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New data on the Early - Middle Badenian transition in the NW Transylvanian Basin (Romania) revealed by the planktonic foraminifera assemblages

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Abstract. The planktonic foraminifera assemblages recovered from two cores drilled in Cluj-Napoca (NW Transylvanian Basin) demonstrate connections of the basin to the open seas before the middle Badenian evaporite deposition. Assemblages suggest clear changes in the environments, with an initial transgressive trend, followed by a decrease in the rate of sea-level rise, and finally a sea-level fall. The occurrence of planktonic foraminifera (mainly *Globorotalia*) offers a good potential for correlation of the pre-evaporitic interval with the uppermost Langhian and can be used for tracing the early-middle Badenian boundary.

Keywords: biostratigraphy, planktonic foraminifera, paleoenvironments, Badenian, Paratethys, Transylvanian Basin.

INTRODUCTION

Regional tectonic changes during the Badenian (Middle Miocene) determined the evolution of the Transylvanian Basin in back-arc settings, characterized by a low-rate of subsidence (Krézsek and Bally, 2006). The early Badenian in the Transylvanian Basin was marked by a widespread transgression of warm waters providing optimum conditions for diverse and abundant foraminifera assemblages (Popescu and Crihan, 2008). Subsequently, the regional tectonic evolution gradually changed the depositional and paleoenvironmental settings (Krézsek et al., 2010, DeLeeuw et al., 2013), influenced by volcanic eruptions (deposition of the Dej Tuff - Szakács et al., 2012) and basin isolation trend. The environmental change became very abrupt during the middle Badenian, when the evaporites deposition started due to the restricted connections with the open seas (Popescu, 1975; Filipescu, 1996).

Previous works on Badenian formations in Cluj-Napoca area were carried out by Şuraru (1961), Mészáros et al. (1976), Nicorici et al. (1979), Mészáros and Clichici (1988), Mészáros et al. (1991), Şuraru et al. (1991), and Suciu (2005).

This contribution brings new data on the evolution of the basin at the transition between early and middle Badenian by describing the changes in the foraminifera assemblages collected from a continuous sequence of mudstones from the top of "*Globigerina* marls" (Popescu, 1975, 1987) just below the middle Badenian gypsum.

MATERIAL AND METHODS

Nine samples were studied from two wells (S1 - 6 samples and S2 – 3 samples), drilled in Cluj-Napoca (NW Transylvanian Basin, Fig. 1) through marine offshore mudstones around the lower-middle Badenian boundary. The samples (250 g of sediment per sample) were processed by standard micropaleontological methods. The foraminifera were recovered on a 63 µm sieve and studied under stereomicroscope. Some characteristic specimens were subsequently examined under scanning electron microscope at the Department of Biology, Babes-Bolyai University (Pl. I).

RESULTS

Foraminifera assemblages and paleoenvironments

The identified foraminifera assemblages are abundant, well preserved, dominated by planktonic taxa (> 90% of the assemblages), and common for the subtropical, offshore and normal salinity conditions of the Middle Miocene. Two distinct types of planktonic foraminifera assemblages were identified:

1) assemblage with large taxa, such as *Globigerinoides trilobus* (Reuss, 1850), *Globigerina bulloides* d'Orbigny, 1826, *Globigerina praebulloides* Blow, 1959, *Globorotalia* div. sp., common in the lower part of the investigated interval;
2) assemblage with small taxa, such as *Tenuitella* div. sp., *Tenuitellinata uvula* (Ehrenberg), *Globigerina* div. sp., *Globorotalia (Jenkinsella) bella* Jenkins, 1967, *Globorotalia (Jenkinsella) mayeri* Cushman and Ellisor, 1939, *Globorotalia (Hirsutella) scitula* (Brady, 1882), *Globorotalia (Obandyella) transsylvanica* Popescu, 1972, dominant in the upper part of the investigated interval.

The benthics are less abundant in the micropaleontologic assemblage, containing both agglutinated and calcareous

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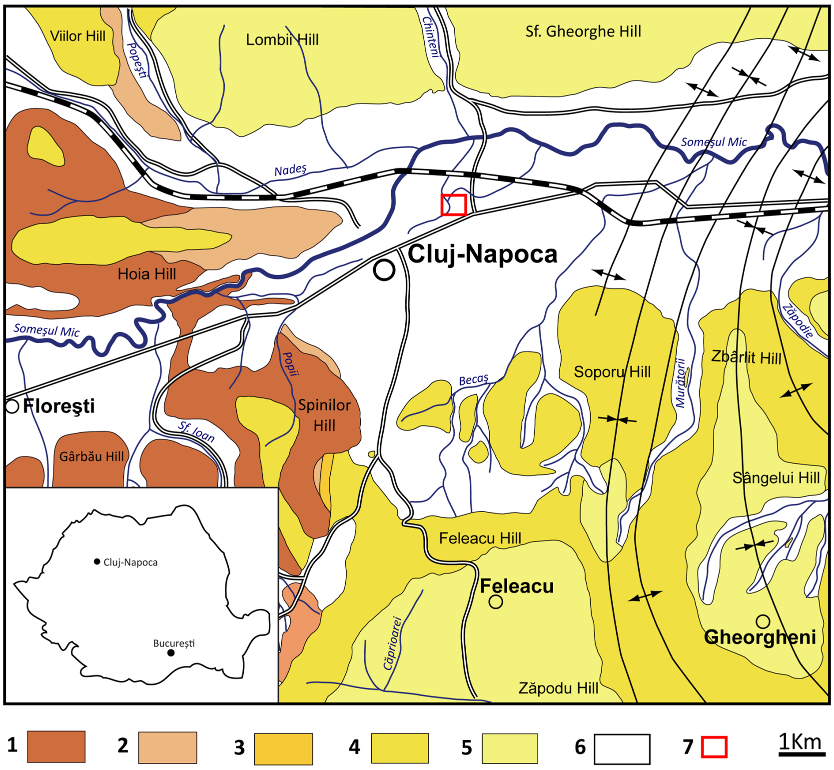

Fig. 1. *Simplified geological map of the Cluj-Napoca area: 1 – Eocene, 2 – Oligocene, 3 – Lower Miocene, 4 – Badenian, 5 – Sarmatian, 6 – Quaternary, 7 - location of wells.*

species, and occur mainly in the transitional zone from the top of the first planktonic assemblage. The common identified taxa are: *Bathysiphon sp., Reticulophragmium crassum* (Reuss, 1867)*, Bulimina aculeata* d'Orbigny, 1826, *Heterolepa dutemplei* (d'Orbigny, 1846), *Cibicidoides pseudoungerianus* (Cushman, 1922), *Nonion commune* (d'Orbigny, 1846), etc.

This succession of populations suggests an initial transgressive trend, with parasequences developed between initial floodings (large planktonics) and environmental stabilization (planktonics and benthics). The spreading of large planktonics was probably stimulated by the transgressive interval, characterized by optimum climatic conditions and oligotrophic environments (Schmidt et al., 2008). Subsequently, small planktonics became abundant, as observed near the top of the investigated interval. Small planktonics are usually associated to unstable habitats with high turbulence (Schmidt et al., 2008) and high organic input (eutrophic conditions). In our case, these conditions probably occurred as a consequence of a decreased rate in sea-level rise (highstand), which initiated an increased progradation and higher organic input. The falling stage systems tract is represented by the gypsum deposition (base of the MLM4 sequence of Krézsek and Filipescu, 2005).

Comparable successions of assemblages were described from the Lower Miocene (Beldean et al., 2012) and Middle Miocene (Filipescu and Silye, 2008) of the Transylvanian Basin. These assemblages were interpreted as controlled by the late stages of sea-level rise, before distinct events of basin isolation produced by tectonic events. The succession of these foraminifera assemblages offer clues for the initiation of active regional tectonics, which isolated important parts of the Paratethys, as proven by the deposition of middle Badenian salt and gypsum.

Biostratigraphy

Popescu (1975) proposed the use of *"Orbulina suturalis / Globorotalia (T.) bykovae* Zone*"* for the stratigraphic interval situated below the Badenian gypsum and pointed the specific differences in tracing the upper boundary of the *Orbulina suturalis* Zone in the Mediterranean and Paratethys. The species *Orbulina suturalis* could not be identified in the investigated samples, but more common are *Globorotalia (J.) bella*, *Globorotalia (J.) mayeri*, *Globorotalia (H.) scitula*, *Globorotalia (O.) transsylvanica,* small *Globigerina* and tenuitellids (S1 at 24.5 and 25 m; S2 at 24.5 and 28.2 m)

According to Popescu and Crihan (2011), *Globorotalia (Obandyella) transsylvanica* is common in the middle Badenian (equivalent to the late Langhian). Additionally, the presence of *Globorotalia* (*Hirsutella) scitula* also suggests a late Langhian age (Kennett and Srinivasan, 1983).

Popescu (1987) described the *Globoturborotalita druryi – Globigerinopsis grilli* Biozone for the earliest middle Badenian (Fig. 2). The index taxa for this zone are not always present in the investigated sequences. Popescu (1999) named the same zone as *Globoturborotalita druryi / Globorotalia transsylvanica* Biozone. Additionally, high abundances of globorotaliids and similar assemblages were described from the same stratigraphic level in the Transylvanian Basin (Filipescu, 2001), Sylesian Basin (Gonera, 2013) and Polish Carpathian Foredeep (Peryt, 2013).

Beside the possible effects of nutrient supply produced by regional tectonics and water circulation, other influences were possible around the early – middle Badenian boundary. Gonera (2013) suggested a cooling event, based on the appearance of *Globorotalia (Obandyella) transsylvanica*. However, a change in the foraminifera assemblages is obvious in our samples too by the occurrence of small planktonics just before the mid Badenian gypsum deposition. If the change was caused by such a climatic event, the correlation potential of the assemblage with small planktonics must be high enough to be used at least at a regional scale.

For all the reasons mentioned above, we propose tracing the early – middle Badenian boundary in Paratethys at the occurrence of the assemblage with small planktonic

Epoch	Age			Foraminiferal biozones	
	standard	regional		standard*	regional**
Middle Miocene	Serravallian	Badenian	late	*Fohsella 'praefohsi'*	*Velapertina*
	13.82 Ma				
	Langhian		middle	*Fohsella peripheroacuta*	*Globoturborotalita druryi / Globorotalia transsylvanica*
			early	*Orbulina suturalis*	*Orbulina suturalis / Globorotalia bykovae*
				Praeorbulina glomerosa	*Praeorbulina glomerosa*
	15.97 Ma				

Fig. 2. *Geocronologic and biostratigraphic correlation table for the studied interval (boundary ages after Gradstein et al., 2012; * based on Wade et al., 2011; ** based on Popescu, 1999).*

foraminifera. Additionally, we suggest a revision of the currently used biozones and a further replacement with more representative one. Subsequent to a detailed examination of the representative sites in the Central Paratethys, probably a suitable candidate would be the *Globorotalia transsylvanica* Biozone due to its particular abundance of small planktonic foraminifera dominated by *Globorotalia* s.l., observed in the Transylvanian Basin (Filipescu, 2001; Filipescu and Filipescu, current paper), Carpathian Foredeep (Peryt, 2013), Upper Silesia Basin (Gonera, 2013), and other locations.

CONCLUSIONS

Foraminifera assemblages studied from the base of middle Badenian suggest a specific succession of paleoenvironments, with an initial transgressive trend, followed by highstand stable environments and subsequent basin isolation.

The distinctive assemblage with small planktonic foraminifera reveals clear paleoenvironmental changes and therefore has a high potential for stratigraphic correlation. A revision of the biozone characterizing the base of middle Badenian of the Paratethyan area is required; a possible candidate would be a newly defined *Globorotalia transsylvanica* Biozone. Additionally, the specific sequence of fossil foraminifera populations gives new possibilities to refine the stratigraphic resolution within the biozone.

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Plate I. (scale bar 100mm)

Fig. 1. - *Reticulophragmium crassum* (REUSS) – well S1, 24.5m;
Fig. 2. - *Bulimina aculeata* D'ORBIGNY - well S1, 27.0m;
Fig. 3. - *Cibicidoides pseudoungerianus* (CUSHMAN) - well S1, 27.0m;
Fig. 4. - *Nonion commune* (D'ORBIGNY) - well S1, 24.1m;
Fig. 5. - *Globigerina bulloides* D'ORBIGNY - well S2, 24.5m;
Fig. 6. - *Globigerina praebulloides* BLOW - well S2, 24.5m;
Fig. 7. - *Tenuitellinata uvula* (EHRENBERG) - well S2, 27.0m;
Figs. 8, 9. - *Globorotalia (Jenkinsella) bella* JENKINS - well S1, 24.5m, well S2, 28.2m;
Fig. 10. - *Globorotalia (Hirsutella) scitula* BLOW - well S1, 30.0m;
Fig. 11. - *Globorotalia (Obandyella) transsylvanica* Popescu - well S2, 28.2m;
Fig. 12. - *Globigerinoides trilobus* (REUSS) - well S1, 30.0m.

PLATE I