BADENIAN NANNOFOSIL ZONATION - THE CARPATHIAN AREA, ROMANIA

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Abstract. Detailed 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 Discosaster 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 Discocystis variabilis - NN6a, typical for Wielician Substage; Syracosphaera histrica - NN6b, Syracosphaera dalmatica - NN6c and Calcidiscus pataecus - NN6d, which characterise the Kossowan Substage. It was also demonstrated that the use of the Langhian Global Stage as subdivision of the Badenian regional chronostratigraphic unit is not legitimised 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 Kossowan, 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 identified nannoplankton assemblages within the standard zones Sphenolithus heteromorphus – NN5 and Discosaster 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 allow 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, established by Popenescu (1951) and Olteanu (1951), is represented by the "globigerina maris"; "salties breccia with salt masses", "radiolarian shales" and "spiralis maris". For the biostratigraphic study of these formations, the next reference geological sections were selected (Fig. 1): Câmpinți Valley, Lupa Valley and Piatra Verde Hill in the Slănic Syncline; Albele Valley, Pârâu Râu Valley and Clușeni Hill (lower basin of the Tăzliu Mare river) in Măgirești – Perchiu Subunit; Tăzliu Mare Valley, Câlărași Valley and Galașu Mare Valley (north respectively south of the Tăzliu-Trotuș rivers confluence) in the Pietricica Subunit; Valea Dosului Brook, Popoși and Cheia quarries, Slatina Valley, Valea Gardului Brook (north-west Transylvania) and Steaja Valley (south Transylvania) in the Transylvanian Depression; Calva Valley, Răduñita Brook, Ilovița Brook, 36 Bucovași and 50 Pietroșița wells (south of Caransebeș) in the Caransebeș - Mehadia Basin (Pannonian Depression). These geological sections, classical lithostratigraphic units are partially or completely developed, known (as Fig. 1):

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1-3 Slănic Tuff (Murgeanu et al., 1968) and Rachitaș Sandstones (Athanasius, 1913), developed in the extra-Carpatican area, Dej and Ciceu-Gurăști formations (Popenescu, 1970) from the Transylvanian Depression, Lower Calva Formation (Mărunțeanu et al., 1996) from Caransebeș – Mehadia Basin, synonyms of the "globigerina maris", predominantly constituted of marls, sandstones, tuffs and tufifs;

- Evaporitic Formation (Șandulescu et al., 1995), developed in the extra-Carpatican area, the lowermost part of Mires Formation (Popenescu, 1972) from the Transylvanian Depression and upper part of Calva Formation of the Caransebeș – Mehadia Basin, the lithostratigraphic equivalents of the "salt breccia", represented by evaporitic rocks (gypsum and salt), breccias, gypsiferous sandstones and bituminous shales (extra-Carpatican area and the Transylvanian Depression) or only clays, marls, sandstones and coals (in the Pannonian Depression);

- Brâșoii Formation (Mărunțeanu, 1999), Clinciu Limestones (Preda, 1917) and Haloș Formation (Dumitrescu, 1952) from Subcarpathian Unit, Mires Formation (Popenescu, 1972) from Transylvanian Depression, the Upper Calva and Belciug formations of the Caransebeș – Mehadia Basin, synonyms of the "radiolarian shales" and "spiralis maris", 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 jaffi MULLER, 1974, Helicosphaera walbersdorffensis MULLER, 1974 and Rhabdosphaera pannonica BALDI-BEKE, 1960 in the NN5 Zone assemblages, from the upper part of the "globigerina maris";
Figure 1 - Stratigraphic succession of the nannofossil bioevents in the Badenian deposits of Romania

- the successive extinctions of Coccolithus eopelagicus (BRAMLETTE & RIEDEL, 1954) and Cyclicargolithus abisectus (MÜLLER, 1970) WISE, 1973 also in the NN5 Zone assemblages, from the upper part of the "Globigerina maris";
- the first concomitant appearances of Helicosphaera wallichii (LOHMANN, 1902).

BOUDREAX & HAY, 1969 and Discoaster brouweri TAN, 1927 emend. BRAMLETTE & RIEDEL, 1954 identified in the nannofossil community which characterises the uppermost part of the NN5 Zone, from the upper half of the "Globigerina maris";
- the last occurrences of Sphenolithus heteromorphus DEFLANDRE, 1953 which marks the NN5 - NN6 zones boundary, recorded in the terminal part of the "Globigerina maris";
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 (KAMPFTNER, 1927) LOEBLICH & TAPPAN, 1963, Scapholithus fossiliis DEFLANDRE, 1954 and Rhabdolithus poculif BONA & KERNERNE, 1964 also in the NN6 Zone assemblage, from the "Spiralis maris";
* the first appearance of Calculidiscus pateucus (GARTNER, 1967) emend. MÂRÇU, 1999 in the uppermost part of the "Spiralis maris", characterized in totality by NN6 Zone;
* the extinction of Cyclicargolithus floridanus (ROTH & HAY, 1987) BUKRY, 1971 which marks the NNS-NN7 zones boundary, after the "Spiralis maris" deposition.

**Biozonation (Fig.2)**

**Sphenolithus heteromorphus – NN5 Zone**

**Definition:** between LO (last occurrence) of Helicosphaera ampliaperta BRAMLETTE & WILCOXON, 1987 and LO of Sphenolithus heteromorphus.

**Authors:** Bramlette & Wilcoxon, 1987.


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

**Age:** Early – Middle Badenian or Moravian – Earliest Wielenian.

**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 – Wielenian boundary.

**Geminilithella rotula – NN5a Subzone**

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

**Authors:** here defined.

**Type section:** Piatra Verde quarry, Slănic Prahova.

**Content:** the characteristic assemblage of this subzone contains typical NN5 Zone nanofossils, represented by Discaster exilis Discaster variabilis, Discaster musicus, numerous specimens of Calculidiscus leptoporous (MURRAY & BLACKMANN, 1998) LOEBLICH & TAPPAN, 1971 and Calculidiscus macintyrei (BUKRY & BRAMLETTE, 1968) 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 walbersdorferensis 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 glamerosa/Globigerinoides sicanus and Candorbulina universa / Globorotalia bykovae foraminifera zones (Popescu, 1970, 1998).

**Helicosphaera wallachii – NN5b Subzone**

**Definition:** FO of Discaster brouweri Tan or of Helicosphaera wallachii to LO of Sphenolithus heteromorphus.

**Authors:** here defined.

**Type section:** Câmpina Valley, north of Câmpina.

**Content:** the characteristic nanofossil assemblage of this subzone contains the same typical NN5 Zone species associated with Helicosphaera wallachii and Discaster brouweri.

**Remarks:** the species Braarudosphaera bigelowii (GRAN & BRAARUD, 1935) DEFLANDRE, 1947, Micractinos vespertus DEFLANDRE, 1954 and Rhabdosphera pannonica quantitatively predominant in the nanofossil community.

**Age:** Earliest Middle Badenian or Earliest Wielenian.

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

**Correlations:** corresponds to the lower part of the Globolurborotalia duylul / Globorotalia transyslvanica foraminifera Zone (Popescu, 1998).

**Discaster exilis – NN6 Zone**

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

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

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

**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 (Wielenian) and Late (Kossian) Badenian.

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

**Discaster exilis – NN6 Zone**

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

**Authors:** here defined.

**Type section:** 36 Bucușnița Well, Caransebeș – Mehadia Basin.

**Content:** the calcareous nanofossil 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 nanoplankton.

**Age:** most of Middle Badenian or of Wielenian.

**Distribution:** in the uppermost part of "Globigerina marls" and "salt breccia" or in their lithostratigraphic equivalents.
**Correlations:** corresponds with most part of *Globoturborotalita druryi/Globorotalia transsylvanica* foraminifera Zone (Popescu, 1998).

**Syracosphera histrica – NN6b Subzone**

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

*Authors:* here defined.

*Type section:* 36 Bucenița Well, Caransebeș – Mehadia Basin.

*Content:* the same nannoplankton community as NN6a Subzone, associated with *Syracosphera 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 *Syracosphera histrica*.

*Age:* Badenian or Early Kossowan.

*Distribution:* in the “radiolarian shales” or its lithostratigraphic equivalents.

*Correlation:* corresponds to the lower part of *Velapertina* foraminifera Zone (Popescu, 1975).
Syracolithus dalmaticus - NN 6c Subzone

**Definition:** FO of *Syracolithus dalmaticus* to FO of *Calcisicus patecus*.

**Authors:** here defined.

**Type section:** Piatra Verde Quarry, Slănic Prahova.

**Content:** The calcareous nannoplankton assemblage contains the same species as the NN5b Subzone, to which *Syracolithus dalmaticus*, *Scapholithus fossili* and *Rhabdolithus poculi* are added.

**Remarks:** The first occurrence of the species *Scapholithus fossili*, slightly subsequent to the *Syracolithus dalmaticus* first occurrence, can approximate the boundary between the NN5b-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-Carpodian area.

**Age:** Upper Badenian or Upper Kossovian.

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

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

**Calcisicus patecus - NN6d Subzone**

**Definition:** FO of *Calcisicus patecus* to LO of *Cyclagrolithus floridanus*.

**Authors:** here defined.
Type section: Plata Verde Quarry, Slanic Prahova. 
Content: the nanofossil assemblage of this subzone is dominated by *Calcidiscus palaetus* and by the small sized *Reticulofenestraidae*, of the type *Reticulofenestra minuta* ROTH, 1970 and *R. minutula* (GARTNER, 1987) HAQ & BERGGREN, 1978.
Remarks: the nanoplankton assemblage of this subzone is very much like that of the NNT Zone (which in the Central Paratethys lacks the zonal index *Discostaet kugleri*), from which it differs by the presence of *Cyclograptus floridanus* whose extinction was recorded at the boundary between NN6-NN7.
Age: Uppermost Badenian or Uppermost Kossovian. 
Distribution: in the terminal parts of the *Spiralis maris* 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 NANOPLANKTON**

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 Wielcian 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 + Wielcian) and Kossovian.

Detailed studies on calcareous nanoplankton assemblages, performed both in the Central Paratethys (Martini & Müller, 1975; Lehotayova & Molicova, 1975; Rögl & Müller, 1976; Fuchs & Stradner, 1977; Popescu & Gheta, 1984; Nagymarosy, 1985; Mărunțeanu, 1985, 1988; etc.) and in the Tethys (Martini, 1998; Theodoridis, 1984; Rio et al., 1997; Fornaciari et al., 1996, 1997; etc.), demonstrated the unreliability of these correlations.

Thus, the stratigraphic distribution of calcareous nanofossil 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 NN5 Zone, which was also identified within the lower part of the Wielcian.

Detailed studies of the Badenian calcareous nanoplankton from the entire Carpathian area on the territory of Romania (Mărunțeanu & Crihan, 1998; Mărunțeanu & Chira, 1998; Mărunțeanu, 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 *Helicoceras perchi-nielseni*, *Helicoceras waltrains* and *Discoaster musicus* zones (Theodoridis, 1984) or *Sphenolithus heteromorphus* / *Helicoceras walbersdorfiensis* - MN5a and *Helicoceras walbersdorfiensis* / *Sphenolithus heteromorphus* - MN5b subzones (Fornaciari et al., 1996);
- the Wielcian, characterized by the *Helicoceras walbersdorfiensis* - MN5b and *Discoaster variabilis* - NN5a subzones, can be correlated with the Uppermost Langhian, defined by the uppermost parts of the *Discoaster musicus* Subzone (Theodoridis, 1984) or *Helicoceras walbersdorfiensis* / *Sphenolithus heteromorphus* Subzone (Fornaciari et al., 1996) and with the Lowermost Serravallian, defined by the *Helicoceras walbersdorfiensis* and *Helicoceras stallis* subzones (Theodoridis, 1984) or *Sphenolithus heteromorphus* / *Reticulofenestra pseudoumbilicatus* - MN5a Subzone (Fornaciari et al., 1996);
- the Kossovian, characterized by the *Syracosphaera histrica* - NN6b, *Syracosphaera dalmatina* - NN6c and *Calcidiscus palaetus* - NN6d subzones, corresponds to the Lower Serravallian, defined by the *Helicoceras intermedia* Zone (Theodoridis, 1984) or partly, by *Helicoceras walbersdorfiensis* - MN7 Zone (Fornaciari et al., 1996).

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