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Analele Stiintifice ale Universitatii "Al. I. Cuza" din Iasi
Seria Geologie 58 (1) (2012) 5–21

AUI GEOLOGIE

The evolution of the Sarmatian palaeoclimate in North-Eastern Romania: A palaeobotanical approach

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Abstract

In the present paper, 24 palaeobotanical assemblages were analysed and, by applying the Coexistence Approach method, the MAT (Mean Annual Temperature), MAP (Mean Annual Precipitations), CMT (Coldest Month Mean Temperature) and WMT (Warmest Month Mean Temperature) were calculated for the Sarmatian deposits from the north-east of Romania. The values calculated for the climatic parameters were used to obtain palaeoclimatic maps with their distribution in the studied area. During the Sarmatian period, the climate was warm-temperate, with mean annual temperatures between 12.1–18.8°C, average precipitation of 958–1234 mm, and mean temperatures of the hot season between 23.1–26.9°C. The present study also includes a comparison between the Sarmatian palaeoclimate and the modern climate from the same area.

Keywords: palaeoclimat maps, Sarmatian, North Eastern of Romania, Coexistence approach.

Introduction

In the terrestrial realm, the reconstruction of past climatic and environmental conditions and changes is largely based on fossil plant remains. Several papers regarding the Sarmatian palaeoclimate and palaeovegetation from North-Eastern Romania have been published by David (1922); Barbu (1934); Givulescu (1963, 1968); Macarovici and Paghida (1966); Micu et al. (1985); Petrescu and Balintoni (2004); Ţibuleac (2009); Ţabără (2008); Chirilă (2011); Ţabără and Chirilă (2012) a.o. The main aim of the present study was the palaeoclimatic evaluation of the Sarmatian deposits from the north-east of Romania, through the observation and interpretation of the differences recorded from the Volhynian up to the Chersonian, as well as the geographical distribution of palaeoclimatic

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parameters as deduced based on palaeobotanical assemblages. The palaeobotanical assemblages analysed are located in the Moldavian Platform, the Scythian Platform and the Comănești Basin.

The Moldavian Platform represents the Romanian area of the Eastern European Platform and is considered the oldest platform unit of Romania (Ionesi, 1994). Its western limit is at the contact of the Pericarpathic area with the Miocene and Sarmatians deposits on the Straja – Solca – Păltinoasa – Tg. Neamţ – Bacău line (Ionesi et al., 2005). The southern part of the Moldavian Platform is separated from the Scythian Platform by the Fălciu – Munteni – Plopana fault. In the north and east, the Republic of Moldavia constitutes the limit (Fig. 1).

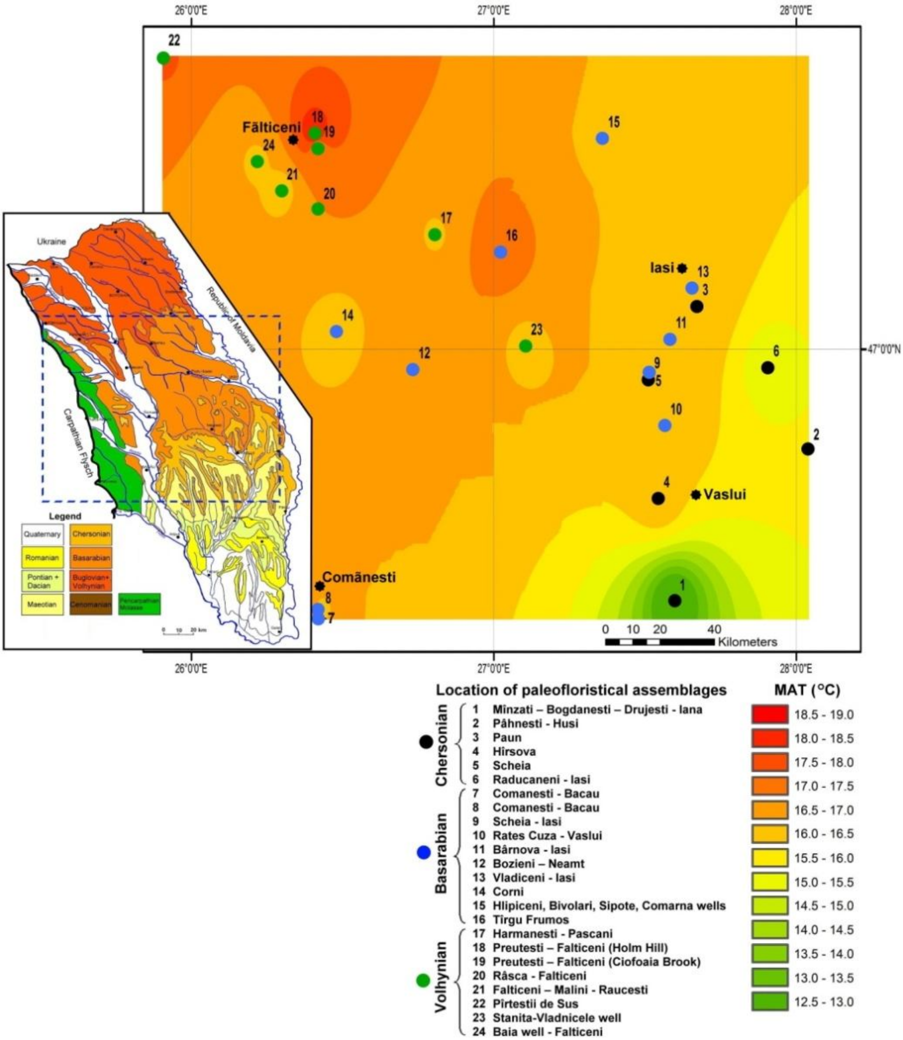

Fig. 1 Map of the mean annual temperature reconstructed for the Sarmatian from North-Eastern Romania (middle values of the coexistence intervals). Geological map (according to Ionesi et al., 2005). The locations of the palaeofloristic assemblages studied (1–24) are presented in Table 1.

The Scythian Platform is considered a younger platform, compared to the Moldavian Platform (Săndulescu, 1984). It is located south of the Moldavian Platform, being separated from the North Dobrogean Orogen by the Sfântu Gheorghe – Oancea – Adjud fault. The last cycle of sedimentation started in the Upper Badenian, in a manner similar to that of the Moldavian Platform, with the exception that in the Scythian Platform the sedimentation continued until the Romanian period.

The Comăneşti Basin is located in the vicinity of the Eastern Carpathians, on the middle course of the Trotuş River. This sedimentary basin represented a subsidence area with a molasse character during the Sarmatian and Maeotian. Because of different subsidence speeds within the basin, this was divided into several cuvettes (Micu et al., 1985). The Sarmatian and Maeotian deposits from the Comăneşti Basin are discordantly and transgressively disposed over the external Carpathian Flysch (the Tarcău and Vrancea nappes).

The Sarmatian deposits studied in the present paper are represented through all of the three stages: Volhynian, Basarabian and Chersonian.

Materials and method

All the palaeofloristic assemblages are presented in Table 1, based on stratigraphic age, with cited references. Figure 1 shows the geographic distribution of the assemblages analysed and the MAT values calculated for the Volhynian, Basarabian and Chersonian deposits.

24 palaeobotanical assemblages were used for the present palaeoclimatical study (Table 1). A palynological assemblage consists of an outcrop or a drilled well from where 5–20 palynological samples of the same age were collected and analysed. The taxa of macroflora are largely those from previous palaeobotanical studies (see the references in Table 1).

In order to obtain quantitative palaeoclimatic data, the Coexistence Approach (CA) of Mosbrugger and Utescher (1997) was applied to the fossil flora. The method follows the nearest living relative concept. Based on the climatic requirements of the nearest living relatives (NLR) of fossil plant taxa in a fossil assemblage, it calculates the coexistence intervals for various climatic parameters, allowing a maximum number of NLR taxa to coexist. The palaeoclimatic estimations obtained are based on the climatic requirements of the studied taxa. In the present paper, we have established the maximum, minimum and average values for the MAT (Mean Annual Temperature), MAP (Mean Annual Precipitations), CMT (Coldest Month Mean Temperature) and WMT (Warmest Month Mean Temperature). The coexistence intervals for the taxa analysed have been taken from Mosbrugger and Utescher (2010, personal communication) and a palaeoflora database (http://www.palaeoflora.de).

The quantity of sediments for the palynological analyses was of approximately 50 g for each sample. This amount was treated with HCl (37%) in order to remove the carbonates, and HF (48%) so as to remove the silicate minerals.

The separation of palynomorphs from the residue resulting from the chemical reaction described above was performed using $ZnCl_2$ with a density 2.0 g/cm^3 as heavy liquid, with centrifugal action. Microscopic slides 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 ×100, ×400.

The palaeoclimatic maps with the distribution of the MAT, MAP, CMT and WMT were drafted using the GIS program ArcView. The data were interpolated using the “inverse distance weighting (IDW)” method.

Table 1 Palaeoclimatic parameters calculated using the Coexistence Approach method for the Sarmatian from North-Eastern Romania

Age		**Assemblage number**	**Formation**	**Location**	**Paleobotanical assemblage**	**Climatic parameter**	**Minimum value set by (MAT, CMT, WMT - °C; MAP - mm/yr)**		**Maximum value set by (MAT, CMT, WMT - °C; MAP - mm/yr)**		**References**
SARMATIAN	Chersonian	1	Balta – Păun Formation	Mînzaţi – Bogdăneşti – Drujeşti - Iana	microflora	MAT	*Sequoiapollenites* sp.	9.1	*Retitriletes lusaticus*	16.5	Ţabără, Sava, 2011
						MAP	*Ilexpollenites* sp.	641	*Sequoiapollenites* sp.	1520	
						CMT	*Sequoiapollenites* sp.	-2.7	*Intratriporopollenites instructus*	13.3	
						WMT	*Hydrosporis levis*	18.1	*Intratriporopollenites instructus*	28.1	
		2	Huşi Formation	Pâhneşti - Huşi	microflora	MAT	*Cyrillaceaepollenites* div. sp.	14.4	*Intratriporopollenites instructus*	16.6	Ţabără, 2008
						MAP	*Cyrillaceaepollenites* div. sp.	803	*Inaperturopollenites concedipites*	1522	
						CMT	*Cyrillaceaepollenites* div. sp.	3.7	*Intratriporopollenites instructus*	13.3	
						WMT	*Cyrillaceaepollenites* div. sp.	23.6	*Cyrillaceaepollenites* div. sp.	28.1	
		3	Balta – Păun Formation	Păun	macroflora	MAT	*Salix varians*	15.9	*Parrotia* sp.	16.8	Macarovici, Paghida, 1966
						MAP	*Liquidambar europaea*	897	*Carpinus grandis*	1355	
						CMT	*Liquidambar europaea*	-0.1	*Tilia* cf. *grandidentata*	13.3	
						WMT	*Zelkova zelkovaefolia*	21.7	*Tilia* cf. *grandidentata*	28.1	
		4	Balta – Păun Formation	Hîrsova	macroflora	MAT	*Laurus princeps*	12.5	*Laurus princeps*	20.5	Barbu, 1934
						MAP	*Carpinus grandis*	735	*Carpinus grandis*	1355	
						CMT	*Fagus pristina*	-11.5	*Carpinus grandis*	16.3	
						WMT	*Carpinus grandis*	18.9	*Quercus neriifolia*	28.3	
		5	Balta – Păun Formation	Şcheia	macroflora	MAT	*Laurus princeps*	12.5	*Laurus princeps*	20.5	David, 1922
						MAP	*Carpinus grandis*	735	*Carpinus grandis*	1355	
						CMT	*Carpinus grandis*	-12.9	*Carpinus grandis*	16.3	
						WMT	*Carpinus grandis*	18.9	*Carpinus grandis*	28.9	
		6	Balta – Păun Formation	Răducăneni - Iaşi	microflora	MAT	*Cedripites* div. sp.	11.6	*Cedripites* div. sp.	18.4	Ţabără, 2008
						MAP	*Zonalapollenites* div. sp.	338	*Cedripites* div. sp.	1577	
						CMT	*Cedripites* div. sp.	-0.3	*Cedripites* div. sp.	12.5	
						WMT	*Cedripites* div. sp.	19.4	*Zonalapollenites* div. sp.	28.8	
	Basarabian	7	Şupanu Formation	Comăneşti - Bacău	macroflora	MAT	*Salix varians*	15.9	*Castanea atava*	17.4	Givulescu, 1963, 1968; Micu et al. 1985
						MAP	*Liquidambar europaea*	897	*Taxodium dubium*	1281	
						CMT	*Engelhardtia orsbergensis*	5	*Acer tricuspidatum*	13.3	
						WMT	*Engelhardtia orsbergensis*	24.7	*Quercus pseudocastanea*	28.3	
		8	Şupanu Formation	Comăneşti - Bacău	microflora	MAT	*Momipites punctatus*	15.6	*Zonalapollenites* div. sp.	17.2	Ţabără, Chirilă, 2011
						MAP	*Gleicheniidites* sp.	1183	*Inaperturopollenites hiatus*	1281	
						CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Zonalapollenites* div. sp.	6.6	
						WMT	*Gleicheniidites* sp.	25.4	*Cyrillaceaepollenites* div. sp.	28.1	
		9	Şcheia Formation	Şcheia - Iaşi	microflora	MAT	*Reevesiapollis triangulus*	15.6	*Juglanspollenites maculosus*	17.2	Ţabără, Olaru, 2004

Age		Assemblage number	Formation	Location	Paleobotanical assemblage	Climatic parameter	Minimum value set by (MAT, CMT, WMT - °C; MAP - mm/yr)		Maximum value set by (MAT, CMT, WMT - °C; MAP - mm/yr)		References
						MAP	*Reevesiapollis triangulus*	1187	*Inaperturopollenites hiatus*	1281	
						CMT	*Momipites punctatus*	5	*Juglanspollenites maculosus*	7	
						WMT	*Gleicheniidites* sp.	25.4	*Tricolporopollenites henrici*	28.3	
		10	Bârnova – Muntele Formation	Rateş Cuza - Vaslui	microflora	MAT	*Engelhardtioipollenites microcoryphaeus*	15.6	*Juglanspollenites maculosus*	17.2	Ţabără, 2008
						MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
						CMT	*Compositoipollenites rizophorus*	5	*Juglanspollenites maculosus*	7	
						WMT	*Compositoipollenites rizophorus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
		11		Bârnova - Iaşi	microflora	MAT	*Araliaceoipollenites edmundi*	15.7	*Juglanspollenites maculosus*	17.2	Ţabără, 2006
						MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
						CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Zonalapollenites* div. sp.	6.6	
						WMT	*Engelhardtioipollenites microcoryphaeus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
		12	Dealul Mare Formation	Bozieni – Neamţ	microflora	MAT	*Engelhardtioipollenites microcoryphaeus*	15.6	*Cedripites* div. sp.	18.4	Ţabără et al., 2009
						MAP	*Gleicheniidites* sp.	1183	*Inaperturopollenites hiatus*	1281	
						CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Cedripites* div. sp.	12.5	
						WMT	*Gleicheniidites* sp.	25.4	*Nyssapollenites kruschi accessorius*	27.9	
		13	*Cryptomactra* Formation	Vlădiceni - Iaşi	microflora	MAT	*Araliaceoipollenites edmundi*	15.7	*Juglanspollenites maculosus*	17.2	Ţabără, 2008
						MAP	*Zonalapollenites* div. sp.	1162	*Inaperturopollenites hiatus*	1281	
						CMT	*Compositoipollenites rizophorus*	5	*Zonalapollenites* div. sp.	6.6	
						WMT	*Compositoipollenites rizophorus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
		14	Corni Formation	Corni - Neamţ	macroflora	MAT	*Salix varians*	15.9	*Carpinus kisseri*	16.5	Ţicleanu, Micu, 1978
						MAP	*Liquidambar europaea*	897	*Carpinus kisseri*	1355	
						CMT	*Liquidambar europaea*	-0.1	*Juglans* sp.	7	
						WMT	*Zelkova zelkovaefolia*	21.7	*Quercus pseudocastanea*	28.3	
		15	*Cryptomactra* Formation	Hlipiceni, Bivolari, Şipote, Comarna wells	microflora	MAT	*Araliaceoipollenites edmundi*	15.7	*Juglanspollenites maculosus*	17.2	Brânzilă, Ţabără, 2005
						MAP	*Zonalapollenites* div. sp.	1162	*Inaperturopollenites hiatus*	1281	
						CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Zonalapollenites* div. sp.	6.6	
						WMT	*Engelhardtioipollenites microcoryphaeus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
		16	? *Cryptomactra* Formation	Tîrgu Frumos	microflora	MAT	*Inaperturopollenites hiatus*	13.3	*Polypodiaceoisporites* sp.	21.7	this study
						MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
						CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Polypodiaceoisporites* sp.	14.8	
						WMT	*Monocolpopollenites tranquillus*	22.8	*Inaperturopollenites dubius*	28.1	
	Vo lhy	17		Hărmăneşti - Paşcani	microflora	MAT	*Tricolporopollenites cingulum* ssp. *fusus*	15.7	*Juglanspollenites maculosus*	17.2	Ţabără, 2008
						MAP	*Tricolporopollenites cingulum*	823	*Inaperturopollenites hiatus*	1281	

Age	Assemblage number	Formation	Location	Paleobotanical assemblage	Climatic parameter	Minimum value set by (MAT, CMT, WMT - °C; MAP - mm/yr)		Maximum value set by (MAT, CMT, WMT - °C; MAP - mm/yr)		References
						ssp. *fusus*				
					CMT	*Momipites punctatus*	5	*Juglanspollenites maculosus*	7	
					WMT	*Tricolporopollenites cingulum* ssp. *fusus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
	18		Preuteşti – Fălticeni (Holm Hill)	microflora	MAT	*Engelhardtioipollenites microcoryphaeus*	15.6	*Zelkovaepollenites* div. sp.	21.9	this study
					MAP	*Momipites punctatus*	1162	*Inaperturopollenites hiatus*	1281	
					CMT	*Momipites punctatus*	-4	*Zelkovaepollenites* sp.	7	
					WMT	*Momipites punctatus*	21.7	*Quercopollenites* sp.	27.8	
	19		Preuteşti – Fălticeni (Ciofoaia Brook)	microflora	MAT	*Araliaceoipollenites edmundi*	15.7	*Cedripites* sp.	18.4	Chirilă, Ţabără, 2010
					MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
					CMT	*Neogenisporis neogenicus*	1.8	*Cedripites* div. sp.	12.5	
					WMT	*Engelhardtioipollenites microcoryphaeus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
	20	Fălticeni – Boroaia Formation	Râşca - Fălticeni	microflora	MAT	*Cyrillaceaepollenites* div. sp.	15.6	*Cedripites* div. sp.	18.4	Chirilă, Ţabără, 2008
					MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
					CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Cedripites* div. sp.	12.5	
					WMT	*Engelhardtioipollenites microcoryphaeus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
	21		Fălticeni – Mălini - Răuceşti	macroflora	MAT	*Sapindus* sp.	13.4	*Corylus avellana*	19	Ţibuleac, 2001, 2009
					MAP	*Carpinus grandis*	735	*Acer* sp.	1355	
					CMT	*Glyptostrobus europaeus*	-2.7	*Acer* sp.	13.3	
					WMT	*Carya denticulata*	19.3	*Pteris* sp.	28.2	
	22		Pîrteştii de Sus	macroflora	MAT	*Salix varians*	15.9	*Typha latissima*	19.2	Ţabără, Florea, 2008
					MAP	*Carpinus grandis*	735	*Carpinus grandis*	1355	
					CMT	*Zelkova zelkovaefolia*	-12.8	*Zelkova zelkovaefolia*	13.6	
					WMT	*Zelkova zelkovaefolia*	21.7	*Carpinus grandis*	28.9	
	23		Stăniţa-Vlădnicele well	microflora	MAT	*Engelhardtioipollenites microcoryphaeus*	15.6	*Juglanspollenites maculosus*	17.2	Brânzilă et al., 2011
					MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
					CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Juglanspollenites maculosus*	7	
					WMT	*Engelhardtioipollenites microcoryphaeus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	
	24	Fălticeni – Boroaia Formation	Baia well - Fălticeni	microflora	MAT	*Engelhardtioipollenites microcoryphaeus*	15.6	*Juglanspollenites maculosus*	17.2	Chirilă, 2011
					MAP	*Engelhardtioipollenites microcoryphaeus*	823	*Inaperturopollenites hiatus*	1281	
					CMT	*Engelhardtioipollenites microcoryphaeus*	5	*Juglanspollenites maculosus*	7	
					WMT	*Engelhardtioipollenites microcoryphaeus*	24.7	*Cyrillaceaepollenites* div. sp.	28.1	

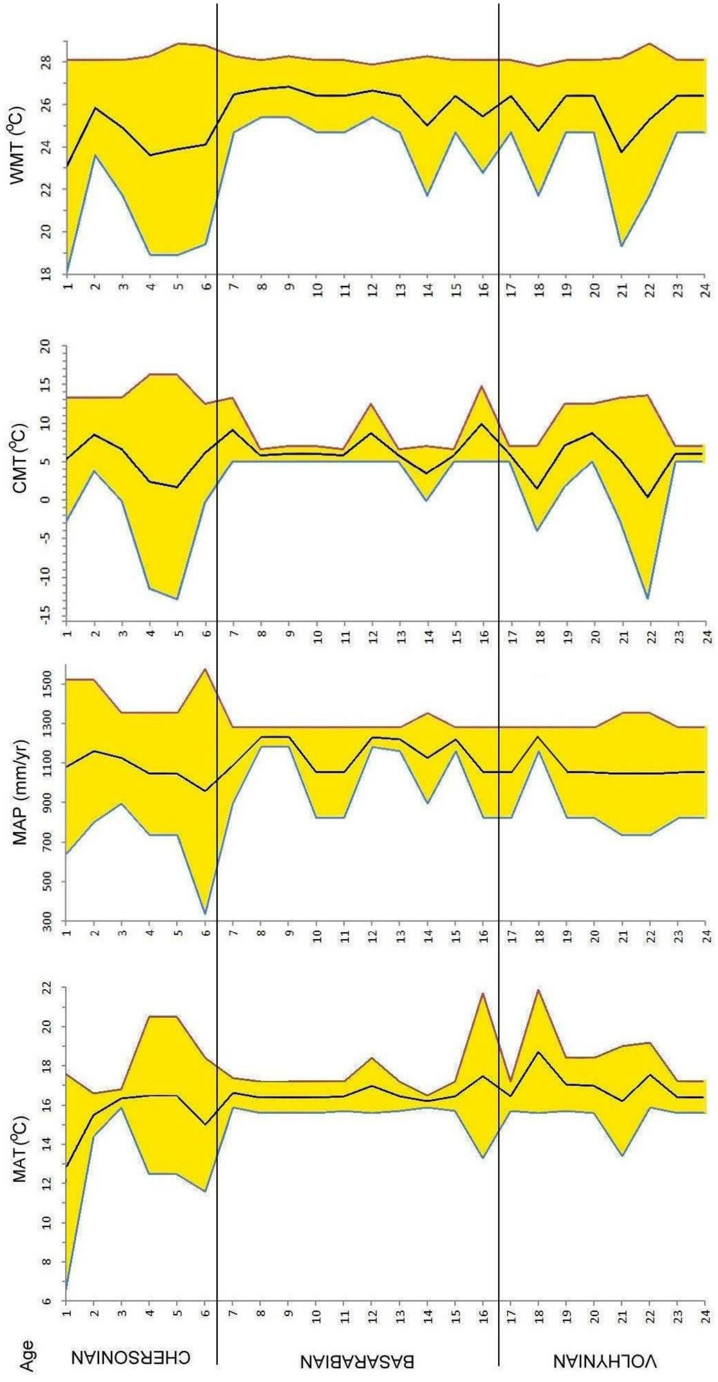

Fig. 2 Values of the MAT, MAP, CMT and WMT calculated based on the Coexistence Approach method for the Sarmatian deposits from North-Eastern Romania. The locations of the palaeofloristic assemblages (1–24) are presented in Table 1.

The reconstruction of the palaeoclimate

The present study is based on 4 palaeoclimatic parameters: Mean Annual Temperature, Mean Annual Precipitation, Mean Temperature of the Warmest Month, and Mean Temperature of the Coldest Month. All the quantitative climatic data obtained from the 24 Sarmatian localities are provided in Table 1 and figs. 1–5. A palaeoclimatic diagram from the data obtained has revealed oscillations of the MAT, MAP, CMT and WMT from the Sarmatian area investigated (Fig. 2). The palaeoclimatic maps obtained based on the geographic distribution of the studied assemblages are presented in figs. 1, 3–5.

A similar study, regarding the palaeoclimatic reconstruction of the Tortonian deposits (between ~11 and ~7 Ma ago) from Central and Southern Europe, was carried out by Bruch et al. (2006). The palaeoclimatic maps drafted by the authors reveal that only 2 assemblages from North-Western Romania were analysed, namely Delureni – Pannonian, and the Oaş Basin – Late Pannonian. For North-Eastern Romania, the authors calculated the following values: MAT 15–16°C, MAP 1100–1200 mm, CMT 3–5°C, and WMT 26–27°C.

1 Volhynian

For the palaeoclimatic interpretation of the Volhynian deposits, 8 palaeofloristic assemblages from the Moldavian Platform were analysed. Many of these assemblages belong to the Fălticeni – Boroaia Formation, intercepted in Baia borehole and the following outcrops: Preuteşti, Râşca, and Mălini – Răuceşti. The Upper Volhynian palaeoclimate was determined based on palynoflora from the Hărmăneşti – Paşcani area.

The average MAT fluctuated between 16.2°C for the Fălticeni – Mălini – Răuceşti area and 18.8°C for the assemblage from Preuteşti (Holm Hill) (Figs. 1, 2). 7 of the 8 Volhynian assemblages display a MAT of 16–17°C. Based on the integrated data from figs. 1 and 2, we noticed a gradual decrease of the MAT from the Volhynian to the Upper Chersonian.

The values of the annual precipitation fluctuate between 1045 and 1221 mm, with an average of 1045–1052 mm (Fig. 3).

The lowest CMT value during the Sarmatian was calculated for the Volhynian deposits (Fig. 4). For the north-western part of the Moldavian Platform (the Pîrteştii de Sus area), we calculated a CMT of 0.4°C (Fig. 4), a value that could be attributed to the vicinity with the mountainous area. Generally, the CMT values calculated for the Volhynian deposits are between 5 and 8°C.

During the warmer season, the WMT values calculated within the present study range between 23.8 and 26.4°C (Fig. 5). Lower values were obtained for the areas near the Eastern Carpathians.

2 Basarabian

In order to establish the palaeoclimatic parameters for the Basarabian deposits from North-Eastern Romania, 10 palaeofloristic assemblages were studied. The Lower Basarabian was analysed based on the Cryptomactra Formation (the outcrop from Târgu-Frumos and the boreholes from Hlipiceni, Bivolari, Şipote and Comarna), as well as the palaeofloristic assemblage described by Ţicleanu and Micu (1978) as belonging to the Corni Formation (Corni village – Neamţ county). Palaeoclimatic data regarding the Upper Basarabian were calculated based on the vegetation from the Dealul Mare Formation, the Bârnova-Muntele Formation, the Şcheia Formation (the Moldavian Platform), and the Şupanu Formation from the Comăneşti Basin.

The mean annual temperature of the Basarabian does not fluctuate greatly, being framed between 16.2 and 17.5°C. The values are similar to those calculated for the Volhynian deposits (Figs. 1, 2). Regarding the Şupanu Formation (Comăneşti Basin), we noticed that the macro- and microflora is composed of taxa that are typical for the warm climate, although they grew in an intra-mountainous basin.

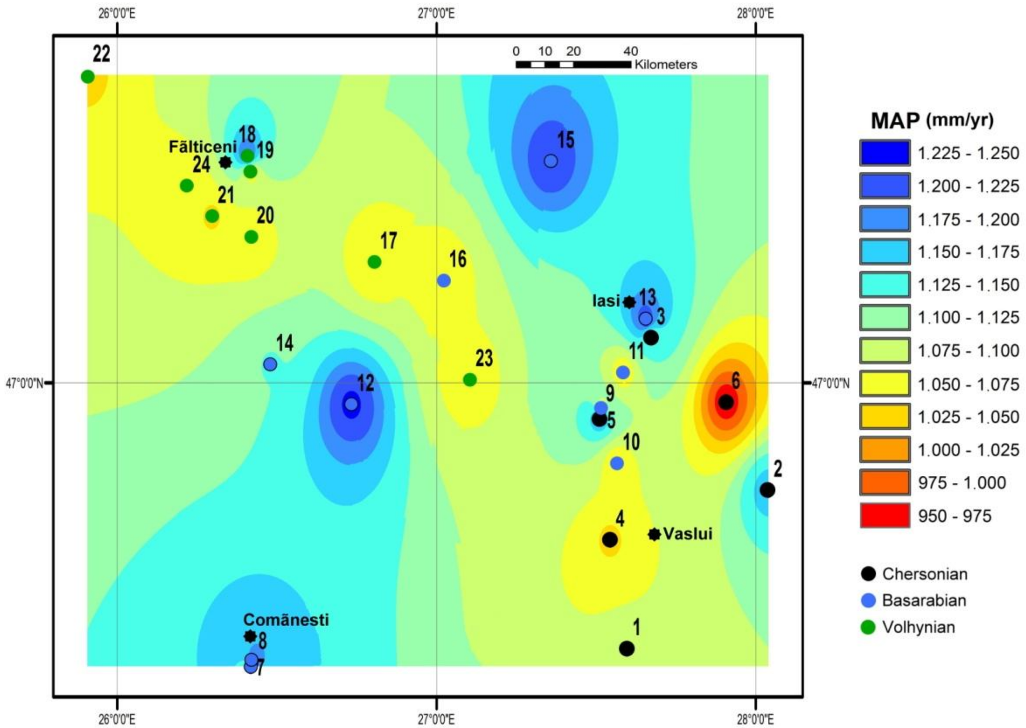

Fig. 3 Palaeoclimatic map of the Sarmatian based on MAP values (middle values of the coexistence intervals).

The value of the mean annual precipitation for the Basarabian deposits is the highest of the entire Sarmatian (Fig. 3). The microflora from the Cryptomactra Formation and the Dealul Mare Formation indicate average values between 1222 and 1232 mm. Similar values have been calculated for the Basarabian deposits from the Şupanu Formation (Comăneşti Basin).

The results obtained for the CMT of the cold season indicate few high values (~ 9–10°C), calculated on the Târgu Frumos, Bozieni and Comăneşti palaeoflora (Fig. 4). Compared to the Volhynian, we noticed an increase in the thermal values during the cold season of the Basarabian.

For the summer period of the Middle Sarmatian, we calculated the highest value from the interval analysed. For example, for the palaeoflora from the Şcheia Formation, the Dealul Mare Formation and the Şupanu Formation we calculated values between 26.5 and 26.9°C (Fig. 5).

Overall, the mean annual temperature of the Basarabian displays values similar to those of the Volhynian. However, we noticed that during the Middle Sarmatian the average amount of precipitation was higher, compared to the Volhynian. Locally, the average temperatures in the winter and the summer were higher during the Basarabian than during the Volhynian.

3 Chersonian

The Chersonian palaeoclimate from North-Eastern Romania was reconstructed based on the interpretation of assemblages identified in the Balta-Păun Formation (the outcrops from Răducăneni, Şcheia, Păun a.o.), as well as the Huşi Formation (Table 1).

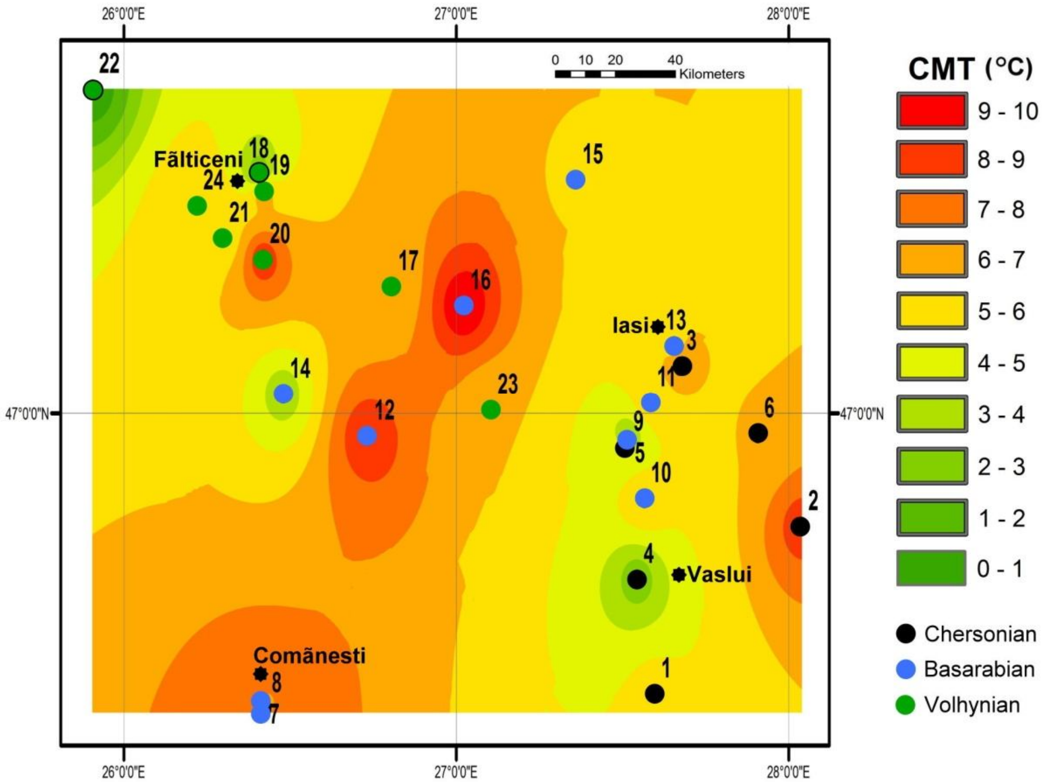

Fig. 4 Palaeoclimatic map of the Sarmatian based on CMT values (middle values of the coexistence intervals)

At the limit between the Basarabian and the Chersonian from North-East Romania, a regression of the following palaeoclimatic parameters was observed: MAT (with 1.5°C), MAP and WMT (Ţabără and Chirilă, 2012). A possible cause for this thermal decline could be the volcanic eruptions in the Eastern Carpathians, as well as their high altitude (approx. 2400 m according to Petrescu and Balintoni, 2004).

The palaeoclimatic parameters of the Chersonian result from the interpretation of 6 palaeobotanic assemblages from the eastern part of the studied area (Fig. 1). The mean annual temperature ranges between 12.1 and 16.5°C, the lowest value being obtained based on microflora of Upper Chersonian age from the following boreholes: Mânzaţi, Bogdăneşti, Drujeşti and Iana. It must be mentioned that the palynologic assemblages in these four boreholes are represented by a small number of taxa, the palaeoclimatic parameters being calculated using only seven species (Ţabără and Sava, 2011).

During the Chersonian, the amount of precipitation was lower than during the Basarabian, the values spanning between 958 mm (Răducăneni microflora) and 1163 mm (Pîhneşti – Huşi microflora). The average temperature during the winter season fluctuates between 1.7°C and 8.5°C.

A significant decrease is visible during the summer period of the Lower Chersonian (Figs. 2, 5). The value of this parameter is between 23.1 and 25.9°C.

In conclusion, the Chersonian (~ 9 – 11 Ma ago) was a period of climatic regress (regarding the temperatures and the amount of precipitation), compared to the Lower and Middle Sarmatian. This cooling trend persisted until the Quaternary.

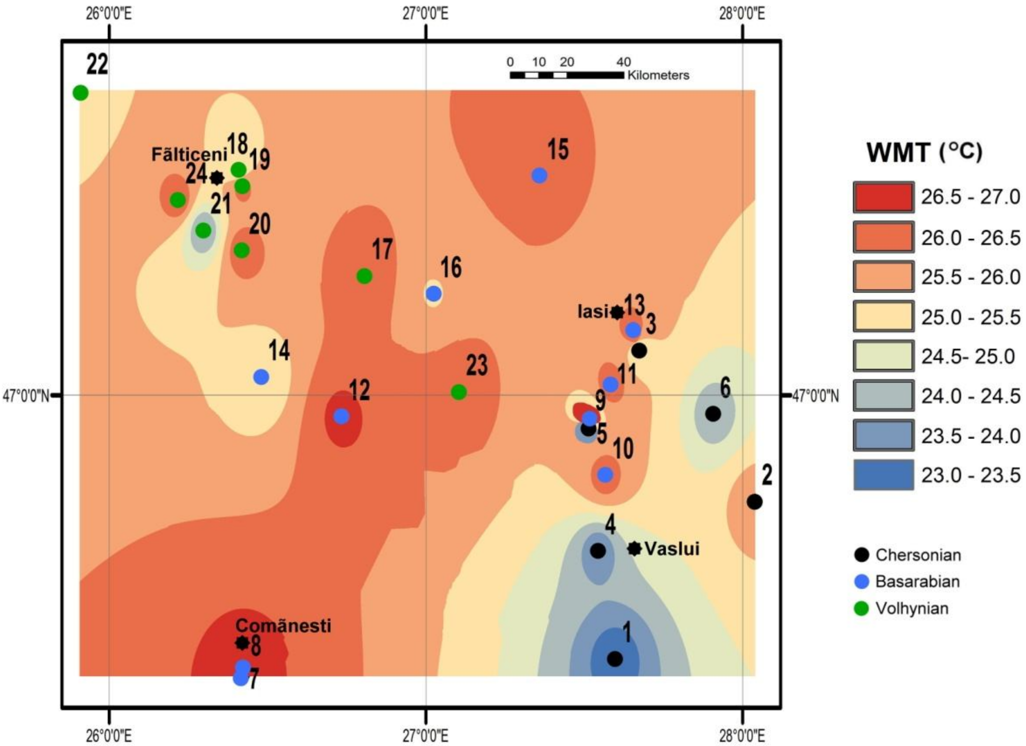

Fig. 5 Palaeoclimatic map of the Sarmatian based on WMT values (middle values of the coexistence intervals).

From the palaeobotanical assemblages analysed, based on the values calculated for the MAT, MAP, CMT and WMT, one can deduce several taxa of great importance when it comes to palaeoclimatic estimation (Fig. 6 A-H and Plate I). Thus, *Engelhardtioipollenites microcoryphaeus* (21%) is the most important taxon in terms of the minimum MAT value, while the maximum value is influenced by *Juglanspollenites maculosus* (34%). The minimum MAP value is set by *Engelhardtioipollenites microcoryphaeus* (29%), while the maximum value is given by *Inaperturopollenites hiatus* (59%). Regarding CMT, the minimum value is set by *Engelhardtioipollenites microcoryphaeus* (33%), and the maximum value is influenced mainly by *Juglanspollenites maculosus* (21%). For the WMT, the minimum value is given by *Engelhardtioipollenites microcoryphaeus* (25%), and the maximum value is set by *Cyrillaceaepollenites* div. sp. (46%). Based on the arguments above (Fig. 6 A-H), one may conclude that the minimum values of the MAT, MAP, CMT and WMT are set by *Engelhardtioipollenites microcoryphaeus*, while the maximum values are influenced by *Juglanspollenites maculosus* (for MAT and CMT), *Inaperturopollenites hiatus* (for MAP), and *Cyrillaceaepollenites* div. sp. (for WMT).

Table 2 contains a comparison between the values obtained for the Sarmatian deposits and the present climatic values for Romania.

It must be noted that the modern climate of Romania (temperate-continental, specific to Central Europe) displays smaller values regarding the temperature and the amount of precipitation, compared to those from the Sarmatian (9–12,5 Ma ago). These differences are due to the different palaeogeographic conditions that this region has experienced over the last 13 Ma. During the Sarmatian, the so-called Galitian Gulf (the northern part of the Dacian Basin) existed in the area analysed, and around it there was vegetation disposed according to altitude. Thus, in the coastal areas there was a subtropical swamp forest populated by *Taxodium, Glyptostrobus, Byttneriophyllum* (taxa currently missing from this area), as well as numerous ferns. The riparian forest of the low land was represented by *Engelhardtia, Salix, Myrica, Cyrilla, Liquidambar,* palms a.o., while the mixed mesophytic forest included species such as *Quercus, Fagus, Carya, Carpinus, Acer* a.o. Taxa such as *Abies, Picea* and *Pinus* characterized the mountainous area.

Table 2 Comparison between the values obtained for the Sarmatian deposits and the present climatic values for Romania (National Meteorological Administration, 2008).

Climatic parameters	Sarmatian	Present day
MAT (°C)	12.1–18.8	8.5–11
MAP (mm)	958–1234	637 (average on Romania)
CMT (°C)	0.4–9.9	-3 to -5
WMT (°C)	23.1–26.9	22–24

With the regression of the Sarmatian Sea toward the south-east, this warm-climate vegetation partially disappeared (swamp vegetation, some species of subtropical riparian forest), following the emergence of a new habitat.

The modern climate of Romania is temperate-continental, with average annual temperatures (in the north) ranging from 8.5 to 9°C, and a mean annual precipitation of about 637 mm (more abundant in the mountains). Winters are harsh due to cold air masses coming from the east, and the warm season displays average values between 22 and 24°C.

Conclusions

The palaeoclimatic data presented in the present study cover a surface of approximately 45,600 km^2, throughout which Sarmatian deposits crop out, located in the north-eastern part of Romania.

In order to obtain these values, 24 palaeofloristic assemblages (micro- and macroflora) have been analysed, and based on them palaeoclimatic maps were devised for the MAT, MAP, CMT and WMT of the studied area. The mean annual temperatures of the Volhynian are between 16.2 and 18.8°C, with a decreasing trend between the lower part of the Sarmatian and the end of this period. The cold season from the Lower Sarmatian was characterized by the lowest values (0.4°C), calculated in the north-western part of the studied area (the Pîrteştii de Sus assemblage).

The Basarabian climate displays MAT values similar to those from the Volhynian. However, locally, the values of the MAP, CMT and WMT were higher, compared to the Volhynian. With the beginning of the Chersonian, because of palaeogeographic evolution, a slight regress of the palaeoclimatic parameters was noticed. The

MAT values ranged between 12.1 and 16.5°C, those of the MAP between 958 and 1163 mm, and those of the WMT between 23.1 and 25.9°C.

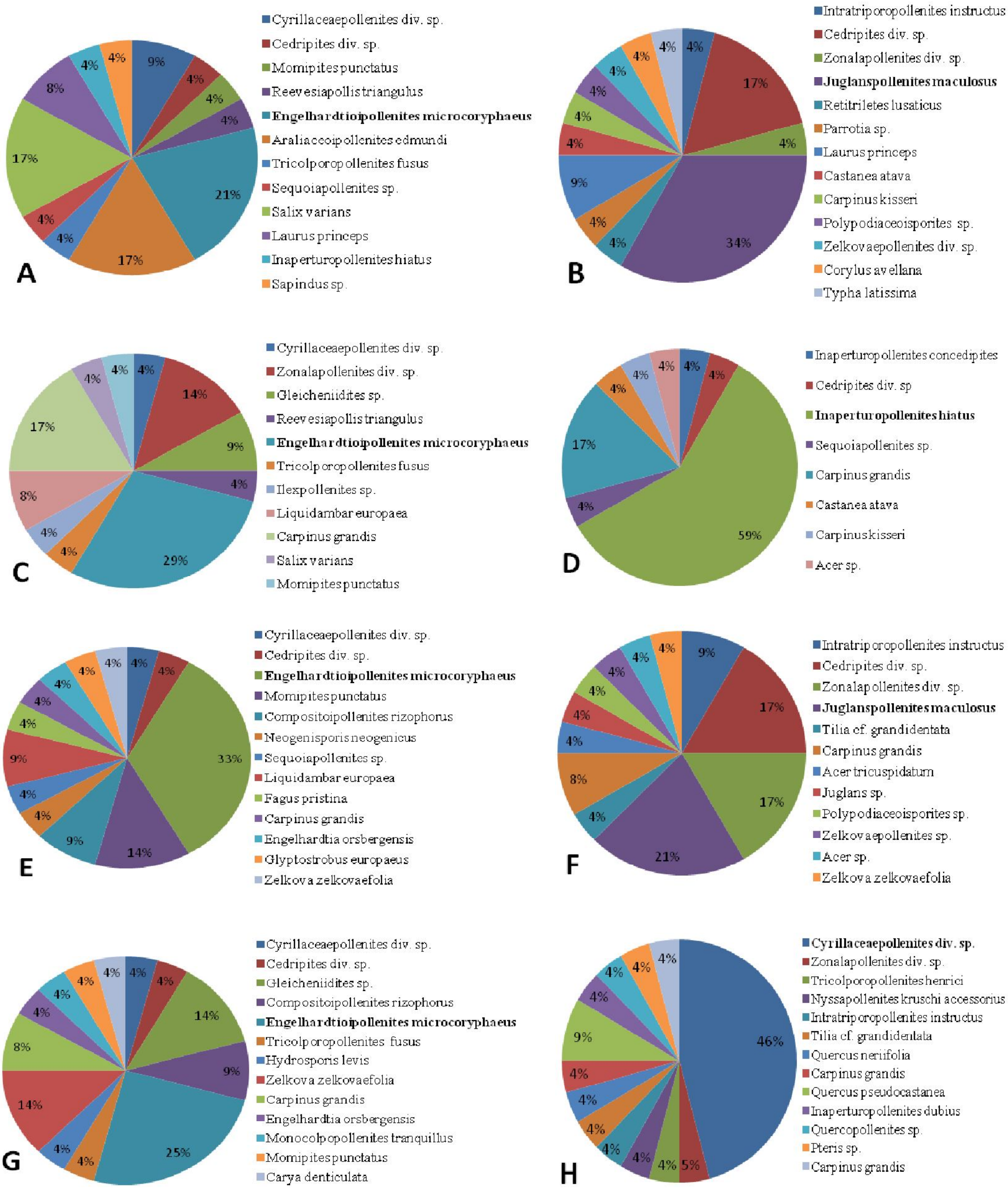

Fig. 6 The percentages of the Min and Max values for the MAT, MAP, CMT and WMT from the palaeofloristic assembalges studied. Legend: A - MAT Min value, B - MAT Max value, C - MAP Min value, D - MAP Max value , E - CMT Min value, F - CMT Max value, G - WMT Min value, H - WMT Max value.

Another conclusion that was reached was that the minimum values of the MAT, MAP, CMT, WMT are determined by *Engelhardtioipollenites microcoryphaeus,* while the maximum values are established by *Juglanspollenites maculosus* (for MAT and CMT)*, Inaperturopollenites hiatus* (for MAP), and *Cyrillaceaepollenites* div. sp. (for WMT) (Fig. 6). Therefore, we believe that the taxa above play a very important role in the palaeoclimatic interpretation of the Sarmatian deposits from North-Eastern Romania.

Acknowledgements

The authors wish to express their gratitude toward their colleague Mitică Pintilei for his assistance in devising the palaeoclimatic maps.

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Received March, 2012
Revised: April, 2012
Accepted: April, 2012

CAPTION OF PLATE

Plate I

1. *Piceapollis tobolicus* (PANOVA 1966) KRUTZSCH 1971
2, 3. *Inaperturopollenites hiatus* (POTONIÉ 1931) THOMSON et PFLUG 1953
4. *Alnipollenites* sp.
5. *Laevigatosporites gracilis* WILSON **-** WEBSTER 1946
6. *Pityosporites alatus* (POTONIÉ 1931) THOMSON et PFLUG 1953
7. *Tricolporopollenites microhenrici* (POTONIÉ 1930) KRUTZSCH 1960
8. *Cyrillaceaepollenites exactus* (POTONIÉ 1931) POTONIÉ 1960
9. *Juglanspollenites maculosus* (POTONIÉ 1931) NAGY 1985
10. *Liquidambarpollenites stigmosus* (POTONIE 1931)RAATZ 1937 ex POTONIE 1960
11. *Faguspollenites* sp.
12, 13. *Quercopollenites petrea* NAGY 1969
14. *Aceripollenites rotundus* NAGY 1969
15. *Intratriporopollenites instructus* (POTONIÉ 1931) THOMSON et PFLUG 1953
16. *Quercopollenites granulatus* NAGY 1969
17. *Engelhardtioidites microcoryphaeus* (POTONIÉ 1931) THOMSON et THIERGART ex POTONIÉ 1960

Plate I