Carpathian Journal of Earth and Environmental Sciences, May 2012, Vol. 7, No. 2, p. 195 - 208

PALAEOCLIMATIC ESTIMATION FROM MIOCENE OF ROMANIA, BASED ON PALYNOLOGICAL DATA

Daniel ŢABĂRĂ[1] & Gabriel CHIRILĂ[1]
[1] „Al. I. Cuza" University of Iaşi, Department of Geology, 20A Carol I Blv., 700505 Iaşi, Romania.
tabara_d@yahoo.com, gabiflogeoc@yahoo.com

Abstract: Few climatic parameters available for the stratigraphic interval between Aquitanian – Pontian from Romania, have been obtained after analysis of the palynological associations using the Coexistence Approach. The results obtained for MAT (mean annual temperature), MAP (mean annual precipitations), WMT (mean temperature of the warmest month), CMT (mean temperature of the coldest month), have been synthesised and palaeoclimatic diagrams have been plotted, revealing visible climatic fluctuation for the analysed interval. Palaeoclimatic curve was calculated for Dacian Basin, covering the southern and eastern part of Romania and Transylvanian Basin (Central-Western area of the country). MAT with high value have been observed for the Burdigalian (approximately 18.4°C), then a general trend of cooling was observed. The calculated values of MAP from the Miocene reach from 957–1353 mm. Beginning with the Late Miocene, a slight cooling and some drying is recorded in Dacian Basin due to a regional palaeogeographic reorganizations and tectonic processes. Our study provides a new insight into palaeoclimatic evolution from Romania, based on palynological data.

Keywords: palynology, palaeoclimate reconstruction, Coexistence approach, Miocene, Paratethys, Romania.

1. INTRODUCTION

The Paratethys Domain began was formed in early Oligocene as result of a collision movements of Afro-Arabian plate and Eurasian plate in Alpine tectonics (Allen and Armstrong, 2008). At the end of the Lower Miocene this great epicontinental sea was separated into three sub-basins, namely Western, Central and Eastern Paratethys (Ivanov et al., 2010).

Palynological assemblages analyzed in this paper are distributed in marine and freshwater basins, belonging to the eastern part of Central Paratethys (Transylvanian Basin) and western part of Eastern Paratethys (Dacian Basin) (Fig. 1).

During Lower Miocene, the Dacian Basin was not configured as a unit with its own complex, separation as basin occurred during Middle Sarmatian (Saulea et al., 1969). Due to reduction of communication with the Mediterranean Basin the salinity decreased and the brackish water area gradually retreating toward Euxinian Basin. The complete silting of the Dacian Basin occurred during Middle Dacian.

Transylvanian Basin is an intra-Carpathian episutural Basin with Upper Cretaceous- Neogene age, which had a roughly circular form during Upper Miocene - Pliocene (Krézsek and Filipescu, 2005). This is located within the Carpathian area being separated by Pannonian Basin by the Apuseni Mountains (Fig. 1). The sedimentary filling of the basin has a thickness of over 5000 m (Ciupagea et al., 1970) and was divided into four tectonostratigraphic megasequences (Krézsek and Bally, 2006): Upper Cretaceous (rift), Paleogene (sag), Lower Miocene (flexural basin) and Middle to Upper Miocene (backarc sequence dominated by gravitational tectonics).

The main objective of this study was to offer a synthesis of palynological data from the Miocene period of Romania. Palaeoclimatical reconstruction from this paper was accomplished applying on bibliographical data (20 palynological assemblages) and own studied palynofloras (16 assemblages) (Table 1). One palynological assemblages consists of many taxa (view in 20-30 palynological slides), the same age, identified in different geographical locations.

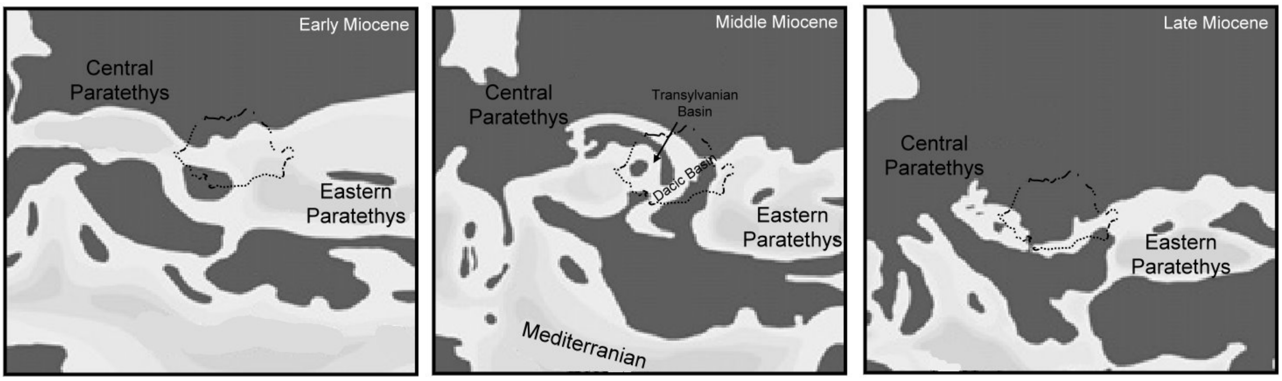

Figure 1. Palaeogeographic sketch-maps of the Paratethyan area (after Rögl, 1998; Harzhauser & Piller, 2007).

Until now, in Romania, this type of reconstructions was based on macrofloras from Transylvanian Basin, accomplished by Givulescu (1997) (MAT for the interval between Upper Eocene – Lower Pleistocene). Using microfloras, the MAT (mean annual temperature) for the interval Paleocene – Pliocene was determined by Petrescu & Balintoni (2004).

The authors previously cited, presented a curve of the altitudinal variations of the Romanian Carpathians on the same stratigraphic interval, in the same paper. In the Moldavian Republic, palaeoclimatical reconstructions (MAT, MAP - mean annual precipitations, CMT - mean temperature of the coldest month, WMT - mean temperature of the warmest month) have been obtained from the analysis of a macroflora from the interval between Sarmatian and Maeotian by Ştefârţă (1997).

In the past decade, several palaeoclimatical reconstructions based on Neogene palaeoflora from the Paratethys area have been completed by Ivanov et al. (2002, 2007a, 2010); Jiménez-Moreno et al. (2005); Bruch et al. (2006, 2007); Utescher et al. (2007); Erdei et al. (2007); Syabryaj et al. (2007); Kayseri and Akgun (2008); Bozukov et al. (2009).

2. MATERIALS AND METHOD

36 palynological assemblages (Table 1) were used for the present palaeoclimatic estimations. They originate from the Miocene deposits encountered in outcrops and drilled wells from Moldova, Transylvania, South Dobrogea, Oltenia and Banat area (Fig. 2).

Microfloristic data sets concerning Aquitanian, Burdigalian, Badenian and Pontian have been taken from publications by Petrescu et al. (1990, 1997, 1998, 2001, 2002); Petrescu (2003); Stoicescu (2004); Brişan (2004); Guşă-Popescu (2006) (Table 1). The palaeoclimatical interpretation of the Sarmatian was performed on the based on the analysis of newly collected samples from the Moldavian Platform. Data regarding the Maeotian are missing from our paper due to the lack of microfloristic inventory for this time slice in Romania.

We applied the Coexistence Approach (CA) method (Mosbrugger & Utescher 1997) for all the 36 palynological associations. This method is used for quantitative terrestrial palaeoclimate reconstructions for the Cenozoic. It relies on the assumption that fossil plant taxa have similar climatic requirements as their nearest living relatives. The aim of the coexistence approach is to find an interval for a given fossil flora and a given climate parameter, in which all nearest living relatives of the fossil flora can coexist.

Figure 2. Geographical location of palynological assemblages used for this paper (detailed explanations is presented in Table 1).

Palaeoclimatic estimations obtained are based on climatic requirements (minimum and maximum values for MAT, MAP, CMT, WMT) of 70 taxa (Plate 1 - 3). These values of the coexistence intervals have been taken from Gebka et al. (1999); Olivares et al. (2004); Kou et al. (2006); Akkiraz et al. (2006, 2008), Mosbrugger and Utescher (2010, personal communication) and palaeoflora database (http://www.palaeoflora.de).

The quantity of sediments for the analysis was approximately 50 g for each sample (this method was applied for the 16 palynological assemblages cited in Țabără, Olaru, 2004; Brânzilă, Țabără, 2005; Chirilă, Țabără, 2008; Țabără 2008, see Table 1).

Samples have been treated with HCl (37%) to remove the carbonate and HF (48%) to remove the silicate minerals. The separation of palynomorphs from the residue resulting from the chemical reaction above described was performed using $ZnCl_2$ with a density 2.00 g/cm^3 as heavy liquid with centrifugal action. Microscopic slide were made using glycerine jelly as a mounting medium. The visualisation of the palynomophs was accomplished with a Leica DM1000 microscope, using the amplification of X100, X400.

3. PALAEOCLIMATE RECONSTRUCTION

The present study is based on 4 palaeoclimatic parameters:

- Mean annual temperature (MAT)
- Mean annual precipitation (MAP)
- Mean temperature of the warmest month (WMT)
- Mean temperature of the coldest month (CMT)

Palaeoclimatic diagrams resulting from the obtained data have revealed oscillations of the MAT, MAP, CMT, WMT (Figure 3, 4, 5, 6) from the Aquitanian – Pontian of Romania. These values have been compared to palaeoclimatic data obtained from the Romanian Miocene (Givulescu 1997), North-Western and West of Bulgaria (Ivanov et al. 2002, 2007b), Serbia (Utescher et al. 2007) and Pannonian Basin from Hungary (Erdei et al. 2007).

3.1. Lower Miocene

3.1.1. *Dacian Basin*.

Palaeoclimatic data from Oligocene-Miocene limit were obtained from analyzed samples of Upper Dysodilic Shale Formation (Stoicescu, 2004). The coexistence interval for MAT values based on palynological assemblage is between 13.3 – 17.2°C and MAP value is between 578–1520 mm. The CMT is 0.9 – 7°C and WMT value range between 23.6 – 28.1°C (Table 1). Regarding the end of Oligocene (Chattian), Petrescu (2003) observed an „invasion of temperate taxa" which indicates a cooling of climate. The same cooling at the Chattian – Aquitanian boundary was observed by Givulescu (1997) based on palaeofloras from Valea Jiului (MAT value calculated was 15°C).

The climatological data used for Burdigalian was acquired from Gura Şoimului Formation, Lower Salifer Formation and Hârja Formation from Slănic – Oituz Half-Window which belongs to the Eastern Carpathian Flysh. The highest values of MAT, MAP and CMT were recorded for Gura Şoimului Formation (Figs. 3, 4, 5). Palaeoclimatic data calculated for studied microflora from Gura Şoimului Formation show a MAT with a value of 15.6 – 21.3°C, MAP range between 897 – 1613 mm and CMT value is 9.6 – 16.3°C. As shown in figure 3, the value of MAT calculated for Burdigalian are higher than those from Aquitanian.

3.1.2. *Transylvanian Basin*

For this basin, Petrescu (1994) have described a palynological assemblage with Middle Aquitanian age from Dealul Cotului Formation (North-Western Transylvania) (Fig. 2). Since this period, a slight increase of MAT, MAP and CMT was observed, compared with analyzed deposits of Lower Aquitanian from East Carpathian Flysch. (Figs. 3, 4, 5). The obtained values are following: MAT between 15.7 – 18.4°C (approximately 17°C), MAP between 1122 – 1281 mm and CMT varies between 9.6 – 12.5°C. For the same palynoflora, Petrescu (2003) establishes a MAT of approximately 17°C. Another palynological association with Upper Aquitanian age was cited from the South-Eastern part of the Hațeg Basin by Petrescu & Popescu (2002). The calculation of MAT, MAP, CMT and WMT from this stratigraphic interval indicates values naerly identical in both palynological association (Dealul Cotului Formation and Hațeg Basin).

Mean annual temperatures calculated by Givulescu (1997) for the „pluvial subtropical forest with Lauraceae" from Coruş (Cluj) with Upper Aquitanian age, indicate higher values by approximately 2°C compared to temperatures presently calculated from Aquitanian microflora using the Coexistence approach (Fig. 3). Obtained MAT data for Aquitanian deposits from Pannonian Basin (Erdei et al., 2007) are comparable with values calculated by us from Transylvanian Basin (Fig. 3).

Palynological assemblages with Burdigalian age used for palaeoclimatic estimation are located in the Western part of Romania, in the Bozovici and Borod Basin (Fig. 2). The highest values of MAT (approximately 17.8°C) and MAP (approximately 1353 mm) were observed in Lower Burdigalian deposits from Borod Basin (North-Western Transylvanian Basin). The Burdigalian macroflora from North-Western part of Transylvanian Basin has previously been cited by Petrescu (1969) at Tihău (Sălaj county).

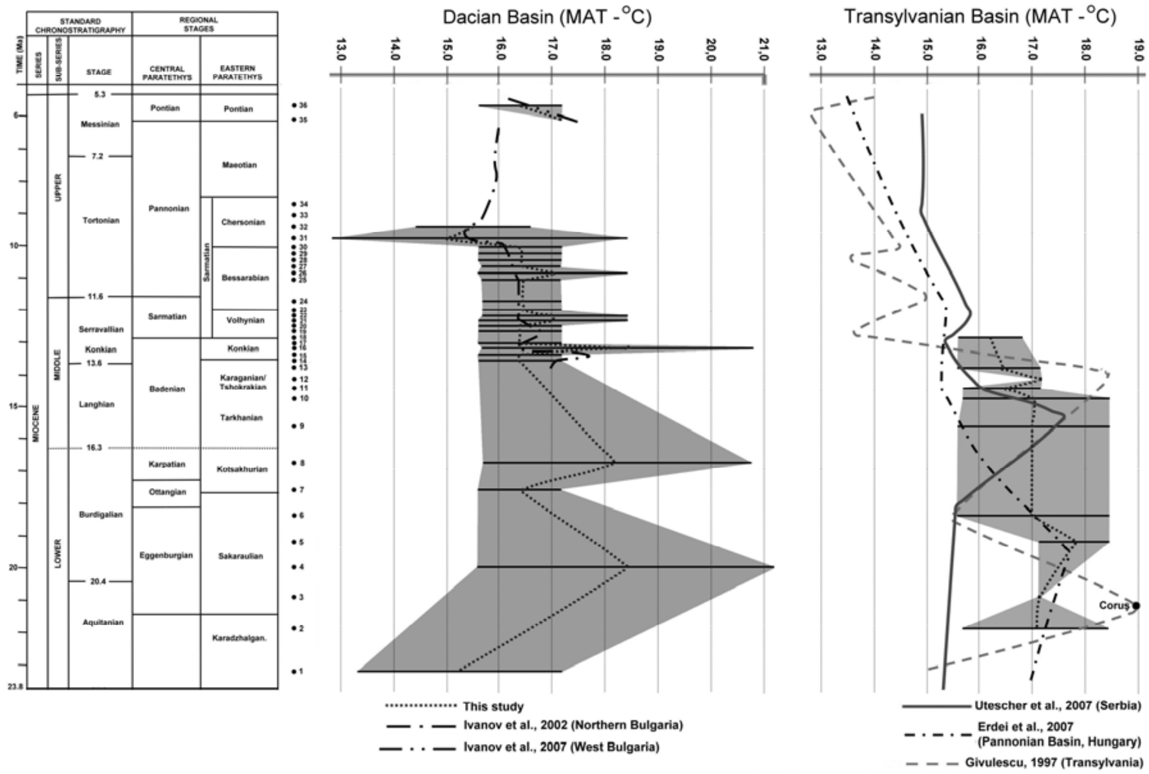

Figure 3. The trend of climate variables (MAT) from the Miocene of Romania, correlated with other palaeoclimatic curves obtained from the same stratigraphic interval from the North-West of Bulgaria, Serbia and Hungary. The drawn curves represent the average of the coexistence interval. 1, 2…36, palynological assemblages analysed (see explanation in Table 1).

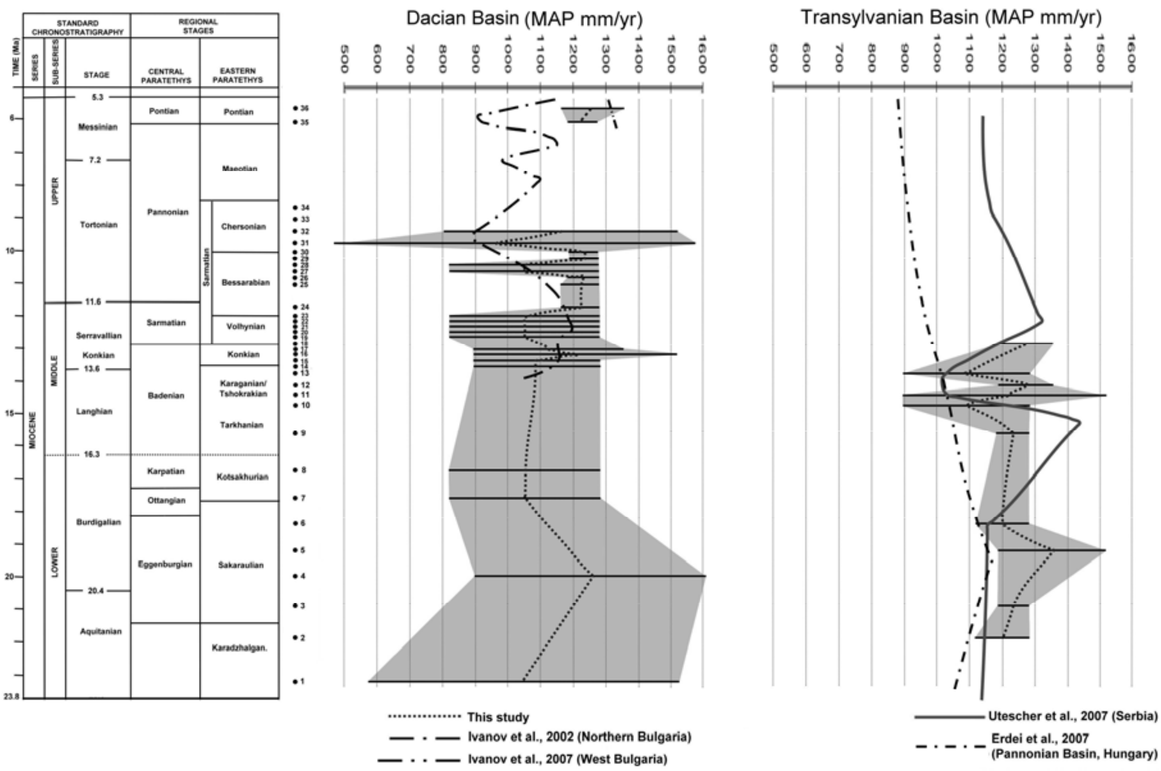

Figure 4. The variation of the MAP from the Miocene of Romania, correlated with other palaeoclimatic curves obtained from the same stratigraphic interval from the North-West of Bulgaria, Serbia and Hungary. The drawn curves represent the average of the coexistence interval. 1, 2…36, palynological assemblages analysed (see explanation in Table 1).

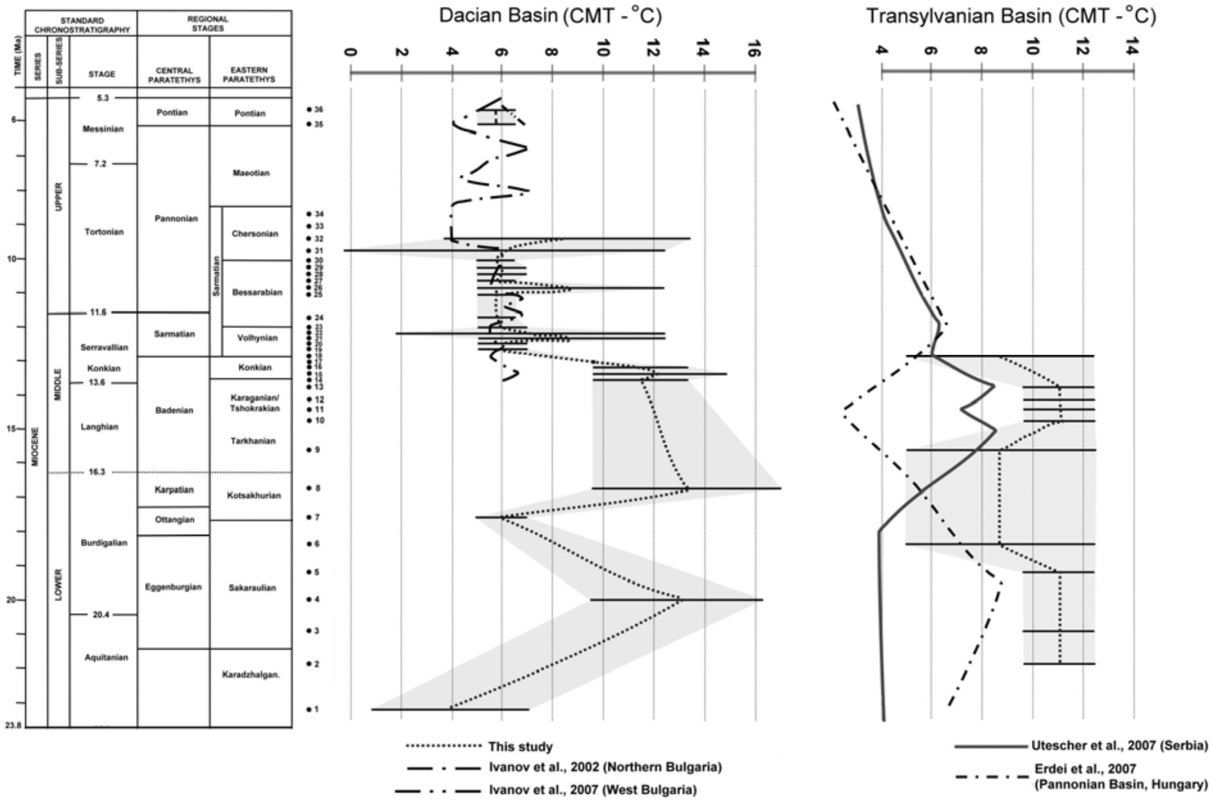

Figure 5. The palaeoclimatic chart for CMT value from Miocene deposits of Dacian and Transylvanian Basin. 1, 2…36, palynological assemblages analysed (see explanation in Table 1).

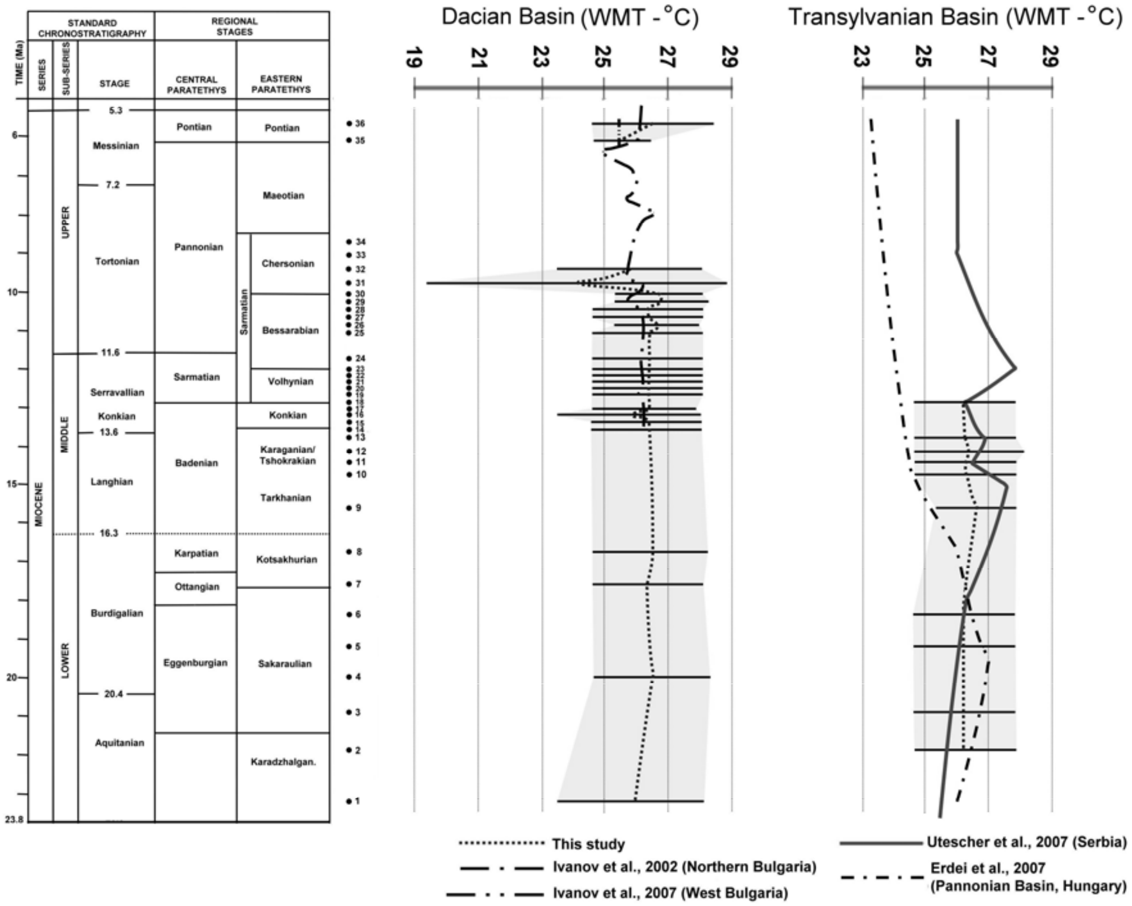

Figure 6. The values of WMT obtained based on palynological assemblages from Miocene deposits of Romania (see explanation in Table 1).

Table 1. Palaeoclimatic parameters calculated for Romanian Miocene using Coexistence approach.
* geological formations analyzed by us (palynological assemblages)

Chronostratigraphy: Series	Sub-series	Stage	REGIONAL STAGES: Central Paratethys	Eastern Paratethys		Formation	Location	Geological age determination	MAT (°C)	MAP (mm/yr)	CMT (°C)	WMT (°C)	Associations number	Reference
MIOCENE	UPPER	Messinian	Pontian	Pontian			Valea Vişenilor - Mehedinţi	molluscs	15,6 – 17,2	1162 - 1355	5 – 6,6	24,6 – 28,3	36	Petrescu et al., 2001
							Batoţi - Mehedinţi	molluscs	17,2	1187 - 1281	5 – 6,6	24,7 – 26,4	35	Petrescu et al., 2002
			Pannonian	SARMATIAN	Chersonian	* Huşi Formation	Oţeleni - Huşi	molluscs	Insufficient taxa for palaeoclimatic estimations				34	Ţabără, 2008
		Tortonian				* Huşi Formation	Paiu Quarry – Vaslui	molluscs					33	Ţabără, 2008
						* Huşi Formation	Pâhneşti - Huşi	molluscs	14,4 – 16,6	803 - 1522	3,7 – 13,3	23,6 – 28,1	32	Ţabără, 2008
						* Balta – Păun Formation	Răducăneni - Iaşi	molluscs	11,6 - 18,4	338 - 1577	-0,3 - 12,5	19,4 - 28,8	31	Ţabără, 2008
					Bessarabian	*Şupanu Formation	Comăneşti - Bacău	molluscs	15,6 – 17,2	1183 - 1281	5 – 6,6	25,4 – 28,1	30	Ţabără, Chirilă, 2011
						* Şcheia Formation	Şcheia - Iaşi	molluscs, foraminifera	15,6 – 17,2	1187 - 1281	5 - 7	25,4 – 28,3	29	Ţabără, Olaru, 2004
						* Bârnova – Muntele Formation	Rateş Cuza - Vaslui	molluscs, foraminifera	15,6 – 17,2	823 - 1281	5 - 7	24,7 – 28,1	28	Ţabără, 2008
						* Bârnova – Muntele Formation	Bârnova - Iaşi	molluscs, foraminifera	15,7 – 17,2	823 - 1281	5 – 6,6	24,7 – 28,1	27	Ţabără, 2006
						*Dealul Mare Formation	Bozieni – Neamţ	molluscs, foraminifera	15,6 – 18,4	1183 - 1281	5 – 12,5	25,4 – 27,9	26	Ţabără et al., 2009
						* *Cryptomactra* Formation	Vlădiceni - Iaşi	molluscs, foraminifera	15,7 – 17,2	1162 - 1281	5 – 6,6	24,7 – 28,1	25	Ţabără, 2008
	MIDDLE	Serravallian	Sarmatian			* *Cryptomactra* Formation	Hlipiceni, Bivolari, Şipote, Comarna wells (Moldavian Platform)	molluscs, foraminifera	15,7 – 17,2	1162 - 1281	5 – 6,6	24,7 – 28,1	24	Brânzilă, Ţabără, 2005
					Volhynian		* Hărmăneşti - Paşcani	molluscs, foraminifera	15,7 – 17,2	823 - 1281	5 - 7	24,7 – 28,1	23	Ţabără, 2008
						* Fălticeni – Boroaia Formation	Preuteşti – Fălticeni	molluscs, foraminifera	15,7 – 18,4	823 - 1281	1,8 – 12,5	24,7 – 28,1	22	Chirilă, Ţabără, 2010
						* Fălticeni – Boroaia Formation	Râşca - Fălticeni	molluscs, foraminifera	15,6 – 18,4	823 - 1281	5 – 12,5	24,7 – 28,1	21	Chirilă, Ţabără, 2008
							Stăniţa-Vlădnicele well (Moldavian Platform)	molluscs, foraminifera	15,6 – 17,2	823 - 1281	5 - 7	24,7 – 28,1	20	Brânzilă et al., 2011
						* Fălticeni – Boroaia Formation	Baia well - Fălticeni	molluscs, foraminifera	15,6 – 17,2	823 - 1281	5 - 7	24,7 – 28,1	19	Chirilă, 2008
							Mereşti - Harghita (SE of Transylvania)	foraminifera, nannoplankton	15,6 – 16,8	1187 - 1355	5 – 12,5	24,7 - 27,9	18	Petrescu et al., 1988
		Konkian	Badenian	Konkian			Ivăncăuţi (Botoşani)	foraminifera, molluscs	15,6 – 17,2	897 - 1355	9,6 - 9,6	24,7 - 27,9	17	Guşă - Popescu, 2006
							Truşeşti (Botoşani)	foraminifera, molluscs	15,7 – 20,8	897 - 1520	9,6 - 13,3	23,6 – 28,1	16	Guşă - Popescu, 2006
							Ţibrinu (south Dobrogea)	foraminifera	15,6 - 17,2	897 - 1281	9,6 – 14,8	24,7 - 28,1	15	Guşă - Popescu, 2006
		Langhian		Karaganian/ Tshokrakian			Gherghina (south Dobrogea)	foraminifera	15,6 - 17,2	897 - 1281	9,6 – 13,3	24,7 - 28,1	14	Guşă - Popescu, 2006
							Praid (east of Transylvanian Basin)	foraminifera, nannoplankton	15,6 – 17,2	897 - 1281	9,6 – 12,5	24,7 - 27,9	13	Brişan N., 2004
							Sărăţel (NE of Transylvania)	foraminifera, nannoplankton	17,2 – 17,2	1187 - 1355	9,6 – 12,5	24,7 – 28,1	12	Brişan N., 2004
						Ocna Dej Formation	Turda (Transylvania)	foraminifera, nannoplankton	15,7 – 17,2	897 - 1520	9,6 – 12,5	24,7 - 27,9	11	Petrescu, Bican - Brişan N., 1997
				Tarkhanian		Ocna Dej Formation	Ocna Dej (Transylvania mine)	foraminifera, nannoplankton	15,7 – 18,4	897 - 1281	9,6 – 12,5	24,7 - 27,9	10	Petrescu, Meseşan, 1993
							Lăpugiul de Sus (NV of Transylvania)	molluscs, nannoplankton	15,6 - 18,4	1183 - 1281	5 - 12,5	25,4 - 27,9	9	Petrescu et al., 1990
	LOWER	Burdigalian	Karpatian	Kotsakhurian		Hârja Formation	Slănic - Oituz Half-Windows	nannoplankton	15,7 – 20,8	823 - 1281	9,6 - 17	24,7 – 28,3	8	Stoicescu, 2004
			Ottnangian			Lower Salifer Formation	Slănic – Oituz Half-Windows	nannoplankton, palynomorphs	15,6 - 17,2	823 - 1281	5 - 7	24,7 - 28,1	7	Stoicescu, 2004
			Eggenburgian	Sakaraulian			Bozovici Basin (well 6442B - Lighidia)	mammalia	15,6 – 18,4	1122 - 1281	5 – 12,5	24,7 - 27,9	6	Petrescu, Nicorici, 1989
							Borod Basin (well 575 Cetea)	molluscs, foraminifera	17,2 - 18,4	1187 - 1520	9,6 - 12,5	24,7 - 27,9	5	Petrescu, Popa, Bican - Brişan N., 2000
						Gura Şoimului Formation	Slănic – Oituz Half-Window	foraminifera, nannoplankton	15,6 – 21,3	897 - 1613	9,6 – 16,3	24,7 – 28,3	4	Stoicescu, 2004
		Aquitanian		Karadzhalgan.			SE of Haţeg Basin	molluscs	17,2 – 17,2	1187 - 1281	9,6 – 12,5	24,7 - 27,9	3	Petrescu, Popescu, 2002
						Dealul Cotului Formation	NV of Transylvania	molluscs	15,7 – 18,4	1122 - 1281	9,6 – 12,5	24,7 - 27,9	2	Petrescu, 1994
						Upper Dysodilic Shale Formations	Slănic – Oituz Half-Window	nannoplankton, palynomorphs	13,3 – 17,2	578 - 1520	0,9 - 7	23,6 – 28,1	1	Stoicescu, 2004

Several arctotertiary taxa which indicate an MAT with value between 15.5 - 16°C have been identified in this location. Similar values of MAT, MAP and WMT obtained from Burdigalian deposits of Transylvanian Basin have been presented from deposits with the same age from Pannonian Basin (Erdei et al., 2007).

3.2. Middle Miocene

3.2.1. *Dacian Basin*

Middle Miocene is between Lower Badenian and Middle Bessarabian (16.3 – 11.6 Ma) (Harzhauser and Piller, 2007). The MAT value of Middle Miocene microflora from Dacian Basin marks a gradual decrease compared to values calculated for Burdigalian deposits (Fig. 3).

Palaeoclimatic values from the Upper Badenian derive from interpretation of Țibrinu and Gherghina microflora (South Dobrogea). Therefore, MAT value was estimated between 15.6 – 17.2 °C and MAP range between 897-1281 mm (Table 1). Also, the microflora from the Truşeşti and Ivăncăuți (Northern Moldavian Platform) have an Upper Badenian age. The value of MAT calculated based on above palynological assemblages indicates a temperature increase to about 18°C, and MAP was between 897 – 1520 mm. This last increase of MAT during Upper Badenian was also presented in North-Western Bulgaria (MAT of 17.5°C, according with Ivanov et al., 2002).

To the East, in the Ukraine Plain (Korobki region), Syabryaj et al. (2007) estimated for Upper Badenian a MAT of 15.6° C and the MAP between 1304 – 1356 mm.

Palaeoclimatical estimation for Volhynian and early Bessarabian period was performed analysing from deposits mainly of the Moldavian area (Moldavian Platform) (Chirilă and Țabără, 2008, 2010; Țabără, 2008). At the end of Badenian and the beginning of the Sarmatian, MAT decreased by approximately 1,5°C (Fig. 3), showing values between 16.4 - 17°C for the Volhynian and early Bessarabian from Moldavian area. The same slight decrease was observed for CMT values, from 10 to 12°C durring Upper Badenian at approximately 6 - 8°C in Volhynian and Lower Bessarabian (Fig. 5). Palaeoclimatic values calculated for WMT had small variation during Badenian and Lower and Middle Sarmatian (Fig. 6).

In the Moldavian Republic, palaeoclimatic estimations for a Volhynian palaeoflora have shown a climate similar to the actual climate from western Mediterranean Sea: MAT of approximately 15°C, WMT 25°C, CMT 3–6°C and MAP of approximately 1000 mm (Ştefârță 1997). For the Bessarabian from the same area, Ştefârță establish following climatic parameters: MAT 11° C, WMT 23° C, CMT with value higher than -2° C and MAP with maximum 700 mm. According with data presented by author, a drop in MAT by 4° C between Volhynian and Bessarabian is visible. This difference in temperature was not observed in the present palynological analysis.

3.2.2. *Transylvanian Basin*

Palynological association from Lăpugiul de Sus, Ocna Dej, Turda, Sărățel and Praid with Badenian age of Transylvanian Basin are interpreted.

The Lower Badenian from Lăpugiul de Sus (Petrescu et al., 1990) indicates MAT with value around 17°C, the deposits from this area yield a subtropical marine fauna, characterised by presence of colonial hexacorals (*Heliastrea*). The MAP of the ancient bay from Lăpugiu was found to range from 1800 – 2000 mm (Petrescu, 2003) and approximately 1230 mm according with our estimations.

Palaeoclimatic estimations for Middle Badenian (Wieliczian) have been assumed after the analysis of the microflora from salt deposits of Ocna Dej, Turda, Sărățel and Praid. The MAT for the area cited above, in our opinion, ranged between 16 - 17°C, MAP 1089 – 1270 mm, CMT approximately 11°C and WMT 26,3°C. Petrescu and Brişan (1997) observe a climatical transition for the Wieliczian between Lower Badenian (subtropical-warm) and Upper Badenian (temperate-warm climate), which reveals a "neogenisation" of the microflora.

The Badenian–Sarmatian limit from Transylvanian Basin correspond to a slight thermal regress assumed by Petrescu et al. (1988) who calculated the MAT from Mereşti-Harghita to a value of 15°C. The same regress of MAT from the limit previously cited was observed by Givulescu (1997) in Transylvanian area. According to this author, the stratigraphic interval between Lower Sarmatian and Pannonian, belongs to a domain with pluvial temperate-warm climate and oscillation in precipitation amounts which vary from "seasonally dry" to "moist, wet and rainy".

In Hungary, Nagy (1992) for Lower Sarmatian (13 – 13.5 Ma) has established a minimum of subtropical and tropical taxa, the last ones disappearing from this area in Lower Pannonian (= Upper Bessarabian – Chersonian).

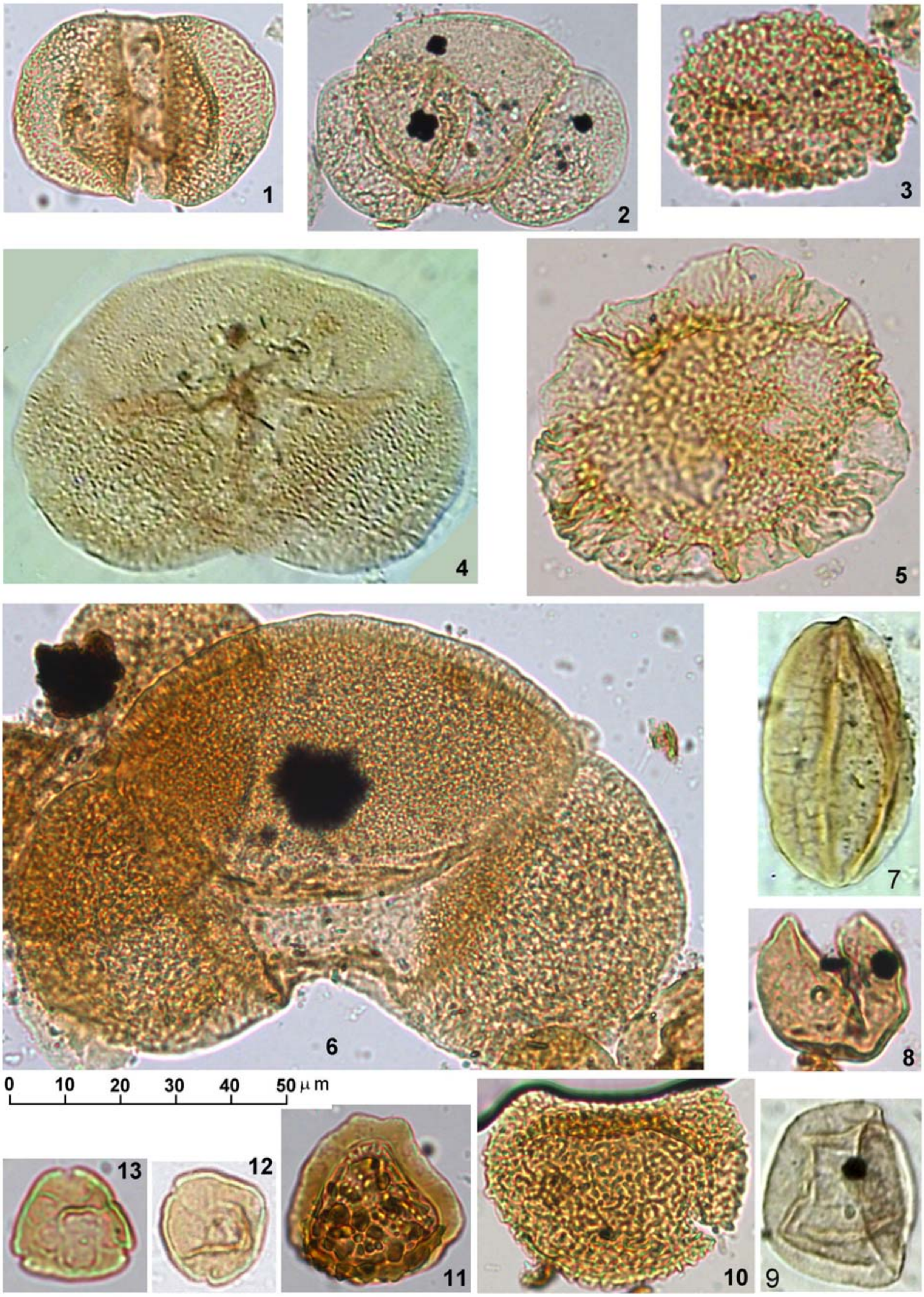

Plate 1. 1. *Pinus haploxylon* type (*Cathaya*); 2. *Pinus diploxylon* type; 3. *Sciadopitys* sp.; 4. *Picea* sp.; 5. *Tsuga* sp.; 6. *Abies* sp.; 7. *Ephedra* sp.; 8. *Taxodium*; 9. *Taxodioideae*; 10. *Osmunda* sp.; 11. *Pteris* sp.; 12, 13 *Engelhardia* sp.

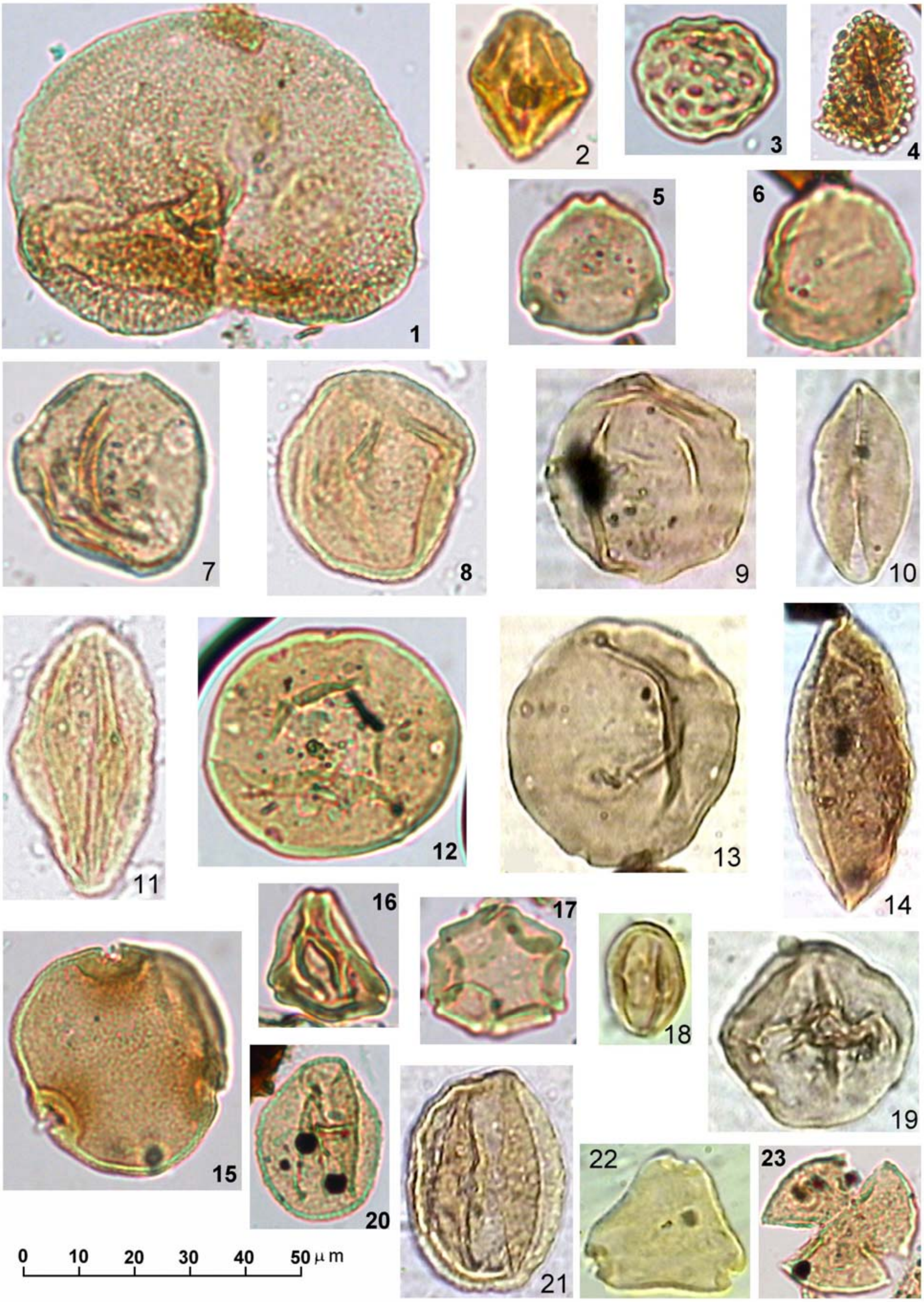

Plate 2. 1. *Cedrus* sp.; 2. *Cyrilla* sp.; 3. *Chenopodiaceae*; 4. *Ilex* sp.; 5, 6 *Myricipites* sp.; 7. *Liquidambar* sp.; 8. *Fagus* sp.; 9. *Carpinus* sp.; 10. *Palmae*; 11. *Cissus* / *Parthenocissus*; 12. *Carya* sp.; 13. *Juglans* sp.; 14. *Magnolia* sp.; 15. *Tilia* sp.; 16. *Betula* sp.; 17. *Alnus* sp.; 18. *Castanea* sp.; 19. *Nyssa* sp.; 20, 21 *Quercus* sp.; 22. *Symplocos* sp.; 23. *Acer* sp.

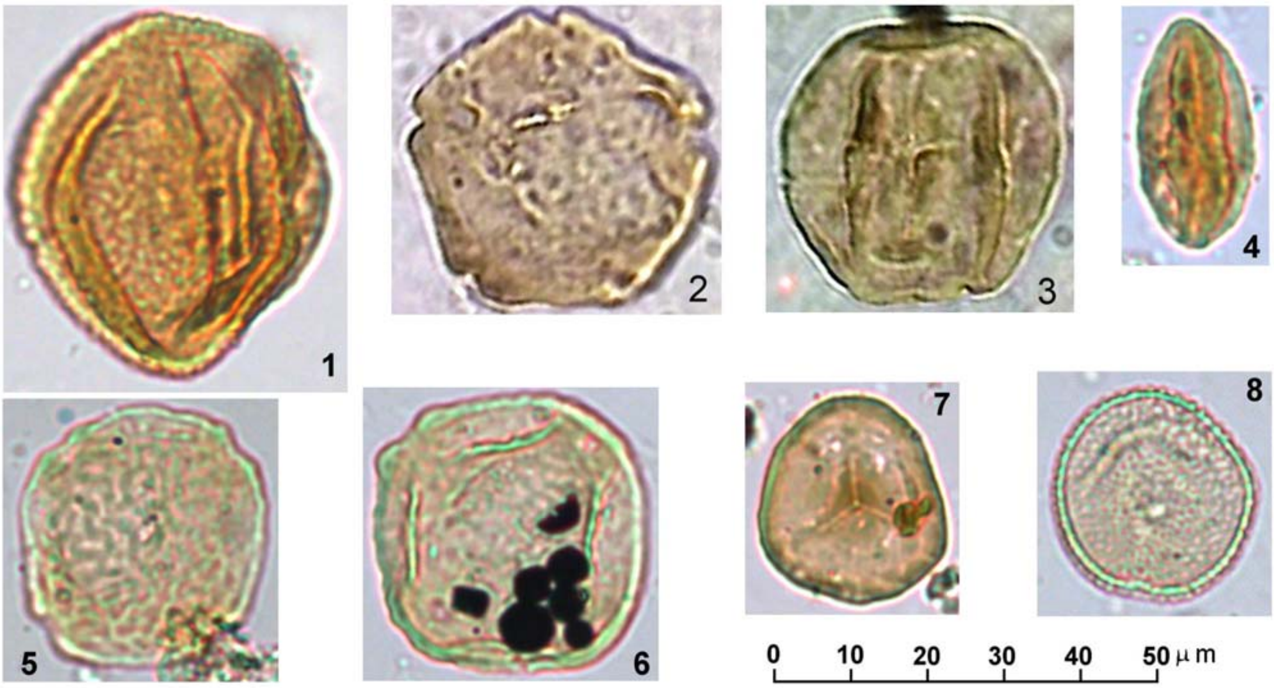

Plate 3. 1. Mastixiaceae; 2. *Pterocarya* sp.; 3. Sapotaceae; 4. *Quercus* sp.; 5. *Ulmus* sp.; 6. *Zelkova* sp.; 7. *Sphagnum* sp.; 8. *Sparganium* / *Typha*.

3.3. The Late Miocene

3.3.1. *Dacian Basin*

In Eastern Paratethys, the Miocene period is between Upper Bessarabian (11.6 Ma) and Upper Pontian (5.3 Ma) (Popov et al., 2006; Harzhauser and Piller, 2007).

Palaeoclimatic estimations from Upper Bessarabian and Chersonian have been assumed by us, based on a microflora from North-Eastern Dacian Basin (Moldavian Platform) (Ţabără, 2008). The Upper Bessarabian deposits from this area has similar palaeoclimatic values with those from upper part of Middle Miocene. Palaeoclimatic parameters have following values: MAT of 16.4 – 17°C, MAP 1052 – 1234 mm, CMT between 5.8 – 8.7°C and WMT with a value of 26.5°C.

The Bessarabian–Chersonian limit represents the beginning of few climatic changes in Moldavian Platform and not only. Based on this study, we conclude that beggining with 10 - 11 Ma. ago, the climate from this region has a decreasing of the MAT (with 1,5°C), MAP and WMT (Fig. 3, 4, 6). Unlike the regression of climatic parameters cited above, the average of temperatures in winter (CMT) are roughly similar to those calculated from Upper Bessarabian. As the cause of this cooling at the Bessarabian – Chersonian limit, we have examined two possible aspects: the volcanic eruptions from Eastern Carphatians at the beginning of the Chersonian (the sedimentation moment of the Nuţasca-Ruseni tuff) and higher altitudinal values of the same mounts (approximately 2400 m, after Petrescu & Balintoni 2004) which may have conditioned these periods of cooling. We have to specify that some Chersonian palynological associations identified in Paiu Quarry and Oţeleni (both sites situated in Vaslui county, Fig. 2) (Ţabără 2008) did not offer enough taxa for palaeoclimatic estimations.

A decrease in MAT and MAP at the Bessarabian – Chersonian limit, was observed also in North-West Bulgaria by Ivanov et al. (2002). An increase in percentage of the Chenopodiaceae pollen is also mentioned in the Upper Bessarabian palynological spectra which will become more abundant in Chersonian (up to 16%). This xerophytic herbaceous association which covered open landscapes was also identified in Upper Bessarabian from Moldavian Platform, in Cryptomactra Formation (Ţabără 2008).

The appearance of this xerophytic vegetation was possible with the decrease of the Sarmatic Sea level from North-West to South-East during the Bessarabian in Moldo-Galiţian Gulf.

The climatic parameters established for Volhynian and Bessarabian from Bulgaria show the following values (Ivanov et al. 2002): MAT between 15.6–17.2°C, CMT 5–7° C and WMT 24.6–27.8°C. For Chersonian a lower MAT with 2°C was calculated regardless with the Bessarabian and Volhynian. The same cooling was observed by the authors for CMT and WMT curves (Figs. 5, 6). In this paper, palaeoclimatic estimations revealed by microfloristic content with Maeotian age cannot be obtained because such associations are absent. Some climatic parameters obtained after the analysis of a Maeotian macroflore have been mentioned by Stefârță (1997). From the Seimen outcrop (south of Moldavian Republic), the author cites few taxa characteristics for an temperate broadleaf forest which vegetate in climatic conditions specific for an relative warm region of the temperate area, having MAT of approximately 9°C and MAP 700–800 mm. In the East of the Moldavian Republic, Syabryaj et al. (2007) mentioned the following climatic parameters for Lower Maeotian from southern Ukrainian plain: MAT coexistence interval between 4.9–17.4°C; CMT between -0.1–10.2°C; WMT between 17.1–27°C and MAP between 389–971 mm.

For North-West Bulgaria, Ivanov et al. (2002) mentioned for Maeotian a MAT of approximately 16°C and oscillations of MAP between 900–1150 mm. From the Serbian Republic (the southern part of Pannonian Basin System), for the same period, Utescher et al. (2007), established a MAT of approximately 15°C and MAP of 1150 mm.

Palaeoclimatic estimations for Pontian have been made after analysis of palynological assemblages from South-West Romania (Batoți - Mehedinți and Valea Vişenilor - Mehedinți county, Petrescu et al. 2001, 2002). Using the Coexistence approach for the previously cited palynological association reveals a MAT of approximately 16.4 – 17.2°C and MAP 1234 - 1258 mm (coexistence interval between 1162 - 1355 mm) in Pontian (Table 1). The CMT for the mentioned period was approximately 5.8°C and WMT about 26°C.

Similar values of MAT for the North-Western part of Bulgaria have been obtained by Ivanov et al. (2002). According to data presented by the author for the Lower Pontian, the value of the coexistence interval for MAT was 15.6–17.2°C, CMT 5–7°C and MAP 1187–1308 mm. From Western Bulgaria (Ivanov et al., 2007b) present palaeoclimatic values. approximately equal to those calculated by us for the South-Western of Romania (Figs. 3, 4, 5, 6). Based on a Upper Pannonian – Pontian palaeoflora identified in central part of Serbia (Crveni Breg Grocka area) and in the Western part of this country (Osojna-Kladovo), Utescher et al. (2007) established a value of MAT lower with 1.5-2° C (14.8°C), comparative with ours and Ivanov et al. (2002, 2007b) results. The precipitation regime of the Upper Pannonian – Pontian from Serbia (the central a nd western part) was comprised in the coexistence interval 897–1297 mm, CMT between -0.1–5.8°C and WMT between 25.7–26.7°C. Pontian climatic parameters from the Ukrainian plain (locality Chaplinka, at approximately 50 km at north of Danube Delta) show lower values than previously cited data, with a MAT between 13.8–14.5°C, WMT 23–24,1°C and MAP 897–1151 mm (Syabryaj et al., 2007).

4. CONCLUSIONS

Climatic parameters assumed in present paper have been obtained using Coexistence approach, applied on a number of 36 palynological assemblages from the Miocene of Romania. Those associations have been highlighted from eastern part of Central Paratethys (Transylvanian Basin) and western part of Eastern Paratethys (Dacian Basin).

The lower part of Miocene shows a slight increased of palaeoclimatic parameters compared with the end of Oligocene, to a MAT value of 18,4°C during sedimentation of Gura Şoimului Formation (Slănic-Oituz Half-Window). In Transylvanian Basin, the highest values of MAT (approximately 17.8°C) and MAP (approximately 1353 mm) have been calculated for Borod area with Burdigalian age.

The microflore from Middle Miocene deposits of Dacian Basin from South Dobrogea (Gherghina and Țibrinu) indicate a value of MAT between 15,6 – 17,2°C and MAP of 897 – 1281 mm. The Upper Badenian from northern Moldavian Platform indicates a slight increase of MAT to approximately 18°C and a MAP between 897 – 1520 mm. The Lower Sarmatian from the same area shows a decrease of MAT with approximately 1.5°C compared with Badenian values.

Palaeoclimatic estimation of Badenian deposits from Transylvanian Basin indicates a MAT with gradual decrease from its base to the top of this age. The Badenian - Sarmatian limit correspond, as in Dacian Basin, to a slight thermal regress of MAT reaching at 15°C in the lower part of the Sarmatian deposits from Mereşti-Harghita.

Palaeoclimatic values at the beginning of the Upper Miocene come from the interpretation of a microflore from North-Eastern part of Dacian Basin (Moldavian Platform). The climatic parameters of Upper Bessarabian have approximately similar values to those identified in the upper part of the Middle Miocene. The MAT value was 16.4 – 17 °C, MAP 1052–1234 mm, CMT between 5.8 to 8.7 °C and WMT values was 26.5 °C.

A particularity of the palaeoclimatic evolution of the Late Miocene is represented by the Bessarabian–Chersonian transition from Moldavian Platform. Due to volcanic eruptions along the Upper Sarmatian, and influenced by palaeogeographic changes from this period (the regression of the Sarmatian Sea towards south, the high altitudes of Eastern Carpathians), a drop in MAT (with 1.5°C), MAP and WMT was observed.

Palaeoclimatic estimation of Pontian deposits come from microflora assemblage of South-Western part of Romania. Therefore the values calculated for these deposits are: MAT of approximately 16.4 – 17.2 °C, MAP coexistence interval of 1162-1355 mm, CMT value was 5.8°C and WMT about 26°C.

Acknowledgements

The authors thank Dr. Torsten Utescher (Steinmann Institute, Bonn University) for providing values of coexistence intervals for palynological taxa used in palaeoclimatic estimation presented in this paper. The authors also wish to thank to Dimiter Ivanov for improving the first draft of this manuscript.

REFERENCES

Akkiraz, M. S, Akgün, F., Örçen, S., Bruch, A. A., Mosbrugger, V., 2006. *Stratigraphic and palaeoenvironmental significance of Bartonian - Priabonian (Middle - Late Eocene) microfossils from the Başçeşme Formation, Denizli Province, Western Anatolia.* Turkish Journal of Earth Sciences 15, 155-180.

Akkiraz, M. S, Kayseri, M. S., Akgün, F., 2008. *Palaeoecology of coal-bearing eocene sediments in Central Anatolia (Turkey) based on quantitative palynological data*. Turkish Journal of Earth Sciences 17, 317–360.

Allen, M. B., Armstrong, H. A., 2008. *Arabia–Eurasia collision and the forcing of mid-Cenozoic global cooling*. Palaeogeography, Palaeoclimatology, Palaeoecology 265 (1–2), 52–58.

Bozukov, V., Utescher, T., Ivanov, D., 2009. *Late Eocene to early Miocene climate and vegetation of Bulgaria*. Review of Palaeobotany and Palynology 153, 360–374.

Brânzilă, M., Ţabără, D., 2005. *The palynological content of Lower Basarabian (The clays with Cryptomactra) on the Moldavian Platform*. Analele Ştiinţifice ale Universităţii „Al. I. Cuza" Iaşi, Geol., T. XLIX – L (2003-2004), 277 – 291.

Brânzilă, M., Chirilă, G., Jitaru, M., 2011. *Micropaleontological content of Sarmatian from southern Moldavian Platform - backbulge depozone.* Acta Palaeontologica Romaniae, VII, 45-59.

Brişan, N., 2004. *The palynology of the Salt Formation with Badenian age from Trasansilvanian Basin*. PhD. Thesis, „Babeş-Bolyai" University, Cluj-Napoca (in Romanian).

Bruch, A.A., Utescher, T., Mosbrugger, V., Gabrielyan, I., Ivanov, D.A., 2006. *Late Miocene climate in the circum - Alpine realm - a quantitative analysis of terrestrial palaeofloras*. Palaeogeography, Palaeoclimatology, Palaeoecology 238, 270–280.

Bruch, A., Uhl, D., Mosbrugger, V., 2007. *Miocene climate in Europe - Patterns and evolution. A first synthesis of NECLIME*. Palaeogeography, Palaeoclimatology, Palaeoecology, 253, 1–7.

Chirilă, G., Ţabără, D., 2008. *Palaeofloristic study of the Volhynian from Râşca (Moldavian Platform) - Palaeoclimatic and palaeoenvironment implications*. Acta Palaeontologica Romaniae, VI, Iaşi, 29 - 42.

Chirilă, G., Ţabără, D., 2010. *Palynological study of the Volhynian deposits from the Ciofoaia Brook (Moldavian Platform) – Palaeoclimatic and palaeoenvironmental implications*. Analele Ştiinţifice ale Universităţii „Al. I. Cuza" Iaşi, Geologie, Tom LVI, nr. 2, p. 25 – 44.

Ciupagea, D., Păucă, M., Ichim, T., 1970. *Geology of the Transylvanian depression*. Academia Republicii Socialiste Romania, Bucharest, 256 p. (in Romanian).

Erdei, B., Hably, L., Kázmér, M., Utescher, T., Bruch, A., 2007. *Neogene flora and vegetation development of the Pannonian domain in relation to palaeoclimate and palaeogeography*. Palaeogeography, Palaeoclimatology, Palaeoecology 253, 115–140.

Gebka, M., Mosbrugger, V., Schilling, H-D., Utescher, T., 1999. *Regional-scale palaeoclimate modelling on soft proxy-data basis an example from the Upper Miocene of the Lower Rhine Embayment*. Palaeogeography, Palaeoclimatology, Palaeoecology, 152, 225–258.

Givulescu, R., 1997. *The history of fossil forests from Transylvanian Tertiary*. Ed. Carpatica, Cluj-Napoca, 172 p. (In Romanian).

Guşă – Popescu, C. T. 2006. *Palynological and microfaunistical study of the Badenian from Moldavian Platform and Southern Dobrogea*. PhD. Thesis, Univ. „Al. I. Cuza" Iaşi, 253 p. (In Romanian).

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, 253 (1–2), 8–31.

Ivanov, D., Ashraf, A.R., Mosbrugger, V., Palamarev, E., 2002. *Palynological evidence for Miocene climate change in the Forecarpathian Basin (Central Paratethys, NW Bulgaria).* Palaeogeography, Palaeoclimatology, Palaeoecology 178, 19–37.

Ivanov, D., Ashraf, A.R., Mosbrugger, V., 2007a. *Late Oligocene and Miocene climate and vegetation in the Eastern Paratethys area (northeast Bulgaria), based on pollen data*. Palaeogeography, Palaeoclimatology, Palaeoecology 255, 342–360.

Ivanov, D., Ashraf, A.R., Utescher, T., Mosbrugger, V., Slavomirova, E., 2007b. *Late Miocene vegetation and climate of the Balkan region: Palynology of the Beli Breg Coal Basin sediments*. Geologica Carpathica, 58 (4): 367-381.

Ivanov, D., Utescher, T., Mosbrugger, V., Syabryaj, S., Djordjević-Milutinović, D., Molchanoff, S., 2010. *Miocene vegetation and climate dynamics in Eastern and Central Paratethys (Southeastern Europe).* Palaeogeography, Palaeoclimatology, Palaeoecology, 304, 262–275.

Jiménez-Moreno, G., Rodríguez-Tovar, F.-J., Pardo-Igúzquiza, E., Fauquette, S., Suc, J.-P., Müller, P., 2005. *High-resolution palynological analysis in late early-middle Miocene core from the Pannonian Basin, Hungary. Climatic changes, astronomical forcing and eustatic fluctuations in the Central Paratethys*. Palaeogeography, Palaeoclimatology, Palaeoecology 216, 73–97.

Kayseri, M. S., Akgun, F., 2008. *Palynostratigraphic, Palaeovegetational and Palaeoclimatic Investigations on the Miocene Deposits in Central Anatolia (Corum region and Sivas Basin)*. Turkish Journal of Earth Sciences, 17: 361-403.

Kou, X.Y., Ferguson, D. K., Xu, J.X., Wang, Y.F., Li, C.S., 2006. *The reconstruction of paleovegetation and paleoclimate in the Late Pliocene of west Yunnan, China*. Climatic Change 77, 431–448.

Krézsek, C., Filipescu, S., 2005. *Middle to Late Miocene sequence stratigraphy of the Transylvanian Basin (Romania).* Tectonophysics 410 (1–4), 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, 23, 405–442.

Mosbrugger, V., Utescher, T., 1997. *The coexistence approach - a method for quantitative reconstructions of Tertiary terrestrial palaeoclimate data using plant fossils.* Palaeogeography, Palaeoclimatology, Palaeoecology, 134, 61-86.

Nagy, E., 1992. *A comprehensive study of Neogene sporomorphs in Hungary*. Geologica Hungarica, fasciculus 53, Budapesta. 379 p.

Olivares, C.A., Antón, M.G., Manzaneque, F.G., Juaristi, C.M., 2004. *Palaeoenvironmental interpretation of the Neogene locality Caranceja (Reocín, Cantabria, N Spain) from comparative studies of wood, charcoal, and pollen.* Review of Palaeobotany and Palynology 132, 133 - 157.

Petrescu, I., 1969. *Datas regarding fossil flora from Tihău (NV Transilvania*). Contribuții Botanice, 281 – 289, Cluj Napoca (in Romanian).

Petrescu, I., 1994. *Palynological aproach to the lower Miocene formations (facies of the Sînmihai Beds) in the NW Transylvania (Romania). The Miocene from the Transylvanian Basin,* 19 – 28, Cluj - Napoca.

Petrescu, I., 2003. *The Palynology of the Tertiary*. Editura Carpatica, p. 249, Cluj – Napoca (in Romanian).

Petrescu, I., Meszaros, N., Filipescu, S., Buda, A., 1988. *Contributions to the stratigraphic knowledge of the neogen deposits in borehole 12 – Mereşti (SE Transylvanian Basin).* Studia Universitatis „Babeş-Bolyai", Geologia - Geografia., XXXIII, 2, 15 - 24, Cluj - Napoca.

Petrescu, I., Meszaros, N., Chira, C., Filipescu, S., 1990. *Lower Badenian paleoclimate at Lăpugiu de Sus (Hunedoara County) on account of paleontological investigation.* Studia Universitatis „Babeş-Bolyai", Geologia, XXXV, 2, 13 - 22, Cluj - Napoca.

Petrescu, I., Meseşan, M., 1993. *Palynological research concerning the salt-formation from Ocna Dej (Romania).* Paleoclimatic Approach. Contribuții Botanice, 123 - 128, Cluj - Napoca.

Petrescu, I., Bican – Brişan, N., 1997. *Contributions to microfloras from salt of Turda*. Studia Universitatis „Babeş-Bolyai", Geologia, XLII, 2, 103 - 112, Cluj - Napoca (in Romanian).

Petrescu, I., Popa, M., Bican – Brişan, N., 2000. *The presence of Lower Miocene (Eggenburgian) in borehole 575 Cetea (East of Borod Basin, NW-rn Romania).* Studia Universitatis „Babeş-Bolyai", Geologie, XLV, 2, 63 – 78, Cluj – Napoca.

Petrescu, I., Bican-Brişan, N., Meilescu, C., Pătruțoiu, I., 2001. *Palynological researches concerning the Ponțian on the Vişenilor Valley and Boereasca Valley – NE of Drobeta Turnu Severin (SW^{rn} Romania).* Studia Universitatis „Babeş-Bolyai", Geologia, XLVI, 2, 95 - 109, Cluj - Napoca.

Petrescu, I., Popescu, D., 2002. *Les premières données palynologiques concernant l'Égérien du sud-est de la Dépression de Hațeg.* Studia Universitatis „Babeş-Bolyai", Geologia, Special Issue, 1, 301 - 312, Cluj - Napoca.

Petrescu, I., Bican – Brişan, N., Meilescu, C., Pătruțoiu, I., 2002. *The palynology of the Pontian from Batoți – Mehedinți (South – Western Romania)*. Acta Palaeontologica Romaniae, III, Iaşi, 347 – 353.

Petrescu, I, Balintoni, I., 2004. *Paleoclimate and paleorelief in Romania during the Tertiary period.* Analele Ştiințifice ale Universității „Al. I. Cuza" Iaşi, Geologie, Tom XLIX-L, 183 - 190.

Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F.F., Shcherba, I.G., Kovac, M., 2004. *Lithological-Paleogeographic maps of Paratethys. 10 Maps Late Eocene to Pliocene.* Courier Forschungsinstitut Senckenberg, 250, 1–46.

Popov, S.V., Shcherba, I.G., Ilyina, L.B., Nevesskaya, L.A., Paramonova, N.P., Khondkarian, S.O.,

Magyar, I., 2006. *Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean.* Palaeogeography, Palaeoclimatology, Palaeoecology, 238 (1–4), 91–106.

Rögl, F., 1998. *Palaeogeographic considerations for Mediterranean and Paratethys seaways (Oligocene to Miocene)*. Ann. Naturhist. Mus. Wien 99 A, 279–310.

Saulea, E., Popescu, I., Săndulescu, J., 1969. *Atlas litofacial. VI – Neogen, 1;200.000*. 11 maps, 2 plates (text in Romanian and in French). Institutul Geologic, Bucureşti.

Stoicescu, A. 2004. *The palynology and biostratigraphy of the Lower Miocene and bitumens from Slănic-Oituz half-windows*. PhD. Thesis, „Al. I. Cuza" Univ, Iaşi, p. 163. (In Romanian).

Syabryaj, S., Molchanoff, S., Utescher, T., Bruch, A.A., 2007. *Vegetation and palaeoclimate in the Miocene of Ukraine*. Palaeogeography, Palaeoclimatology, Palaeoecology, 253, 153–168.

Ştefârță, A., 1997. *Miocene flora from Nistru-Prut area.* Review for habilitation degree in biological science based on published papers. Chişinău, 48 p. (In Romanian).

Țabără, D., Olaru, L., 2004. *Contributions à l'étude palynologique des argiles du Basarabienne supérieur de Şcheia*. Acta Palaeontologica Romaniae, IV, Cluj-Napoca, 485-492.

Țabără, D., 2008. *The palynology of the Middle and Upper Sarmatian from Moldavian Platform*. Editura Universității „Al. I. Cuza" Iaşi, 319 p. (in Romanian).

Utesher, T., Djordjevic-Milutinovic, D., Bruch, A., Mosbrugger, V., 2007. *Paleoclimate and vegetation change in Serbia during last 30 Ma*. Palaeogeography, Palaeoclimatology, Palaeoecology, 253, 141–152.

Received at: 16. 11. 2011
Revised at: 10. 02. 2012
Accepted for publication at: 14. 02. 2012
Published online at: 15. 02. 2012