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Sarmatian foraminiferal assemblages from southern Transylvanian Basin and their significance for the reconstruction of depositional environments

- Extended abstract of the PhD thesis -

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Keywords: foraminifera, Transylvanian Basin, Sarmatian, biostratigraphy, palaeoecology, depositional environments

Chapter 1 – Introduction

The Sarmatian sedimentary record of the Transylvanian Basin is part of the topmost megasequence, and has about 1.000 m thickness on average (Krézsek and Filipescu, 2005). Although outcrops in a large area from the southern part of the basin, and several studies were focused on its geological features (see Ciupagea et al., 1970; Lubenescu, 1981; Popescu et al., 1995), and foraminiferal assemblages (e.g. Marinescu et al., 1972; Popescu et al., 1995), the facies control over the Sarmatian foraminiferal assemblages of the Southern Transylvanian Basin was poorly studied and understood until recently. Nonetheless, a detailed systematical description and illustration of the Sarmatian benthic foraminifera from the Southern Transylvanian Basin have never been carried out.

The aims and objectives of this study are therefore the following:

1. To analyse around 180 samples collected from sedimentologically interpreted Sarmatian outcrops in the Southern Transylvanian Basin in order to document and describe the recovered foraminiferal faunas.
2. To analyse the biostratigraphic significance of the recovered foraminiferal assemblages.
3. To characterise the sedimentological facies in terms of their micropaleontological content, and to provide interpretations on palaeoecological and sedimentological factors affecting these assemblages.

Chapter 2 – History of geological investigations in the southern part of the Transylvanian Basin

The geological exploration of the Southern Transylvania Basin has more than 200 years of history beginning with the publication of the book written by Johann Ehrenreich von Fichtel in 1780. This was fallowed until today by many works focusing on stratigraphy, palaeontology and tectonics, which results were concluded in sysnthesis written by Hauer and Stache (1863), Koch (1894, 1900), and Ciupagea et al. (1970). In the later years the most important studies focused on the tectonics, structural evolution, sedimentology and sequence stratigraphy of the Transylvanian Basin (e.g. Huismans et al., 1997; Ionescu et al., 2009; Krézsek and Filipescu, 2005; Krézsek and Bally, 2006; Krézsek et al., 2010).

The geophysical exploration of the Southern Transylvanian Basin have begun in 1933 (Ciupagea et al., 1970) and had important consequences on our understandings of the basin's geological features. The results of the geophysical investigations were used as part of studies on the tectonic evolution and geological structure of Transylvanian Basin i.e. Ciulvau and Bertotti (1994), Ciupagea et al. (1969), and Visarion and Velciu (1981).

Chapter 3 – The geology of the southern part of the Transylvanian Basin

3.1. The basement of the Southern Transylvanian Basin

The Transylvanian and the Eastern Pannonian basins share the same basement (Csontos and Vörös, 2004), which consist of a stack of basement-involved thrust sheets assembled by the Mid-Cretaceous (Săndulescu, 1984, 1988). These imply Palaeozoic crystalline units (Ciupagea et al., 1970; Săndulescu and Visarion, 1978; Visarion and Veliciu, 1981), ophiolites or island-arc volcanics (e.g. Burchfiel, 1976; Ionescu et al., 2009) and associated Permian to Mid-Cretaceous sedimentary rocks (e.g. Ciupagea et al., 1970), similar to those outcropping in the surrounding mountains (Ciulavu, 1999). These combined nappes are known as Tisza-Dacia terrane (Csontos and Vörös, 2004) or as Inner Dacides, Transylvanides, and Middle Dacides (Săndulescu, 1984). However it is important to mention that the Inner Dacides are missing from the basement of the Southern Transylvanian Basin (see Krézsek and Bally, 2006).

3.2. The sedimentary infill of the Southern Transylvanian Basin

The sedimentary record of the Transylvanian Basin is locally more than 5 km thick and can be subdivided into four tectonostratigraphic megasequences: 1) Upper Cretaceous (extensional, gravitational collapse); 2) Paleogene (sag); 3) Lower Miocene (flexural); and 4) Middle to Upper Miocene (back-arc), based on regional unconformities and/or their correlative conformity surfaces (see Krézsek and Bally, 2006).

The lithostratigraphic units and fossil content of these tectonostratigraphic megasequences are quite well known, although the Upper Cretaceous and Paleogene sediments outcrop only in relatively small areas (see Fig. 1), whilst the main part of the region is covered by Middle to Upper Miocene (see Fig. 1, and Tab. 1). The available outcrop data is completed by the subsurface data of about 38 deep-wells which penetrated below the Middle Miocene (Lower Badenian) strata (see Falk, 2007).

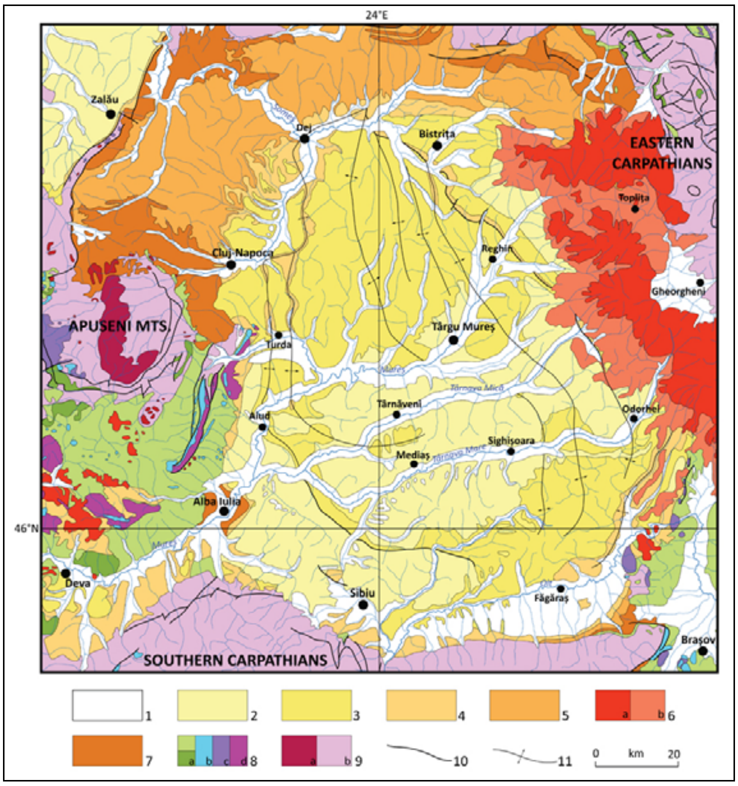

Figure 1. The geological map of the Transylvanian Basin: 1. Quternay; 2. Pannonian; 3. Sarmatian; 4. Badenian; 5. Lower Miocene; 6. Neogene volcanic arc (a. volcaninc rocks; b. volcano-sedimentary deposits); 7. Paleogene; 8. Mesozoic (a. Cretaceous; b Jurassic; c. Triassic; d. Triassic-Jurassic volcanic arc); 9. Pre-Mesozoic (a,. magmatites; b. metamorphites) - from Filipescu et al. (2009)

Regional stage (Central Paratethys)		**Foraminiferal biozones (based on Popescu, 1995, 2000)**		**Lithostratigraphic Units (based on Filipescu, 2001; Ilie, 1955; Lubenescu, 1981; Popescu et al., 1995; Rado et al., 1980)**		
Pannonian		ostracods *Ammonia* acme ostracods		Vingard Fm.		Ocland Formation
				Săcădate Fm.	Guşteriţa Fm.	
Sarmatian	Bess.	*Porosononion aragviensis*		Dobârca Formation		Mereşti Formation
	Bess.	*Dogielina sarmatica*				
	Volhynian	*Elphidium reginum*	*Articulina sarmatica*			
	Volhynian	*Varidentella reussi*				
	Volhynian	*Anomalinoides dividens*				Mărtiniş Formation
Badenian	Late	*Velapertina*		Pietroasa Formation		
	Middle			Ocna Dejului Formation		
	Middle	*Globoturborotalita druryi / Globorotalia transsylvanica*		Dej Tuff		
	Early	*Orbulina suturalis / Globorotalia bykovae*				
	Early	*Praeorbulina glomerosa*		?Tălmaciu Conglomerates		?"Perşani Conglomerates"

Table 1. Synthetic chart of Middle to Late Miocene lithostratigraphic units of Southern Transylvania. Regional stages based on Harzhauser and Piller (2004) and Rögl (1998a).

Chapter 4 – The Sarmatian in the southern part of the Transylvanian Basin

4.1. The concept of Sarmatian

The term "Sarmatian", as a chronostratigraphic unit, was introduced by Suess on 5 July, 1866 (see Suess, 1866). However his reference in the original text to Barbot de Marny generated a long lasting controversy regarding the priority of the definition (see Ionesi et al., 2005; Papp, 1974). The various interpretations and correlations of the Sarmatian in the Transylvanian Basin reflect the uncertainties of the Sarmatian/Pannonian boundary (see Krézsek, 2005) and the correlation problems between the Sarmatian of the Central and Eastern Paratethys. Therefore the Sarmatian of the Transylvanian Basin was correlated 1) with the entire Sarmatian (= Sarmatian s.l.) from the Eastern Paratethys (e.g. Gräf et al., 1973; Török, 1933); 2) with the Volhynian + Bessarabian (e.g. Filipescu, 1999; Gräf et al., 1971; Popescu, 1995); and 3) with the Volhynian + Lower Bessarabian (e.g. Krézsek and Filipescu, 2005).

4.2. Lithostratigraphy

In the southern part of the Transylvanian Basin a few lithostratigraphic units were defined so far (see Tab. 1): the *Dobârca Formation* (Lubenescu, 1981), which conformably overlie the former unit in the south-western part of the Transylvanian Basin, and the *Mărtiniş Formation* (Țicleanu in Rado et al., 1980) and *Mereşti Formation* (Țicleanu in Rado et al., 1980) in the eastern part of the basin.

4.3. Biostratigraphy

As a consequence of the scarcity or absence of planktonic fossils within the Sarmatian sedimentary record, the biostratigraphic zonations proposed in different basins (or countries) of the Central and Eastern Paratethys are based exclusively on benthic fossils (e.g. Boda, 1974; Görög, 1992; Grill, 1941; Jiříček, 1972; Koiava, 2006; Kojumdgieva et al., 1989; Łuczkowska, 1967; Papp, 1956; Venglinski, 1975).

In Romania the biostratigraphic zonations of the Sarmatian foraminifera in use was performed by Popescu (1995) on assemblages from various part of Romania, including the Transylvanian Basin. The mollusc zonations in use were defined by Ionesi et al. (2005) in the Moldavian Platform, and by Lubenescu (1981) in the Transylvanian Basin.

Chapter 5 – Material and methods

Around 180 samples were collected for this research from 139 surface outcrops located in the southern part of the Transylvanian Basin. However for various reasons we have chosen the 31 most-significant samples for this study. This number proved to be sufficient for the first general characterization of the Sarmatian foraminiferal assemblages of the Southern Transylvanian Basin. Every outcrop was sedimentologically interpreted with the help of Dr. Csaba Krézsek (see in Krézsek et al., 2010), and the outcrops were pictured by Prof. Dr. Sorin Filipescu and Dr. Csaba Krézsek.

The foraminiferal assemblages were used to infer on palaeoecological conditions based on palaeoecological indices calculated with PAST ver. 1.94b of Hammer et al. (2001), calcareous benthic morphogroups and recent analogies. The age of the sampled strata was determined based on the available biostratigraphic frameworks (e.g. Popescu, 1995).

Morphogroup		Morphotype	Foraminiferal groups	Mode of life	Feeding habit	Main genera
S1		Planspiral with rounded margin	Non-keeled elphidiids and nonioniids	infaunal	herbivore and detritivore	*Nonion, Elphidiella, Porosononion, Elphidium* (non-keeled)
S2		Planspiral with spines and/or keeled	Keeled and spinose elphidiids	epifaunal	herbivore	*Elphidium* (keeled)
S3		Planoconvex trochospiral	Temporary or permanently attached rotalids	epifaunal	omnivore	*Rosalina*, *Discorbis, Schakoinella*
S4		Planocovex or biconvex, low trochospiral	Free rotalids	infaunal	?herbivore	*Ammonia*, *Aubignyna*
S5	S5a	Enrolled milioline	Miliolids	epifaunal	herbivore, detritivore	*Cycloforina, Triloculina, Pseudotriloculina, Varidentella*
	S5b	Partly uncoiled milioline	Miliolids	epifaunal	herbivore, detritivore	*Articulina, Articularia*
S6		Lenticular to flattened ovoidal or ovoidal	Biseriate planspiral buliminids and unilocular lagenids	infaunal	detritivore	*Cassidulina*, *Islandiella*, *Fissurina, Oolina*
S7	S7a	Flattened tapered	Bolivinids	infaunal	?detritivore	*Bolivina*
	S7b	Tapered and cylindrical	Bi-to triseriate and trochospiral buliminids	infaunal	?detritivore	*Bulimina, Caucasina, Buliminella, Fursenkoina, Orthomorphina*
S8		Planoconvex trochospiral, with many pores	Low trochospiral rotalids	?epifaunal	?	*Anomalinoides, ?Lobatula*

Table 2. Morphogroups and morphotypes used in this study, partly based on Corliss and Chen (1988) and Tóth and Görög (2008). Morphotypes and the mode of life of genera based mainly on Corliss and Chen (1988), Kaiho (1991, 1999), and Murray (1991), whilst the feeding habit compiled after Murray (1991).

Chapter 6 – Results and discussions

6.1. Foraminiferal assemblages and related lithofacies

The investigated outcrops revealed the existence of different lithofacies within the Sarmatian of the studied area. These lithofacies usually can be recognized at more than one outcrop therefore we present the most important outcrops grouped according to their dominant sedimentological characters. The description of the presented 25 outcrops and the interpretation of their sedimentological features are based on own data and on Krézsek et al. (2010), whilst the defined 21 benthic and planktonic foraminiferal assemblages are based on foraminiferal abundance and diversity, along with the distribution of calcareous benthic morphogroups and relative abundance of the main genera. The results of this chapter are summerized on the Table 4.

6.2. Planktonic foraminifera in Sarmatian: consequences in regional correlation, biostratigraphy and chronostratigraphy

6.2.1. The *Streptochilus* Assemblage Biozone

In some assemblages (e.g. mixed *Bolivina*-*Nonion* Assemblage 16; Toarcla B) several small *Bolivina*-like biseriat specimens were observed. The SEM investigation of these revealed features which fits very well with those of the planktonic genus *Streptochilus* and prove that several *Bolivina*-like foraminiferal specimens found in our in fact planktonics belonging to the genus *Streptochilus*. The occurrence of *Streptochilus* in the Upper Sarmatian i.e. strata with evolved species of genus *Porosononion* in shallow-water depositional settings (e.g. Nicoleşti) supported the separation of a new *Streptochilus* Assemblage Biozone, which was published as part of this thesis by Filipescu and Silye (2008).

6.2.2. Chronostratigraphical consequences of the Sarmatian *Streptochilus*

The presence of the *Streptochilus* species in the Late Sarmatian assemblages, give new correlation potential for the Upper Sarmatian on regional level. Moreover based on the FO occurrences of the identified *Streptochilus globulosum* and *S. latum* (see Boltovskoy, 1978; de Klasz et al., 1989), the definition of the Sarmatian/Pannonian boundary should be revised, and it's correlation with the Serravallian/Tortonian boundary reconsidered.

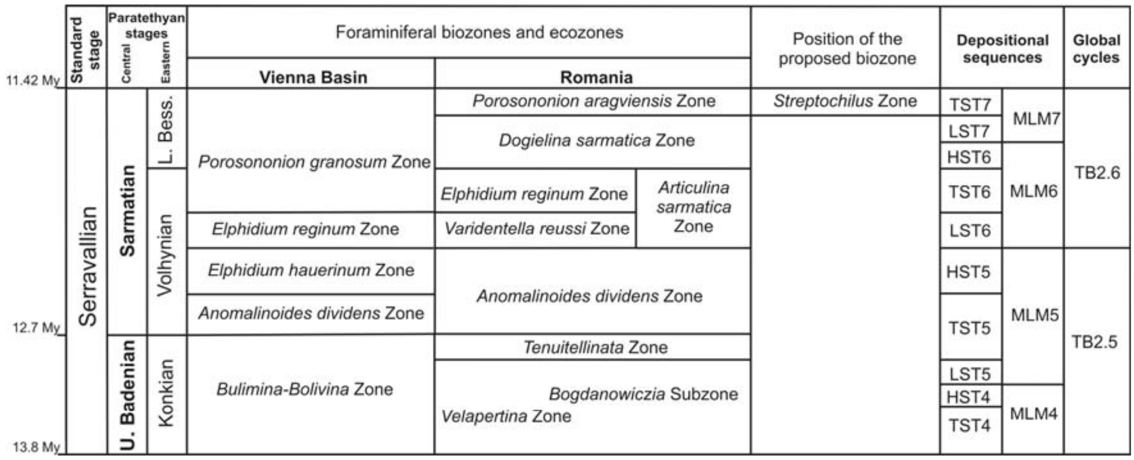

Figure 2. Chronostratigraphy, biostratigraphy and sequence stratigraphy of the Upper Badenian and Sarmatian in Romanian and the Transylvanian Basin and their correlation to the Vienna Basin. Foraminiferal biozonation in the Vienna Basin according to Grill (1941), Harzhauser and Piller (2004), and Rögl (1998c); biozonation in the Transylvanian Basin based on Filipescu (2004a), Filipescu and Silye (2008), and Popescu (1975, 1995); depositional sequences according to Krézsek and Filipescu (2005); global cycles based on Haq et al. (1988). The correlation of the Central and Eastern Paratethys stages according to Harzhauser and Piller (2004) and Rögl (1998a), whilst ages based on Harzhauser and Piller (2004), Hilgen et al. (2005), Lier et al. (2009), Lourens et al. (2004a, 2004b). Note the position of the *Streptochilus* Zone, drawn here after Filipescu and Silye (2008).

6.3. Chronology of the Sarmatian foraminiferal assemblages

The identified foraminiferal assemblages were sorted in time order (see Tab. 3) based on the occurrences of marker taxa (Filipescu et al., 2005; Popescu, 1995, 1998) controlled by the data on stratigraphic correlation of outcrops, depositional sequences amd subsurface data of the Southern Transylvanian Basin (Krézsek and Filipescu, 2005; Krézsek et al., 2010). These data were further improved by data on stratigraphical distribution of ostracods (in Wanek, 1992) associated to various foraminiferal assemblages.

Regional stages		Foraminiferal biozones		Dep. seq.	Palaeoenvironment			
Central	Eastern				Marginal	Inner shelf	Outer shelf	Bathyal
SARMATIAN	L. Bessarabian	*Porosononion aragviensis* Zone	*Streptochilus* Zone	?HST	**Asmb. 1** Feliceni			
				TST7		**Asmb. 12** Nicoleşti; **Asmb. 13** Nicoleşti; Ulieş	**Asmb. 20** Şoroştin 3&4; **Asmb. 21** Archita2; Mărtiniş1	**Asmb. 17&18** Cenade 3&4; **Asmb. 15&16** Toarcla A&B
		Dogielina sarmatica Zone		LST7		**Asmb. 2** Berghin 1; **Asmb. 14** Noul Român		
	Volhynina	*Elphidium reginum* Zone	*Articulina sarmatica* Zone	HST6		**Asmb. 4&5** Sărata A&B; **Asmb. 9** Arpaşu; **Asmb. 11** Răşinari		
				TST6		**Asmb. 10** Mihai Viteazu; **Asmb. 6** Buneşti 1		
		Varidentella reussi Zone		LST6		**Asmb.7** Dobârca 2; **Asmb. 8** Apoldu de Sus		
		Anomalinoides dividens Zone		HST5		**Asmb. 3** Dobârca 1		
				TST5		Dacia		**Asmb. 19** Ruşi

Table 3. The foraminiferal assemblages and outcrops presented in this study correlated to the chronostratigraphy, biostratigraphy and sequence stratigraphy of Sarmatian in the Transylvanian Basin. Foraminiferal biozonation based on Filipescu and Silye (2008) and Popescu (1995); depositional sequences according to Krézsek and Filipescu (2005). The correlation of the Central and Eastern Paratethys stages according to Harzhauser and Piller (2004), and Rögl (1998). The palaeoenvironmental zonations of the assemblages based on the interpretation presented in Chapter 6.1. of the thesis

6.4. Palaeoenvironments, palaeoecology and palaeogeography

6.4.1. Palaeoenvironments and palaeoecology

The Sarmatian sedimentary record of the Southern Transylvanian Basin was deposited in fluvial, marginal marine (paralic), shallow-marine ramp (lower shoreface, inner and outer shelf) and deep-water palaeoenvironments. These can be characterized with specific lithofacies and/or foraminiferal assemblages (see Tab. 4 and Fig. 3), whilst the genetically linked and coeval facies associations can be grouped in two depositional systems: 1) sand-gravel and a 2) mud-sand depositional systems (see Krézsek et al., 2010).

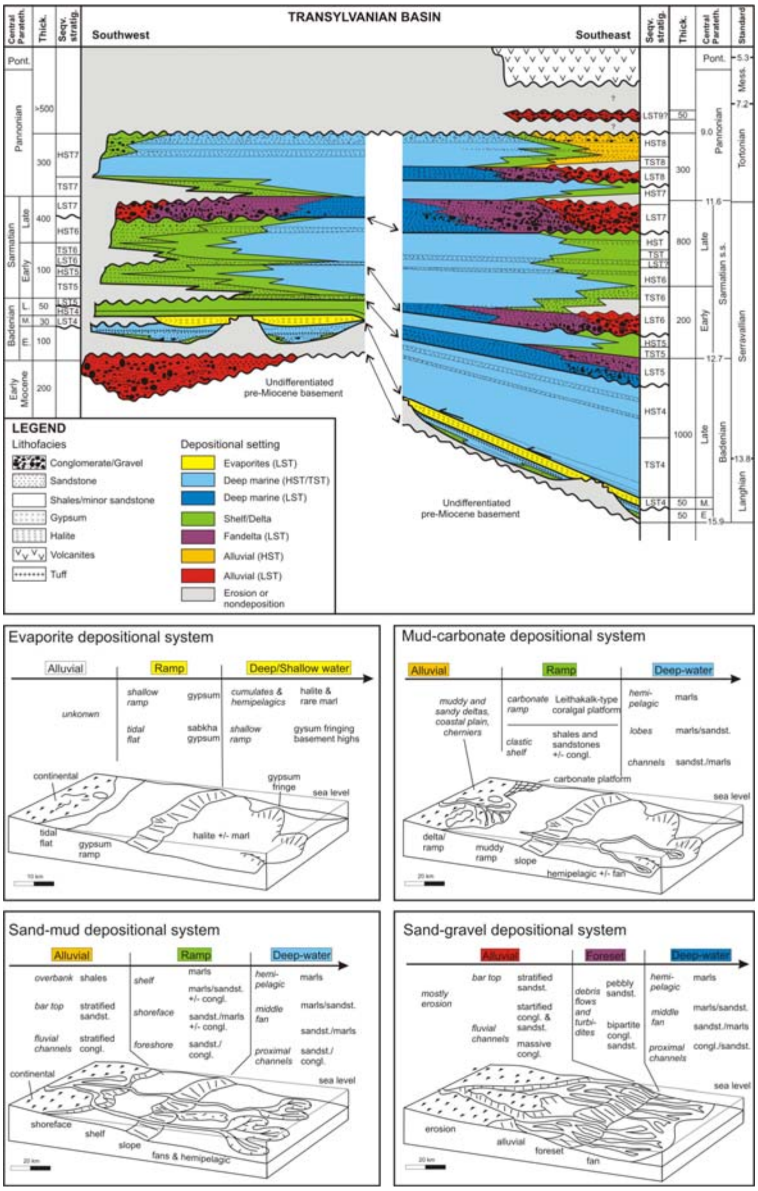

Figure 3. Miocene sedimentary evolution and depositional models of the Southern Transylvanian Basin (after Krézsek et al., 2010). The systems tract annotation follows Krézsek and Filipescu (2005). The correlation of the Central Paratethys and standard chronostratigraphy after Rögl (1998a) and Loursen et al. (2004b). Ages based on Hilgen et al. (2005), and Lourens et al. (2004a, 2004b). Note the dominance of sand-mud and sand-gravel systems during the Sarmatian.

Table 4. Lithofacies associations, description and interpretation of facies associations (based on Krézsek et al., 2010), microfauna (this study) and representative outcrops of the Southern Transylvanian Basin. The location of the outcrops is shown on the map in the Appendix 3 of the full text version. Annotations: Sa1 – Lower Sarmatian, Sa2 – Upper Sarmatian.

Lithofacies	Description	Interpretation	Microfauna	Representative outcrop and their age
Fluvial				
Massive conglomerates	Meter-scale granule to boulder-size clast- or matrix supported conglomerates. Ungraded/graded ± crude horizontal imbrication, channelized or irregular base.	Channel fill debris flows and longitudinal bedforms	absent	Sa1: Dacia Sa2: Ulieş
Stratified conglomerate	Meter-scale pebble to cobble sized clast-supported conglomerates. Graded with planar cross-stratification or through cross-stratification. Frequently scoured base.	Transverse bars or minor channel fills	absent	
Gravel lag	1-2 clast thick row of imbricated pebbles and cobbles that form discontinuous patches at the base of stratified sandstones or conglomerates	Minor channel lag	absent	Frequent
Stratified sandstone	Decimetre-scale medium to coarse-grained, sandstone and pebbly sandstone. Fining upwards, planar and through cross-stratification, horizontal lamination	Sand dunes (bar top assemblages), low-energy channel fill	absent	Frequent
Shallow-marine ramp				
Conglomerate	Decimetre to meter-scale pebble to boulder-sized clast supported conglomerates with a coarse sandy to pebbly sandstone matrix; erosional lower boundaries and highly-variable thicknesses; vaguely defined tabular or horizontal stratification; some may be massive and fining upwards.	Distributary channels incised on the inner shelf (mostly upper shoreface)	absent	Sa2: Berghin
Pebbly sandstones	Decimetre-scale well-sorted coarse-grained horizontally stratified sandstones with scattered granule to boulder sized pebble lags. The stratification is formed by centimetre-scale fining- or coarsening-upwards units. Large-scale low angle cross-stratification and low angle erosional surfaces.	Foreshore/Upper shoreface pebbly sandstones. Frequently associated with major conglomerate channels and gravel lags	absent	Sa2: Berghin, Dobârca valley
Coarse sandstone with gravel lag	Decimetre-scale beds up to 1-2 m thick of medium to coarse grained, well sorted and mostly fining upwards sandstones; occasionally pebbly and with minor lenticular conglomerates. Tabular and swaley cross stratification, minor horizontal lamination. Low angle truncations and gravel lags are frequent.	Large-scale upper shoreface dunes with gravel lags and minor conglomerate channels	absent	Sa1: Daia Română, Petreşti; Fişer, Buneşti, Dobârca valley (e.g. Dobârca 1) Sa2: Mureni
Bioclastic sandstone and shale	Centimetre to decimetre-scale coarse to medium grained, frequently bioclastic sandstones alternating with centimetres thick shale; the sandstone/shale boundary is sharp; rare pebble lags; the upper surface of the sandstones is not graded; wave-current ripples, hummocky cross-stratification, horizontal lamination; shales are bioturbated.	Minor lower shoreface sandy dunes with suspension fallout marls	Sa1: shallow-water benthic foraminifera (e.g. *Ammonia* spp., *Elphidium* spp., *Nonion* spp., miliolids), mysids, and ostracods Sa2: shallow-water benthic foraminifera (e.g. *Ammonia* spp., *Porosononion* spp.)	Sa1: Sărata A&B, Dobârca valley (Dobârca 1) Sa2: Mureni2

Table 4. (continued)

Lithofacies	Description	Interpretation	Microfauna	Representative outcrop and their age
Marl with sandstone and conglomerate	Centimetres-scale laminated brown and whitish marls/shales and ripple-laminated fine-grained sandstones that form several mater thick successions occasionally interbedded with centimetre-scale fining-upwards bioclastic sandstones and conglomerates; sandstones have horizontal to ripple lamination; conglomerates are massive or planar cross stratified	Inner shelf close to the storm-wave base with frequent tempestites	shallow-water microfauna Sa1: e.g. *Porosononion* spp., *Elphidium* spp.), ostracods Sa2: e.g. *Ammodiscus* sp., *Ammonia* spp., *Aubignyna* spp., *Porosononion* spp., *Nonion* spp., *Bolivina* spp., ostracods	Sa1: Buneşti 1&2, Dobârca valley (e.g. Dobârca 1) Sa2: Mureni, Ulieş, Dobârca valley, Feliceni (lower part)
Marls with fine-grained sandstone	Centimetre-scale marls locally in alternation with minor fine-grained sandstone; unidirectional ripples and horizontal lamination, carbonate rich laminas	Inner to outer shelf below or sometimes close to the storm-wave base	Sa1: benthic foraminifera (e.g. *Elphidium* spp., *Nonion* spp., *Cassidulina* spp, *Bolivina* spp., *Anomalinoides dividens*, miliolids), rare planktonic foraminifera (e.g. *Tenuitellinata* spp., *Globigerina* spp.), ostracods, and molluscs Sa2: rotaliids, mysids, ostracods	Sa1: Dobârca valley (e.g. Dobârca 2), Arpaşu de Jos, Răşinari, Mihai Viteazu, Grânari, Apoldu de Sus Sa2: Noul Român, Mureni 2
Fandelta				
Bipartite conglomerate and sandstone	Decimetre to meters-scale fining-upwards, clast or matrix supported pebble to boulder sized massive conglomerates, with [a(p)a(i)]-type imbrication that form multi-storey amalgamated units. The conglomerates are covered by decimetre thick horizontally laminated or massive coarse-grained sandstones. Pebbles to boulder-sized imbricated lags are frequent; high-angle depositional dips.	Bipartite flows consisting of lower cohesionless debris flows and upper turbidity currents and debris falls deposited on gravely Gilbert-type fandelta foresets	absent	Sa2: Nicoleşti (lower part), Ulieş
Pebbly sandstone and sandstone	Decimetre to meters-scale massive or horizontally laminated pebbly sandstones that fine upwards into sandstones. Frequent imbricated [a(p)a(i)] pebble lags and shale rip-ups; rare lenticular cross-stratified pebble conglomerates; low angle depositional dips and erosional surfaces; bioturbation	High-density turbidites or sandy debris flows and debris falls probably deposited on sandy fandelta low angle foresets. Minor conglomerate channels.	absent	Sa2: Mohu, Câlnic
Deep-water				
Massive sandstone and conglomerate	Several meters thick fining upwards massive coarse-grained sandstones with frequent internal amalgamation surfaces sometimes capped by low density turbidites (Tbc). Frequent shale rip-ups. The sandstones may be interbedded with meters-thick channelized units formed by pebble- to boulder-sized, clast or matrix supported, frequently imbricated [a(p)a(i)] conglomerates.	Proximal submarine channel fills formed by high density turbidites, gravely debris flows and some low density turbidites	absent	Sa1: Cobor Sa2: Archita 2
Sandstones with minor marls	Decimetre to several meter-scale Bouma-type (Tab, Tabc, and Tbc) sandy turbidites interbedded with decimetre thick marls. Non-erosional parallel bed boundaries. Rare small-scale sandy channels and shale rip-ups.	Submarine channels late fill or submarine fan lobe dominated by low-density turbidites and interbedded with suspension fall-out pelagics. High density turbidites may occur.	Sa1: planktonic foraminifera (*Tenuitella* spp., *Tenuitellinata* spp., *Globigerina* spp.), rare benthic foraminifera (e.g. *Bolivina* spp., *Oolina* spp, allochtonous specimens) Sa2: rotaliids and ostracods	Sa1: Felmer Sa2: Bârghiş, Cenade3&4, Jibert, Marpod, Toarcla A&B

Table 4. (continued)

Lithofacies	Description	Interpretation	Microfauna	Representative outcrop and their age
Marls with minor sandstones	Decimetre to meter scale laminated or massive marls associated with minor fine to medium grained Bouma-type (Tbc, Tcd) sandy turbidites. Non-erosional parallel bed boundaries. No rip-ups or channels.	Submarine fan levee or outer lobe fringe; dominated by suspension fall-out with minor amount of low-density turbidites	Sa1: planktonic foraminifera, benthic foraminifera (e.g. *Bolivina* spp., *Fissurina* spp. *Oolina* spp., *Anomalinoides dividens*, allochtonous specimens of rotaliids?), ostracods Sa2: ?transported benthic foraminifera (e.g. *Elphidium* spp., *Porosononion* spp.), *Anomalinoides dividens,* planktonic foraminifera (*Tenuitellinata* spp., *Streptochilus* spp.) and rare ostracods	Sa1: Ruşi 2, Brădeni, Grânari Sa2: Soroştin 2&4, Vărd
Marls	Decimetre- to meter scale massive or laminated marl and calcareous marl.	Pelagites, suspension fall-out on the basin plain	Sa1: ?transported rotaliids, and rare planktonic foraminifera (e.g. *Tenuitellinata* spp., *Tenuitella* spp) and rare rotaliids	Sa1: Grânari Sa2: Archita2
Evaporite				
Gypsum	Decimetre to meter thick massive (alabaster) or thinner fibrous gypsum beds. Sometimes associated with thin calcareous marls or limestones.	Sabkha to shallow (< 5m) platform	Absent	Sa1: Daia Română

6.4.2 Palaeogeography

The evolution of the palaeoenvironments inferred based on the foraminiferal assemblages (this study) and the evolution and alternation of the depositional systems (Krézsek et al., 2010) allowed the reconstruction of the general palaeogeography of the Southern Transylvanian Bain (see Fig. 4), and its connections to the open seas.

Basin scale palaeogeography

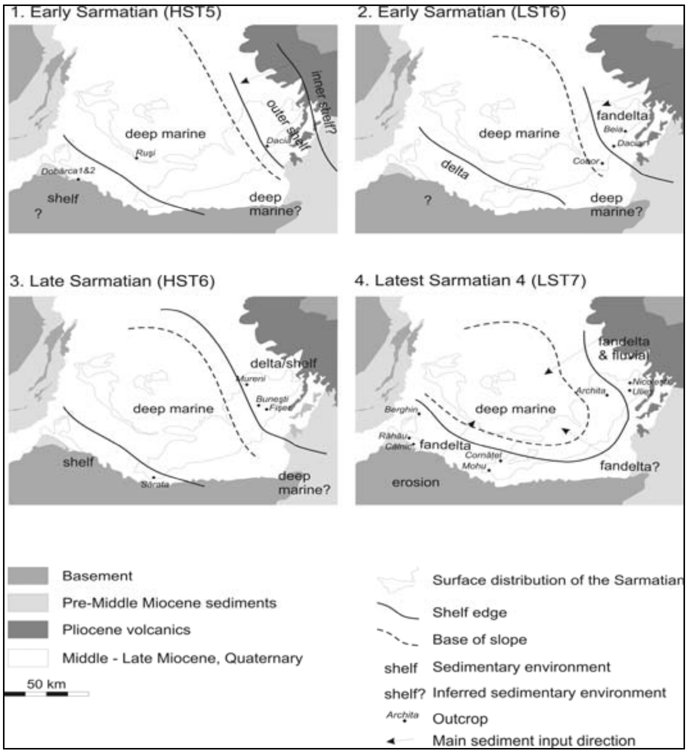

Figure 4. Palaeogeographic reconstructions for selected Sarmatian systems tracts of the Southern Transylvanian Basin (modified after Krézsek et al., 2010). The shallow-marine palaeoenvironments were established with the beginning of the Early Sarmatian, and persisted throughout the Sarmatian. The shelf areas were dominated by the mud-sand depositional system during the relative sea level transgressive and highstand system tracts. The shelves were mainly covered by fandeltas during the lowstands.

Regional palaeogeography

The Sarmatian is often depicted as having very restricted or no connections towards the open oceans, and specifically not to the Indo-Pacific region (e.g. Paramonova et al., 2004; Rögl, 1998b). Moreover the faunal change observable at the Badenian/Sarmatian boundary (e.g. Harzhauser and Piller, 2007) was explained by Rögl (1999) by a serious shift in the oceanic connections of the Paratethyan area from the Late Badenian connection to the Indo-Pacific to a very narrow and short lasting connection towards the Atlantic during the Early Sarmatian. In contrary, the planktonic content of the Sarmatian foraminiferal assemblages in the Transylvanian Basin suggest connections to the Indo-Pacific regions during the Sarmatian, at least during the transgressive events.

Chapter 7 – Taxonomy

The taxonomic work of this thesis contains the description of the 100 species, severals of them (e.g. *Ammodiscus* aff. *gullmarensis*, the planktonic foraminifera) described for the first time from the Sarmatian of the Southern Transylvanian Basin or Central Paratethys. The identified species of benthic and planktonic foraminifera have been arranged in taxonomic order following the suprageneric classifications of Loeblich and Tappan (1988, 1992), except the species belonging to the genera *Tenuitella* and *Tenuitellinata* which systematic classification follows Li (1987). Species identifications have been based in large part on the taxonomic works of Brestenská (1974), Cicha and Zapletalová (1963), Cicha et al. (1998), Didkowski and Satanovskaja (1970), Filipescu (2004b), Görög (1992), de Klasz et al. (1989), Li (1987), Li et al. (1992), Łuczkowska (1972, 1974), Papp and Schmid (1985), Popescu (1995), and Venglinski (1958).

Chapter 8 – Conclusions

This study focused on the description of the Sarmatian foraminiferal assemblages from the Southern Transylvanian Basin, and their significance for the reconstruction of sedimentary facies. The palaeogeographic significance of the recovered assemblages and their usefulnes for the reconstruction of the basin's history were also inferred and discussed.

The foraminiferal assemblages demostrates based on morphogroup analysis and recent analogies the existence of marginal estuarian or deltaic to outer shelf/bathyal palaeoenvironmets during the Sarmatian. Each of these can be characterized by specific foraminiferal assemblages, or even within the same palaeoenvironment (e.g. inner shelf) several sub-palaeoenvironments can be separated based on the variations observed in the compositiona of the foraminiferal assemblages.

The sea-level fluctations and the evolution of the palaeoenvironments can be quite well modeled based on Sarmatian calcareous benthic and planktonic foraminiferal assemblages. The most obviously the transgressive events can be indetified. Almost every transgressive setting recognized based on the variations of the sedimentary facies correlates with the plancktonic invasions starting from the Early Sarmatian and ending with the Late Sarmatian (TST7). The sediments deposited by highstand system tracts can be characterized by well structured and abundant shelf assemblages (e.g. Arpaşu, Răşinari, and Sărata) or even by the appearance of marginal marine assemblages with agglutinated foraminifera (e.g. Feliceni). The reworked assemblages (e.g. at Berghin) or hypersaline lagoon assemblages (Mihai Viteazu) can be assigned to lowstand events.

The differences observed between the Early and Late Sarmatian foraminiferal assemblages as regards their species content and the relative abundance of the morphogroups suggests that the Early Sarmatian, probably well-ventilated Transylvanian Basin, changed into a basin with stratified water column and hypoxic bottom in the Late Sarmatian. This may have been a result of the tectonic isolations.

Two interesting foraminiferal groups presented in this study complete our inventory of Sarmatian foraminifera from the Transylvania Basin. Agglutinated foraminifera (*Ammodiscus* aff. *gullmarensis*) related to particular deltaic Sarmatian palaeoenvironment and rare biseriate (*Streptochilus*) or trochospiral microperforate (*Tenuitella*, *Tenuitellinata*) planktonic foraminifera related to transgressive events. The later demonstrated that the open sea connections of the Transylvanian Basin (and thus of the Central Paratethys) persisted until the Late Sarmatian, in agreement whit data on fossil diatoms (see Saint Martin and Saint Martin, 2005).

The absence of Sarmatian shallow-water carbonates (see Fig. 4) observable in other Paratethyan basins (see Cornée et al., 2009; Pisera, 1996) and the presence of deep-marine palaeoenvironments are the most striking characters of the Sarmatian sedimentary record from the Transylvanian Basin.

Selected references

Boda, J., 1974. A magyarországi szarmata emelet rétegtana. *Földtani Közlöny*, v. 104, 3, p. 249-260.

Boltovskoy, E., 1978. Late Cenozoic benthonic foraminifera of the Ninetyeast Ridge (Indian Ocean). *Marine Geology*, v. 26, 1-2, p. 139-175.

Brestenská, E., 1974. Die Foraminiferen des Sarmatien s. str. In: Brestenská, E. (ed.) M_5 Sarmatien (sensu E. Suess 1866). Die Sarmatische Schichtengruppe und ihr Stratotypus. *Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys*, v. 4, p. 243-293, VEDA, Bratislava.

Burchfiel, B.C., 1976. Geology of Romania. *Special Paper*, v. 158. Geological Society of America, 82 pp.

Cicha, I., Zapletalová, I., 1963. Die Vertreter der Gattung Bolivina (Foraminifera - Protozoa) in Miozän der Westkarpaten. *Sborník Ustředniho Ustavu Geologického, Oddíl paleontologický*, v. 28(1961), p. 115-183.

Cicha, I., Rögl, F., Rupp, C., Ctyroka, J., (eds.), 1998. Oligocene - Miocene foraminifera of the Central Paratethys. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, v. 549. Verlag Waldemar Kramer, Frankfurt am Main, 1-325 pp.

Ciulavu, D., Bertotti, G., 1994. The Transylvanian Basin and its Upper Cretaceous substratum. *Romanian Journal of Tectonics and Regional Geology*, v. 75, Suppl. 2, p. 59-64.

Ciulavu, D., 1999. Tertiary tectonics of the Transylvanian Basin. *PhD thesis*, Vrije Universiteit, Amsterdam, 152 pp.

Ciupagea, D., Paucă, M., Ichim, T., 1970. Geologia Depresiunii Transilvaniei. Editura Academiei RSR, Bucureşti, 256 pp.

Ciupagea, D.T., Airinei, Ş., Stoenescu, S., Popescu, M., Popescu, C., Taloş, D., 1969. Nouveaux éléments d'interprétation géologique des résultats géophysiques dans la partie sud-ouest de la dépression de Transylvanie. *Revue Roumaine de Géologie, Géophysique et Géographie. Géophysique*, v. 13, 1, p. 87-103.

Corliss, B.H., Chen, C., 1988. Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology*, v. 16, 8, p. 716-719.

Cornée, J.-J., Moissette, P., Saint Martin, J.-P., Kázmér, M., Tóth, E., Görög, Á., Dulai, A., Müller, P., 2009. Marine carbonate systems in the Sarmatian (Middle Miocene) of the Central Paratethys: the Zsámbék Basin of Hungary. *Sedimentology*, v. 56, 6, p. 1728-1750.

Csontos, L., Vörös, A., 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 210, 1, p. 1-56.

de Klasz, I., Kroon, D., Van Hinte, J.E., 1989. Notes on the foraminiferal genera *Laterostomella* De Klasz and Rérat and *Streptochilus* Brönnimann and Resig. *Journal of Micropalaeontology*, v. 8, 2, p. 215-226.

Falk, I., 2007. Evoluția terțiară a Depresiunii Transilvaniei cu privire la geneza capcanelor rupturale, flexurale şi stratigrafice pentru hidrocarburi. *PhD*, Babeş-Bolyai University, Cluj-Napoca, 206 pp.

Fichtel, J.E.v., 1780. Beytrag zur Mineralgeschichte von Siebenbürgen. Zweyter Theil welcher die Geschichte des Steinsalzes enthält. Raspische Buchhandlung, Nürnberg, 134 pp.

Filipescu, S., 1999. The significance of foraminifera fauna from the Feleac Formation (Transylvanian Basin, Romania). *Studia Universitatis Babeş-Bolyai, Geologia*, v. 44, 2, p. 125-131.

Filipescu, S., 2001. Cenozoic Lithostratigraphic Units in Transylvania. In: Bucur, I.I., Filipescu, S., Săsăran, E. (eds.) Algae and carbonate platforms in western part of Romania. 4th Regional Meeting of IFAA Cluj-Napoca 2001 - Field Trip Guidebook. p. 75-92, Cluj University Press, Cluj-Napoca.

Filipescu, S., 2004a. *Bogdanowiczia pocutica* Pishvanova in the Middle Miocene of Transylvania - paleoenvironmental and stratigraphic implications. In: Codrea, V., Petrescu, I., Dica, P.E. (eds.) *Acta Palaeontologica Romaniae*, v. 4, p. 113-117, Supergraph, Cluj-Napoca.

Filipescu, S., 2004b. *Anomalinoides dividens* bioevent at the Badenian/Sarmatian boundary - a response to paleogeographic and paleoenvironmental changes. *Studia Universitatis Babeş-Bolyai, Geologia*, v. 49, 2, p. 21-26.

Filipescu, S., Silye, L., Krézsek, C., 2005. Sarmatian micropaleontological assemblages and sedimentary paleoenvironments in the Southern Transylvanian Basin. In: Csíki, Z., Grigorescu, D., Lazăr, I. (eds.) *Acta Palaeontologica Romaniae*, v. 5, p. 173-179, Ars Docendi, Bucureşti.

Filipescu, S., Silye, L., 2008. New Paratethyan biozones of planktonic foraminifera described from the Middle Miocene of the Transylvanian Basin (Romania). *Geologica Carpathica*, v. 59, 6, p. 537-544.

Filipescu, S., Krézsek, C., Săsăran, E., Silye, L., Wanek, F., Beldean, C., 2009. Field trip guide - 3rd International Workshop on the Neogene of the Central and South-Eastern Europe, Cluj-Napoca, May 20-24, 35 pp.

Görög, Á., 1992. Sarmatian foraminifera of the Zsámbék basin, Hungary. *Annales Universitatis Scientiarium Budapestinensis de Rolando Eötvös nominatae, Geologica*, v. 29, p. 31-153.

Gräf, I., Pană, I., Fesci, V., 1971. Die Sarmat-Mäot-Grenze im Gebiet des oberen Archita-Tals östlich von Sighişoara (SR Rumänien). *Geologie*, v. Jahrgang 20, 1, p. 62-73.

Gräf, I., Rado, G., Mitrea, G., 1973. Asupra prezenţei sarmaţianului superior (kersonian) în regiunea de la est de Satu Nou (sud-estul Bazinului Transilvaniei). *Studii şi cercetări de geologie, geofizică, geografie. Geologie*, v. 18, 1, p. 235-244.

Grill, R., 1941. Stratigraphische Untersuchungen mit Hilfe von Mikrofaunen im Wiener Becken und der benachbarten Molasse-Anteilen. *Oel und Kohle*, v. 31, 595-602.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. Past: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*, v. 4, 1, art 4, p. 1-9.

Haq, B.U., Hardenbol, J., Vail, P.R., 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea level change. In: Wilgus, C.K., Hastings, B.J., Posamentier, H.W., van Wagoner, J.C., Ross, C.A., Kendall, C.G.S.C. (eds.) Sea-level Change: an Integrated Approach. *SEPM Special Publication*, v. 42, p. 71-108.

Harzhauser, M., Piller, W.E., 2004. Integrated stratigraphy of the Sarmatian (Upper Middle Miocene) in the western Central Paratethys. *Stratigraphy*, v. 1, 1, p. 65-86.

Harzhauser, M., Piller, W.E., 2007. Benchmark data of a changing sea: palaeogeography, palaeobiogeography and events in the Central Paratethys during the Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 253, 1-4, p. 8-31.

Hauer, F.R.v., Stache, G., 1863. Geologie Siebenbürgens. Verein für Siebenbürgische Landeskunde, W. Braumüller, Wien, 636 pp.

Hilgen, F., Abdul Aziz, H., Bice, D., Iaccarino, S., Krijgsman, W., Kuiper, K., Montanari, A., Raffi, I., Turco, E., Zachariasse, W.-J., 2005. The Global boundary Stratotype Section and Point (GSSP) of the Tortonian Stage (Upper Miocene) at Monte Dei Corvi. *Episodes*, v. 28, 1, p. 6-17.

Huismans, R.S., Bertotti, G., Ciulavu, D., Sanders, C.A.E., Cloetingh, S., Dinu, C., 1997. Structural evolution of the Transylvanian Basin (Romania): a sedimentary basin in the bend zone of the Carpathians. *Tectonophysics*, v. 272, 2-4, p. 249-268.

Ilie, M.D., 1955. Cercetări geologice în Bazinul Transilvaniei (regiunea Alba Iulia - Sibiu - Făgăraş - Rupea). *Anuarul Comitetului Geologic*, v. 28, p. 251-360.

Ionescu, C., Hoeck, V., Tomek, C., Koller, F., Balintoni, I., Besutiu, L., 2009. New insights into the basement of the Transylvanian Depression (Romania). *Lithos*, v. 108, 1-4, p. 172-191.

Ionesi, L., Ionesi, B., Roşca, V., Lungu, A., Ionesi, V., 2005. Middle and Upper Sarmatian on Moldavian Platform. Editura Academiei Române, Bucureşti, 558 pp., *(in Romanian)*.

Jiříček, R., 1972. Problém hranice sarmat/panon ve Vídeňské, Podunajské a Východoslovenské pánvi. *Mineralia Slovaca*, v. 14, 4, p. 39-81.

Kaiho, K., 1991. Global changes of Paleogene aerobic/anaerobic benthic foraminifera and deep-sea circulation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 83, 1-3, p. 65-85.

Kaiho, K., 1999. Effect of organic carbon flux and dissolved oxygen on the benthic foraminiferal oxygen index (BFOI). *Marine Micropaleontology*, v. 37, 1, p. 67–76.

Koch, A., 1894. Az erdélyrészi medencze harmadkori képződményei. I rész: Paleogén csoport. *A Magyar Királyi Földtani Intézet Évkönyve*, v. 10, 6, p. 161-356.

Koch, A., 1900. Az erdélyrészi medencze harmadkori képződményei. II. Neogén csoport. Magyarhoni Földtani Társulat, Budapest, 329 pp.

Koiava, K., 2006. The biostratigraphy of Sarmatian deposits of Eastern Georgia on the base of Foraminifera. *PhD thesis*, Alexandre Djanelidze Institute of Geology, Tbilisi, 163 pp., *(in Georgian)*.

Kojumdgieva, E.I., Paramonova, N.P., Belokrys, L.S., Muskhelishvili, L.V., 1989. Ecostratigraphic subdivision of the Sarmatian after molluscs. *Geologický Zborník - Geologica Carpathica*, v. 40, 1, p. 81-84.

Krézsek, C., 2005. Sedimentology and architecture of Pannonian deposits from the eastern part of the Transylvanian Basin. *PhD thesis*, Babeş-Bolyai University, Cluj-Napoca, 170 pp., *(in Romanian)*.

Krézsek, C., Filipescu, S., 2005. Middle to late Miocene sequence stratigraphy of the Transylvanian Basin (Romania). *Tectonophysics*, v. 410, 1-4, p. 437-463.

Krézsek, C., Bally, A.W., 2006. The Transylvanian Basin (Romania) and its relation to the Carpathian fold and thrust belt: Insights in gravitational salt tectonics. *Marine and Petroleum Geology*, v. 23, 4, p. 405-442.

Krézsek, C., Filipescu, S., Silye, L., Maţenco, L., Doust, H., 2010. Miocene facies associations and sedimentary evolution of the Southern Transylvanian Basin (Romania): Implications for hydrocarbon exploration *Marine and Petroleum Geology*, v. 27, 1, p. 191-214.

Li, Q., 1987. Origin, phylogenetic development and systematic taxonomy of the *Tenuitella plexus* (Globigerinitidae, Globigerininina). *Journal of Foraminiferal Research*, v. 14, 4, p. 298-320.

Li, Q., Radford, S.S., Banner, F.T., 1992. Distribution of microperforate tenuitellid planktonic foraminifers in holes 747A and 749B, Kerguelen Plateau. In: Wise, S.W., Jr., Schlich, R., *et al.*, Proceedings of the Ocean Drilling Program, Scientific Results, v. 120, College Station, TX, p. 569-594.

Lirer, F., Harzhauser, M., Pelosi, N., Piller, W.E., Schmid, H.P., Sprovieri, M., 2009. Astronomically forced teleconnection between Paratethyan and Mediterranean sediments during the Middle and Late Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 275, 1-4, p. 1-13.

Loeblich, A.R., Tappan, H., 1988. Foraminiferal genera and their classifications. Van Nostrand Reinhold Co., New York, 970 pp.

Loeblich, A.R., Tappan, H., 1992. Present status of foraminiferal classification. In: Takayanagi, Y., Saito, T. (eds.) Studies in Benthic Foraminifera. *Proceedings of the Fourth International Symposium on Benthic Foraminifera, Sendai, 1990 (Benthos '90)*, p. 93-102, Tokai University Press, Tokyo, Japan.

Lourens, L., Hilgen, F., Schackleton, N.J., Laskar, J., Wilson, B., 2004a. Appendix 2. Orbital tuning calibrations and conversions for the Neogene Period. In: Gradstein, F.M., Ogg, J.G., Smith, A.G. (eds.) A Geologic Time Scale 2004. p. 469-484, Cambridge University Press, Cambridge, UK.

Lourens, L., Hilgen, F., Schackleton, N.J., Laskar, J., Wilson, B., 2004b. The Neogene Period. In: Gradstein, F.M., Ogg, J.G., Smith, A.G. (eds.) A Geologic Time Scale 2004. p. 409-440, Cambridge University Press, Cambridge, UK.

Lubenescu, V., 1981. Studiul biostratigrafic al Neogenului superior din sud-vestul Transilvaniei. *Anuarul Institutului de Geologie şi Geofizică*, v. 58, p. 123-202.

Łuczkowska, E., 1967. Some new species of Foraminifera from the Miocene of Poland. *Rocznik Polskiego Towarzystwa Geologicznego*, v. 37, 2, p. 233-241, *(in Polish)*.

Łuczkowska, E., 1972. Miliolidae (Foraminiferida) from Miocene of Poland. Part I. Revision of the classification. *Acta Palaeontologica Polonica*, v. 17, 3, p. 341-377.

Łuczkowska, E., 1974. Miliolidae (Foraminiferida) from Miocene of Poland. Part II. Biostratigraphy, Palaeoecology and Systematics. *Acta Palaeontologica Polonica*, v. 19, 1, p. 1-176.

Marinescu, F., Gheorghian, D., Orăşanu, T., 1972. Jour III. In: Marinescu, F. (ed.) Néogène de la dépression de Transylvanie du Banat et du Bassin dacique. Guide de l'Excursion de la V^{e} Réunion du Grupe de Travail pour la Paratéthys. p. 49-65, Institute Geologique, Bucharest.

Papp, A., 1956. Fazies und Gliederung des Sarmats im Wiener Becken. *Mitteilungen der Geologischen Gesellschaft in Wien*, v. 47 (1954), p. 35-98.

Papp, A., 1974. Diskussion des Begriffes Sarmatische Stufe bzw. Sarmatien. In: Brestenská, E. (ed.) M_5 Sarmatien (sensu E. Suess 1866). Die Sarmatische Schichtengruppe und ihr Stratotypus. *Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys*, v. 4, p. 31-34, VEDA, Bratislava.

Papp, A., Schmid, M.E., 1985. Die fossilen Foraminiferen des tertiären Beckens von Wien. Revision der Monographie von Alcide d'Orbigny (1846). *Abhandlungen der Geologischen Bundesanstalt*, v. 37, p. 1-311.

Paramonova, N.P., Shcherba, I.G., Khondkarian, S.O., Gürs, K., Iosifova, J.I., Jakubovskaja, V.T., Kovac, M., Magyar, I., Pinchuk, T.N., Popov, S.V., Zastrozhnov, A.S., 2004. Map 7: late Middle Miocene (Late Serravallian, Sarmatian s. str., Middle Sarmatian s. l.) 12-11M a. In: Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F.F., Shcherba, I.G., Kovac, M. (eds.) Lithological-Paleogeographic maps of Paratethys: 10 maps Late Eocene to Pliocene. *Courier Forschungsinstitut Senckenberg*, v. 250, p. 27-29.

Pisera, A., 1996. Miocene reefs of the Paratethys: a review. In: Franseen, E., Esteban, M., Ward, W., Rouchy, J.-M. (eds.) Models for Carbonate Stratigraphy from Miocene Reef Complexes of the Mediterranean regions. *SEPM Concepts in Sedimentology and Paleontology* v. 5, p. 97-104, Tulsa, Oklahoma.

Popescu, G., 1975. Études des foraminifères du Miocène inférieur et moyen du nord-ouest de la Transylvanie. *Memoriile Institutului de Geologie şi Geofizică*, v. 23, p. 5-121.

Popescu, G., 1995. Contribution to the knowledge of the Sarmatian Foraminifera of Romania. *Romanian Journal of Paleontology*, v. 76, p. 85-98.

Popescu, G., Mărunţeanu, M., Filipescu, S., 1995. Neogene from Transylvania Depression. X . Congress RCMNS, Bucureşti 1995, Guide to excursion A1. *Romanian Journal of Stratigraphy*, v. 76, 3, p. 1-27.

Popescu, G., 1998. Oligocene and Miocene of the Transylvanian Basin. In: Cicha, I., Rögl, F., Rupp, C., Ctyroka, J. (eds.) Oligocene - Miocene foraminifera of the Central Paratethys. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, v. 549, p. 56-61.

Popescu, G., 2000. Lower and middle Miocene agglutinated foraminifera from the Carpathian area. In: Bucur, I.I., Filipescu, S. (eds.) *Acta Palaeontologica Romaniae*, v. 2, p. 407-425, Presa Universitară Clujeană, Cluj-Napoca.

Rado, G., Ţicleanu, N., Gheorghian, M., Popescu, A., 1980. Date noi privind litobiostratigrafia depozitelor miocenului şi pliocenului din regiunea Comăneşti-Lueta-Mărtiniş (jud. Harghita). *Studii şi cercetări de geologie, geofizică, geografie. Geologie*, v. 25, p. 95-108.

Rögl, F., 1998a. Paratethys Oligocene-Miocene stratigraphic correlation. In: Cicha, I., Rögl, F., Rupp, C., Ctyroka, J. (eds.) Oligocene - Miocene foraminifera of the Central Paratethys. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, v. 549, p. 3-7.

Rögl, F., 1998b. Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene and Miocene). *Annalen des Naturhistorischen Museums in Wien*, v. 99A, p. 279-310.

Rögl, F., 1998c. The Styrian Basin. In: Cicha, I., Rögl, F., Rupp, C., Ctyroka, J. (eds.) Oligocene - Miocene foraminifera of the Central Paratethys. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, v. 549, p. 49-50.

Rögl, F., 1999. Meditrerranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). *Geologica Carpathica*, v. 50, 4, p. 339-349.

Saint Martin, S., Saint Martin, J.-P., 2005. Enregistrement par les diatomées des variations paléoenvironnementales durant le Sarmatien dans l'aire paratéthysienne (Roumanie). *Comptes Rendus Palevol*, v. 4, 1-2, p. 191-201.

Săndulescu, M., Visarion, M., 1978. Considérations sur la structure tectonique du soubassement de la Dépression de Transylvanie. *Dări de Seamă ale Şedinţelor, Institutul de Geologie şi Geofizică*, v. 64(1976-1977), 5, p. 153-173.

Săndulescu, M., 1984. Geotectonics of Romania. Romanian Academy Publishing House, Bucharest, 336 pp., *(in Romanian)*.

Săndulescu, M., 1988. Cenozoic Tectonic History of the Carpathians. In: Royden, L.H., Horváth, F. (eds.) The Pannonian Basin: a study in basin evolution. v. AAPG Memoir 45, p. 17-25, Tulsa, Oklahoma.

Suess, E., 1866. Untersuchungen über den Charakter der österreichischen Tertiärablagerungen. II. Über die Bedeutung der sogenannten brackischen Stufe oder der Cerithienschichten. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Classe, Abteilung 1*, v. 54, 7, p. 218-257.

Török, Z., 1933. Cercetări geologice în judeţul Târnava-Mare. *Anuarul liceului "Principele Nicolae" din Sighişoara pe anii 1929/30-1932/33*, p. 1-88.

Venglinski, I.V., 1958. Foraminiferi miocenu Zakarpattia. Vidavictvo Akademia Nauk Ukrainskoi RSR, Kiev, 246 pp.

Venglinski, I.V., 1975. Foraminiferi i biostratigrafia miocenovikh otlozenii Zakarpatskovo progiba. Naukova Dumka, Kiev, 262 pp.

Visarion, M., Veliciu, S., 1981. Some geological and geophysical characteristics of the Transylvanian Basin. *Earth Evolution Sciences*, v. 3-4, p. 212-217.

Wanek, F., 1992. Studiul biostratigrafic al ostracodelor sarmaţiene şi pannoniene din Bazinul Transilvaniei. Staţiunea de cercetări Arcalia, Universitatea Babeş-Bolyai, Cluj-Napoca, p. 49.