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BIODIVERSITY AND PALEOECOLOGY OF THE MIOCENE CALCAREOUS NANNOPLANKTON FROM SIBIU AREA (TRANSYLVANIA, ROMANIA)

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Abstract The present study focuses on the biodiversity and paleoecology of the Miocene (Badenian, Sarmatian and Pannonian) calcareous nannoplankton from Dobârca, Apoldu de Sus and Vurpăr (Sibiu area) which were compared with other known occurrences, especially from Alba Iulia area.
The Badenian assemblages contain about 33 species belonging to 17 genera, and contain the marker species for NN5 and NN6 biozones (Martini, 1971), while the Sarmatian assemblages contain only few species of the genera *Calcidiscus, Reticulofenestra, Rhabdosphaera, Coccolithus*, a.o. The Pannonian assemblages contain especially species of the genera *Noelaerhabdus* and *Isolithus*, but sometimes in a great number of specimens.

Key words: Nannoplankton, Badenian, Sarmatian, Pannonian, biodiversity, paleoecology, Sibiu, Romania.

INTRODUCTION

The calcareous nannoplankton, represented by unicellular, micron-sized golden-brown algae (Haptophyte), constitutes the calcareous phytoplankton which provides the largest amounts of calcified organisms.

The calcareous nannoplankton/ nannofossils biodiversity of the Miocene was considered based on the analysis of species from several representative sections from Transylvania, especially from Sibiu area (Dobârca, Apoldu de Sus, Vurpăr) (Fig. 1), as compared to other areas, like Alba-Iulia (Lopadea, Geoagiu).

Previous studies concerning the geology of the studied area belong to Ilie (1955), Codarcea et al. (1968), a. o. Studies concerning the calcareous nannofossils were realised by Meszaros et al. (1977), Malacu (2007), a.o.

GENERAL CONSIDERATIONS CONCERNING THE MARINE BIODIVERSITY

Marine biodiversity is very important for understanding the causes and consequences of biodiversity on a global scale (Williamson 1997 fide Quinn et al., 2004). Biodiversity as a concept includes the variability in the natural world (Angel 1997 fide Quinn et al., 2004); however it is common to deal with numbers of species in order to quantify biodiversity. Estimations of species diversity vary considerably depending upon the criterion used to define a species (Williamson 1997 fide Quinn et al., 2004). Several analyses from marine environments indicate that measurements of biodiversity based upon morphospecies are likely to be underestimated (Knowlton 1993 fide Quinn et al., 2004).

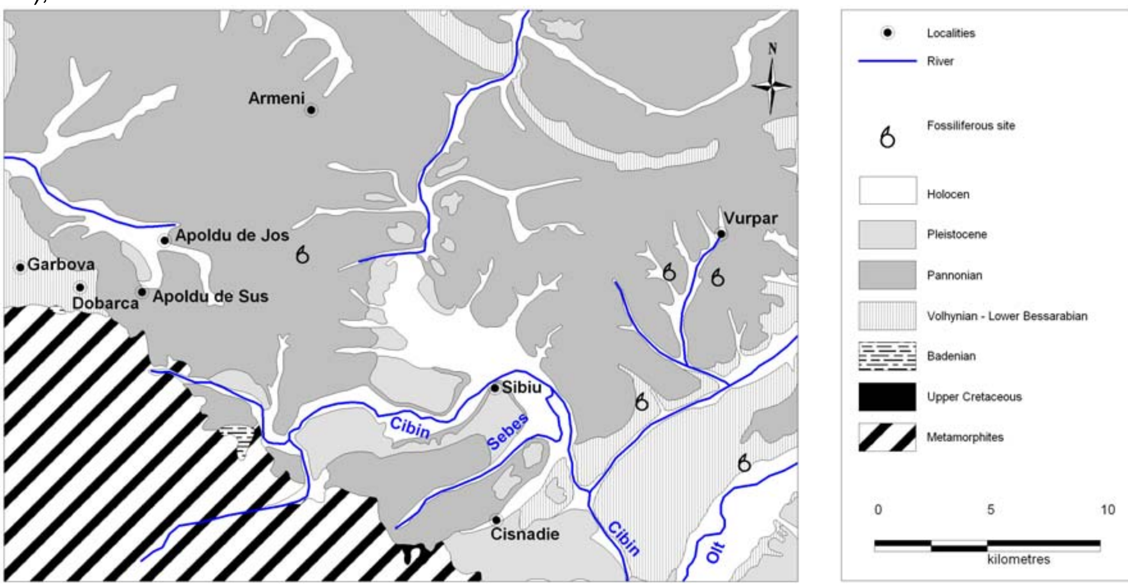

Figure 1 Geological map of Sibiu area (Dobârca, Apoldu de Sus and Vurpăr), (after the geological map of Codarcea et al., 1968, modified).

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Biodiversity represents a measure of the relative diversity of organisms that are present in different ecosystems. Diversity, in this definition, includes diversity within a species and among species, and also the diversity between ecosystems.

Biodiversity refer also to the totality of the species and ecosystems from a region and the taxonomic richness of a geographic area.

Biodiversity has an ecological, respectively paleoecological signification, too. All species provide a function to an ecosystem. Finally, biodiversity is important because each species can offer data concerning how life evolved and will continue to evolve.

The global diversity of the present coccolithophores and respectively of the calcareous nannoplankton is strongly influenced by oligotrophic, low-latitude water masses, climate, and oceanography. It played a primary role in the development of habitats, as proven when comparing the global diversity of calcareous nannoplankton with paleoclimate records. Therefore, for the Cenozoic nannoplankton, diversity is strongly connected with paleoclimate trends, with high diversity recorded during warm intervals and respectively low diversity during cool periods. The appearance of microplankton/ microfossils - for fossil species: foraminifera, calcareous dinoflagellates, a.o., indicated a significant biodiversity, frequently reflected by the evolution in the past; some of them were considered as morphospecies that underwent extinction.

CONSIDERATIONS CONCERNING THE CALCAREOUS NANNOPLANKTON BIODIVERSITY DURING THE NEOGENE

Coccolitophores and associated calcareous phytoplankton are the most abundant calcifying organisms inhabiting our planet. Their fossil record is equally impressive, perhaps being the most abundant and stratigraphically complete of any fossil group. As such, they provide a valuable proxy for Mesozoic-Cenozoic phytoplankton health and robust data concerning rates and patterns of evolutionary change. Their present biogeography and diversity is closely correlated with climatic and oceanographic zones, and their fossils provide data on this relationship throughout time.

The calcareous nannoplankton has a history of more than 225 M.a. (Triassic-present) built-up by using phylogenetic models and a new synthesis of diversity data and rates of evolutionary change. Nannoplankton diversity has been compiled from published stratigraphic data, and especially from a number of comprehensive synthetic works (Aubry 1984, Perch-Nielsen 1985, a.o.). The combined information from nannoplankton phylogenetic trees and diversity data provide us with an outstanding record of the evolutionary history for this phytoplankton group.

Cenozoic diversity records are closely correlated with climate change, *i.e.* increasing diversity associated with climate warming and decreasing diversity with cooling. This contrasts with Mesozoic diversity patterns and indicates that the magnitude, rates and duration of Cenozoic cooling prevented diversification trough biogeographic differentiation and, instead, lead to suppression of diversity at temperate and high latitudes.

As concerns the Neogene calcareous nannoplankton, for example the discoasters were considered long time as indicating warm waters through geological times, because they abundantly appear at low latitudes; thus it was presumed that they are sensitive to temperature variations. Later, it was remarked that their abundance is affected not only by temperature, but also by the presence of nutrients. Taxons as *Discoaster pentaradiatus, D. brouweri, D. asymmetricus* are more abundant at low latitudes in warm, more productive intervals, and, in contrast, *D. variabilis* and *D. surculus* indicate a sensitivity at the temperature changes, and show a higher abundance in colder intervals.

Sphenolithus, like *Discoaster* genera are nannoliths with a large distribution. Together with *Discoaster, Sphenolithus* is considered characteristic to warm water assemblages, at lower latitudes, probably preferring shallower waters. The studies concerning the biologic variability versus climate show a weak correlation between the relative abundance of some taxa and the abiotic records.

The use of calcareous nannoplankton as climatic signal was remarked in numerous studies (Chira, 1999, Chira et al., 2000, a.o.)

There are studies concerning the biodiversity, ecology and paleoecology of calcareous nannofossils, subjects intensely debated recently, which still require to be explained, and which bring important information for both present and fossil forms, with practical applications on environment, paleoenvironment, and oil deposits studies.

MATERIAL AND METHODS

About 47 samples were analysed from Dobârca, 7 samples from Apoldu de Sus and

30 samples from Vurpăr, for their nannofossil content.

The smear slides were studied under the optical microscope, with 1000x magnification.

CALCAREOUS NANNOPLANKTON BIODIVERSITY DURING THE MIOCENE IN TRANSYLVANIA

The study of the calcareous nannoplankton from Sibiu area (Dobârca, Apoldu de Sus, Vurpăr) points out the presence of Miocene calcareous nannofossils (Badenian, Sarmatian and Pannonian).

On Dobârca Valley rich calcareous nannofossil assemblages, with *Sphenolithus heteromorphus*, *Discoaster exilis* a.o. corresponding to the Badenian, and assemblages rich in species of *Calcidiscus* (*C. macintyrei* and *C. leptoporus*), *Reticulofenestra*, *Rhabdosphaera*, *Braarudosphaera*, ascidian spicules and calcispheres (species of *Toracosphaera*), characteristic for the Sarmatian are present. The Sarmatian assemblages contain also: *Helicosphaera, Umbilicosphaera, Holodiscolithus, Calciosolenia, Coccolithus (C. miopelagicus* si *C. pelagicus), Pontosphaera, Sphenolithus (S. abies* and *S. moriformis), Discoaster (D. brouwerii, D. musicus, D. exilis, D. variabilis)*.

Sometimes entire coccospheres of *Calcidiscus macintyrei, Coccolithus pelagicus*, a.o. are preserved, which prove a still environment and good conditions of preservation.

In Apoldu de Sus area, Pannonian assemblages are present, dominated by species of *Noelaerhabdus* and *Isolithus* (*I. pavelici si I. semeneko*), and also: *Coccolithus pelagicus, Helicosphaera carteri, Pontosphaera multipora*, a.o.

Pannonian nannoplankton assemblages, dominated by the genera *Noelaerhabdus* and *Isolithus*, are present also in Sibiu area, similar to the Alba Iulia area (Lopadea, Geoagiu, a.o.). The appearance of the Pannonian calcareous nannoplankton was only sporadically mentioned until know.

In the Central Paratethys, Jerkovic (1970, 1971) performed the first studies on such assemblages. He described a new genus, *Noelaerhabdus*, with three species: *Noelaerhabdus bozinovicae*, *N. bekei, N. braarudi*, from Pannonian sediments of Belgrad area, in Serbia & Montenegro.

Bona (1964) and Bona & Gal (1985) described calcareous nannoplankton assemblages from sediments with *Congeria banatica* (Mecsek Mountain, Hungary), which contain: *Noelaerhabdus signatories, N. jerkovici* and *N. tegulatus*. A new genus – *Bekelithella*, respectively *Bekelithella echinata* was also described.

Table 1. Calcareous nannofossils from Dobârca, Apoldu de Sus and Vurpăr (Sibiu area) (according to the classification of Young & Bown, 1997).

NANNOFOSSIL SPECIES	DOBÂRCA	APOLDU DE SUS	VURPĂR
CALCAREOUS NANNOFOSSILS			
HETEROCOCCOLITS			
Family Helicosphaeraceae			
Helicosphaera carteri (WALLICH, 1877) KAMPTNER (1954)	X	X	X
Helicosphaera walbersdorfensis MÜLLER (1974)		X	
Helicosphaera wallichii (LOHMANN, 1902) OKADA & MCINTYRE (1997)	X		
Helicosphaera stalis THEODORIDIS (1984)	X		
Family Pontosphaeraceae			
Pontosphaera multipora (KAMPTNER, 1948) ROTH (1970)		X	
Family Calciosoleniaceae			
Calciosolenia murrayi DEFLANDRE IN DEFLANDRE & FERT (1954)	X	X	
Family Syracosphaeraceae			
Syracosphaera histrica KAMPTNER (1941)	X	X	

Family Rhabdosphaeraceae			
Rhabdosphaera cf. *poculi* (BONA & KERNERNE SUEMEGI, 1964) MUELLER (1974)	X		
Rhabdosphaera pannonica BALDI-BEKE (1960)	X	X	
Family Noelaerhabdaceae			
Cyclicargolithus floridanus (ROTH & HAY *in* HAY *et al*., 1967) BUKRY (1971)	X		
Reticulofenestra pseudoumbilicus (GARTNER, 1967) GARTNER (1969)	X	X	X
Noelaerhabdus jerkovici BONA & GAL (1985)		X	X
Noelaerhabdus bekei JERKOVIC (1971)		X	X
Noelaerhabdus bozinovicae JERKOVIC (1971)		X	X
Family Coccolithaceae			
Coccolithus miopelagicus BUKRY (1971)	X	X	
Coccolithus pelagicus (WALLICH, 1877) SCHILLER (1930)	X	X	X
Family Calcidiscaceae			
Calcidiscus leptoporus (MURRAY & BLACKMAN, 1898) LOEBLICH & TAPPAN (1978)	X	X	
Calcidiscus premacintyrei THEODORIDIS (1984)	X		
Calcidiscus macintyrei (BUKRY & BRAMLETTE, 1969) LOEBLICH & TAPPAN (1978)	X	X	X
Calcidiscus pataecus (BUKRY & BRAMLETTE, 1969) LOEBLICH & TAPPAN (1978)	X		
Umbilicosphaera jafari MÜLLER (1974)	X		
Umbilicosphaera rotula (KAMPTNER, 1956) VAROL (1982)	X		
HOLOCOCCOLITHS			
Family Calyptrosphaeraceae			
Holodiscolithus macroporus (DEFLANDRE *in* DEFLANDRE & FERT, 1954) ROTH (1970)	X		
NANNOLITHS			
Family Braarudosphaeraceae			
Braarudosphaera bigelowii (GRAN & BRAARUD, 1935) DEFLANDRE (1947)	X		
Family Discoasteraceae			
Discoaster musicus STRADNER (1959)		X	
Discoaster cf. *deflandrei* BRAMLETTE & RIEDEL (1954)	X		
Discoaster brouwerii TAN (1927) emended BRAMLETTE & RIEDEL (1954)	X		X
Discoaster variabilis MARTINI & BRAMLETTE (1963)	X	X	
Discoaster exilis MARTINI & BRAMLETTE (1963)		X	
Family Sphenolithaceae			
Sphenolithus heteromorphus DEFLANDRE (1953)	X	X	
Sphenolithus moriformis (BRÖNNIMANN & STRADNER, 1960) BRAMLETTE & WILCOXON (1967)	X	X	
Sphenolithus abies DEFLANDRE *in* DEFLANDRE & FERT (1954)	X	X	
Sphenolithus neoabies BUKRY & BRAMLETTE	X		
Family Lithostromationaceae			
Isolithus semenenko LULJEVA (1989)		X	X
Isolithus pavelici (CORIC & VRSALJKO)		X	X
Family Triquetrorhabdulaceae			
Triquetrorhabdulus rugosus BRAMLETTE & WILCOXON (1967)	X		
CALCAREOUS DINOFLAGELLATES			
Thoracosphaera heimii (LOHMANN 1919) KAMPTNER 1941	X		
ASCIDIAN SPICULE			
Micrascidites vulgaris (LOHMANN 1919) KAMPTNER 1941	X	X	X

From Northern Serbia & Montenegro, Pannonian calcareous nannofossils were mentioned by Mihajlovici (1993) and from boreholes in Hungary by Kollany (2000) (fide Coric, 2004).

In the Central Paratethys recent studies concerning the Pannonian calcareous nannofossils belong to Coric & Gross (2004), Coric (2005), a.o.

Pannonian calcareous nannofossils belonging to the genera *Noelaerhabdus* and *Bekelithella* were also mentioned from Romania by Mărunțeanu et al. (1994); Mărunțeanu (1995, 1996, 1997, 1998a, 1998b), Chira & Mărunțeanu (2000), Chira (2001).

Isolithus species were mentioned for the first time from the Pannonian deposits of Romania by Chira (2006), in assemblages with *Noelaerhabdus* species.

In the Intra-Carpathian area, the calcareous nannofossils identified in the Middle-Late Pannonian deposits (C, D, E Pannonian – corresponding to the Meotian stage - Mărunțeanu, 1998b), have an endemic character being widespread especially in the Pannonian Basin. The *Noelaerhabdus* and *Bekelithella* species are dominant, while subordinately *Coccolithus pelagicus, Calcidiscus leptoporus, Braarudosphaera bigelowii, Reticulofenestra pseudoumbilicus* are also present. The nannofossil assemblages of the "*Congeria banatica* Beds" (Middle Pannonian) are dominated by the presence of *Noelaerhabdus bekei, N. bozinovicae, N. jerkovici.* The same species accompanied by *Noelaerhabdus bonagali, N. mehadicus* were recorded in the "*Congeria czjeky* Beds" (Late Pannonian).

New species of *Noelaerhabdus* were described: *Noelaerhabdus bonagali* Mărunțeanu and *Noelaerhabdus mehadicus* Mărunțeanu (Late Pannonian) (Mărunțeanu, 1996).

Based on the evolution of *Noelaerhabdus*, two nannoplankton biozones were defined for the Middle and Late Pannonian: *Noelaerhabdus bozinovicae* Zone and *Noelaerhabdus bonagali* Zone (Mărunțeanu, 1998a).

Noelaerhabdus bozinovicae Zone was defined from the first occurrence of *Noelaerhabdus bozinovicae* Jerkovici to the first occurrence of *Noelaerhabdus bonagali* Mărunțeanu (Middle Pannonian – C, D). This zone was correlated with the upper part of the NN10 zone (Martini, 1971), and the debut of the NN11 zone. The nannofossil assemblage is dominated by *Noelaerhabdus* species, with various morphostructures.

Noelaerhabdus bonagali Zone was defined from the first to the last occurrence of *Noelaerhabdus bonagali* Mărunțeanu and it corresponds to the Late Pannonian (E). This zone was correlated with the lower part of the NN11 zone. It was remarked that the zone contains only *Noelaerhabdus* and *Bekelithella* species, characterized by intraspecific structure stability (Mărunțeanu, 1998b).

CONCLUSIONS

The biodiversity and palaeoecology of the calcareous nannofossils from Sibiu area: Dobârca, Apoldu de Sus, Vurpăr was investigated.

The Badenian assemblages contain about 33 species belonging to 17 genera, and contain the marker species for NN5 and NN6 biozones (Martini, 1971), while the Sarmatian assemblages contain only few species of the genera *Calcidiscus, Reticulofenestra, Rhabdosphaera, Coccolithus*, a.o. The Pannonian assemblages contain especially species of the genera *Noelaerhabdus* and *Isolithus*, but sometimes in a great number of specimens.

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PLATES

Plate I:

(x2000)

Figs. 1a, 1b, 2a, 2b - *Coccolithus pelagicus* (WALLICH, 1877) SCHILLER (1930) - 12a, 13a - NII, 12b,13b – N+

Fig. 3 – Pannonian calcareous nannofossils with *Noelaerhabdus* species – N+

Plate II:

(x2000)

Fig. 1 – *Discoaster* cf. *musicus* STRADNER (1959) - NII
Fig. 2 – *Syracosphaera* cf. *histrica* KAMPTNER (1941) - N+
Figs. 3a, 3b – *Umbilicosphaera jafari* MUELLER (1974) - 3a - NII, 3b – N+
Fig. 4 – *Sphenolithus* cf. *abies* DEFLANDRE *in* DEFLANDRE & FERT (1954) - N+
Figs. 5a, 5b – *Calcidiscus premacintyrei* THEODORIDIS (1984) - 5a - NII, 5b – N+
Figs. 6a, 6b – *Calcidiscus macintyrei* (BUKRY & BRAMLETTE 1969) LOEBLICH & TAPPAN (1978) - 6a - NII, 6b – N+
Fig. 7 – *Holodiscolithus macroporus* (DEFLANDRE in DEFLANDRE & FERT, 1954) ROTH (1970) - NII
Figs. 8a, 8b – *Calcidiscus leptoporus* (MURRAY & BLACKMAN; LOEBLICH & TAPPAN) - 7a - NII, 7b - N+
Fig. 9 – *Discoaster musicus* STRADNER (1959) - NII
Fig. 10 – *Rhabdosphaera* cf. *poculi* MARTINI (1969) - NII
Fig. 11 – *Cyclicargolithus floridanus* (ROTH & HAY *in* HAY *et al*., 1967) BUKRY (1971) – N+
Figs. 12a, 12b, 13a, 13b – *Coccolithus pelagicus* (WALLICH, 1877) SCHILLER (1930) - 12a, 13a - NII, 12b,13b – N+
Figs. 14a, 14b – *Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE (1947) - 14a - NII, 14b – N+
Figs. 15a, 15b, 16a, 16b, 17a, 17b – Ascidian spicules - 15a, 16a, 17a - NII, 15b, 16b, 17b – N+

Plate III
(x 2000)

Fig. 1 – *Sphenolithus* cf. *heteromorphus* DEFLANDRE (1953) - N+
Figs. 2a, 2b – *Sphenolithus abies* DEFLANDRE *in* DEFLANDRE & FERT (1954) - 2a - NII, 2b – N+
Fig. 3 – *Sphenolithus neoabies* (BUKRY & BRAMLETTE, 1969) - N+
Figs. 4a, 4b – *Sphenolithus moriformis* BROENNIMANN & STRADNER, 1960) BRAMLETTE & WILCOXON (1967) - 4a - NII, 4b – N+
Figs. 5a, 5b, 6a, 6b – *Calcidiscus macintyrei* (BUKRY & BRAMLETTE, 1969) LOEBLICH & TAPPAN (1978) - 5a, 6a - NII, 5b, 6b – N+
Figs. 7a, 7b - *Calcidiscus* cf. *pataecus* (BUKRY & BRAMLETTE, 1969) LOEBLICH & TAPPAN (1978) - 7a - NII, 7b – N+
Figs. 8a, 8b – *Coccolithus pelagicus* (WALLICH, 1877) SCHILLER (1930)- 8a - NII, 8b – N+
Figs. 9a, 9b – *Helicosphaera carteri* (WALLICH, 1877) KAMPTNER (1954) - 9a - NII, 9b – N+
Figs. 10a, 10b – *Cyclicargolithus floridanus* (ROTH & HAY *in* HAY *et al*., 1967) BUKRY (1971) - 10a - NII, 10b – N+
Figs. 11a, 11b – *Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE (1947) -

11a - NII, 11b – N+

Figs. 12a, 12b – *Thoracosphaera heimii* (LOHMANN 1919) KAMPTNER (1941) - 12a - NII, 12b – N+

Figs. 13, 14 – Ascidian spicules - N+

Plate IV

(x 2000)

Figs. 1,2,3,4 - *Isolithus semenenko* LULJEVA (1989) – NII

Figs. 5,6,7,8 - *Isolithus pavelici* CORIC & VRSALJKO – NII

Figs. 9, 10, 11, 13, 14, 16 - *Noelaerhabdus bekei* JERKOVIC (1971) – NII

Figs. 12, 15 - *Noelaerhabdus jerkovic* BONA & GAL (1985) – NII

Figs 17a,17b - *Coccolithus miopelagicus* BUKRY (1971) – 17a - NII, 17b - N+

Figs 18a, 18b - *Calcidiscus leptoporus* (MURRAY & BLACKMAN, 1898) LOEBLICH &TAPPAN (1978) –18a - NII, 18b - N+

Figs 19a, 19b - *Reticulofenestra pseudoumbilicus* (GARTNER, 1967) GARTNER (1969) – 19a - NII, 19b - N+

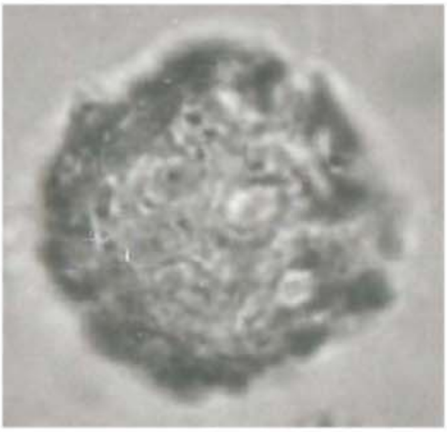
Fig 20: *Discoaster* cf. *deflandrei* BRAMLETTE & RIEDEL (1954) - NII

Fig 21: *Discoaster variabilis* MARTINI & BRAMLETTE (1963) - NII

Figs 22a, 22b, 23, 24: *Noelaerhabdus* sp. and *Isolithus pavelici* CORIC & VRSALJKO and *Isolithus semenenko* LULJEVA (1989) – 22a - NII, 22b - N+, 23 - NII, 24 - NII.

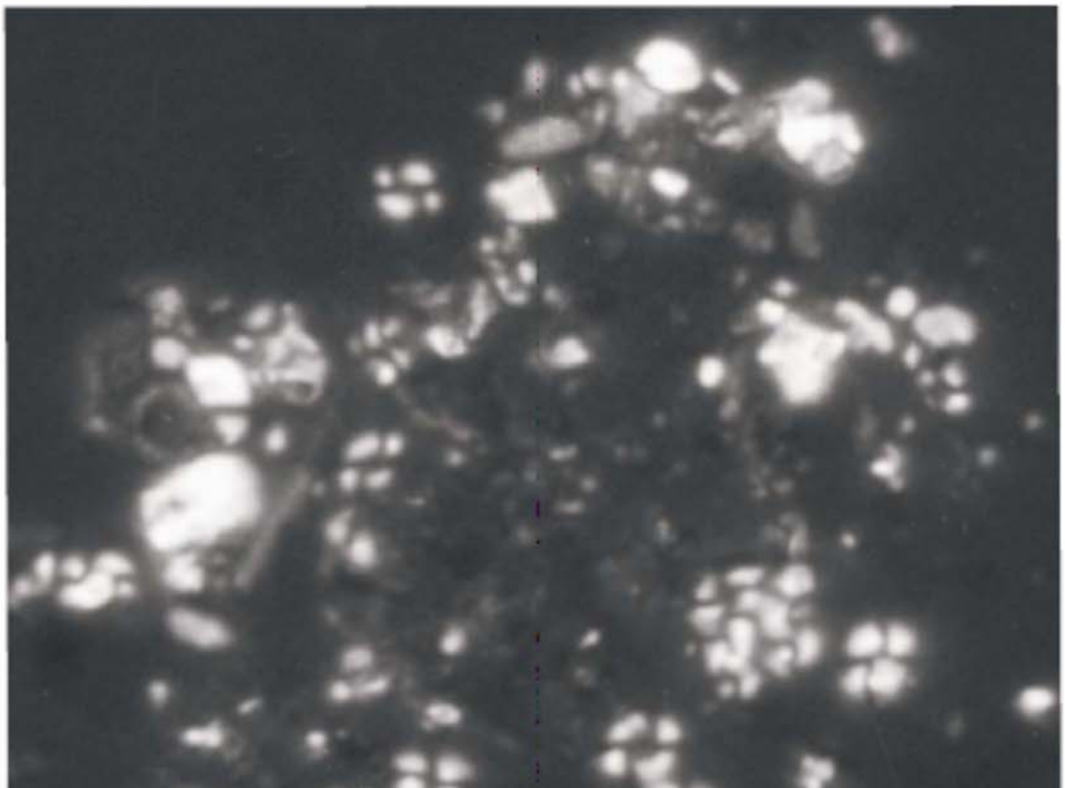
1a

1b

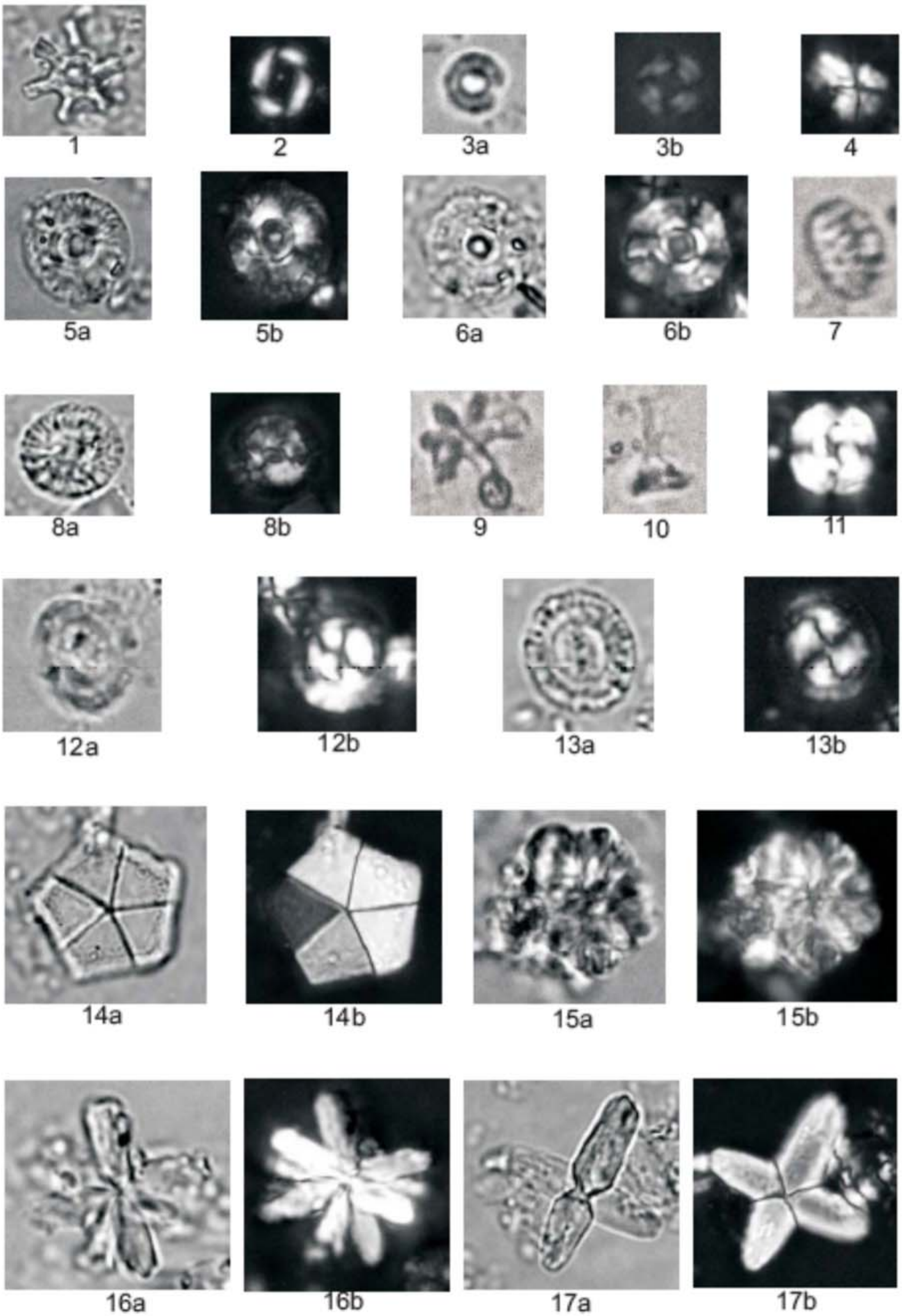


2a

2b



3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3b
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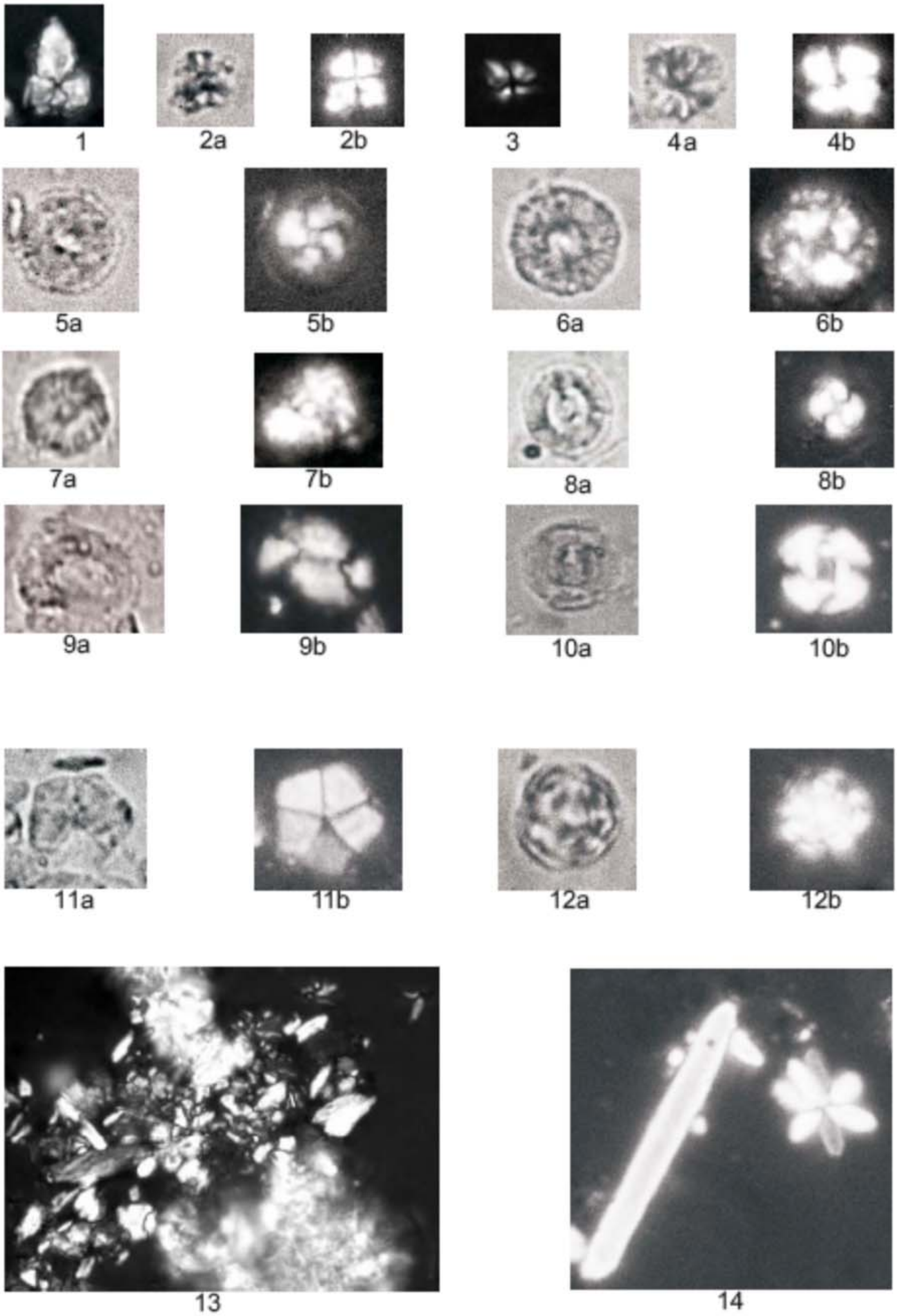
17b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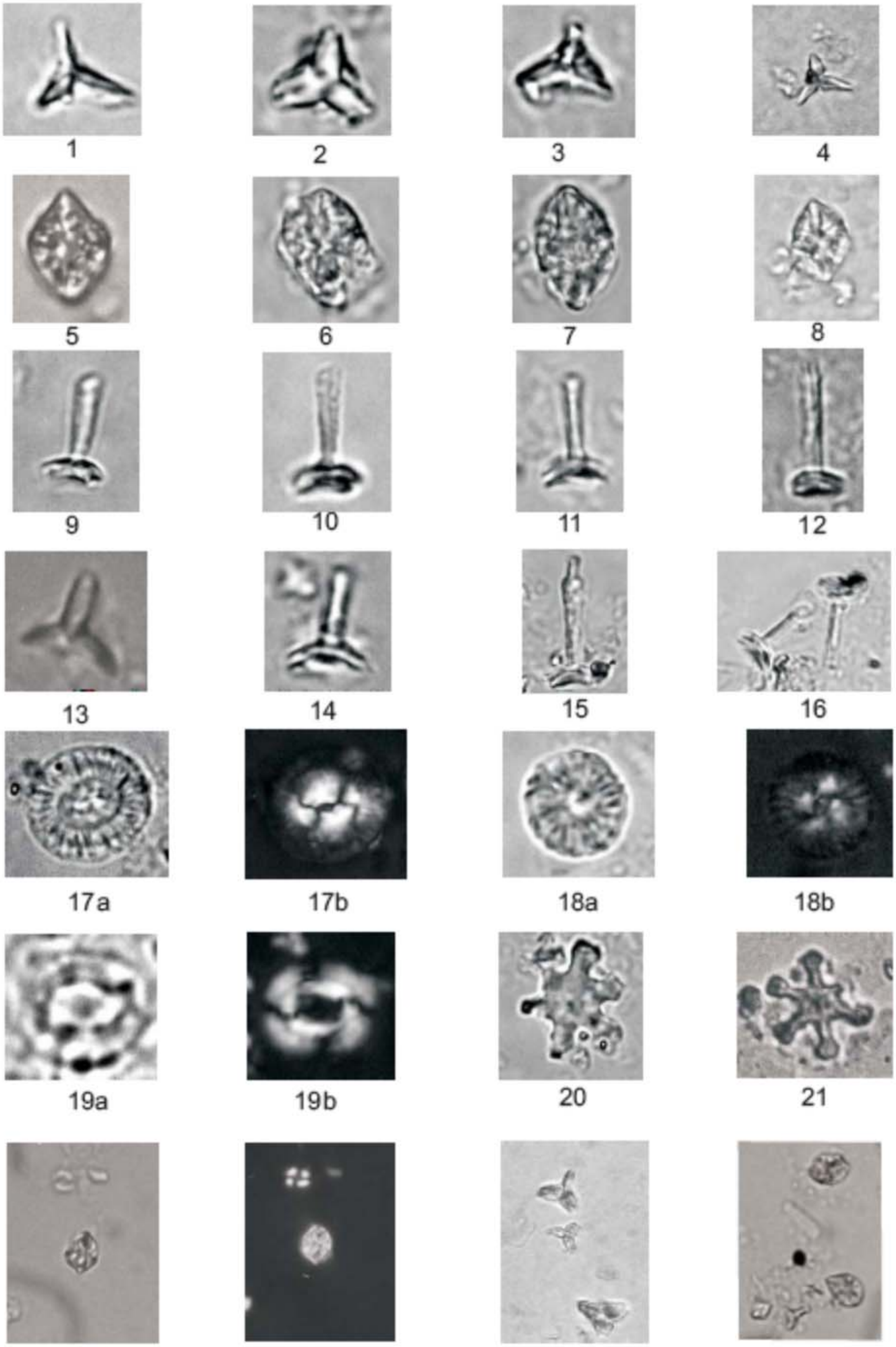
13
14



1 2 3 4
5 6 7 8
9 10 11 12
13 14 15 16
17a 17b 18a 18b
19a 19b 20 21
22a 22b 23 24