ACTA PALAEONTOLOGICA ROMANIAE V. 2 (1999), P. 261-267

BADENIAN NANNOFOSSIL ZONATION - THE CARPATHIAN AREA, ROMANIA

MARIANA MĂRUNŢEANU[1], MONICA CRIHAN[2], CARMEN CHIRA[3]

Abstract. Detalied studies of the Badenian calcareous nannofossils of Romania permitted the establishment of many bioevents, very important for regional and worldwide biostratigraphic correlations. On their basis, the *Sphenolithus heteromorphus* - NN5 and *Discoaster exilis* - NN6 standard zones, which exclusively characterise Badenian nannoplankton assemblages, were subdivided in many subzones, as follows: *Geminilithella rotula* - NN5a, that defines the Moravian Substage; *Helicosphaera wallichii* - NN5b and *Discoaster variabilis* - NN6a, typical for Wielician Substage; *Syracosphaera histrica* - NN6b, *Syracolithus dalmaticus* - NN6c and *Calcidiscus pataecus* - NN6d, which characterise the Kossovian Substage. It was also demonstrated that the use of the Langhian Global Stage as subdivision of the Badenian regional chronostratigraphic unit is not legitimated by the nannofossil stratigraphic distribution.

Keywords: Badenian; calcareous nannoplankton; Standard Zonation; subzones.

INTRODUCTION

The regional Badenian stage (marine Middle Miocene) and its subdivisions Moravian, Wielician and Kossovian, were defined and described in the Central Paratethys by Cicha et al. (1968) and Papp et al. (1978).

The study of the calcareous nannofossils of marine Middle Miocene deposits from the Carpathian area, made on numerous geological sections, allowed us: to select a lot of reference sections in the major structural units; to place the identifieded nannoplankton assemblages within the standard zones *Sphenolithus heteromorphus* – NN5 and *Discoaster exilis* – NN6 (Martini, 1971; Martini & Müller, 1986); to detail these nannofossil biozones, by defining and characterising more subzones; to identify some regional and global nannofossil bioevents which alllow a strict correlation between the regional and global chronostratigraphic units of the Middle Miocene.

LITHOSTRATIGRAPHY

In the Carpathian area, within the marine Middle Miocene, the classical lithostratigraphic succession, etablished by Popescu (1951) and Olteanu (1951), is represented by "the *Globigerina* marls"; "salt breccia with salt massifs", "radiolarian shales" and "*Spirialis* marls". For the biostratigraphic study of these formations, the next reference geological sections were selected (fig. 1): Câmpiniţa Valley, Lupa Valley and Piatra Verde Hill in the Slănic Syncline; Albele Valley, Pârâul Rău Valley and Clenciu Hill (lower basin of the Tazlăul Mare river) in Măgireşti – Perchiu Subunit; Tazlăul Mare Valley, Călugăru Valley and Haloşu Mare Valley (north respectively south of the Tazlău -Trotuş rivers confluence) in the Pietricica Subunit; Valea Dosului Brook, Popeşti and Cheia quarries, Slatina Valley, Valea Gardului Brook (north-west Transylvania) and Steaja Valley (south Transylvania) in the Transylvania Depression; Calva Valley, Răduliţa Brook, Iloviţa Brook, 36 Bucoşniţa and 50 Pietroşniţa wells (south of Caransebeş) in the Caransebeş – Mehadia Basin (Pannonian Depression).

On these geological sections, classical lithostratigraphic units are partially or completely developed, known as (Fig.1):

- Slănic Tuff (Murgeanu et al., 1968) and Rachitaşu Sandstones (Athanasiu, 1913), developed in the extra-Carpathian area, Dej and Ciceu-Giurgeşti formations (Popescu, 1970) from the Transylvanian Depression, Lower Calva Formation (Mărunţeanu et al., 1996) from Caransebeş - Mehadia Basin, synonyms of the "globigerina marls", predominantly constituted of marls, sandstones, tuffs and tuffits;
- Evaporitic Formation (Săndulescu et al., 1995), developed in the extra-Carpatian area, the lowermost part of Mireş Formation (Popescu, 1972) from the Transylvanian Depression and upper part of Calva Formation of the Caransebeş – Mehadia Basin, the lithostratigrafic equivalents of the "salt breccia", represented by evaporitic rocks (gypsum and salt), breccias, gypsiferous sandstones and bituminous shales (extra-Carpathian area and the Transylvanian Depression) or only clays, marls, sandstones and coals (in the Pannonian Depression);
- Brăteşti Formation (Mărunţeanu, 1999), Clenciu Limestones (Preda, 1917) and Haloş Formation (Dumitrescu, 1952) from Subcarpathian Unit, Mireş Formation (Popescu, 1972) from Transylvania Depression, the Upper Calva and Belcovăţ formations of the Caransebeş - Mehadia Basin, synonyms of the "radiolarian shales" and "Spirialis marls" , constituted of argilaceous shales, marls, clays, sometimes limestones, sands and sandstones.

BIOSTRATIGRAPHY – CALCAREOUS NANNOPLANKTON

Bioevents (Fig. 1)

The following bioevents were identified within the Carpathian Badenian molasse:

- the first successive occurrences of *Umbilicosphaera jafari* MÜLLER, 1974, *Helicosphaera walbersdorfensis* MÜLLER, 1974 and *Rhabdosphaera pannonica* BALDI-BEKE, 1960 in the NN5 Zone assemblages, from the upper part of the "*Globigerina* marls";

[1] *Geological Institute of Romania, Caransebeş, 1, RO-79678 Bucureşti 32, Romania*
[2] *"Petrol – Gaze" University, Bucureşti Blvd.,39, Ploieşti, Romania*
[3] *"Babeş-Bolyai" University, Department of Geology, Kogălniceanu, 1, RO-3400 Cluj-Napoca, Romania*

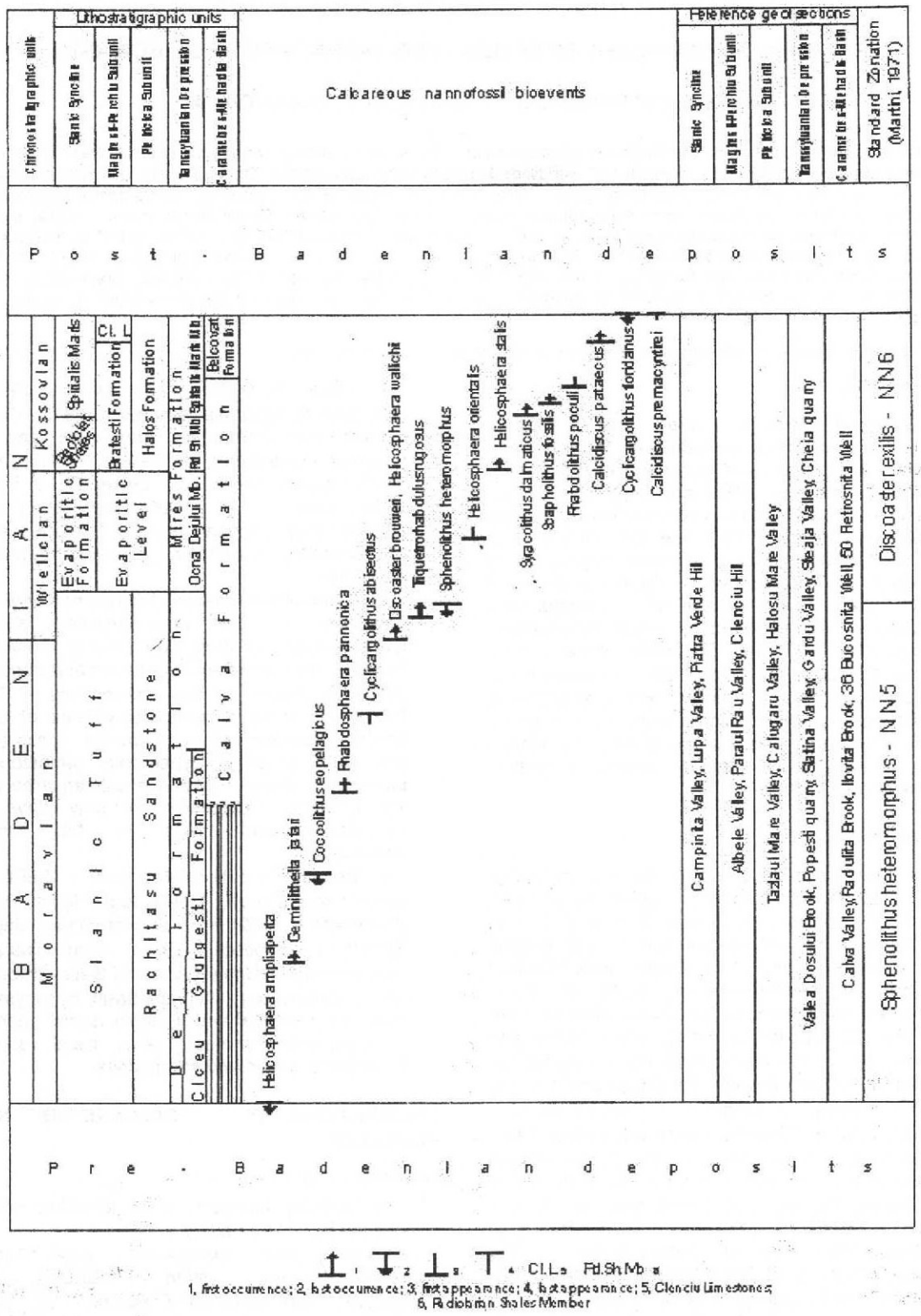


Figure 1 - Stratigraphic succession of the nannofossil bioevents in the Badenian deposits of Romania

- the successive extinctions of *Coccolithus eopelagicus* (BRAMLETTE & RIEDEL, 1954) BRAMLETTE & SULLIVAN, 1961 and *Cyclicargolithus abisectus* (MÜLLER, 1970) WISE, 1973 also in the NN5 Zone assemblages, from the upper part of the "*Globigerina* marls";
- the first concomitent appearances of *Helicosphaera wallichii* (LOHMANN, 1902) BOUDREAUX & HAY, 1969 and *Discoaster brouweri* TAN, 1927 emend. BRAMLETTE & RIEDEL, 1954 identified in the nannofossil community which characterises the upermost part of the NN5 Zone, from the upper half of the "*Globigerina* marls";
- the last occurrences of *Sphenolithus heteromorphus* DEFLANDRE, 1953 which marks the NN5 – NN6 zones boundary, recorded in the terminal part of the "*Globigerina* marls";

- the first appearances of *Helicosphaera stalis* THEODORIDIS, 1984 in the NN6 Zone community, from the lowermost part of the "radiolarian shales";
- the first successive occurrences of *Syracolithus dalmaticus* (KAMPTNER, 1927) LOEBLICH & TAPPAN, 1963, *Scapholithus fossilis* DEFLANDRE, 1954 and *Rhabdolithus poculi* BONA & KERNERNE, 1964 also in the NN6 Zone assemblage, from the "*Spirialis* marls";
- the first appearance of *Calcidiscus pataecus* (GARTNER, 1967) emend. MĂRUNŢEANU, 1999 in the uppermost part of the "*Spirialis* marls", characterized in totality by NN6 Zone;
- the extinction of *Cyclicargolithus floridanus* (ROTH & HAY, 1967) BUKRY,1971 which marks the NN6-NN7 zones boundary, after the 'Spirialis marls" deposition.

***Biozonation** (Fig.2)*

Sphenolithus heteromorphus – NN5 Zone

Definition: between LO (last occurrence) of *Helicosphaera ampliaperta* BRAMLETTE & WILCOXON, 1967 and LO of *Sphenolithus heteromorphus*.

Authors: Bramlette & Wilcoxon, 1967.

Content: the zonal characteristic assemblage contains mainly the following species: *Discoaster exilis* MARTINI & BRAMLETTE, 1963, *Discoaster musicus* STRADNER, 1959, *Discoaster variabilis* MARTINI & BRAMLETTE, 1963, *Geminilithella rotula* (KAMPTNER, 1956) BACKMAN, 1980, *Holodiscolithus macroporus* (DEFLANDRE, 1954) ROTH, 1970 and *Sphenolithus heteromorphus*).

Remarks: both in the intra- and extra- Carpathian areas, the extinction of *Helicosphaera ampliaperta* can be approximated by the first occurrence of *Discoaster exilis*.

Age: Early – Middle Badenian or Moravian - Earliest Wielician.

Distribution: only in the "*Globigerina* marls" or in its lithostratigraphic equivalents.

On the basis of the regional bioevents two subzones can be defined, the boundary between them corresponding with Moravian – Wielician boundary.

Geminilithella rotula – NN5a Subzone

Definition: LO of *Helicosphaera ampliaperta* to FO of *Discoaster brouweri*.

Authors: here defined.

Type section: Piatra Verde quarry, Slănic Prahova.

Content:: the characteristic assemblage of this subzone contains typical NN5 Zone nannofossils, reprezented by *Discoaster exilis Discoaster variabilis*, *Discoaster musicus*, numerous specimens of *Calcidiscus leptoporus* (MURRAY & BLACKMANN, 1898) LOEBLICH & TAPPAN, 1971 and *Calcidiscus macintyrei* (BUKRY & BRAMLETTE, 1969) LOEBLICH & TAPPAN, 1978, *Sphenolithus heteromorphus*, etc.

Remarks: within this subzone, several first occurrences were identified at different stratigraphic levels: FO of *Umbilicosphaera jafari* followed by FO of *Helicosphaera walbersdorfensis* and FO of *Sphenolithus abies* DEFLANDRE, 1953; the last species occurs earlier in the intra– Carpathian area than in the extra – Carpathian area.

Age: Early Badenian or Moravian.

Distribution: in the "*Globigerina* marls" and its lithostratigraphic equivalents.

Correlations: can be correlated with *the Candorbulina glomerosa/Globigerinoides sicanus* and *Candorbulina universa / Globorotalia bykovae* foraminifera zones (Popescu, 1970, 1998).

Helicosphaera wallichii – NN5b Subzone

Definition: FO of *Discoaster brouweri* Tan or of *Helicosphaera wallichii* to LO of *Sphenolithus heteromorphus*.

Authors: here defined.

Type section: Câmpiniţa Valley, north of Câmpina.

Content: the characteristic nannofossil assemblage of this subzone contains the same typical NN5 Zone species associated with *Helicosphaera wallichii* and *Discoaster brouweri*.

Remarks: the species *Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE, 1947, *Micrantolithus vesper* DEFLANDRE, 1954 and *Rhabdosphaera pannonica* quantitatively predominante in the nannofossil community.

Age: Earliest Middle Badenian or Earliest Wielician.

Distribution: in the upper part of the "*Globigerina* marls" or of its lithostratigraphic equivalents.

Correlations: corresponds to the lower part of the *Globoturborotalita druryi / Globorotalia transsylvanica* foraminifera Zone (Popescu, 1998)

Discoaster exilis – NN6 Zone

Definition: between LO of *Sphenolithus heteromorphus* and FO of *Discoater kugleri* or of LO of *Cyclicargolithus floridanus*.

Authors: Hay (1970), emend. Martini (1971).

Content: the characteristic assemblage of this zone is reprezented by the same species as the NN5 Zone, excepting *Sphenolithus heteromorphus*, *Coccolithus eopelagicus* and *Cyclicargolithus abisectus*.

Remarks: in the Central Paratethys, the beginning of this zone can be approximated with FO of *Triquetrorhabdulus rugosus* BRAMLETTE & WILCOXON, 1967; the abundance of *Cyclicargolithus floridanus* decreases toward the top of the biozone.

Age: Middle (Wielician) and Late (Kossovian) Badenian.

Distribution: in the uppermost part of "*Globigerina* marls", "Radiolarian shales" and "*Spirialis* marls" or in their lithostratigraphic equivalents.

Discoaster exilis – NN6 Zone can also be divided in more subzones which allow a strict dating of the Badenian deposits.

Discoaster variabilis – NN6a Subzone

Definition: between LO of Sphenolithus heteromorphus and FO of *Helicosphaera stalis*.

Authors: here defined.

Type section: 36 Bucoşniţa Well, Caransebeş – Mehadia Basin.

Content: the calcareous nannofossil community of this subzone contains the same species as NN5b Subzone (excepting *Sphenolithus heteromorphus*) associated with *Triquetrorhabdulus rugosus*.

Remarks: this subzone can be better defined in the Pannonian Depression because here the evaporitic deposits are replaced by a lutito-arenitic facies very rich in nannoplankton.

Age: most of Middle Badenian or of Wielician.

Distribution: in the uppermost part of "*Globigerina* marls" and "salt breccia" or in their lithostratigraphic equivalents.

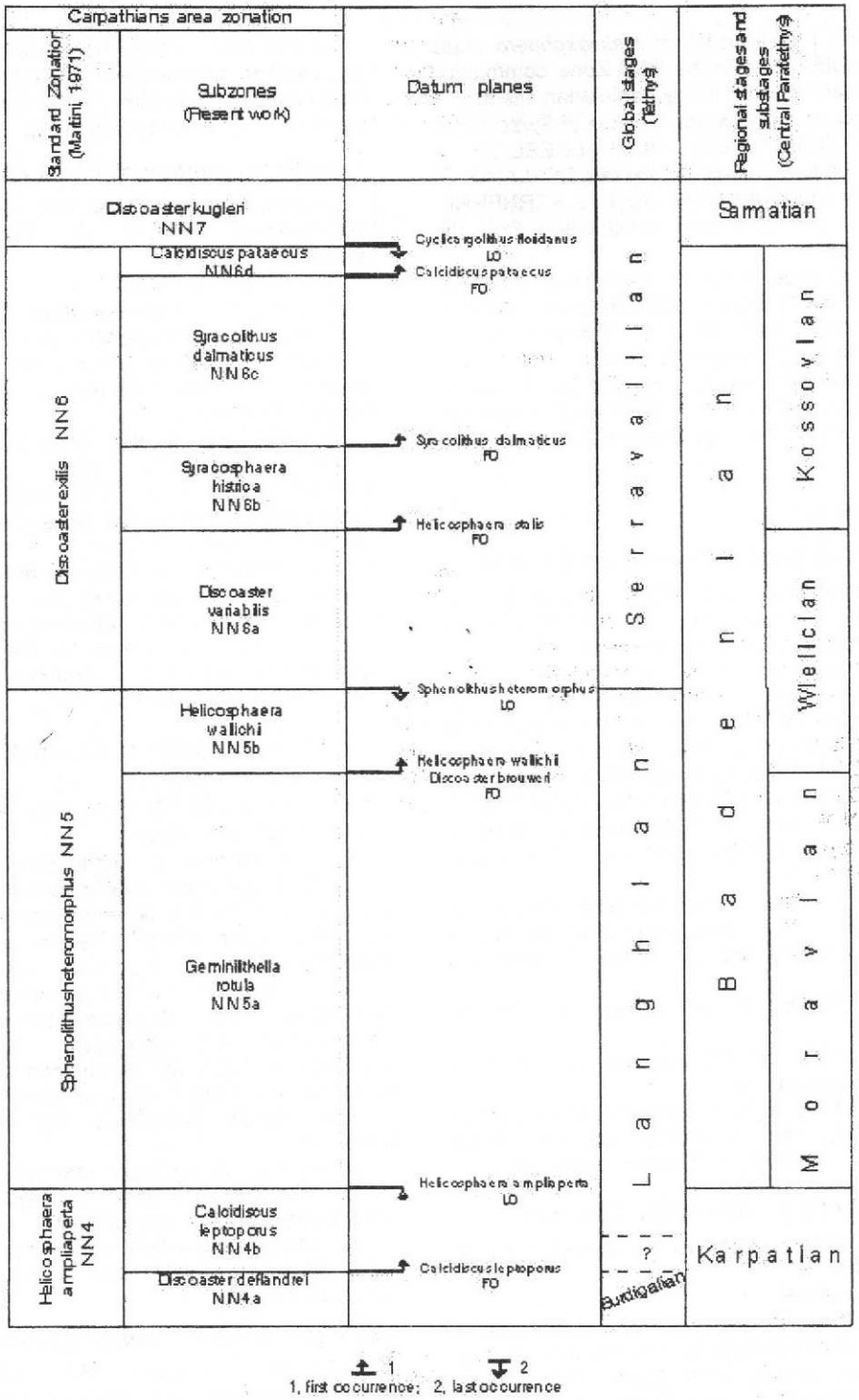


Figure 2 - Badenian nannofossil stratigraphy in Carpathians area - Romania

Correlations: corresponds with most part of *Globoturborotalita druryi/Globorotalia transsylvanica* foraminifera Zone (Popescu, 1998).

Syracosphaera histrica – NN6b Subzone

Definition: between FO of *Helicosphaera stalis* and FO of *Syracolithus dalmaticus* .

Authors: here defined.

Type section: 36 Bucoşniţa Well, Caransebeş – Mehadia Basin.

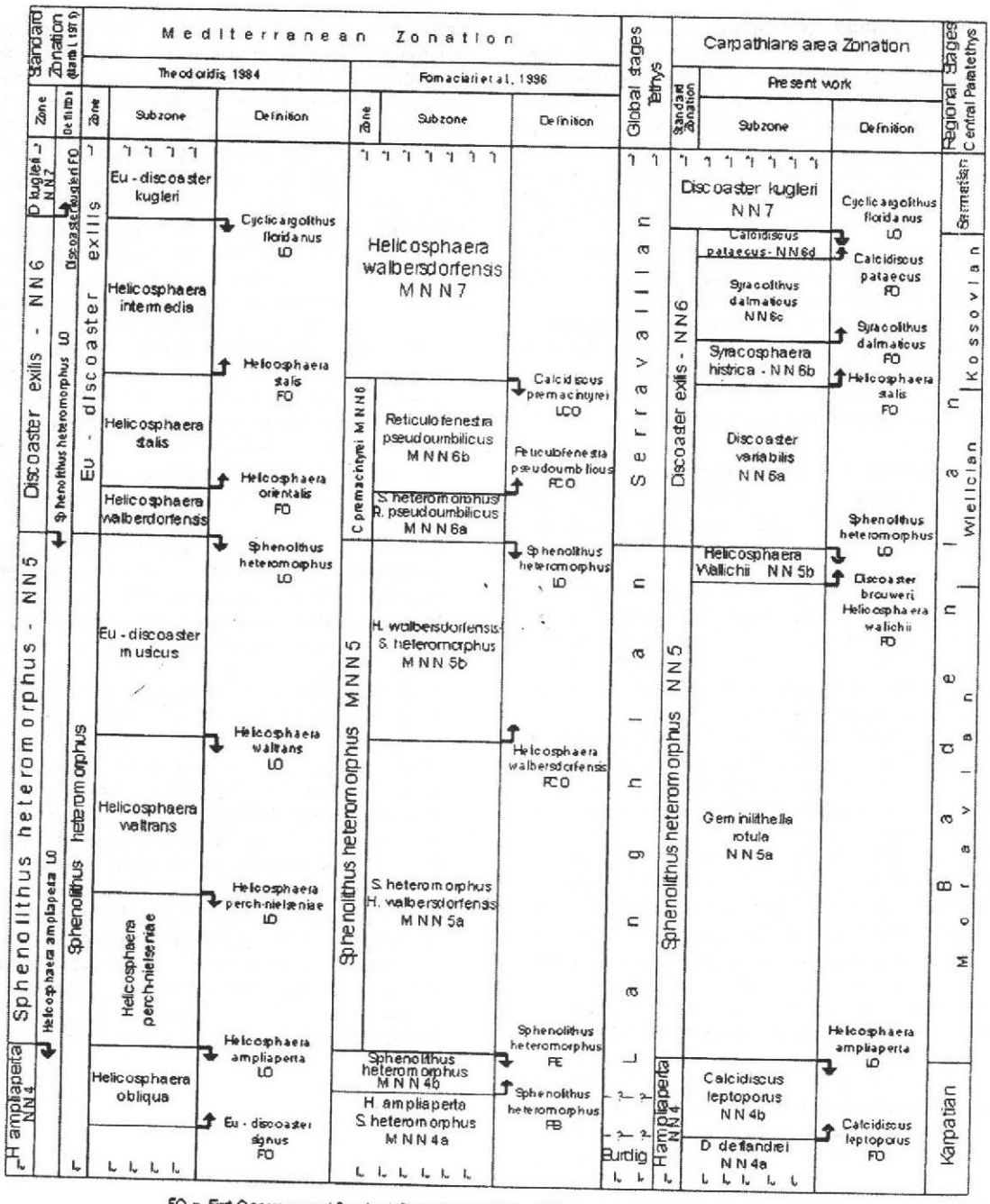
Content: the same nannoplankton community as NN6a Subzone, associated with *Syracosphaera histrica* KAMPTNER, 1941 and *Helicosphaera stalis*.

Remarks: in the extra – Carpathian area, the index species *Helicosphaera stalis* is very rare, therefore the lower boundary of this subzone can be approximated with the first occurrence of *Syracosphaera histrica*.

Age: Badenian or Early Kossovian.

Distribution: in the "radiolarian shales" or its lithostratigraphic equivalents.

Correlation: corresponds to the lower part of *Velapertina* foraminifera Zone (Popescu, 1975).



FO = First Occurrence; LO = Last Occurrence, FCO = First Common and Continuous Occurrence;
LCO = Last Common and Continuous Occurence; PB= Paracme Beginning; PE = Paracme End

Figure 3 - Badenian nannofossil zonation proposed for Carpathians area, compared with standard zonation and Mediterranean zonation.

Syracolithus dalmaticus - NN 6c Subzone

Definition: FO of *Syracolithus dalmaticus* to FO of *Calcidiscus pataecus*.

Authors: here defined.

Type section: Piatra Verde Quarry, Slănic Prahova.

Content: the calcareous nannoplankton assemblage contains the same species as the NN6b Subzone, to which *Syracolithus dalmaticus, Scapholithus fossilis* and *Rhabdolithus poculi* are added.

Remarks: the first occurrence of the species *Scapholithus fossilis*, slightly subsequent to the *Syracolithus dalmaticus* first occurrence, can approximate the boundary between the NN6b-NN6c subzones, when the last of the species is missing due to the the facial control; to be mentioned that *Rhabdolithus poculi* is an endemic nannofossil, typical for the intra-Carpathian area.

Age: Upper Badenian or Upper Kossovian.

Distribution: the assemblage of this subzone was identified only in the "*Spirialis* marls" or in its lithostratigraphic equivalents.

Correlations: corresponds to the upper part of the *Velapertina* foraminifera Zone (Popescu, 1975).

Calcidiscus pataecus - NN6d Subzone

Definition: FO of *Calcidiscus pataecus* to LO of *Cyclicargolithus floridanus*.

Authors: here defined.

Type section: Piatra Verde Quarry, Slănic Prahova.

Content: the nannofossil assemblage of this subzone is dominated by *Calcidiscus pataecus* and by the small sized Reticulofenestridaes, of the type *Reticulofenestra minuta* ROTH, 1970 and *R. minutula* (GARTNER, 1967) HAQ & BERGGREN, 1978.

Remarks: the nannoplankton assemblage of this subzone is very much like that of the NN7 Zone (which in the Central Paratethys lacks the zonal index *Discoaster kugleri*), from which it differs by the presence of *Cyclicargolithus floridanus* whose extinction was recorded at the boundary between NN6-NN7.

Age: Uppermost Badenian or Uppermost Kossovian.

Distribution: in the terminal parts of the "*Spirialis* marls" or of its lithostratigraphic equivalents.

Correlations: corresponds to the terminal part of the *Velapertina* foraminifera Zone (Popescu, 1975).

THE CORRELATION OF REGIONAL AND GLOBAL CHRONOSTRATIGRAPHIC UNITS (MIDDLE MIOCENE) BASED ON CALCAREOUS NANNOPLANKTON

On the basis of planktonic foraminifera, the regional stage Badenian was correlated with the global stages Langhian and partly Serravallian (Papp et al., 1978), considering the Moravian and the Wielician as equivalents of the Langhian, and the Kossovian as equivalent of the Lower Serravallian.

Based on this idea, the Romanian stratigraphers, in conformity with the proposal of Motas et al. (1976), attributed to the Badenian the rank of superstage, subdivided into the stages Langhian (= Moravian + Wielician) and Kossovian.

Detailed studies on calcareous nannoplankton assemblages, performed both in the Central Paratethys (Martini & Müller, 1975; Lehotayova & Molcikova, 1975; Rőgl & Müller, 1976; Fuchs & Stradner, 1977; Popescu & Gheţa, 1984; Nagymarosy, 1985; Mărunţeanu, 1992, 1999; etc.) and in the Tethys (Martini, 1968; Theodoridis, 1984; Rio et al, 1997; Fornaciari et al., 1996, 1997; etc.), demonstrated the unreliability of these correlations.

Thus, the stratigraphic distribution of calcareous nannofossil assemblages emphasized that the lower boundary of the Langhian, placed within the NN4 Zone, is earlier than the lower boundary of the Badenian, marked by the beginning of the NN5 Zone. Moreover, the lower boundary of the Serravallian was proven to correspond to the beginning of the NN6 Zone, which was also identified within the lower part of the Wielician.

Detailed studies of the Badenian calcareous nannoplankton from the entire Carpathian area on the teritory of Romania (Mărunţeanu & Crihan, 1998; Mărunţeanu & Chira, 1998; Mărunţeanu, 1999) suggested the following correlations between the regional and global chronostratigraphic units (Fig. 3):

- the Moravian, characterized by the *Geminilithella rotula* - NN5a Subzone, corresponds to most of the Langhian (excepting the lowermost and the uppermost parts), defined by the *Helicosphaera perch-nielseniae*, *Helicosphaera waltrans* and *Eu-discoaster musicus* zones (Theodoridis, 1984) *or Sphenolithus heteromorphus / Helicosphaera walbersdorfensis* - MN5a and *Helicosphaera walbersdorfensis / Sphenolithus heteromorphus* - MN5b subzones (Fornaciari et al., 1996);
- the Wielician, characterized by the *Helicosphaera wallichii* - NN5b and *Discoaster variabilis* - NN6a subzones, can be correlated with the Uppermost Langhian, defined by the uppermost parts of the *Eu-discoaster musicus* Subzone (Theodoridis, 1984) or *Helicosphaera walbersdorfensis / Sphenolithus heteromorphus* Subzone (Fornaciari et al., 1996) and with the Lowermost Serravallian, defined by the *Helicosphaera walbersdorfensis* and *Helicosphaera stalis* subzones (Theodoridis, 1984) or *Sphenolithus heteromorphus/ Reticulofenestra pseudoumbilicus* - MNN6a and *Reticulofenestra pseudoumbilicus* - MNN6b subzones (Fornaciari et al., 1996);
- the Kossovian, characterized by the *Syracosphaera histrica* - NN6b, *Syracolithus dalmaticus* - NN6c and *Calcidiscus pataecus* - NN6d subzones, corresponds to the Lower Serravallian, defined by the *Helicosphaera intermedia* Zone (Theodoridis, 1984) or partly, by *Helicosphaera walbersdorfensis* - MNN7 Zone (Fornaciari et al., 1996).

REFERENCES

Athanasiu, S. (1913) Cercetări geologice în regiunea carpatică şi subcarpatică din Moldova de sud. Extras din *Anuarul Institutului Geologic*, IV (!910), p. 1-47, Bucureşti.

Bramlette, M.N., Wilcoxon, J.A. (1967) Middle Tertiary calcareous nannoplankton of the Cipero section, Trinidad, W.I. *Tulane Studies in Geology*, 5/3, p. 93-131, Tulane.

Dumitrescu, I. (1952) Cercetări geologice în Vrancea de nord. *Dări Seamă, Comitetul Geologic*, XXXVI (1948-1949), p. 51-61, Bucureşti.

Cicha, I., Senes, J. (1968) Sur la position du Miocene de la Paratethys Centrale dans le cadre du Tertiaire de l'Europe. *Geologick Zbornik*, 9, p. 95 -116, Bratislava.

Fornaciari, E., Di Stefani, A., Rio, D., Negri, A. (1996) Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. *Micropaleontology*, 42/1, p. 37-63, New York.

Fornaciari, E., Rio, D., Ghibauldo, G., Massari, F., Iaccarino, S. (1997) Calcareous plankton biostratigraphy of Serravallian (Middle Miocene) stratotype section (Piedmont Tertiary Basin, NW Italy). *Memorie di Scienze Geologiche.*, 49, p. 127-144, Padova.

Fuchs, R., Stradner, H. (1977) Ueber Nannofossilien im Badenian (Mittelmiozaen) der Zentralen Paratethys. *Beitraege zur Palaeontologie Oesterreich.*, 2, p. 1-58, Wien.

Hay, W.W. (1970) Calcareous Nannofossils. *Oceanic Micropaleontology*, 2, Acad. Press. Ed., p. 1055-1069, London.

Lehotayova, R., Molcikova, V. (1975) The present research results of calcareous nannoflora in relation to biozones of the Neogene of the Central Paratethys. *VI- th RCMNS Congress, Geol. Surv. Prague*, p. 82-86, Prague.

Martini, E. (1968) Calcareous nannoplankton from the type Langhian. Com. Med. Neog. Stratigraphy, IV Sess.Bologna, 1967, *Giornale di Geologia* (2), XXXV, p. 163-172, Bologna.

Martini, E. (1971) Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proceed. II Plankt.Conf. (1970)*, 2, Farinacci Ed., p. 739 - 785, Roma.

Martini, E., Müller, C. (1975) Calcareous nannoplankton from the Karpatian in Austria. *Proceed. VI-th RCMNS Congr.*, p. 125 - 128, Bratislava.

Martini, E., Müller, C. (1986) Current Tertiary and Quaternary calcareous nannoplankton stratigraphy and correlations.

Newsletter of Stratigraphy, 16/2, p. 99-112, Berlin / Stuttgart.

Mărunţeanu, M. (1992) Distribution of the Miocene calcareous nannofossils in the Intra – and Extra – Carpathian areas of Romania. *Knihovnicka ZPN*, 14b, V?2, p.247-261, Hodonin.

Mărunţeanu, M. (1999) Litho- and biostratigraphy (calcareous nannoplankton) of the Miocene deposits from the Outer Moldavides. *Geologica Carpathica*, 50/4, p. 313-324, Bratislava.

Mărunţeanu, M., Serban, E., Rusu, A. (1996) Neogene of Caransebeş-Mehadia Basin. *Romanian Journal of Stratigraphy*, 76, p. 79-87, Bucureşti.

Mărunţeanu, M., Crihan, M. (1998) The study of the Badenian calcareous nannofossils from the Muntenian Subcarpathians. *Romanian Journal of Paleontology*, 78 (in press), Bucureşti.

Mărunţeanu, M., Chira, C. (1998) Marine Middle Miocene calcareous nannoplankton: a comparative study of the Subcarpathians and Transsylvania areas from Romania. *XVI-th Carpath. – Balk.Congr. Wien, 1998.*, Abstr. vol., p. 57, Vienna.

Motaş, I, Marinescu, Fl., Popescu, Gh. (1976) Essai sur Neogene de Roumanie. *Anuar, Institutul de Geologie şi Geofizică*, L, p. 127-147, Bucureşti.

Murgeanu, Gh., Patrulius, D., Gherasi, N., Ghenea, C., Ghenea, A. (1968) Harta geologică a României, sc.1:200.000, foaia 35 Târgovişte, ed. Inst. Geol. Rom., Bucureşti.

Nagymarosy, A. (1985) The correlation of the Badenian in Hungary based on nannofloras. *Annales Universitatis Scientiarum Budapestinensis*, Geol., XXV (1983), p. 33-86, Budapest.

Olteanu, Fl. (1951) Observaţiuni asupra "breciei sării " cu masive de sare din regiunea mio-pliocenă dintre R.Teleajen şi p.Bălăneasa (cu privire specială pentru regiunea Pietrosu - Buzău). *Dări de Seamă Institutul Geologic Român*, XXXII (1943-1944), p.12-18, Bucureşti.

Papp, A., Cicha, I., Senes, J, Steininger, E. (eds.) et al. (1978) Chronostratigraphie und Neostratotypen. Miozan – M4 Badenian. Bd.VI, Veda Ed., 594 p., Bratislava.

Popescu, Gh. (1970) Planktonik foraminiferal zonation in the Dej Tuff Complex. Revue *Roumaine de Geologie, Geophysique et Geographie, Geologie*, XIV/2, p. 189-203, Bucureşti.

Popescu, Gh. (1972) Biostratigrafia depozitelor oligo-miocene de la sud de Preluca, pe baza foraminiferelor planctonice. *Dări de Seamă Institutul de Geologie şi Geofizică,* LVIII (1971), 3, p. 105-127, Bucureşti.

Popescu, Gh. (1975) Foraminiferal study of the Lower and Middle Miocene from north-western Transylvania (in French). *Memoire Inst. Geol. Geophys.*, 23, 121 p., Bucureşti.

Popescu, Gh. (1998) Marine Middle Miocene stratigraphy of the Central Paratethys (Romanian area). *XVI-th Carpath. – Balk.Congr. Wien, 1998, Geol. Ass.*, Abs., p. 489, Wien.

Popescu Gh., Gheţa N., (1984) Comparative evolution of the marine Middle Miocene calcareous microfossils from the Carpathian and Pannonian areas. *Dări de Seamă Institutul de Geologie şi Geofizică*, 69/3, p. 125-133, Bucuresti.

Popescu, Gr. (1951) Observaţiuni asupra breciei sării şi a unor masive de sare din zona paleogenă – miocenă a jud. Prahova. *Dări de Seamă Institutul Geologic Român* XXXII, p.3-12, Bucureşti.

Preda, D.M. (1917) Geologia regiunii subcarpatice din partea de sud a districtului Bacău. *Anuarul Institutului Geologic Român* , VII, p. 428-574, Bucureşti.

Rio, D., Cita, M.B., Iaccarino, S., Gelati, R., Gnaccolini, M. (1997 – im press) Langhian, Serravallian and Tortonian historical stratotypes. In: Montanari, A., Odin, G.S., Coccioni, R. (eds.) Miocene Integrated Stratigraphic Sequence (MISS), Elsevier.

Rőgl, F., Müller, C. (1976) Das Mittelmiozan und die Baden-Sarmat Grenze im Walbersdorf (Burgenland). *Annales Naturalie Museum Wien*, 80, p. 221-232, Wien.

Săndulescu, M., Mărunţeanu, M., Popescu, Gh. (1995) Lower-Middle Miocene formations in the folded area of East-Carpathians. *X-th RCMNS Congr., Guide to Excurssion, Romanian Journal of Stratigraphy*, 76, 5, 32 p., Bucureşti.

Theodoridis, S.A. (1984) Calcareous nannofossil biozonation of the Miocene and revision of the Helicoliths and Discoasters. *Utrecht Micropaleontological Bulletin,* 32, 207 p., Utrecht.