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LITHO- AND BIOSTRATIGRAPHY (CALCAREOUS NANNOPLANKTON) OF THE MIOCENE DEPOSITS FROM THE OUTER MOLDAVIDES

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Abstract: The studies of the Neogene nannoplankton assemblages, identified in the Outer Moldavides, permitted us: to date and to correlate the lithostratigraphic units developed in the Tarcău, Marginal Folds and Subcarpathian nappes of the East Carpathians; to define more nannofossil subzones and to observe a lot of nannofossil bioevents (FAD or LAD), which may characterize the chronostratigraphic units. It was remarked that the boundaries between the Egerian–Eggenburgian, Karpatian–Badenian and Badenian–Sarmatian stages can be characterized by the first occurrences of *Reticulofenestra pseudoumbilicus*, *Discoaster exilis* and *Discoaster kugleri* species. The boundary between the Oligocene and Miocene can also be approximated, in the Outer Moldavides area, by the first occurrences of *Helicosphaera mediterranea*.

Key words: Miocene, East Carpathians, Tarcău, Marginal Folds and Subcarpathian nappes, nannoplakton zonation, nannofossil assemblages.

Lithostratigraphy

In the Outer Carpathian area, the Miocene sedimentary succession is entirely developed only in the Outer Moldavides. The Outer Moldavides represent the external folded zone of the East Carpathians, being constituted, from the West (inside) to the East (outside) by the Tarcău, Marginal Folds and Subcarpathian nappes. Each tectonic unit presents a specific lithofacies (Fig. 1).

Tarcău Nappe

The Late Oligocene-Early Miocene formations of the Tarcău Nappe are represented by the upper parts of the Pucioasa-Fusaru and bituminous lithofacies (Săndulescu et al. 1995), developed in the internal, or external areas of this tectonic unit (Fig. 1).

The first lithofacies includes, in normal stratigraphic succession, the Vineţişu and Upper Dyssodilic Shales and Menilites formations (Fig. 2).

The Vineţişu Formation, Oligocene–Early Eggenburgian in age, shows a constant lithological composition, including grey marls or clays and calcareous sandstones, with oblique to convolute laminations. Two or three cineritic levels occur within the lower half of this formation. Different mechanical structures, such as flute-casts, groove-casts and brush-casts, in the arenitic rocks were observed.

The Upper Dyssodilic Shales and Menilites Formation, belonging to the Eggenburgian (or Early Burdigalian), is composed of bituminous argilitic shales (or dyssodiles) and bituminous silicolitic rocks, with one or two benthonized tuff beds interlayered. The absence of the bioglifs in this bituminous deposits is a result of the anoxic conditions, that characterize the sedimentation environment.

Very well exposed in the Muntenian Subcarpathians is the second bituminous lithofacies, composed, in the normal stratigraphic succession, of the Podu Morii, Upper Kliwa Sandstones (or Buştenari Sands), Upper Menilites and Goru Mişina formations.

The Podu Morii Formation, Late Oligocene–Early Eggenburgian in age, consists of a rhytmic alternation of sandstones and clays. In its uppermost part, dyssodilic shales may be interbedded. Two cineritic interlayerings, that occur in this formation, may be used for stratigraphic correlations.

The Upper Kliwa Sandstones, Eggenburgian (or Early Burdigalian) in age, are represented by massive siliceous sandstones or sands with thin bituminous shales interbedded. In these deposits, flame shaped deformation structures suggesting rapid sedimentation, often appear.

The bituminous lithofacies ends with Upper Menilites, consisting of bituminous silicolits and dyssodilic shales and with Goru Mişina Formation, developed especially in the Marginal Folds Nappe.

Both above mentioned lithofacies are followed by the Cornu Formation, belonging to the Late Eggenburgian–Ottnangian (or Early–Middle Burdigalian). The formation is very well exposed (Figs. 1I-1,-3,-6,-7) only in the Muntenian Subcarpathians. The Cornu Formation starts with the Lower Gypsum Member, constituted of decimetric gypsum beds with centimetric gipsiferous sandstones or clays interlayerings (Fig. 2). Above this member, a sequence consisting of middle-size conglomerates to microconglomerates, breccias, glauconitic sandstones, silty-clays and clays, is developed. In the arenitic and lutitic rocks, flute-marks, crescent-marks and erosion channels were observed.

The overlying formation, Doftana Molasse (Stefănescu & Mărunţeanu 1980), Ottnangian–Karpatian (or Late Burdigalian–Early Langhian) in age, is developed only in the Tarcău Nappe (Figs. 1I-1,-2,-6,-7). It starts with the Brebu Conglomerates, a pile of polymictic weakly cemented conglomerates. The ruditic elements are the result of the transport of two paleorivers, which deposited the detrital material in two alluvi-

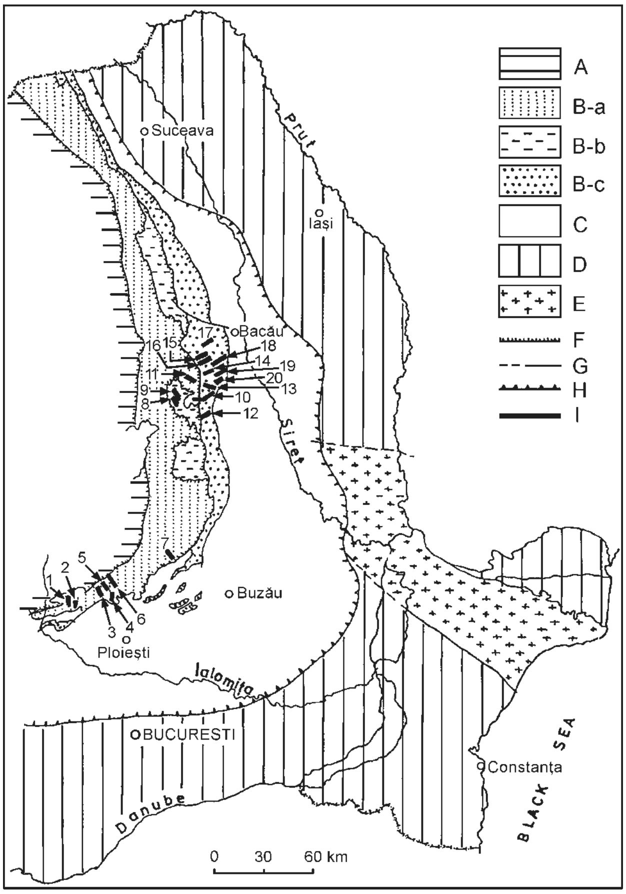


Fig. l. Geological section positions in the Outer Moldavides (Tectonic sketch according to Săndulescu 1984). **A.** Inner Moldavides; **B.** Outer Moldavides: a—Tarcău Nappe, b—Marginal Folds Nappe, c—Subcarpathian Nappe; **C.** foredeep and Neogene molasse depressions; **D.** platforms; **E.** North Dobrogea orogen; **F.** thrust-sheets; **G.** faults; **H.** flexure; **I.** geological sections (1. Prahova Valley—Breaza town; 2. Telega Valley—Telega village; 3. Lupa Valley—Brebu village; 4. Teleajen Valley—Vălenii de Munte town; 5. Piatra Verde Hill—Slănic Prahova town; 6. Teleajen Valley—Homorâciu village; 7. Muscelu Brook—Pătârlage village; 8. Pârâul lui Pătru—Hârja village; 9. Feschi Creek—Hârja village; 10. Oituz Valley—between Grozeşti and Bogdăneşti villages; 11. Vâlcele village; 12. Haloşu Mare Valley—Caşin village; 13. Caraclău Valley—between Caraclău and Brăteşti villages; 14. Bârsăneşti Valley—between Bârsăneşti and Glodosu villages; 15. Scăriga Valley—between Scăriga and Butucari villages; 16. Poiana Valley—between Poiana and Albele villages; 17. Tescani locality; 18. Drăgugeşti Valley—between Helegiu and Drăgugeşti villages; 19. Brătila Valley—between Ciortea and Brătila villages; 20. Tazlău Valley and Trotuş Valley—Oneşti town).

al fans (Grujinski 1971). The rest of the Doftana Molasse consists of microconglomerates and coarse- to fine-grained sandstones alternating with grey or reddish clays or marls. At several levels, thin gypsum or cineritic beds and laminated dolomitic or calcareous shales are interbedded. Among all these lithostratigraphic elements only one, namely a gypsum level (Cireşu Gypsum), located in the middle part of the Doftana Molasse and preceded by a cineritic sequence, may be considered as a geometric marker level.

A classical lithostratigraphic succession (Popescu 1951) of the Badenian deposits is exposed in the axial part of the Slănic Syncline (Figs. 1I-3,-5). It consists of: Slănic Tuff (composed of tuffs and tuffites, interbedded with Globigerina Marls), Evaporitic Formation (with salt breccias, gypsum beds or lens, salt acummulations and very thin silty-clay interlayerings), Radiolarian Shales (represented by argillaceous shales, rich in radiolarians, sands and sandstones) and Spirialis Marls (developed in a predominant lutitic facies).

Marginal Folds Nappe

In this tectonic unit, the Miocene deposits start with the upper part of the Dyssodilic Shales, followed by the Upper Menilites and Goru Mişina Formation. The Goru Mişina Formation (Dumitrescu 1952), Late Eggenburgian (or Early Burdigalian) in age, is very well exposed on the Feschi Creek (Figs. 1I-3). It consists of argillaceous and bituminous shales, silty-clays, clays, sandstones and microconglomerates (Fig. 2). A peculiar feature of this formation is the presence of the shaped-lens gypsum. The evaporites were considered to be redeposited from a shallow water area, situated in the litoral proximity of the sedimentary basin (Săndulescu et al. 1995).

The overlying Salt Formation, also Late Eggenburgian in age, outcrops (Figs. 1I-8,-10) in the Vâlcele Tectonic Window (Săndulescu et al. 1995). It is composed of massive argillaceous breccias (containing "Green Schists", Jurassic or Eocene limestones, conglomerates, sandstones elements), gypsum and thin clay interlayerings. Salt masses are frequently developed in these breccias. Overlying the Salt Formation, the Condor Sandstones (Dumitrescu 1952) is represented by an alternation of microconglomerates (with "Green Schists" element, that prove a foreland-source), arkosian sandstones, clays and marls (Fig. 2).

These sequence of sedimentation continues with the Hârja Formation (Dumitrescu 1952), belonging to the Late Eggenburgian–Ottnangian (or Middle Burdigalian). In the geological type sections (Figs. 1I-8,-11), it consists of a pararythmic alternation of reddish or grey clays and sandstones. The sedimentological features, as ripple-marks, rain-prints and footprints of birds or mammals, suggest a shallow water depositional environment. The presence of the "Green Schists" (Dobrogean type) as elements in the arenitic rocks proves a foreland-source for the detrital material.

The Grey Schlier Formation, Ottnangian–Karpatian (or Late Burdigalian) in age, overlies the previous formation in the continuous sedimentation. This formation outcrops in Vâlcele Brook (Fig. 1I-11), where is incompletely developed, being represented by several gypsum beds, separated by gipsiferous sandstones or marls (an equivalent of the Perchiu Gypsum from Subcarpathian Nappe). In other places of the Marginal Folds Nappe, an alternation of grey marls or clays, sands and sandstones with the Valea Calului Marls interlayerings is developed.

Subcarpathian Nappe

The Late Oligocene-Early Miocene deposits of this tectonic unit contain the same formations (Upper Dyssodilic

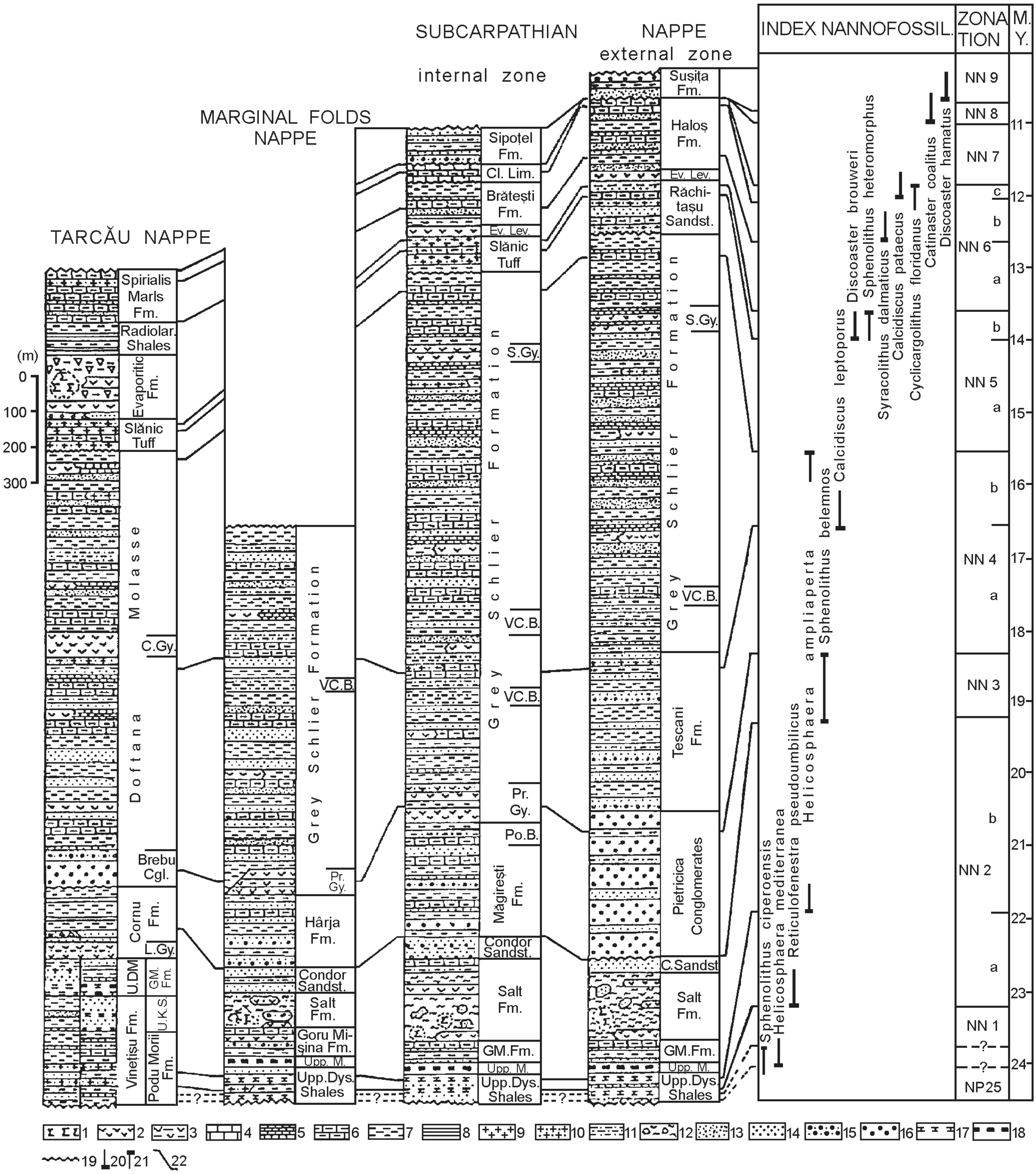


Fig. 2. Neogene stratigraphy in the East-Carpathian Outer Moldavides. **Upp. Dys. Shales** — Upper Dyssodilic Shales; **Upp. M.** — Upper Menilites; **GM.Fm** — Goru Mişina Formation; **U.K.S.** — Upper Kliwa Sandstones; **U.DM** — Upper Dyssodils and Menilites; **pr.Gy.** — Perchiu Gypsum Member; **Po.B.** — Poiana Beds; **VC.B.** — Valea Calului Beds; **C.Gy.** — Cireşu Gypsum Member; **S.Gy.** — Stufu Gypsum Member; **Cl.Lim.** — Clenciu Limestones; **Ev.Lev.** — Evaporic Level. **1**— salt; **2**—gypsum; **3**— gypsiferous clays; **4**— limestones; **5**— calcareous shales; **6**— marls; **7**— clays; **8**— argillaceous shales; **9**— tuffs; **10**— tuffites; **11**— siltitestones; **12**— breccious clays; **13**— sands; **14**— sandstones; **15**— microconglomerates; **16**— conglomerates; **17**— dyssodils; **18**— menilites; **19**— unconformity; **20**— first occurrence of nannofossils; **21**— last occurrence of nannofossils; **22**— biostratigraphic (nannoplankton) correlations.

Shales, Upper Menilites, Goru Mişina, Salt formations and Condor Sandstones) as the Marginal Folds Nappe. In the Subcarpathian Nappe (constituted by Măgireşti-Perchiu, Pietricica and Valea Mare digitations), the Miocene succession, deposited after the Condor Sandstones sedimentation, is represented in two lithofacies (Săndulescu et al. 1980): internal,

Fig. 3. Stratigraphic distribution of nannofossils in the Miocene deposits from the Outer Moldavides.

developed in the Măgireşti-Perchiu digitation (Figs. 1I-10, 1I-13–16) and external, typical for the Pietricica digitation (Figs. 1I-12, 1I-18–20).

The first lithofacies starts with the Măgireşti Formation, Ottnangian (or Middle Burdigalian) in age, represented by irregular alternations of conglomerates, sandstones, reddish or green clays and marls (Fig. 2). The conglomeratic interlyers are a distal effect of the Pietricica Conglomerates from the Pietricica digitation. The Poiana Marls level was distinguished in the uppermost part of this formation (Olteanu 1953). The same sedimentological structures, as in the Hârja Formation, were observed. The sedimentation continues with the Grey Schlier Formation, Late Ottnangian–Karpatian (or Late Burdigalian–Early Langhian) in age, and presents a great lithological variability (clays, marls, sands, sandstones, gypsum beds or lenses, tuffs, tuffites and thin laminated dolomitic or calcareous shales — Fig. 2). In its succession, some lithostratigraphic marker levels were distinguished (Olteanu 1953; Săndulescu 1962): the Perchiu Gypsum in the base; two Valea Calului Marls levels (represented by reddish clays) in the lower part of the succession and the Stufu Gypsum (a massive evaporitic sequence) in the upper part of the Grey Schlier Formation. Between the Valea Calului levels and just below the Stufu Gypsum, two cineritic levels, very important in the lithostratigraphic correlation, can be observed (Fig. 2). The sedimentological features (flute marks, crescent-marks, detritic ridge moulds, current ripples, mudcracks, rain-prints, etc.) together with the presence of the evaporitic rocks and the rarity of the marine nannofossils suggest the alternation of continental and marine sedimentations, in a sea shore environment.

Transgressively deposited above the Grey Schlier Formation, the Badenian sequence is composed, in the normal stratigraphic succession, of the Slănic Tuff (which differs from its equivalent developed in the Tarcău Nappe only through the glauconitic sandstones intercalations), the Evaporitic Level (consisting of gypsum beds associated with thin laminated calcareous shales), the Brăteşti Formation (an irregular alternation of clays, sands and sandstones) and the Clenciu Limestones (constituted of organogeous limestones interbedded with tuffs and tuffites).

The last lithostratigraphic unit of the Măgireşti-Perchiu digitation is represented by the Sipoţel Formation, Early Sarmatian in age. It consits of clays, marls and sandstones (Fig. 2).

The external lithofacies of the Subcarpathian Nappe, developed in the Pietricica digitation and very well exposed in the Central Moldavian Subcarpathians (Figs. 1I-12,-18,-19, -20), starts with the Pietricica Conglomerates, which cover in discontinuity of sedimentation the older deposits. This formation is represented by massive conglomerates with “Green Schists”, Eocene and Jurassic limestones, red sandstones, quartz and quartzite elements. Some sandstones or silty-clay levels are interbedded into the upper part of the conglomeratic succession (Fig. 2). The petrographic and sedimentological studies (Mărunţeanu 1985) prove that the conglomerates are the result of the paleoriver transport, which deposited the detrital material, coming from the foreland-sources, in the great alluvial fans.

Seated in continuity of sedimentation over Pietricica Conglomerates, the Tescani Formation, belonging to the Ottnangian–Early Karpatian (or Middle–Late Burdigalian), is developed. It consists of reddish or grey-greenish clays interbedded with coarse- to fine-grained sandstones. The uppermost part of this formation, contains a cineritic level, stratigraphically equivalent to the first cineritic level of Grey Schlier Formation from the Măgireşti-Perchiu digitation (Fig. 2).

The next lithostratigraphic unit, the Grey Schlier Formation, Late Karpatian (or Early Langhian) in age, presents a similar lithological composition to the upper part of the Grey Schlier Formation from the Măgireşti-Perchiu digitation (Fig. 2).

Overlying these deposits, after a sedimentary gap, the Badenian sequence (Fig. 2) is represented (in the normal stratigraphic succession) by the Răchitaşu Sandstones (composed of glauconitic sandstones with Lithothamnium, Globigerina Marls and dacitic tuffs and tufittes), the Evaporitic Level (with a similar lithological composition to the Măgireşti-Perchiu digitation) and Haloş Formation. The last lithostratigraphic unit, Kossovian in age, is represented by an irregular alternation of clays, sands (more frequent in the lower part of the succession) and sandstones.

In the external lithofacies of the Subcarpathian Nappe, the sedimentation ceased at the end of the Kossovian or the lower Sarmatian deposits were eroded. The Suşiţa Formation, Middle Sarmatian in age, is represented by post-tectonic deposits, which cover the external part of the Subcarpathian Nappe. It consists of conglomerates, clays and sands.

Biostratigraphy — calcareous nannoplankton

For the stratigraphic study of the Early and Middle Miocene deposits, a lot of representative geological sections in the Muntenian (for Tarcău Nappe) and Central Moldavian (for Marginal Folds and Subcarpathian nappes) Subcarpathians were selected (Fig. 1).

In the deposits of the Outer Moldavides, the whole biozone succession, from NN 1 to NN 9 zones, of the Standard Nannoplankton Zonation (Martini 1971; Martini & Müller 1986) was identified.

The Triquetrorhabdulus carinatus-NN 1 Zone was remarked only in the Vineţişu and Podu Morii formations. The nannoplankton assemblages of this zone (Pl. IA) consist of species with Oligocene–Miocene ranges, as *Coccolithus pelagicus, C. eopelagicus, Cyclicargolithus abisectus, Cy. floridanus, Discoaster adamanteus, D. deflandrei, Helicosphaera euphratis, H. intermedia, H. paleocarteri, Sphenolithus conicus, Reticulofenestra minuta, R. minutula* and rare appearances of *Triquetrorhabdulus carinatus. Helicosphaera mediterranea* also has its first occurrence in these communities. It was supposed that this bioevent marks the boundary between the NP 25–NN 1 zones (or between Oligocene and Miocene), because: (1) the disappearances of *Helicosphaera recta, Sphenolithus ciperoensis* and *Zygrablithus bijugatus* are not simultaneous (Fig. 3) and consequently the lower boundary of NN 1 Zone cannot be marked by the above mentioned bioevents; (2) the first occurrences of *Helicosphaera mediterranea* are simultaneous with the first appearances of *Globigerinoides primordius* (Foraminifera), the last one marking the Oligocene-Miocene boundary (Bizon & Bizon 1972; Cita 1976; Berggren et al. 1997; etc.).

The Discoaster druggii-NN 2 Zone was subdivided (Mărunţeanu 1992) into the Sphenolithus dissimilis-NN 2a and Helicosphaera kamptneri-NN 2b subzones, on the basis of the first occurrence of *Helicosphaera ampliaperta,* which corresponds to the disappearance of *Sphenolithus dissimilis.* The NN 2a Subzone, identified in the Vineţişu and Podu Morii formations, contains *Reticulofenestra pseudoumbilicus, Discoaster druggii, Sphenolithus dissimilis* (Pl. IB) and the whole species community of the NN 1 Zone (Fig. 3). The NN 2b Subzone, with *Helicosphaera ampliaperta, H. kamptneri* (Pl. IB) and all species, excepting *Sphenolithus dissimilis*, of the NN 2a Subzone (Fig. 3), in the Vineţişu, Podu Morii, Upper Kliwa Sandstones, Goru Mişina formations, Lower Gypsum Member, Salt Formation and in the lower part of Condor Sandstones. It is very probably that the boundary between NN 2 and NN 3 zones is situated within the Lower Gypsum Member or within the Condor Sandstones Formation.

The Sphenolithus heteromorphus-NN 3 Zone is characterized by *Sphenolithus belemnos, Helicosphaera ampliaperta, H. kamptneri, H. intermedia, Coccolithus pelagicus, C. miopelagicus, Cyclicargolithus abisectus, Cy. floridanus, Discoaster adamanteus, Reticulofenestra pseudoumbilicus, R. gelida*, etc. (Fig. 3; Pl. IIA). These nannofossils were identified only in the lower parts of the Cornu, Hârja and Măgireşti formations.

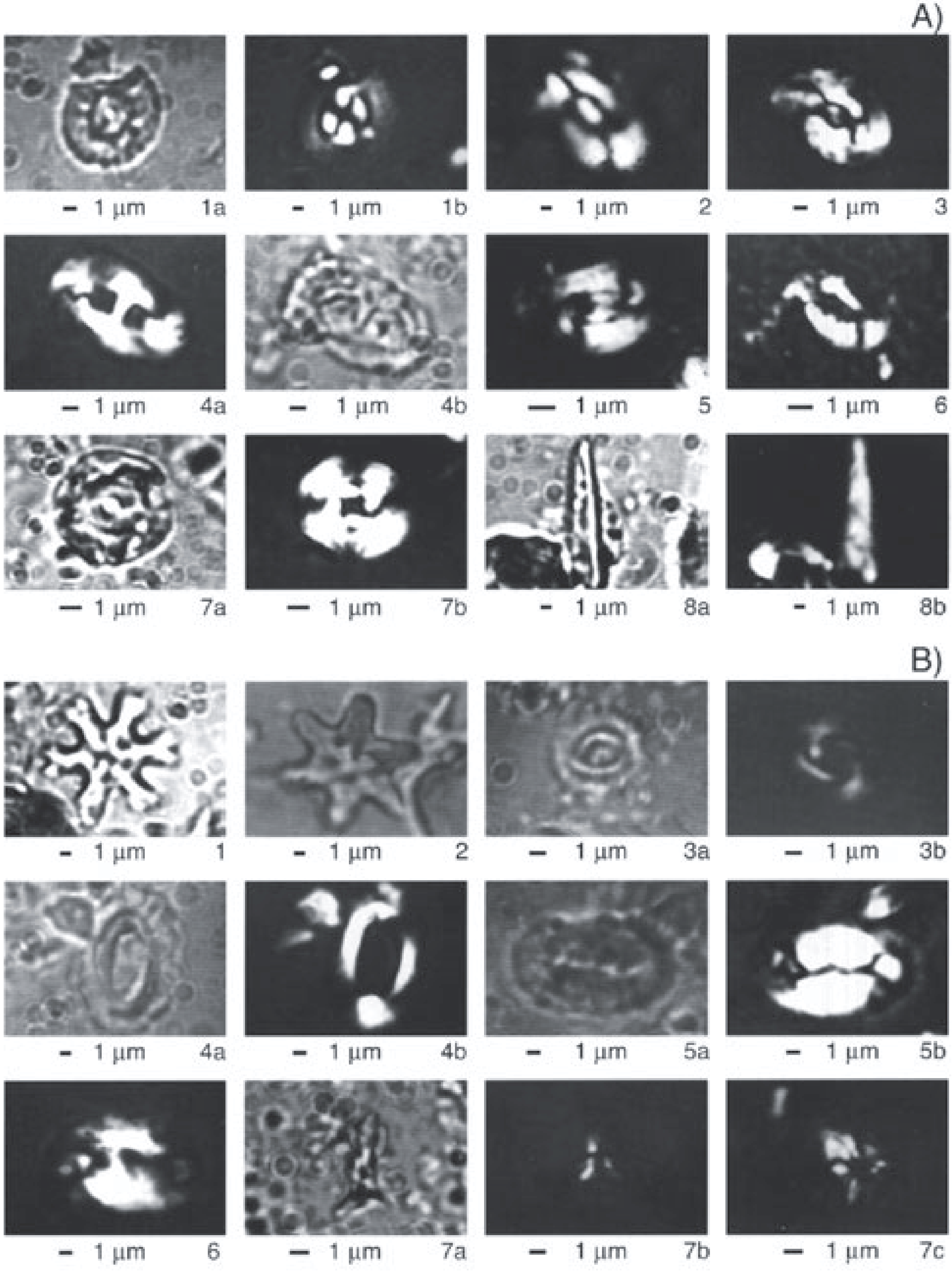
The Helicosphaera ampliaperta-NN 4 Zone was subdivided (Mărunţeanu 1992) into two subzones: Discoaster adamanteus-NN 4a and Calcidiscus leptoporus-NN 4b subzones. The boundary between these two subzones is marked by the first occurrence of *Calcidiscus leptoporus*. Assemblages with *Helicosphaera ampliaperta, H. kamptneri, H. paleocarteri, Discoaster adamanteus, D. deflandrei, Cyclicargolithus floridanus, Pontosphaera multipora, Braarudosphaera bigelowii, Coccolithus pelagicus, C. miopelagicus, Sphenolithus moriformis, Reticulofenestra pseudoumbilicus*, etc. (Fig. 3), belonging to the NN 4a Subzone, are developed in the Doftana Molasse (just below Cireşu Gypsum), in the lower part of the Grey Schlier Formation and in the Tescani Formation (below the first cineritic level). The NN 4b Subzone was identified only in the Doftana Molasse (above Cireşu Gypsum) and in the upper part of the Grey Schlier Formation (above the first cineritic level). It is characterized by a nannoplankton content with *Calcidiscus leptoporus, Helicosphaera ampliaperta, Calcidiscus macintyrei, C. annula, Discoaster musicus, Discoaster variabilis* and *Sphenolithus heteromorphus* (Fig. 3; Pl. IIB).

The Sphenolithus heteromorphus-NN 5 Zone was recognized in the top of the Doftana Molasse or in the top of the Grey Schlier Formation and in the Slănic Tuff or Răchitaşu Sandstones. Its very rich nannofossil content (Pl. IIIA) consists of *Sphenolithus heteromorphus, Discoaster exilis, D. variabilis, D. formosus, D. musicus, Holodiscolithus macroporus, Calcidiscus annula,* etc. (Fig. 2). *Discoaster brouweri, Helicosphaera wallichii* and *Sphenolithus abies* have simultaneous first occurrences before the disappearence of *Sphenolithus heteromorphus*, that is in the upper part of NN 5 Zone. It was observed that these nannofossil bioevents correspond to the first appearances of *Globigerina druggii* (Foraminifera), index fossil for the Moravian-Wieliczian boundary (Popescu & Gheţa 1984). Consequently the NN 5 Zone can be subdivided, at least in the extra-Carpathians area, into two subzones: the Calcidiscus annula-NN 5a Subzone, developed between the FAD of *Discoaster exilis* and the FAD of *Discoaster brouweri* or of *Helicosphaera wallichii*, characterizing the top of Karpatian Stage and the Moravian Substage; the Helicosphaera wallichii-NN 5b Subzone, defined between the FAD of *Discoaster brouwerii* or of *Helicosphaera wallichii* and the LAD of *Sphenolithus heteromorphus*, corresponding to the lower part of the Wieliczian Substage.

The Discoaster exilis-NN 6 Zone with *Discoaster brouweri, D. variabilis, D. exilis, Helicosphaera wallichii, Sphenolithus*

Plate I: Nannoplankton assemblages of the NN 1 and NN 2 zones. **A** — Nannofossils from the Vineţişu Formation—NN 1 Zone. **Fig. 1.** *Coccolithus pelagicus* (Wallich); 1a-NII, 1b-N+; Lupa Valley· **Fig. 2.** *Helicosphaera intermedia* Martini; N+; Lupa Valley. **Fig. 3.** *Helicosphaera euphratis* Haq; N+; Lupa Valley. **Fig. 4.** *Helicosphaera mediterranea* Müller; 4a-N+, 4b-NII; Teleajen Valley—Homorâciu. **Fig. 5.** *Reticulofenestra lockeri* Müller; N+; Teleajen Valley—Homorâciu. **Fig. 6.** *Helicosphaera scissura* Müller; N+; Teleajen Valley—Homorâciu. **Fig. 7.** *Cyclicargolithus abisectus* (Müller); 7a-NII, 7b-N+; Lupa Valley. **Fig. 8.** *Triquetrorhabdulus carinatus* Martini; 8a-NII, 8b-N+; Lupa Valley. **B** — Nannofossils from the Podu Morii Formation—NN 2 Zone. **Fig. 1.** *Discoaster deflandrei* Bramlette & Riedel; Teleajen Valley—Valenii de Munte. **Fig. 2.** *Discoaster druggii* Bramlette & Wilcoxon; Teleajen Valley— Valenii de Munte. **Fig. 3.** *Reticulofenestra pseudoumbilicus* (Gartner); 3a-NII; 3b-N+; Teleajen Valley—Valenii de Munte. **Fig. 4.** *Helicosphaera ampliaperta* Bramlette & Wilcoxon; 4a-NII; 4b-N+; Teleajen Valley—Valenii de Munte. **Fig. 5.** *Helicosphaera kamptneri* Hay & Mohler; 5a-NII, 5b-N+; Teleajen Valley—Valenii de Munte. **Fig. 6.** *Helicosphaera mediterranea* Müller; N+; Teleajen Valley—Valenii de Munte. **Fig. 7.** *Sphenolithus dissimilis* Bukry & Percival; 7a-NII, 7b,c-N+; Teleajen Valley—Valenii de Munte.

Plate II: Nannoplankton assemblages of the NN 3 and NN 4 zones. **A** — Nannofossils from the Hârja Formation—NN3 Zone. **Fig. 1.** *Sphenolithus* cf. *belemnos* Bramlette & Wilcoxon; 1a-NII, 1-bN+; Pârâul lui Patru. **Fig. 2.** *Helicosphaera ampliaperta* Bramlette & Wilcoxon; N+; Pârâul lui Patru. **Fig. 3.** *Reticulofenestra minuta* Roth; N+; Pârâul lui Patru. **Fig. 4.** *Helicosphaera kamptneri* Hay & Mohler; 4a-NII, 4b-N+; Pârâul lui Patru. **Fig. 5.** *Reticulofenestra pseudoumbilicus* (Gartner); 5a-NII; 5b-N+; Pârâul lui Patru. **Fig. 6.** *Braarudosphaera bigelowii* (Gran & Braarud); 6a-NII, 6b-N+; Pârâul lui Patru. **Fig. 7.** *Pontosphaera multipora* (Kamptner); 7a-NII, 7b-N; Pârâul lui Patru. **B** — Nannofossils from the Grey Schlier Formation—NN 4 Zone. **Fig. 1.** *Coccolithus pelagicus* (Wallich); 1a-NII, 1b-N+; Bârsaneşti Valley—Bârsaneşti. **Fig.** 2. *Calcidiscus leptoporus* (Murray & Blackmann); 2a-NII, 2b-N+; Drăgugeşti Valley—Helegiu. **Fig. 3.** *Calcidiscus macintyrei* (Bukry & Bramlette) 3a-NII, 3b-N+; Drăgugeşti Valley—Helegiu. **Fig. 4.** *Helicosphaera ampliaperta* Bramlette & Wilcoxon; 4a-NII, 4b-N+ ; Bârsaneşti Valley—Bârsaneşti. **Fig. 5.** *Cyclicargolithus floridanus* (Roth & Hay); 6a-NII, 6b-N+; Drăgugeşti Valley—Helegiu.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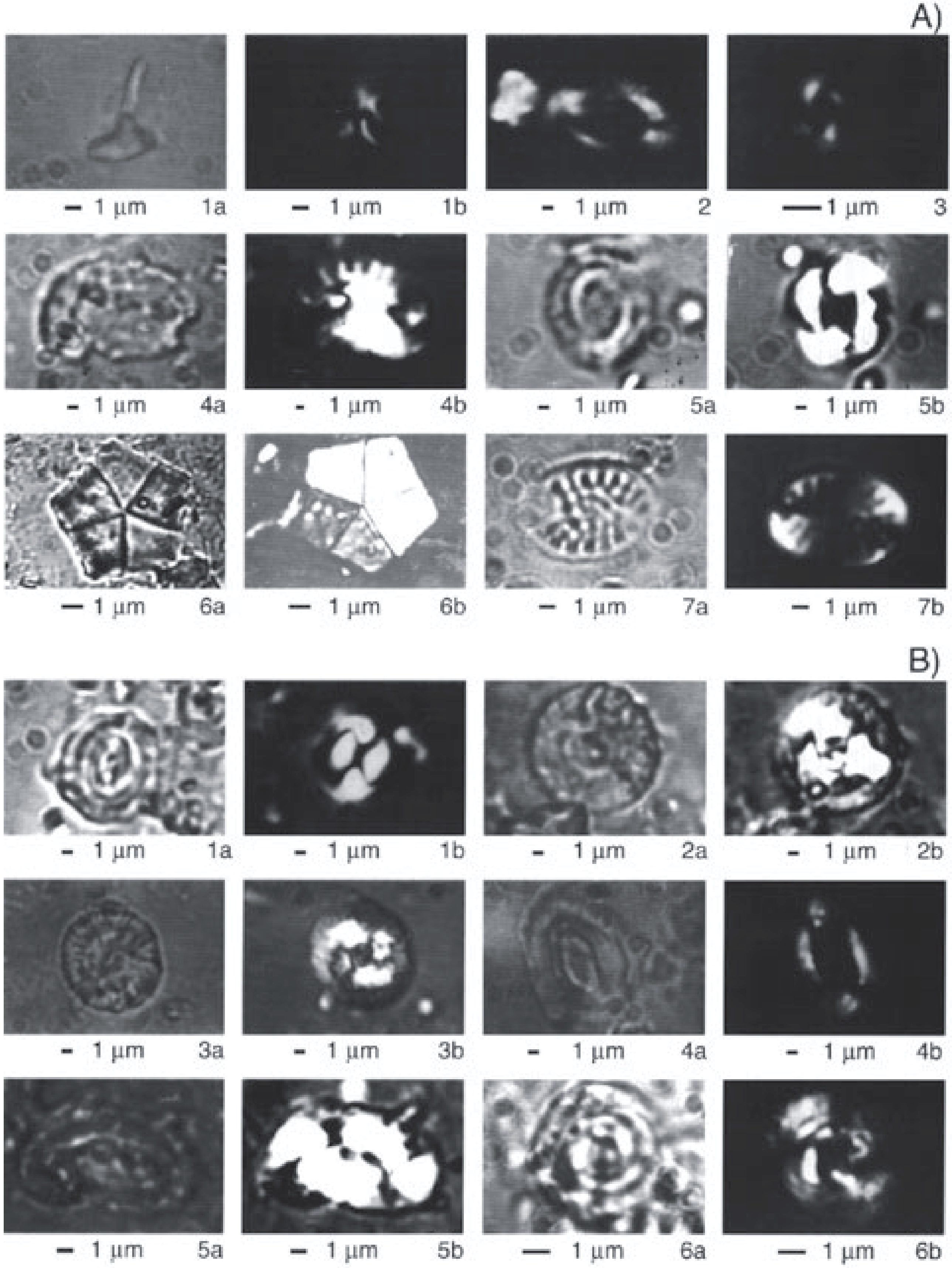
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B)
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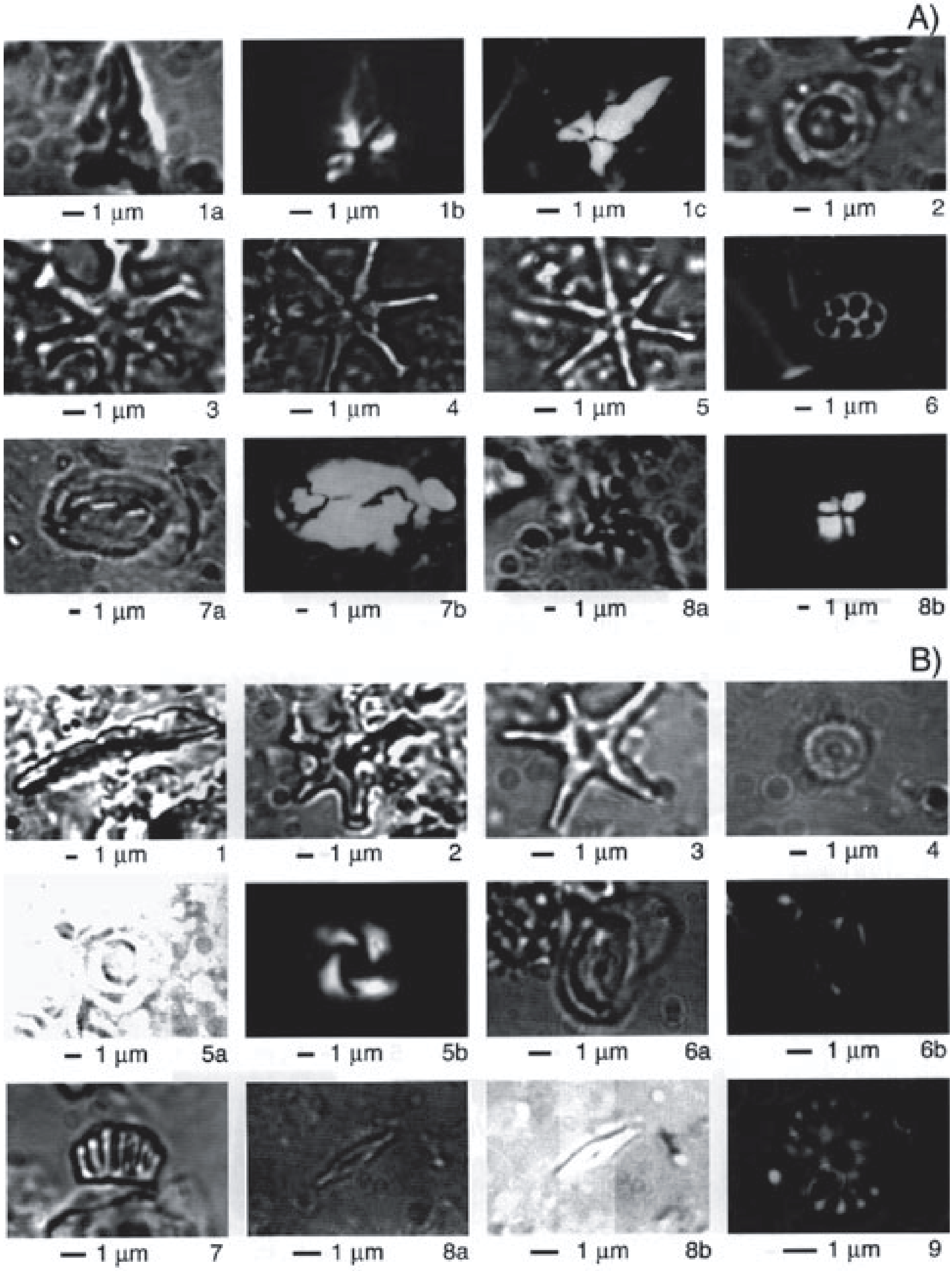
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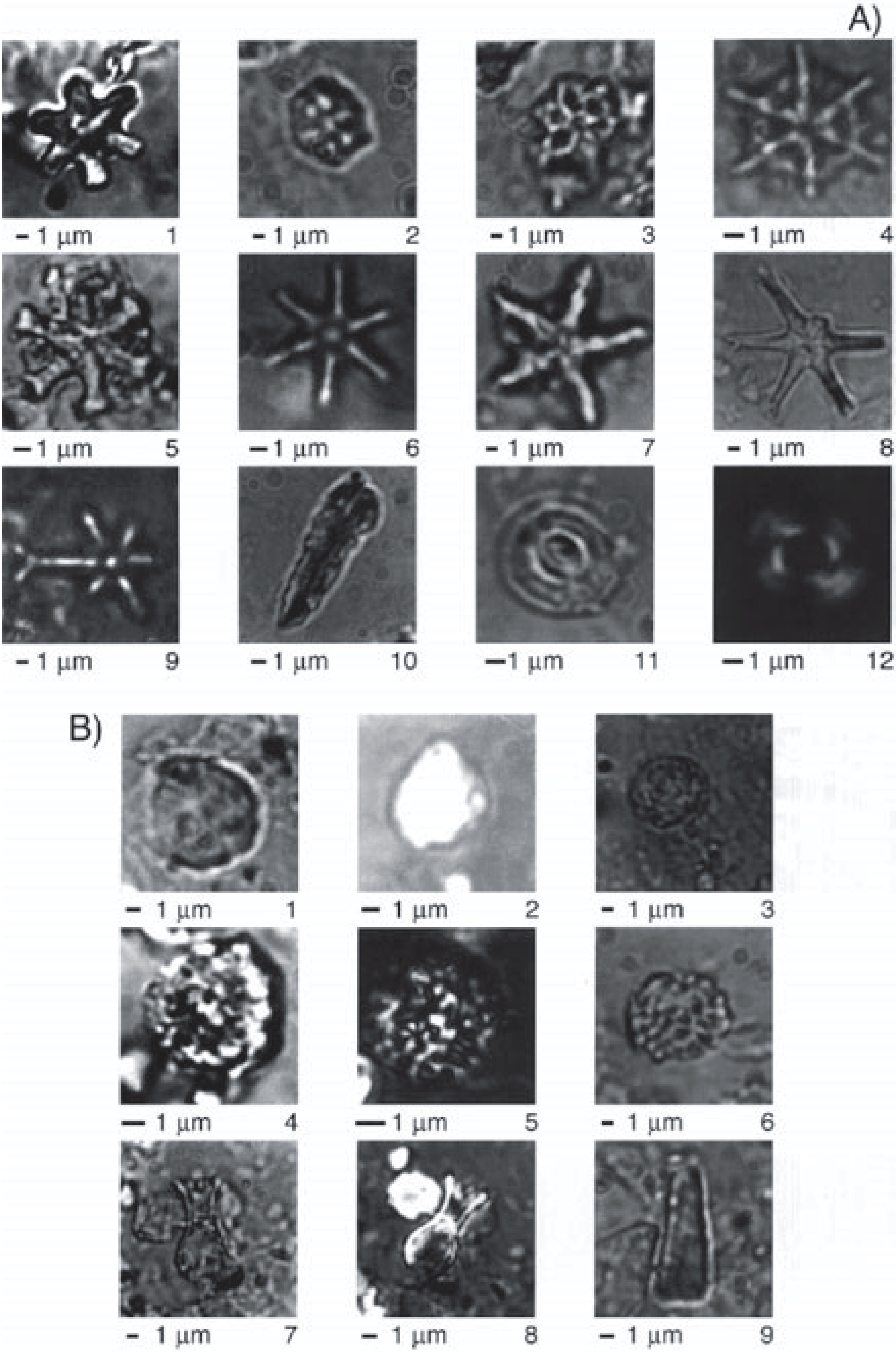
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abies, etc. (Pl. IIIB) characterizes the rest of the Badenian succession, beginning with the uppermost part of the Slănic Tuff or of the Răchitaşu Sandstones and ending with the Clenciu Limestones or Haloş Formation. More first occurrences were observed in the distinct stratigraphic levels of this zone (*Syracolithus dalmaticus* at the base of Spirialis Marls, Brăteşti Formation and Haloş Formation; *Scapholithus fossilis* in the Spirialis Marls and Haloş Formation, as well as at the base of Clenciu Limestones; *Calcidiscus pataecus* in the uppermost part of the Badenian succession) (Fig. 3). In the NN 6 Zone, the following subzones, corresponding to the Middle and Late Badenian, can be defined: the Discoaster variabilis-NN 6a Subzone, from the LAD of *Sphenolithus heteromorphus* to the FAD of *Syracolithus dalmaticus*; the Syracolithus dalmaticus— the NN 6b Subzone, between the FAD of *Syracolithus dalmaticus* and the FAD of *Calcidiscus pataecus*; the Calcidiscus pataecus-NN 6c Subzone, from the FAD of *Calcidiscus pataecus* to the LAD of *Cyclicargolithus floridanus*.

The Discoaster kugleri-NN 7 Zone was identified only in the lower part of the Sipoţel Formation, being characterized by a poor nannoplankton assemblages (Fig. 3) with *Coccolithus pelagicus, C. miopelagicus, Sphenolithus moriformis, S. abies, Calcidiscus leptoporus, C. macintyrei, Reticulofenestra pseudoumbilicus, R. gelida, R. minuta, R. minutula, Umbilicosphaera jafari, Discoaster brouweri* and very rare appearances of *Discoaster kugleri* (Pl. IVA).

In the upper part of the Sipoţel Formation, a nannofossil community, belonging to the Catinaster coalitus-NN 8 Zone was recognized. The first occurrences of *Catinaster coalitus* and *C. calyculus* (Pl. IVA) characterize this zone.

The Discoaster hamatus-NN 9 Zone, containing *Discoaster hamatus, D. brouweri, D. calcaris, D. challangeri, Triquetrorhabdulus rugosus,* etc. (Pl. IVA; Fig. 3) was identified only in the lower part of the Suşiţa Formation. In the upper part of this formation, a poor nannoplankton content, composed only of *Thoracosphaera* and *Scyphosphaera* species (Pl. IVB), was observed.

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Plate III: Nannoplankton assemblages of the NN 5 and NN 6 zones. **A** — Nannofossils from the Răchitaşu Sandstone and Slănic Tuff—NN 5 Zone. **Fig. 1.** *Sphenolithus heteromorphus* Deflandre; 1a-NII, 1b,c-N+; Răchitaşu Sandstone; Tazlau Valley—Oneşti. **Fig. 2.** *Calcidiscus annula* (Cohen); NII; Răchitaşu Sandstone; Tazlau Valley—Oneşti. **Fig. 3.** *Discoaster variabilis* Martini & Bramlette; Răchitaşu Sandstone; Tazlau Valley—Oneşti. **Fig. 4.** *Discoaster exilis* Martini & Bramlette; Slănic Tuff; Caraclău Valley—Brăteşti. **Fig. 5.** *Discoaster brouweri* Tan; Slănic Tuff; Caraclău Valley—Brăteşti. **Fig. 6.** *Holodiscolithus macroporus* (Deflandre); Slănic Tuff; Caraclău Valley—Brăteşti. **Fig. 7.** *Helicosphaera wallichii* (Lohmann); 7a-NII, 7b-N+; Slănic Tuff; Caraclău Valley—Brăteşti. **Fig. 8.** *Sphenolithus abies* Deflandre; 8a-NII, 8b-N+; Răchitaşu Sandstones; Tazlau Valley—Oneşti. **B** — Nannofossils from Brăteşti, Haloş and Clenciu formations—NN 6 Zone. **Fig. 1.** *Triquetrorhabdulus farnsworthi* (Gartner); NII; Haloş Formation; Haloşu Mare Valley. **Fig. 2.** *Discoaster musicus* Stradner; Haloş Formation; Haloşu Mare Valley. **Fig. 3.** *Discoaster brouweri* Tan; Haloş Formation; Haloşu Mare Valley. **Fig. 4.** *Umbilicosphaera jafari* Müller; NII; Haloş Formation; Haloşu Mare Valley. **Fig. 5.** *Reticulofenestra pseudoumbilicus* (Gartner); 5a-NII, 5b-N+; Haloş Formation; Haloşu Mare Valley. **Fig. 6.** *Helicosphaera walbersdorfensis* Müller; 6a-NII, 6b-N+; Brăteşti Formation; Caraclău Valley—Brăteşti. **Fig. 7.** *Holodiscolithus macrosporus* (Deflandre); Brăteşti Formation Caraclău Valley—Brăteşti. **Fig. 8.** *Scapholithus fossilis* Deflandre; 8a-NII, 8b-N+; Haloş Formation; Haloşu Mare Valley. **Fig. 9.** *Calcidiscus pataecus* (Gartner); Clenciu Limestones; Caraclău Valley—Brăteşti.

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Plate IV: Nannoplankton assemblages of the NN 7, NN 8, NN 9 and NN10? zones. **A** — Nannofossils from the Sipoţel and lower part of Suşiţa formations—NN 7, NN 8, NN 9 zones. **Fig. 1.** *Discoaster kugleri* Martini & Bramlette; Sipoţel Formation; Brăteşti Hill. **Fig. 2.** *Catinaster coalitus* Martini & Bramlette; Sipoţel Formation; Brateşti Hill. **Fig. 3.** *Catinaster* sp.; Sipoţel Formation; Brăteşti Hill. **Fig. 4.** *Catinaster calyculus* Martini & Bramlette; Sipoţel Formation; Brăteşti Hill. **Fig. 5.** *Discoaster variabilis* Martini & Bramlette; Sipoţel Formation; Brăteşti Hill. **Fig. 6.** *Discoaster brouweri* Tan; Sipoţel Formation; Brăteşti Hill. **Fig. 7.** *Discoaster hamatus* Martini & Bramlette; Suşiţa Formation; Trotuş Valley—Oneşti. **Fig. 8.** *Discoaster calcaris* Gartner; Suşiţa Formation; Trotuş Valley—Oneşti. **Fig. 9.** *Discoaster challangeri* Bramlette & Riedel; Suşiţa Formation; Trotuş Valley—Oneşti. **Fig. 10.** *Triquetrorhabdulus rugosum* Bramlette & Wilcoxon; Suşiţa Formation; Trotuş Valley—Oneşti. **Figs. 11, 12.** *Reticulofenestra pseudoumbilicus* (Gartner); 11-NII; 12-N+; Suşiţa Formation; Trotuş Valley—Oneşti. **B** — Nannofossils from upper part of the Suşiţa Formation—NN10? **Figs. 1, 2.** *Toracosphaera heimii* (Lohmann); 1-NII; 2-N+; Trotuş Valley—Oneşti. **Fig. 3.** *Toracosphaera deflandrei* Kamptner; NII; Trotuş Valley—Oneşti. **Figs. 4, 5.** *Toracosphaera saxea* Stradner; 4-NII; 5-N+; Trotuş Valley—Onesti. **Fig. 6.** *Toracosphaera albatrosina* Kamptner; NII; Trotuş Valley—Onesti. **Figs. 7, 8.** *Scyphosphaera amphora* Deflandre; 7-NII, 8-N+; Trotuş Valley—Oneşti. **Fig. 9.** *Scytosphaera conica* Kamptner; NII; Trotuş Valley —Oneşti.

Nannofossil bioevents and chronostratigraphic units

In the stratigraphic distribution of the Miocene nannofossils, from the Outer Moldavides deposits, a lot of bioevents (first and last occurrences) were observed. Comparing these bioevents with the nannofossil species distribution from the stratotypes of the Paratethys (Lehotayová 1974; Müller 1974; Lehotayová & Báldi-Beke 1975; Martini & Müller 1975b,c; Lehotayová & Molciková 1975, 1978; etc.) and global (Martini 1968, 1988; Lizaud 1972; Martini & Müller 1975a; Müller & Pujol 1979; Demarque & Perrieux 1984; etc.) Miocene stages, may be remarked: (1) the FAD of *Helicosphaera mediterranea* approximates the boundary between Oligocene and Miocene; (2) the FAD of *Discoaster druggii* or of *Reticulofenestra pseudoumbilicus* characterize the beginning of the Eggenburgian; (3) FAD of *Helicosphaera ampliaperta* marks the boundary between the Aquitanian and Burdigalian; (4) FAD of *Calcidiscus leptoporus* approximates the beginning of Langhian; (5) LAD of *Helicosphaera ampliaperta* or FAD of *Discoaster exilis* characterize the beginning of the Badenian; (6) the FAD of *Discoaster kugleri* or the LAD of *Cyclicargolithus floridanus* show the boundary between the Badenian and Sarmatian.

Consequently, from the nannoplankton point of view, the following correlations between Mediterranean and Paratethys Neogene stages are possible: (1) the Aquitanian corresponds to the Late Egerian and Early Eggenburgian (NN 1 Zone and NN 2a Subzone); (2) the Burdigalian can be correlated with the Late Eggenburgian, Ottnangian and probably Early Karpatian (NN 2b Subzone, NN 3 Zone and NN 4a Subzone); (3) the Early Langhian corresponds to the Late Karpatian (NN 4b Subzone) and the Late Langhian to the Early Badenian (Moravian and the basal Wieliczian — NN 5 Zone); (4) the Serravallian can be correlated with the Middle and Late Badenian (Wieliczian and Kossovian — NN 6 Zone) and Early Sarmatian (Volhynian — NN 7 and the beginning of the NN 8 zones); (5) the beginning of the Tortonian corresponds to the Middle Sarmatian (or Early Bassarabian — upper part of the NN 8 and lower part of the NN 9 zones).

Conclusions

The sedimentological features of the Outer Moldavides deposits and their fossiliferous contents characterize the following sedimentation types: marine by the beginning of the Early Miocene and Badenian, marginal-marine in the Early Miocene and brackish in the Sarmatian. In the Early Miocene, the detrital material proceeded predominantly from foreland-sources and in the Middle Miocene from Carpathian-sources. The continuous and discontinuous stratigraphic distributions of the calcareous nannoplankton, in the above mentioned deposits, suggest paleogeographical connections of long (by the beginning of the Miocene and in the Badenian) or of short (in the Early Miocene and Sarmatian) duration between the Outer Moldavides (constitutive part of the Central Paratethys) and Tethys environments.

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