3	0	0	0	4	0	0	1	1	1	0

Table 6: Lenart–avtocesta 0 and 1 sections

SAMPLE	Lat-1	Lc-1	Lc-2	Lc-3	Lc-4	Lc-5	Lc-6	Lc-7	Lc-8	Lc-9	Lc-10	Lc-11	Lc-12	Lc-13
SPECIES \ PRESERVATION	M	M	M	M	M	M	M	M	M	M	P	M	P	P
Calcidiscus leptoporus			·								·	·		
Calciosolenia sp.	·	·					·				·			
Coccolithus miopelagicus	·	·	·	·	·		·	·		·	·	·		
Coccolithus pelagicus	●	●	●	●	●	•	●	●	●	●	•	●	·	·
Coronocyclus nitescens									·			·		
Cyclicargolithus floridanus	·		·	·		·	·		·	·				
Discoaster deflandrei	·										·			
Helicosphaera carteri	●	●	•	●	●	•	●	●	●	●	●	•	·	·
Helicosphaera granulata				·			·							
Helicosphaera intermedia			·							·				
Helicosphaera minuta	•	•	·	•	·	·	•	·	·	•	·	·		
H. perch-nielseniae			·				·			·		·		
Helicosphaera vedderi					·					·	·			
Helicosphaera waltrans	·		·	·	·		·							
Orthorhabdus serratus	•	·		•		·								
Pontosphaera callosa											·			
Pontosphaera multipora	•			·			·	·	·			·		
Reticulofenestra gelida	·	•	•	•	•	·	·	•	·	•	•	•	·	·
Reticulofenestra haqii	•	•	●	•	•	·	·	•	•	•	·	•	·	
Reticulofenestra minuta		●	●	●	●	•	●	●	●	●	•	●	·	
Reticulofenestra minutula	•	·		·	·	·		·		·		·		
Reticulofenestra perplexa				·		·								
R. pseudoumbilica (<7μm)		•		•	•	·	•	·	•	·	·	·		
Rhabdosphaera procera					·						·			
Rhabdosphaera sicca										·				
Sphenolithus heteromorphus	·	·	·	·	·	·	·	·	·	•		·	·	
Sphenolithus moriformis	·	·		·	·	·			·	·		·		
Syracosphaera sp.				·	·				·				·	
Thoracosphaera fossata	·								·				·	·
Thoracosphaera heimii										·	·			
Thoracosphaera saxea								·				·		
Umbilicosphaera rotula		·												
Umbilicosphaera jafari														
Autochtonous species (No.)	16	14	13	18	15	13	15	12	14	17	15	16	8	4
Cribrocentrum reticulatum										·	·			
Pontosphaera desueta									·					
Pontosphaera latelliptica					·									
Reticulofenestra bisecta				·						·				
Reticulofenestra scrippsae		·				·								
Watznaueria barnesae		·			·		·							
Redeposited species (No.)	0	2	0	1	2	1	1	0	1	2	1	0	0	0

Table 7: Lenart–avtocesta 2 section

SAMPLE	Lac-1-3	Lac-4	Lac-5	Lac-6	Lac-7	Lac-8	Lac-9	Lac-10	Lac-11	Lac-12	Lac-13	Lac-14	Lac-15
SPECIES \ PRESERVATION	B	P	M	M	P	P	M	M	P	P	M	M	M
Braarudosphaera bigelowii		·		·		•	·				·	·	·
Calcidiscus premacintyrei						·							·
Calciosolenia sp.			·	·			·						
Coccolithus miopelagicus		·	•	·	·		·	·		·	·	·	·
Coccolithus pelagicus		●	●	•	●	●	●	●	•	•	•	●	●
Coronocyclus nitescens				·									
Cyclicargolithus floridanus		·	·		•	·	·	·		·	·		·
Disciaster variabilis			·			·	·				·		·
Discoaster deflandrei							·						·
Discoaster exilis		·											
Helicosphaera carteri		●	●	•	●	●	●	●	•	●	·	•	●
Helicosphaera granulata								·				·	
Helicosphaera minuta			·	·							·		·
Pontosphaera multipora		·			·	·	·						·
Reticulofenestra gelida			·					·					·
Reticulofenestra haqii			·		·	•	·	•		·	•	•	•
Reticulofenestra minuta		•	•	•	●	•	•	●		●	⬤	●	●
Reticulofenestra minutula								·					·
R. pseudoumbilica (<7μm)		·											·
Rhabdosphaera sicca						·							
Sphenolithus heteromorphus		•	·		•	•	·	•			•	•	•
Sphenolithus moriformis		·			·		·	·			·	·	•
Syracolithus schilleri			·										·
Syracosphaera sp.													·
Thoracosphaera fossata			·		·		·	·			·	·	·
Thoracosphaera heimii			·	·	·		·		·				·
Umbilicosphaera rotula								·			·		
Umbilicosphaera jafari		•											·
Autochtonous species (No.)	0	12	14	9	11	11	15	13	3	6	13	10	22
Biantholithus sparsus													·
Coccolithus formosus		·											·
Micrantholithus sp.		·						·					·
Pontosphaera plana		·											
Reticulofenestra bisecta		·					·		·				·
Reticulofenestra callida													·
Reticulofenestra scrippsae													·
Reticulofenestra umbilica								·					
Sphenolithus conicus				·									·
Sphenolithus cf. *delphix*			·										
Transversopontis pulcheroides			·										
Watznaueria barnesae		·				·		·					
Redeposited species (No.)	0	5	2	1	0	1	1	3	1	0	0	0	7

Table 8A: Partinje section (samples PO 1-20)

SAMPLE	PO-1*	PO-2	PO-3	PO-4	PO-5*	PO-6	PO-7	PO-8	PO-9	PO-10*	PO-11	PO-12	PO-13	PO-14	PO-15*	PO-16	PO-17	PO-18	PO-19	PO-20*
SPECIES \ PRESERVATION	M	M	M	G	G	M	G	M	M	M	M	M	M	M	M	P	P	M	P	M
Braarudosphaera bigelowii				.						.	.		.							
Calcidiscus leptoporus						.														
Calcidiscus premacintyrei																				.
Coccolithus miopelagicus					.	.				.	.				.					
Coccolithus pelagicus	•	●	●	●	●	●	●	●	•	●	●	●	●	●	•	•	•	•	●	●
Cyclicargolithus floridanus	.	.	.	.	.	.	.	.	.	•	.	•	.	.	•	.	.	•	•	.
Discoaster adamantheus								.												
Discoaster deflandrei				.	.	.														.
Discoaster aff. *kugleri*															.					.
Discoaster variabilis	.	.		.	.	.	.			.		.					.			.
Helicosphaera carteri	●	●	●	●	•	●	●	●	●	●	●	●	●	●	●	●	•	●	•	●
Helicosphaera intermedia										.										
Helicosphaera minuta	.		.		.	.	.	.		•	.	.	.	.	•			.		•
Helicosphaera vedderi	.				.						.									
H. walbersdorfensis																				.
Helicosphaera wallichii										.	.	.								
Helicosphaera waltrans	•		.	.	•	.	.		.	.			.	.	.					•
Pontosphaera callosa					.		.								.					
Pontosphaera multipora	.			.			.	.		.		.		.						.
Reticulofenestra gelida	•				•					•					.					.
Reticulofenestra haqii	.	•			.	.	.	•	.		.			.	.		.	.	.	.
Reticulofenestra minuta	●	●	●	⬤	●	●	⬤	●	●	●	⬤	●	●	●				•	.	●
Reticulofenestra minutula	.									.										.
R. pseudoumbilica (<7µm)	•	.	•	●	●	.	•	•	.	●	.	●	•	●	●			•		•
Rhabdosphaera sicca	.	.	•	.	.	•	.	.	.	.	.	.								
Sphenolithus abies											.			.						
Sphenolithus heteromorphus	•	●	●	●	.	●	•	•	●	•	●		•	•		.	.		.	•
Sphenolithus moriformis	.	.	.	•	•	.	.			.		.	.	.		.	.			.
Syracolithus schilleri					.			.								.				
Syracosphaera sp.	.		.	.	.	.	.		.			.								
Thoracosphaera heimii	.																			
Thoracosphaera fossata										.										.
Thoracosphaera saxea	.	.	.	.	.	.	.		.	.	.	.		.						.
Umbilicosphaera jafari			.	.	.			.	.					.						
Autochtonous species (No.)	19	11	13	16	21	17	16	13	12	20	15	13	10	14	11	6	7	7	6	20
Cribrocentrum reticulatum	.									.										
Discoaster obtusus																				
H. perch-nielseniae											.									
Helicosphaera recta	.		.			.				.	•	•	•	•	.					
Pontosphaera plana									.		.									
Reticulofenestra bisecta			.	.	.					.	.									
Sphenolithus conicus	.	•	•	.						.	.									
Sphenolithus cf. *delphix*	•						.			.	.									.
Traversopontis pulcheroides				.							.									
Tribrachiatus orthostylus							.													
Watznaueria barnesae	.		.		.	.		.		.		.						.	.	.
Zyghrablithus bijugatus					.															
Redeposited species (No.)	5	1	4	3	3	2	2	1	1	6	7	2	1	1	1	0	0	1	1	2

Table 8B: Partinje section (samples PO 21-45)

SAMPLE	PO-21	PO-22	PO-23	PO-24	PO-25*	PO-26	PO-27	PO-28	PO-29*	PO-30	PO-31	PO-32	PO-33	PO-34	PO-35*	PO-36	PO-37	PO-38	PO-39	PO-40-45
SPECIES \ PRESERVATION	P	P	P	G	M	G	M	M	G*	P	M	M	G	G	G*	M	M	M	P	B
Braarudosphaera bigelowii			.	.					.		.				.					
Calcidiscus leptoporus									.											
Calcidiscus premacintyrei													.							
Coccolithus miopelagicus				.			.	.			.		.	.	.	.			.	
Coccolithus pelagicus	●	•	●	●	●	●	●	●	●	•	●	●	●	•	●	●	●	●	•	
Cyclicargolithus floridanus	.		•	•	.	•	•	•	•	•	•	•	•	•	.	•	.	.	.	
Discoaster adamantheus															.					
Discoaster aulacos															.					
Discoaster deflandrei			.					.												
Discoaster formosus																		.		
Discoaster variabilis								.					.	.		.	.		.	
Helicosphaera carteri	●	●	●	●	●	●	●	●	●	•	●	●	●	●	●	●	●	●	●	
Helicosphaera intermedia				.													.			
Helicosphaera minuta	.	.		•	.	.	.	.					.				.	.		
Helicosphaera vedderi						.	.	.	.	.			.	.		.			.	
H. walbersdorfensis						.			.	.			.	.						
Helicosphaera wallichii	.		.	.	.											.				
Helicosphaera waltrans				•	.	.		.		.		.	.	.						
Pontosphaera callosa	.														.					
Pontosphaera multipora			.	.			.		.		.		.	.		.			.	
Reticulofenestra gelida					.				.						.					
Reticulofenestra haqii			•	.	.			.	•		.	•			.	.	•	•		
Reticulofenestra minuta				⬤	●	⬤	●	●	●	•	●	⬤	⬤	●	⬤	●	⬤	●	●	
Reticulofenestra minutula					.				.						•					
R. pseudoumbilica (<7µm)	•	•	•	●	●	●	•		●	.	•	●	●	•	.	•	•	.		
Rhabdosphaera sicca								.	.		.		•	.	.	.				
Sphenolithus abies																			.	
Sphenolithus heteromorphus	•	.	.	●	•	.	•	•	●		.	•	●	•	•	•	•	.	.	
Sphenolithus moriformis			.	•		.	•	.	.		.	.	.	.		.		.		
Syracolithus schilleri										.							.			
Syracosphaera sp.											.		.	.						
Thoracosphaera fossata							.	.	.											
Thoracosphaera saxea	.			.	.	.			.		.			.		.	.	.		
Umbilicosphaera jafari				•			.	.	.	.	.		.						.	
Autochtonous species (No.)	9	5	11	17	13	12	13	16	19	10	15	9	18	16	15	15	12	11	11	0
?Biantholithus sparsus							.													
Cribrocentrum reticulatum						.			.											
Discoaster druggii				.																
Discoaster obtusus															.					
Helicosphaera recta								.												
Pontosphaera desueta											.									
Pontosphaera plana								.												
Reticulofenestra bisecta			.					.					.	.	.				.	
Sphenolithus conicus				.	.		.		.				.	.		.				
Sphenolithus delphix															.					
Traversopontis pulcheroides																			.	
Watznaueria barnesae				.	.	.			.	.				.					.	
Zyghrablithus bijugatus															.					
Redeposited species (No.)	0	0	1	3	2	2	2	3	3	1	1	0	2	3	4	1	0	0	3	0

Table 9: Kamenščak section

SAMPLE	KAM-1*	KAM-2	KAM-3	KAM-4	KAM-5*	KAM-6	KAM-7	KAM-8	KAM-9	KAM-10*	KAM-11	KAM-12	KAM-13	KAM-14	KAM-15	KAM-16*	KAM-17	KAM-18	KAM-19	KAM-20*	KAM-21	KAM-22	KAM-23	KAM-24	KAM-25	KAM-26	KAM-27*	KAM-28
SPECIES \ PRESERVATION	M	M	G	G	G	G	M	M	P	M	M	M	M	M	M	G	G	M	G	M	M	M	G	M	P	P	M	M
Braarudosphaera bigelowii	.	.			.	.				.	.	.	•	.	.		.			.				.				.
Calcidiscus leptoporus						.																						
Calciosolenia sp.																				.								
Coccolithus miopelagicus	.		•	.	.		.		.	•		.		.	•	.	.	.	.	.	.	.	.	.			.	.
Coccolithus pelagicus	●	●	⬤	●	•	⬤	●	●	●	●	●	•	●	●	●	⬤	●	●	●	●	●	●	●	●	•	•	●	●
Cyclicargolithus floridanus	•	•	.	•	•	•	•	•	•	•	•	•		.	•	•	●	•	•	•	•	.	•	•	.	.	•	•
Discoaster aulacos						.									.	.												
Discoaster deflandrei			.											.	.	.	.			.								
Discoaster exilis			.			.													.									
Discoaster formosus																		.	.									
Discoaster musicus																			.									
Helicosphaera carteri	●	•	●	•	.	●	•	•	•	•	•	.	.	•	.	.	•	●	●	●	●	•	•	●	.	•	●	●
Helicosphaera intermedia	.	.	•	.	.	.	.		.	.	.					.	.	.									.	
Helicosphaera minuta	•	.	●	•	.		.	.	.	•	.	.	.	•	•	●	●	.	•	•	.	•	.	.			.	.
Helicosphaera vedderi																.												
H. walbersdorfensis			.							.						.							.					
Helicosphaera wallichii																			.									
Helicosphaera waltrans			.		.	.										.				.			.					
Orthorhabdus serratus	.														.					.								
Pontosphaera callosa	.				.		.																.					
Pontosphaera multipora	.	.	.		.	.	.	•	.	.				.		.	•	.	.	.	.	.	.	.		.	.	.
Reticulofenestra gelida	•				.					.						•												
Reticulofenestra haqii	•	●	•	.	.	.		•	•		.	•	.	•	.	•	•	.	•	•	.	•	•	.	•	.	.	•
Reticulofenestra minuta	•	●	●	●	•	●	•	●		.		•	.	•	•	•	●	.	.	.	.	●	●	•	.	.	•	•
Reticulofenestra minutula					.											.				.							.	
Reticulofenestra perplexa																.												
R. pseudoumbilica (<7µm)	•		.	•	.					.		.	.		.	.	•	.					.					
Rhabdosphaera sicca			.	.	.	.					.			.				.				.	.					
Sphenolithus heteromorphus	.	.	•		.	•	.	•	.	.				.	.	.	.	.	.	.	.		.	.			.	
Sphenolithus moriformis			.		.	.				.					.				.	.							.	
Syracosphaera sp.			.	.																		.		.			.	
Thoracosphaera heimii											.							.									.	
Thoracosphaera saxea	.		.	.		.	.			.		.			.	.	.	.		.			.	.			.	.
Umbilicosphaera jafari	.																.	.										
Autochtonous species (No.)	17	10	18	12	17	15	11	8	9	15	9	10	7	12	15	18	15	16	14	17	9	10	14	12	5	6	15	10
Coccolithus formosus		.	.		.	.	.		.											.								.
Cribromentrum reticulatum			.		.	.				.						.												.
Cyclicargolithus luminis	.		.	.	.	.	.	.					.				.		.				.		.	.		.
Cyclicargilithus abisectus	.																											
Discoaster sp.			.										.		.								.	.			.	
Helicosphaera ampliaperta			.		.											.												
Helicosphaera compacta																.												
Helicosphaera euphratis		.								.																		
Helicosphaera mediterranea																.												
Helicosphaera recta										.																		
Lithostromation perdurum			.		.																							
Pontosphaera desueta																											.	
Pontosphaera latelliptica					.	.																						
Pontosphaera plana								.	.	.	.					.							.	.				
Reticulofenestra bisecta	•	•	.		.	.		.	.	.				.		.	.	.	.	.	.		.					.
Reticulofenestra callida																	.	.										
Reticulofenestra hillae																		.										
Reticulofenestra lockeri			.											.														
Reticulofenestra scrippsae					.											.											.	
Reticulofenestra umbilica				.	.								.				.											.
Sphenolithus conicus				.	.	•	.	.		.							.							.	.		.	.
Transversopontis exilis					.	.																						
Tribrachiatus ortostylus						.																						
Zyghrablithus bijugatus																				.								
Redeposited species (No.)	3	3	8	3	11	8	3	4	3	6	1	0	3	2	1	7	5	3	2	3	1	0	4	3	2	1	4	6

Table 10A: Jurovski Dol section (samples JU 1-26)

SAMPLE	JU-1	JU-2*	JU-3	JU-4	JU-5	JU-6*	JU-7	JU-8	JU-9	JU-10*	JU-11	JU-12	JU-13	JU-14*	JU-15	JU-16	JU-17	JU-18	JU-19	JU-20*	JU-21-23	JU-24	JU-25	JU-26*
SPECIES \ PRESERVATION	M	G	M	G	M	G	G	G	G	G	P	M	G	G	M	M	G	M	M	M	B	P	M	G
Calciosolenia sp.						.								.						.				
Coccolithus miopelagicus	.	•		.		.	.	.		.			.	•	.		.		.	.				.
Coccolithus pelagicus	●	●	●	●	●	•	●	●	●	●	•	•	●	●	●	●	•	●	•	●		.	•	●
Coccolithus streckeri										.														
Cyclicargolithus floridanus				.	.	.	•	.	.	.			.	.	.	.	.	.	.	.			.	.
Disciaster variabilis													.		.									
Discoaster aulacos		.																						
Discoaster deflandrei																			.					
Discoaster formosus																		.		.				
Discoaster sp.		.				.								.										
Helicosphaera carteri	●	⬤	●	●	●	●	●	●	●	●	•	●	●	●	●	●	•	●	•	●		.	●	●
Helicosphaera intermedia		.							.	.			.	.	.			.		.				
Helicosphaera minuta	•	.	.	.		.	.	.	.	•		.	.	.			.	.		.			.	.
H. perch-nielseniae										.				.										.
Helicosphaera wallichii		.		.		.				.										.				.
Helicosphaera vedderi		.																						
Helicosphaera waltrans		•	.	.		.	.	.		.			.				.	.		.				.
Orthorhabdus serratus														.										
Pontosphaera desuetoidea						.																		
Pontosphaera multipora	•	•	.	.	.	•	.	.		.		.		.	.	.	.						.	.
Reticulofenestra gelida		•				.				.				.						•				•
Reticulofenestra haqii	●	●	•	●	•	•	•	•	•	•	.	•	●	•	•	•	.	•	•	•		.	●	●
Reticulofenestra minuta	•	●	•	●	•	●	⬤	⬤	⬤	⬤		⬤	●	●	●	●	●	●	⬤	⬤		•	⬤	⬤
Reticulofenestra minutula		•				.				•										.				.
Reticulofenestra perplexa						.								.						.				•
R. pseudoumbilica (<7µm)		•		.		.	.			•			.	.	.		.		.	•				•
Rhabdosphaera sicca		.		.		.	.			.														.
Sphenolithus heteromorphus	.	.	•	.	.	.	•	.	.	•		.	.	.	.	.	.	.		.			.	•
Sphenolithus moriformis	.	.		.			.	.		.	.		.	.	.			.		.			.	.
Syracosphaera sp.		.			.	.						.								.				.
Thoracosphaera saxea	.	.	.				.		.	.				.				.		.			.	.
Triquetrorhabdulus auritus														.										
Umbilicosphaera rotula	.					.			.															
Autochtonous species (No.)	11	21	9	14	8	21	14	11	10	20	4	8	13	20	12	7	11	12	8	20	0	4	10	20
Cyclicargolithus luminis		.																						
Discoaster druggii		.													.									.
Discoaster gemmeus		.																						
Discoaster sp.		.								.														
Helicosphaera ampliaperta																				.				
Helicosphaera euphratis										.														
Helicosphaera mediterranea										.														
Helicosphaera recta							.			.							.							
Helicosphaera cf. *truempyi*																.								
Micula concava														.										
Pontosphaera latelliptica		.																						
Reticulofenestra bisecta		.				.									.								.	.
Reticulofenestra scrippsae	.	.										.				.	.			.				
Sphenolithus cf. *delphix*		.		.									.											
Sphenolithus radians								.																
Transversopontis pulcher		.																						
Transversopontis sigmoidalis																							.	.
Zygrhablithus bijugatus		.																						
Redeposited species (No.)	1	10	0	1	0	1	1	1	0	4	0	1	1	1	2	2	2	0	0	2	0	0	2	3

Table 10B: Jurovski Dol section (samples JU 27-55)

SAMPLE	JU-27	JU-28	JU-29	JU-31*	JU-32	JU-33	JU-34	JU-35	JU-36*	JU-37	JU-38	JU-39	JU-40	JU*-41*	JU*-42	JU*-43	JU*-44	JU*-45*	JU*-46	JU*-47	JU*-48	JU*-49	JU*-52	JU*-53-55
SPECIES \ PRESERVATION	B	M	M	M	P	M	M	M	G	P	G	M	G	M	P	M	M	M	M	P	P	P	P	B
Calcidiscus premacintyrei															·	·	·	·						
Calciosolenia sp.									·				·	·										
Coccolithus miopelagicus		·											·	·	·	·	•	·	·	·				
Coccolithus pelagicus		●	●	●	•	●	●	●	•	·	•	•	●	●	●	●	●	●	·	•	●	•	•	
Coccolithus streckeri																								
Cyclicargolithus floridanus				·		·	·	·	·				·	•			•				·			
Discoaster adamantheus								·								·			·				·	
Discoaster aulacos				·										·		·								
Discoaster braarudii																·								
Discoaster deflandrei																		·			·			
Discoaster exilis									·					·		·		·	·				·	
Discoaster formosus								·								•							·	
Discoaster sp.	·		·						·		·			·		•	·	·			·		●	
Disciaster variabilis		·												·		●		•					·	
Helicosphaera carteri		●	●	●	•	●	●	●	•		•	●	●	•	●	●	●	•	·	•	•	•	•	
Helicosphaera intermedia				·		·		·			·		·								·			
Helicosphaera minuta		·		·	·	·	·	·	•		·		·											
H. perch-nielseniae				·				·																
Helicosphaera wallichii				·				·																
Helicosphaera vedderi				·									·											
Helicosphaera waltrans		·					·	·	·				·											
Orthorhabdus serratus									·				·					·						
Pontosphaera multipora		·	·	·		•	·	·	·			·	·				·	·			·		·	
Reticulofenestra gelida				·					·					●				•						
Reticulofenestra haqii		•	•	·	·	●	•	●	•		·	•	•	•		•	•	·			·			
Reticulofenestra minuta		●	●	●		⬤	⬤	●	●	·	●	●	●	●		•	●	●						
Reticulofenestra minutula														·				·						
Reticulofenestra perplexa				·										·										
R. pseudoumbilica (<7µm)				·										·				·			·			
R. pseudoumbilica (>7µm)																	•	·			·			
Rhabdosphaera sicca													·											
Sphenolithus heteromorphus			·	·			·	·	·				·	•		·	•	·		·	•			
Sphenolithus moriformis					·		·				·			·		·	·			·	·			
Syracosphaera sp.				·																				
Thoracosphaera heimii									·															
Thoracosphaera fossata														·										
Thoracosphaera saxea		·			·	·			·				·	·				·						
Umbilicosphaera jafari																		·						
Umbilicosphaera rotula				·				·	·				·											
Autochtonous species (No.)	1	10	7	18	6	9	10	15	17	2	8	5	17	19	4	15	12	19	5	5	12	2	8	0
Coccolithus formosus																		·						
Cyclicargolithus luminis																		·						
Discoaster binodosus														·										
Discoaster obtusus																		·						
Discoaster sp.								·					·					·			·			
Discoaster tanii																·								
Lithostromation perdurum															·						·			
Micrantholithus sp.																·					·			
Reticulofenestra bisecta				·				·					·	•				·						
Reticulofenestra hillae									·															
Reticulofenestra scrippsae								·						·				·						
Rhabdosphaera crebra													·											
Sphenolithus cf. *delphix*																		·						
Redeposited species (No.)	0	0	0	1	0	0	0	3	1	0	0	0	3	3	1	2	0	7	0	0	3	0	0	0

Table 11: Polička vas section

SAMPLE	PV-1*	PV-2	PV-3*	PV-4	PV-5	PV-6*	PV-7	PV-8	PV-9*	PV-10	PV-11	PV-12*	PV-13	PV-14	PV-15*
SPECIES \ PRESERVATION	G	G	G	M	P	M	M	M	M	M	M	G	M	M	M
Braarudosphaera bigelowii	·														
Calcidiscus leptoporus								·				·			·
Coccolithus miopelagicus	•	•	•	·	•	·	•	·	·	·	·	•	•		·
Coccolithus pelagicus	●	⬤	⬤	⬤	●	⬤	●	●	●	●	●	⬤	●	⬤	⬤
Coccolithus streckeri	·											·			
Coronocyclus nitescens			·			·			·				·	·	
Cyclicargolithus floridanus	·	·	·			·	·	·	·			·	·	·	·
Discoaster aulacos	·		·					·							
Discoaster deflandrei									·						
Discoaster moorei						·									·
Discoaster exilis															·
Discoaster sp.	·		·			·			·					·	
Helicosphaera carteri	●	●	⬤	●	●	⬤	●	●	●	●	●	⬤	●	●	⬤
Helicosphaera granulata												·		·	·
Helicosphaera intermedia	·											·	·		·
Helicosphaera minuta			·			·		·				•			·
H. walbersdorfensis								·				·	·	·	•
Orthorhabdus serratus	·					·						·			
Pontosphaera callosa	·	·													
Pontosphaera multipora	·	•	·	•	·	·		·	·	·		•	·	·	·
Reticulofenestra gelida	●		●			•			·			·			
Reticulofenestra haqii	●	●	●	●	•	•	•	•	●	●	•	•	•	•	•
Reticulofenestra minuta	⬤	⬤	●	⬤	●	⬤	●	•	⬤	⬤	⬤	●	⬤	●	●
Reticulofenestra minutula			·									·			
Reticulofenestra perplexa	•		•			·			·			·			
R. pseudoumbilica (<7μm)	•	·	·			·		·	·			·	·		·
Rhabdosphaera procera	·					•		·					·		
Rhabdosphaera sicca	·	·	•			·		·	·	·		·	·	·	·
Sphenolithus heteromorphus	●	●	●	●	•	●	•	•	•	•	•	•	●	●	●
Sphenolithus moriformis	•	•	·	·	•	•	•	·	·		·	·		•	·
Syracolithus schilleri	·														
Syracosphaera sp.	·					•						·			•
Thoracosphaera fossata	·								·						
Thoracosphaera heimii	·								·			·			·
Thoracosphaera saxea	•	•	•	·		·	•	•	•	•	·	•	•	·	·
Umbilicosphaera jafari	·	·	·					·	·						
Umbilicosphaera rotula		·						·	·			·			
Autochtonous species (No.)	27	15	20	9	8	21	9	19	21	9	8	25	15	14	21
Cribrocentrum reticulatum			·			·			·		·	·			
Discoaster druggii			·					·							
Helicosphaera ampliaperta	·														
Helicosphaera compacta	·														
Helicosphaera mediterranea								·							
H. perch-nielseniae	·														
Helicosphaera recta			·												
Lithostromation perdurum	·	·													
Micula concava												·			
Reticulofeenstra bisecta	·		·					·	·			·	·		
Reticulofenestra scrippsae			·			·									·
Reticulofenestra umbilica			·												
Sphenolithus conicus		·										·			
Sphenolithus cf. *delphix*															·
Sphenolithus radians	·														
Transversopontis exilis			·												
Watznaueria barnesae	·	·										·			
Redeposited species (No.)	7	3	7	0	0	2	0	3	2	0	1	5	1	0	2

Table 12: Lithotamnium limestone sections: Zimica, Zgornji Duplek 1 and 2 and Vinička vas

SAMPLE	ZI-1	ZI-2	ZDa-1	ZDa-2	ZDa-3	ZDb-1	ZDb-2	HL-1	HL-2	HL-3
SPECIES \ PRESERVATION	M	P	B	M	M	P	M	P	M	P
Calciosolenia sp.	.	.					.			
Coccolithus pelagicus	●			•	•	•	●	•	●	•
Coccolithus miopelagicus	•			.	.	.	•	.	•	.
Coronocyclus nitescens								.		.
Calcidiscus leptoporus	.			.						
Coccolithus streckeri				•			•		.	
Cyclicargolithus floridanus						.	.			
Discoaster adamantheus	.			.						
Discoaster aulacos				.						
Discoaster braarudii				.						
Discoaster variabilis	.			.						
Discoaster sp.									.	
Helicosphaera carteri	.			.		•	●	.		
Helicosphaera intermedia	.									
Helicosphaera minuta	.			.			.		.	
H. walbersdorfensis							.		.	
Ortorhabdus serratus	.	.					.			
Pontosphaera multipora							.	.		
Reticulofenestra perplexa	.						•			
Reticulofenestra gellida	.					.	.			
Reticulofenestra haqii	.						•	.	.	
Reticulofenestra minuta	●			●		●	⬤	●	⬤	
Reticulofenestra minutula							•	.	.	
R. pseudoumbilica (<7μm)	.			.		.	.			
Reticulofenestra scrippsae	.					.	•			
Rhabdosphaera sicca				.						
Sphenolithus abies	.			.			.	.		
S. heteromorphus	.	.		•	•		•	•	.	
Sphenolithus moriformis	.				.	.	.		.	
Syracosphaera sp.					.		.		.	
Thoracosphaera fossata	.						.			
Thoracosphaera saxea							.			
Umbilicosphaera jafari	.						.	.	.	
Umbilicosphaera rotula	.			.				.	.	
Autochtonous species (No.)	22	3	0	16	5	9	24	12	14	3
Coccolithus formosus						.				
Lithostromation perdurum	.			.						
Reticulofenestra bisecta						.	.			
Reticulofenestra scrippsae	.					.	•			
Sphenolithus cf. *delphix*					.					
Zygrhablithus bijugatus						.				
Redeposited species (No.)	2	0	0	1	1	4	2	0	0	0

Table 13A: Lenart section (samples L-16 (1-3), LR 1-19)

SAMPLE	L-16(1)	L-16(2)	L-16(3)	LR-1	LR-2	LR-3	LR-4	LR-5	LR-6	LR-7	LR-8	LR-9	LR-10	LR-11	LR-12	LR-13	LR-14	LR-15	LR-16	LR-17	LR-18	LR-19
SPECIES \ PRESERVATION	M	M	M	M	M	M	M	M	M	G	M	M	M	M	G	G	G	M	M	M	M	G
Braarudosphaera bigelowii							·		·													
Calcidiscus carlae																						
Calcidiscus leptoporus							·		·	•			·									
Calcidiscus premacintyrei				·				·		·	·	·	·	·		·	·	·				
Calcidiscus tropicus									·		·	·	·					·				·
Calciosolenia sp.	·			•				·		·						·		·	·	·		
Coccolithus miopelagicus	•	•	•	·									·			·						
Coccolithus pelagicus	⬤	•	⬤	•	•	•	⬤	•	•	•	⬤	•	•	•	•	⬤	⬤	⬤	⬤	⬤	⬤	•
Coccolithus streckeri	•	•		·			·	·						·			·	·				
Coronocyclus nitescens				·			·		·			·	·				·	·		·		
Cyclicargolithus floridanus	•	·	•	●	•	•	•	•	•	•	•	●	●	•	•	•	●	●	●	●	•	·
Discoaster adamantheus				·		·																
Discoaster aulacos	·																					
Discoaster braarudii												·										
Discoaster deflandrei				·																		
Discoaster druggii																						
Discoaster exilis	·	·		·	·	·	·	·							·					·		
Discoaster formosus				·								·										
Discoaster aff. *kugleri*				·						·		·										
Discoaster moorei												·								·		
Discoaster musicus																						
Discoaster stelullus								·						·							·	
Discoaster variabilis	•		·	·	·					·			·							·	·	
Discoaster sp.														·	·			·				
Helicosphaera carteri	•	•	•	•	•	•	⬤	•	•	•	•	•	•	•	•	•	⬤	⬤	⬤	⬤	⬤	•
Helicosphaera wallichii																						
Helicosphaera granulata							·	·	·		·						·	·	·			·
Helicosphaera intermedia																						
Helicosphaera minuta	•	⬤	⬤	•	·	·	·	·	•	•	·	•	·	·	•	•	·	·	·	·	·	•
H. walbersdorfensis	·	·	·	·				·	·			·				•	·	·	·	·		•
Orthorhabdus serratus		·	·	·				·		·						·						
Pontosphaera callosa	·			·	·		·	·	·						·	·	·	·		·	·	
Pontosphaera desuetoidea																						
Pontosphaera geminipora																						
Pontosphaera multipora	·	·	·	·	·	·	·		·	·	·	·	·	·	·	·	•	•	•	•	•	•
Reticulofenestra gellida	·	•	·	•	·			·	•	•	·	·	·		·	•	•	·	·		·	
Reticulofenestra haqii				•	•	·	•	•	•	•	·	●	●	•	•	●	•	·	·	·	•	•
Reticulofenestra minuta	⬤	•	⬤	⬤	⬤	⬤	⬤	•	•	⬤	⬤	•	•	•	•	•	•	⬤	•	⬤	⬤	•
Reticulofenestra minutula	•	•	•	•				·	·	•	·		·	·	•		·	·	·			
Reticulofenestra perplexa																				·		
R. pseudoumbilica (<7µm)	•	●	•	●	•	•	·	·	·	•	•	•	•	●	•	●	•	·	•	·	●	●
R. pseudoumbilica (>7µm)																						
Rhabdosphaera procera	·	·		·									·			·					·	
Rhabdosphaera sicca	·	·		·	·		·	·		·		·	·	·	·	·	·	•	•	·	·	·
Scyphosphaera amphora																						
Sphenolithus abies																						
Sphenolithus heteromorphus	•	•	•	·	·			·	·	·	·					·				·		
Sphenolithus moriformis	·	·		•	•	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·		·
Syracolithus schilleri	·												·	·	·	·			·		·	
Syracolithus dalmaticus																						
Syracosphaera sp.			·	•	·		·	·	·	•		·	·		·	•	·	·	·	·		·
Thoracosphaera fossata	·		·												·	·						
Thoracosphaera heimii		·					·													·		·
Thoracosphaera saxea		·																				
Triquetrorhabdulus auritus																						
Umbilicosphaera jafari				•						·						·						
Umbilicosphaera rotula	·			●	•	●	•	•	•	•	·	•	•	·	•	•	·	·	·	•	·	·
Autochtonous species (No.)	24	20	16	31	17	12	20	23	21	22	16	21	22	17	19	24	20	23	18	22	16	16
Discoaster druggii												·										
H. perch-nielseniae																·						
Helicosphaera recta																				·		
Lithostromation perdurum						·												·				·
Pontosphaera desueta				·																		
Reticulofenestra bisecta										·												
Transversopontis pulcher					·																	
Tribrachiatus bramlettei	·																					
Redeposited species (No.)	1	0	0	1	1	1	0	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1

Table 13B: Lenart section (samples LR 20-40; L-1)

SAMPLE	LR-20	LR-21	LR-22	LR-23	LR-24	LR-25	LR-26	LR-27	LR-28	LR-29	LR-30	LR-31	LR-32	LR-33	LR-34	LR-35	LR-36	LR-37	LR-38	LR-39	LR-40	L-1
SPECIES \ PRESERVATION	G	M	G	G	M	M	M	M	G	G	G	G	G	G	G	G	M	M	G	G	G	G
Braarudosphaera bigelowii																						
Calcidiscus carlae																.						
Calcidiscus leptoporus	.						.			.					.					.		
Calcidiscus premacintyrei													.	.	•	.	.		.		.	
Calcidiscus tropicus											.	.	.	.		.						
Calciosolenia sp.	.	.	.	.				.			.	.	.		.		.			.	.	
Coccolithus miopelagicus			.												.		.	.		.	.	•
Coccolithus pelagicus	⬤	⬤	●	●	●	⬤	●	●	●	●	●	●	●	●	●	●	●	●	⬤	⬤	⬤	●
Coccolithus streckeri			.								.	.	.		.	.		.	.		.	•
Coronocyclus nitescens			.		.					.			.	.				.		.	.	.
Cyclicargolithus floridanus	•	.	.	.		.			.	.			.	.		.	.	.		●		
Discoaster adamantheus		.											.	.	•	•	.	•	.	.	.	.
Discoaster aulacos													.		.	.	.		.		.	
Discoaster braarudii													.		.	•	.	.	•		•	
Discoaster deflandrei															.	.			.		.	
Discoaster druggii																.						
Discoaster exilis	.				.								•	•	•	●		•	●	.	•	•
Discoaster formosus														.	.	•	•	•	•	.	•	
Discoaster aff. *kugleri*															.	.			.		.	.
Discoaster moorei														.	.	.	.	.			.	
Discoaster musicus																.					.	
Discoaster stelullus	.												.	.	•	.	•	•	.	.	•	•
Discoaster variabilis	.				.	.				.			•	•	●	●	•	•	.	.	●	.
Discoaster sp.					.				.		.					.						
Helicosphaera carteri	●	●	●	●	●	●	●	●	•	●	•	●	•	●	•	●	●	●	●	●	●	●
Helicosphaera wallichii															.							
Helicosphaera granulata																						
Helicosphaera intermedia		.			.	.	.						.	.	.	•	•	.		.	.	
Helicosphaera minuta	•	.	•	•	•	•	•	●	●	●	●	•	•	•	•	.	.	•	•	.	.	•
H. walbersdorfensis	•	.	.	•	•	•	•	•	•	•	•	•	•	•	.	.	.	.				
Orthorhabdus serratus																.						.
Pontosphaera callosa	.		.				.	.				.	.	.	.	.	.	.	.		.	
Pontosphaera desuetoidea																			.			
Pontosphaera geminipora															.	.						
Pontosphaera multipora	•	•	•	•	.	•	.	.	.	•	.	.	.	.	•	•	•	.	•	•	•	.
Reticulofenestra gellida	.			.	.	•	•	.			•	.		•	•	•	.		.	•	•	.
Reticulofenestra haqii	•	•	.		.	•	•	•	.	•	•	●	●	●	●	●	●	●	•	●	•	●
Reticulofenestra minuta	⬤	●	●	⬤	●	•	•	⬤	●	⬤	●	●	●	●	●	•	•	●	•	⬤	⬤	●
Reticulofenestra minutula	•	.		.				.		.	•			.				.	.	.	.	•
Reticulofenestra perplexa						.			.	.	.											
R. pseudoumbilica (<7µm)	●	●	●	●	●	•	•	●	●	●	●	.	•	•	●	•	.	•	•	●	●	•
R. pseudoumbilica (>7µm)	.																				.	
Rhabdosphaera procera						.	.	.			.	.				.	.					•
Rhabdosphaera sicca	.	.		.	.	.	.	•	.	•	•		.	.	•	•	•		•		•	
Scyphosphaera amphora														.								
Sphenolithus abies																					.	.
Sphenolithus heteromorphus				.	.															.	.	
Sphenolithus moriformis	.		.	.	.	.	.	.	.	.	.		.		.	.	.	.	.	•	•	•
Syracolithus schilleri										.	.		.	.	.	.	•		.			
Syracolithus dalmaticus																		.				
Syracosphaera sp.	•	.	•	.	.	.	.		.	•	•	•	•	•		•		•		•	•	
Thoracosphaera fossata				.											.							
Thoracosphaera heimii						.				.					.					.	.	
Thoracosphaera saxea																				.	.	
Triquetrorhabdulus auritus	.														.							
Umbilicosphaera jafari					.	.									•		.		.			
Umbilicosphaera rotula	.	.	.	.	•	●	•	●	•	•	•	•	•	•	•	•	●	•	•	•	●	.
Autochtonous species (No.)	23	16	17	17	20	20	17	16	15	20	21	16	27	27	36	37	28	26	27	26	36	22
Broinsonia parca																			.			
Coccolithus formosus															.							
Discoaster tanii																.						
Helicosphaera recta	.	.	.						.			.				.	.		.			
Lithostromation perdurum													.	.		.	.	•	.	.	.	
Pontosphaera plana											.								.			
Retecapsa sp.																			.			
Reticulofenestra bisecta											.		.								.	.
Reticulofenestra callida																.						
Rhabdosphaera vitrea					.																	
Zyghrablithus bijugatus															.	.						
Redeposited species (No.)	1	1	1	0	1	0	0	0	1	0	2	1	2	1	2	5	2	1	4	1	2	1

Table 13C: Lenart section (samples LE 1-45)

SAMPLE	LE-1	LE-3*	LE-5	LE-7	LE-9	LE-11*	LE-13	LE-15	LE-17	LE-19*	LE-21	LE-23	LE-25	LE-27*	LE-29	LE-31	LE-33	LE-35*	LE-37	LE-39	LE-41	LE-43*	LE-45
SPECIES \ PRESERVATION	M	G	G	M	G	G	G	G	G	G	M	G	G	G	G	G	M	M	M	G	G	G	G
Braarudosphaera bigelowii		·		·						·											·		
Calcidiscus leptoporus	·		·	·	·	•	·		•	•		·	·	·	·			·		·		·	·
Calcidiscus macintyrei						·																	
Calcidiscus premacintyrei	•	•		·	·		·	·	·	·		•	•	·	•	•	·	•	·	·	·	·	·
Calciosolenia sp.			·		·				·				·			·	·	·		·			
Coccolithus miopelagicus	·	·	·	•	·	•	·	·	·	·	·	·	·		•	·	·	·	·	•	·	·	·
Coccolithus pelagicus	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	•	⬤	⬤	⬤	⬤	⬤	•	•	⬤	⬤	⬤	⬤
Coccolithus streckeri	·	•	·	•		•	·	·		•	•		·	•		·	·	·	·	•	•	·	·
Coronocyclus nitescens		·						·	·	·	·						·	·	·			·	
Cyclicargolithus floridanus	·	·		·			·		·		·								·				
Helicosphaera carteri	⬤	⬤	⬤	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Helicosphaer wallichii															·						·		
Helicosphaera intermedia	·	·	·	·	·		·		·	·			·			·				·	•	•	•
Helicosphaera minuta	·	·		·				·		·												·	
Orthorhabdus serratus		·			·	·	·		·			·										·	
Pontosphaera callosa	•	·								·										·		·	
Pontosphaera multipora	•	•	•	•	•	•	•	•	•	●	•		•	•	•	•	●		·	•	●	•	•
Reticulofenestra gellida		•				•				•			·	●				●				●	
Reticulofenestra haqii	⬤	⬤	•	•	⬤	•	•	⬤	⬤	⬤	⬤	•	•	•	•	•	•	⬤	⬤	•	•	•	•
Reticulofenestra minuta	⬤	⬤	⬤	⬤	•	•	•	⬤	•	•	•	•	•	•	•	•	⬤	•	•	⬤	⬤	•	•
Reticulofenestra minutula		•				•				•				·									
Reticulofenestra perplexa		•		•		•				•				●				•				●	
R. pseudoumbilica (<7μm)	•	•	●	●	●	•	•	•	●	●	•	•	•	●	•	•	·	·	·	·	·	·	·
R. pseudoumbilica (>7μm)		·				·				·		·		·	·	·		·	·	·		·	·
Rhabdosphaera procera		·				·			·			·	·	·				·	·		·		·
Rhabdosphaera sicca	•	•	·	·	·	·	·		·	·		·	•		·					·	•	•	
Rhadbosphaera sp.		·																					
Sphenolithus abies	·	·	·	·	·	·	•		·		•	•	•	·	·	·				·		·	·
Sphenolithus heteromorphus				·																			
Sphenolithus moriformis	⬤	⬤	⬤	•	•	•	·	•	•	⬤	•	•	•	•	•	•	⬤	•	•	•	•	•	•
Syracolithus schilleri		·	·				·	·		·			•	•		·	·	•	•	·		·	·
Syracosphaera sp.	•	·	·	•	•	•	·	·	·	·	·	·	·	•	·								
Thoracosphaera fossata				·			·																
Umbilicosphaera jafari	·			●	●	•	•	·	·	•	·	·	●	•	●								·
Umbilicosphaera rotula	•	·	·	●	•	·	•	·	·	●	·		•	•	●	•	•		·	•	●	●	
Autochtonous species (No.)	20	28	17	23	18	22	21	16	21	25	15	16	21	20	17	16	14	17	16	19	16	23	17
Coccolithus formosus							·																
Pontosphaera plana	•									•					·		·	·	•			·	
Reticulofenestra bisecta				·			·									·		·					
Reticulofenestra scrippsae																		·					
Transversopontis pulcher											·												
Redeposited species (No.)	1	0	0	1	0	0	2	0	0	1	1	0	0	0	1	1	1	3	1	0	0	1	0

Table 13D: Lenart section (samples LT 1-96, L 9-13, L-17)

SAMPLE	LT-1	LT-6	LT-11	LT-16	LT-21	LT-26	LT-31	LT-36	LT-41	LT-46	LT-51	LT-56	LT-61	LT-66	LT-71	LT-76	LT-81	LT-86	LT-91	LT-96	L-9	L-10	L-11	L-12	L-13	L-17
SPECIES\PRESERVATION	M*	G	G	G	G*	M	G	M	G*	G	G	M	G*	M	G	M	M*	M	G	G	G	G	G	G	G	G
Braarudosphaera bigelowii	.	.			.	.	.						.						.	.				.	.	
Calcidiscus leptoporus	•	.	•	.	.	.	.	.	•	.	•	.	.	•	•	.	•	•	•	•	.	.				.
Calcidiscus macintyrei	.		.		.														.	.		.				
Calcidiscus premacintyrei	.	•	.	.	•		.	.	.	.	•	•	•	.	•	•	.	•	.	.	.	.		.	.	.
Calcidiscus tropicus		.		.	.		.			.	.		.						.							
Calciosolenia sp.	•	.	•	•	.	.		.	•	•	•	.	•	.			.	.		.	.	.	•			
Coccolithus miopelagicus	.	.	.		.	.	.		.		.		.	.			.			.	.	•	•	•	•	.
Coccolithus pelagicus	●	●	●	⬤	●	●	⬤	●	●	●	⬤	●	●	●	●	⬤	●	●	⬤	●	●	⬤	●	●	⬤	●
Coccolithus streckeri	•		.		.	.	.	.				.	.		.	.					•	•	●	•	•	.
Coronocyclus nitescens		.				.			.				.						.						.	
Cyclicargolithus floridanus							.																			
Discoaster variabilis					.						.				.											
Helicosphaera carteri	●	●	●	●	●	●	●	●	●	⬤	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	•
Helicosphaera granulata			.		.					.	.									.						
Helicosphaera intermedia	.	.	.	.	.	.	.	•	•	.	•	.	•	.	.	.		.	.	.	.	.				.
Helicosphaera minuta				.	.		.		.		.												•		.	
H. walbersdorfensis											.						.					.	•	.	.	.
Orthorhabdus serratus					.																.		.		.	
Pontosphaera callosa	.				.	.			.	.	.		.				.		.			.				
Pontosphaera multipora	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	●	•	•	.	.		.
Reticulofenestra gellida	•				.		.		.				•				•			.	.			.	•	.
Reticulofenestra haqii	●	●	⬤	●	⬤	●	⬤	●	●	⬤	●	•	⬤	●	⬤	⬤	⬤	⬤	⬤	⬤	⬤	●	⬤	⬤	●	⬤
Reticulofenestra minuta	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	⬤	●	●	⬤	⬤	⬤	⬤
Reticulofenestra minutula	●				●				•			•	•				.			.	•	•	●	●	●	●
Reticulofenestra perplexa	•	•			.			.	.	.			.	.	•		.						•	.	.	•
R. pseudoumbilica (<7μm)	●	•	●	.	•	.	.	•	●	•	•	•	•	•	•	.	.	.	●	.	⬤	●	●	●	●	●
R. pseudoumbilica (>7μm)	.		.	.	.		.	.	•	•	•		•	.	•	•	•	.	•	•	•	.	.	•	•	.
Rhabdosphaera procera	.			.	.						.		.						.		•	•	•	•	•	.
Rhabdosphaera sicca	•	•	.	.	.	.		.	.		•	.	.	.	.	.	.		.	.						
Sphenolithus abies	•	•	●	•	•	•	•	.	•	●	•	•	•	•	●	.	.	.	.	•	•	•	•	.		.
Sphenolithus moriformis	●	●	●	•	•	●	•	.	•	•	•	•	•	•	•	.	.	.	•	●	•	●	•	•	•	•
Syracolithus dalmaticus		.	.			.		.	.	.	.		.		.	.	.	.	.		.	.	.		.	
Syracolithus schilleri	•	.			•	.	.	.		.	•	.	•	.	•	.	•	•	•	•	•	.	.		•	•
Syracosphaera sp.	•	•	•	•	•	.	.	•	.	.	•	•	•	.		•	•	.	•	•	•	●	●	•	•	•
Thoracosphaera fossata		.											.													
Thoracosphaera heimii			.																				.			
Umbilicosphaera jafari	.		.	.	•			.	•	●	●			•	•	.	.	.	•	•	•		•		•	
Umbilicosphaera rotula	•	•	.	.	●	●	●	•	●	●	●	.	●	.	•	•	●	•	●	●	•	●	•	•	•	•
Autochtonous species (No.)	27	23	23	20	32	21	22	21	25	22	27	18	29	20	20	19	24	18	24	24	24	24	24	20	24	22
?Clathrolithus spinosus											.															
Helicosphaera recta																				.						
Helicosphaera cf. *truempyi*																				.						
Lithostromation perdurum					.		.																			
Micrantholithus flos					.														.							
Pontosphaera desueta					.																					
Pontosphaera plana	.		.			.											.			.						
Reticulofenestra bisecta					.			.	.												.					
Reticulofenestra scrippsae					.																					
Redeposited species (No.)	1	0	1	0	5	1	1	1	1	0	1	0	0	0	0	0	1	0	1	3	1	0	0	0	0	0

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ZRC PUBLISHING
http://zalozba.zrc-sazu.si/
26 €
ISBN 978-961-254-149-1
9 789612 541491 >