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Palynologycal study of the Sarmatian deposits intercepted in the Bilca–Frătăuţii Noi borehole (Suceava County) (Moldavian Platform)

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Abstract

The present study represents an attempt at highlighting the palynological assemblage identified at the level of the Sarmatian deposits intercepted by the drilling from the Bilca–Frătăuţii Noi area (Moldavian Platform).
The palynological results have been interpreted in order to establish the palaeoclimatic conditions during the sedimentation of the studied deposits. Within the drilling in question, we have identified taxa such as the following: *Pityosporites microalatus*, *Pityosporites alatus*, *Pityosporites labdacus*, *Pinuspollenites miocaenicus*, *Abiespollenites latisacatus*, *Monocolpopollenites tranquillus*, *Tricolpopollenites liblarensis*, *Engelhardtioidites microcoryphaeus*, *Leiotriletes* sp. a. o. The method applied so as to estimate the values of the climatic parameters is the "Coexistence Approach," designed by Mosbrugger and Utescher (1997), a method that has been frequently used for the reconstruction of the palaeoclimate from the European Tertiary. The values obtained using this method for the Sarmatian deposits intercepted by the Bilca–Frătăuţii Noi borehole are as follows: Mean annual temperature (MAT) 16.5–18.4°C, Mean annual precipitation (MAP) 887–1281 mm/yr, Mean temperature of the coldest month (CMT) 9.6–133°C, and Mean temperature of the warmest month (WMT) 27.3–28.1°C.

Keywords: Moldavian Platform, palynomorphs, Sarmatian, palaeoclimate, "Coexistence Approach".

Introduction

The samples analysed for the present study were collected from the Bilca–Frătăuţii Noi borehole, Suceava County, belonging to a structural platform unit known in the Romanian

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literature as the Moldavian Platform. This unit represents the western limit of the East European Platform.

The Bilca–Frătăuţii Noi region is situated in the N-W section of the Moldavian Plateau and it is limited in the N by the state border with Ukraine, in the S by the Suceava river, and in the eastern part by the valley of Bilca Mică (a tributary of the Suceava river) and the Galaneşti locality (Fig. 1).

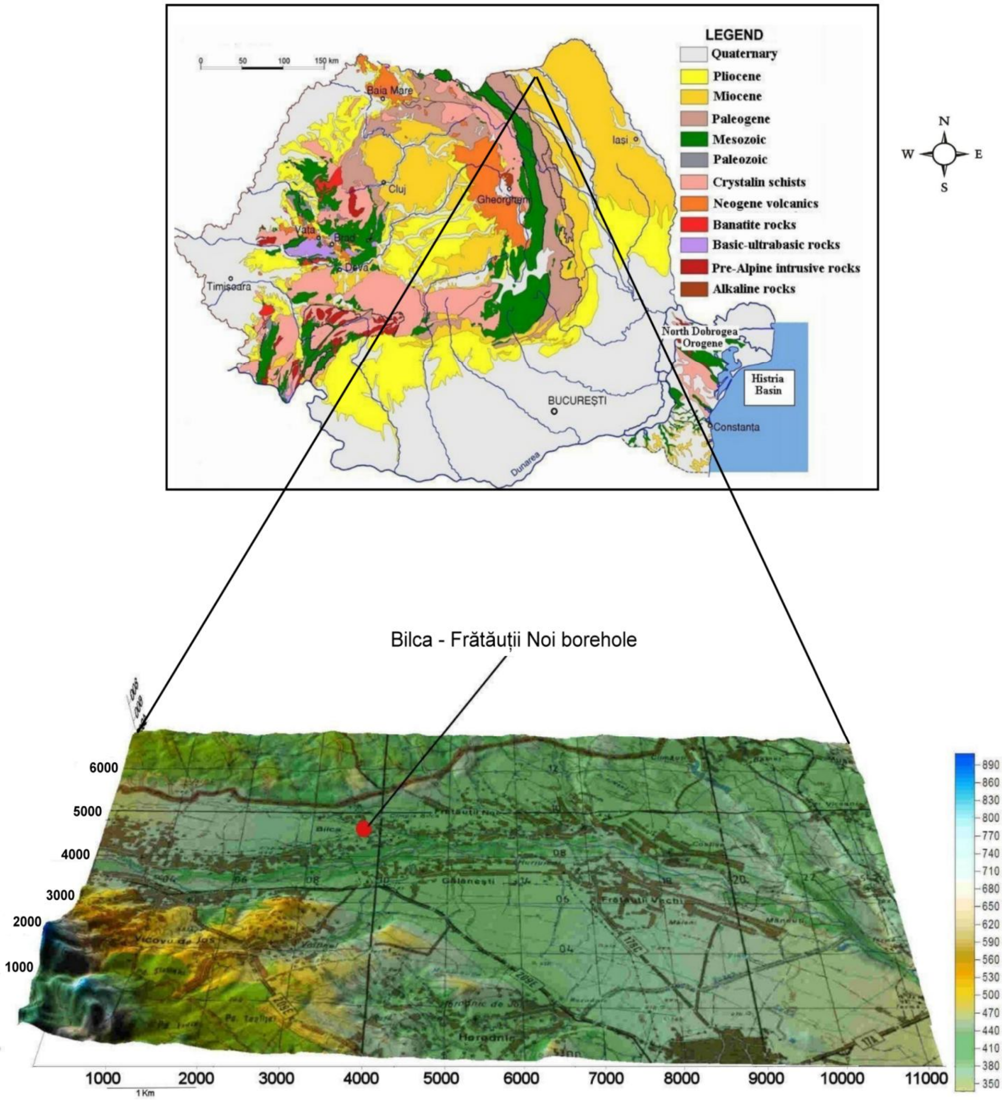

Fig. 1. The position of the Bilca–Frătăuţii Noi borehole. The 3D map of the Bilca–Frătăuţii Noi area was devised using the Digimap and Surfer software, based on the L-35-4 (Rădăuţi-2), 1:100,000 topographic map.

Geological settings

The Moldavian Platform, which represents the Romanian sector of the East European Platform, is considered the oldest platform unit of Romania (Ionesi, 1994). The western limit lies at the contact between the peri-Carpathian area and the Miocene deposits of the platform, on the Straja – Solca – Păltinoasa – Tg. Neamţ – Bacău route (Ionesi et al., 2005).

The lithological succession revealed by the drilling performed in the Bilca–Frătăuţii Noi area is mainly represented by clays, sands and anhydrite, all common for the Upper Badenian. Based on micropalaeontological criteria, Branzila et al. (2005) determined that the deposits intercepted at depths of down to 770 m belong to the Buglovian and have developed in a low-salinity basin, while those in the 770–806 m interval were attributed to the Upper Badenian.

Method

The “Coexistence Approach” (CA) method is based on the assumption that Cainozoic plants had the same climatic requirements as their present correspondents. The purpose of the CA method is to find, for a given fossil and a given climatological parameter, the climatic interval in which all the present correspondents of the fossil flora could coexist. The CA uses only the presence of the taxa in the fossil flora, and not their relative frequency. The fossilization processes influence the taxonomical composition of fossil flora (the presence or absence of a taxon), but, as long as the fossil flora originates from only one ecosystem, this does not, in turn, affect the applicability of the CA method or its correctness.

The “Coexistence Approach” method is based on the following premises:

- present correspondents with very restricted systematic affinities can be identified for fossil taxa;
- the climatic requirements for a fossil taxon are similar to those of its present correspondent;
- the requirements or the climatic tolerance of a present correspondent, and, implicitly, of the fossil taxon, can be deducted from its distribution area. Furthermore, it is assumed that the meteorological station offers adequate data for the description of the climatic tolerance of a modern taxon. The present climatic data used are reliable and of good quality.

The palynological study was carried out on 13 samples collected from the Bilca–Frătăuţii Noi borehole, from depths between 60 and 806 m. The quantity of sediments submitted to analysis was of approximately 50 g for each sample. This amount was treated with HCl (37%) so as to remove the carbonates and, afterwards, with HF (48%) in order to remove the silicate minerals. The separation of the palynomorphs from the residue resulted from the chemical reaction described above was performed through centrifugal action, using $ZnCl_2$ with a density of 2.00 g/cm^3 as heavy liquid. The organic fraction resulted was inserted into a mixture of glycerine and gelatine, 1–2 drops being mounted on the palynological shim. The visualisation of the palynomorphs was accomplished using a biological microscope belonging to the Geology Department of the Faculty of Geography and Geology, with a lens of 100×, 400× that can be used according to the abundance and size of the sporomorphs.

Results and discussion

The palynological assemblage present in the Bilca–Frătăuţii Noi borehole (Table 1) is represented by Gymnospermatophytae (*Pityosporites*, *Pinuspollenites*, *Abiespollenites*, *Cedripites*, *Inaperturopollenites*, *Zonalapollenites*, *Podocarpidites*), Angiospermatophytae

(*Monocolpopollenites*, *Graminidites*, *Quercopollenites*, *Momipites*, *Myricipites*, *Engelhardtioidites*, *Salixipollenites*, *Intratriporopollenites*), Pteridophytae (*Laevigatosporites*, *Leiotriletes*, *Stereisporites*, *Verrucatosporites*) and Phytoplankton (*Tytthodiscus*, *Operculodinium*, *Spiniferites*). Gymnospermatophytae and Angiospermatophytae taxa are dominant, while phytoplankton species (*Operculodinium*, *Spiniferites*, *Hystricosphaera*, *Tytthodiscus)* are present in low quantities. As can be seen in Table 1, samples P112 (806 m), P111 (770 m) and P110 (743 m), collected from the borehole, are characterized by a poor diversity of gymnospermatophytae and angiospermatophytae. In the samples in question, species such as *Pityosporites*, *Zonalapollenites*, *Inaperturopollenites*, *Monocolpopollenites*, *Alnipollenites*, *Quercopollenites*, *Tricolporopollenites* and *Caryapollenites* represent, as percentage, the main taxa. Samples P100 (60 m), P103 (390 m), P104 (450 m) and P105 (500 m) are the richest in palynomophs. Apart from the continental taxa, a marine assemblage with *Operculodinium*, *Hystricosphaera*, *Spiniferites* and *Tytthodiscus* is also present. According to Sluijs et al. (2005), *Spiniferites* and *Operculodinium* indicate a proximal shelf area (inner neritic – outer neritic) with lower water depth.

Dinoflagellate assemblage (marine domain). This assemblage is mainly composed of species of Phytoplankton (*Operculodinium*, *Spiniferites*, *Hystricosphaera*, *Tytthodiscus)*. A higher percentage and greater diversity is present in sample P100, collected from a depth of 60 m (Tab. 1). A species of *Chordosphaeridium* was also identified as reworked from a Paleogene one.

Continental assemblage. Based on the palynological assemblage, we have separated the following biocenosis for the continental palynomorphs: swamp assemblage, mixed mesophytic forest, terrestrial herbs and fern association.

Swamp assemblage. The swamp forest defines the lakeshore vegetation with moderate amounts of *Taxodiaceae* and the riparian genus *Salix*.

The mixed mesophytic forest is well represented by species of fossil pollen, such as *Carpinus*, *Quercus*, *Ulmus*, *Betula*, *Carya* and *Acer*. The ground-covering vegetation of mixed forests consists of herbaceous plants, and the presence of ferns (*Leiotriletes*, *Laevigatosporites*, *Polypodiaceoisporites*, *Verrucatosporites*) indicates humidity.

The high-altitude forest is represented by taxa of Abies and Pinaceae (*Pityosporites alatus*, *Pityosporites labdacus*, *Pityosporites minutus*, *Pityosporites insignis*).

Terrestrial herbs. *Chenopodiaceae* are the dominant group in this association. This category includes the genera *Graminidites*, *Ephedra* and *Artemisia*.

The fern assemblage is represented by *Laevigatosporites*, *Verrucatosporites*, *Leiotriletes*, and *Polypodiaceoisporites*.

Based on the microflora assemblage identified for the Lower Sarmatian, it was established that the characteristic elements of the mixed mesophytic forest are very well represented, while herbs and swamp vegetation are limited.

In conclusion, we can state that, for the Lower Sarmatian, the characteristic features of the mixed mesophytic forest display the best representation, while the presence of swamp-type vegetation and herbal vegetation is more restricted. Dinoflagellates are present in a very low percentage in the composition of the water vegetation from the sedimentary basin.

Researchers (Ivanov et al., 2002; 2010) have noted certain modifications of the vegetation, especially at the Badenian–Lower Sarmatian boundary. For example, Arco-Tertiary elements grow as *Betula*, *Alnus*, *Carpinus*, *Corylus*, *Fagus*, *Eucommia* and *Tilia* during the Sarmatian in NW Bulgaria, while subtropical elements such as *Engelhardia*, *Alangium*, *Reevesia*, *Itea*, *Pandanus*, *Castanopsis*, *Sapotaceae* and *Theceae* decrease. These palaefloristic changes occurred gradually, without major fluctuations being recorded. The authors notice certain common features between the Volhynian and the Upper Badenian, when the climatic conditions were appropriate for the development in the mixed mesophytic forest of warm-temperate and subtropical climate taxa.

A similar change in vegetation was observed in the Sarmatian deposits of the Bilca–Frătăuţii Noi borehole, the common climatic conditions encouraging the development of warm-temperate elements.

Tab. 1 Palynological assemblage identified in the Bilca-Frătăuţii Noi borehole

TAXA	P100 (60m)	P101 (150m)	P102 (210m)	P103 (390m)	P104 (450m)	P105 (500m)	P106 (545m)	P107 (590m)	P108 (641m)	P109 (704m)	P110 (743m)	P111 (770m)	P112 (806m)
Phytoplancton													
Hystrichosphaera sp.	x			x	+	+		+		x			
Tyhodiscus sp.	x		x		x								
Operculodinium sp.	x												
Cordosphaeridium sp. (reworked)	x												
Spiniferites sp.	x												
Oligosphaeridium sp.										x			
Pleurozonaria stellulata (COOK. et MAN. 1960) MÄDLER 1968	x												
Pteridophyta													
Baculatisporites sp.													
Laevigatosporites sp.	x	x											
Laevigatosporites haardti (POT. et VEN. 1934) TH. et PF. 1953	x												
Leiotriletes sp.													
Leiotriletes maxoides maxoides KR. 1962		x											
Stereisporites sp.													
Extrapunctatosporis sp.	x	x											
Extrapunctatosporis miocaenicus KR. 1967	x												
Echinatisporis cycloides KR. 1963										x			
Verrucatosporites favus (POT. 1931) TH. et PF. 1953	x												
Polypodiaceoisporites sp.				x									
Hydrosporis sp.	x												
Gymnospermatophyta													
Pityosporites sp.	+	•	+	•	•	+	+	•	+	x	+	+	+
Pityosporites microalatus (POT. 1931) TH. et PF.1953		x	x	x	x	+		x				x	
Pityosporites alatus (POT. 1931) TH. et PF. 1953				x	x				x				
Pityosporites labdacus (POT. 1931) TH. et PF. 1953	x	x	+	x		x	x	x	x	+	x		x
Pityosporites minutus (ZAKL. 1957) KR. 1971		x	x		x	x	x	x	x	x	x		

TAXA	P100 (60m)	P101 (150m)	P102 (210m)	P103 (390m)	P104 (450m)	P105 (500m)	P106 (545m)	P107 (590m)	P108 (641m)	P109 (704m)	P110 (743m)	P111 (770m)	P112 (806m)
Pityosporites insignis (NAUM. et BOLCH. 1953) KR. 1971				x			x						
Pityosporites cf. Macroinsignis KR. 1971	x					x							
Pinuspollenites miocaenicus NAGY 1985							x			x			
Abiespollenites sp.			x			x			x				
Abiespollenites latisacatus (TREVISAN. 1967) KR. 1971				x		x			x				
Abiespollenites absolutus THIERG. 1937				x		x							
Psophosphaera pseudotsugoides KR. 1971	x												
Piceapollis sp.					x								
Piceapollis planoides KR. 1971			x										
Piceapollis cf. *Neogenicus* NAGY 1969				x									
Podocarpidites sp.							x	x		x			
Zonalapollenites sp.				x			x						
Zonalapollenites verrucatus KR. 1971	x	x				x							
Cycadopites sp.								x					
Cedripites sp.					x		x						
Sciadopityspollenites sp.	x			x			x						
Sciadopityspollenites quintus KR. 1971					x		x						
Sequoiapollenites gracilis KR. 1971					x								
Inaperturopollenites sp.	x	+	x	+	x	+	x	+	x				x
Inaperturopollenites radiatus KR. 1971	x												
Inaperturopollenites hiatus (POT. 1931) TH. et PF. 1953	x												
Araucariacites sp.							x						
Ginkgo sp.		x		x			x		x	x			
Ephedripites sp.	x					x		x					
Angiospermatophyta. Monocotyledonate													
Monocolpopollenites sp.	x	x		x				x				x	
Monocolpopollenites tranquillus (POT. 1934) TH. et PF. 1953	x												
Arecipites trachycarpoides NAGY 1969	x												
Arecipites sp.	x			x									
Graminidites sp.		x				x							
Graminidites media (COOKS. 1947) POT. 1960	x												

TAXA	P100 (60m)	P101 (150m)	P102 (210m)	P103 (390m)	P104 (450m)	P105 (500m)	P106 (545m)	P107 (590m)	P108 (641m)	P109 (704m)	P110 (743m)	P111 (770m)	P112 (806m)
Angiospermatophyta. Dicotyledonate													
Tricolporopollenites pseudocingulum (POT. 1931) TH. et PF. 1953		x											
Tricolporopollenites cingulum (POT. 1931) TH. et PF. 1953 subsp. *oviformis* (POT. 1931) TH. et PF. 1953				x									
Tricolporopollenites microhenrici (POT. 1930) KR. 1960		x	x	x		+						x	x
Tricolporopollenites henrici (POT. 1931) KR. 1960			x		x			x					
Tricolporopollenites sp.	x		x				x						
Quercopollenites sp.	x	+	x	+		+	x	x	+	x	x	x	x
Quercopollenites granulatus NAGY 1969				x		x			x				
Quercopollenites robur NAGY 1969	x												
Faguspollenites sp.	x												
Engelhardtioidites microcoryphaeus (POT. 1931) TH. et THIERG. ex POT. 1960						x	+			x			
Cyrillaceaepollenites exactus (POT. 1931) POT. 1960				x	x	x		x					
Cyrillaceaepollenites megaexactus (POT. 1931) POT. 1960					x		x						
Tricolpopollenites sp.	x			x									
Tricolpopollenites liblarensis (TH. 1950) TH. et PF. 1953 subsp. *liblarensis*	x						+						
Tricolpopollenites liblarensis (TH. 1950) TH. et PF. 1953 subsp. *fallax* (POT. 1934) TH. et PF. 1953	x			+		x		+	x				
Ericipites sp.	x												
Ilexpollenites sp.				x									
Chenopodipollis sp.				x	x		x		x				
Nymphaeaepollenites sp.			x										
Eucommiapollis eucommi (PLANDEROVA 1990) PETRESCU 1999		x											
Nyssapollenites kruschi sp.			x			x							
Magnoliaepollenites sp.		x				x							
Myricipites sp.			x			x							
Momipites sp.	x												
Momipites punctatus (POT. 1931) NAGY 1969	x												
Triatriopollenites rurensis PF. et TH. 1953	x												
Ulmipollenites sp.	x	x		x		x							

TAXA	P100 (60m)	P101 (150m)	P102 (210m)	P103 (390m)	P104 (450m)	P105 (500m)	P106 (545m)	P107 (590m)	P108 (641m)	P109 (704m)	P110 (743m)	P111 (770m)	P112 (806m)
Aceripollenites sp.				x				x					
Alnipollenites sp.			x	x			+						
Betulaepollenites betuloides (PF. 1953) NAGY 1969											x		
Zelkovaepollenites sp.	x												
Caryapollenites sp.				x				x					
Platycaryapollenites sp.					x								
Porocolpopollenite sp.						x							
Intratriporopollenites instructus (POT. 1931) TH. et PF. 1953					x								
Araliaceoipollenites cf. *edmundi* (POT. 1931) POT. 1951	x												
Plicatopollis plicatus (POTONIE 1934) KR. 1962								x					
Salixpollenites sp.	x												
Slowakipollis sp.	x												
Artemisiaepollenites sellularis NAGY 1969											x		

Legend: x – very rare (1-2g grains); + - rare (3-9 grains); • - frequently (10-20 grains).

Palaeoclimatical interpretation based on the palynological assemblage

The method used for the palaeoclimatic estimations is the “Coexistence Approach” (CA), was described by Mosbrugger and Utescher (1997). This method was frequently used for the reconstruction of the European Tertiary palaeoclimate. It is based on the determination of the coexistence approach for all taxa, allowing the establishing, for fossil flora, of their relative life conditions (NLR – Nearest Living Relative) and climate of tolerance (maximum and minim values), following variations of the palaeoclimatic parameters (MAT, MAP, CMT, WMT). It is supposed that the intervals of the coexistence describe the palaeoclimate assumed for the fossil flora. Four palaeoclimatic parameters have been calculated in the present study: Mean annual temperature (MAT), Mean annual precipitation (MAP), Warmest month temperature (WMT), and Coldest month temperature (CMT). The values calculated as part of the present study using the “Coexistence Approach” are the following (Fig. 2): MAT 16.5–18.4°C, MAP 887–1281 mm/yr, CMT 9.6–13.3°C, and WMT 27.3–28.1°C. Table 2 shows taxa that are representative for the minimum and maximum values of the climatic parameters.

The data obtained in the present study are similar to those advanced by Chirilă and Ţabără (2008) for the Volhynian deposits from the Râşca Valley (MAP 16.5–17.2°C, MAP 1300–1355 mm/yr). Thus, for the samples of Volhynian age collected from the Moisea watercourse, Chirilă (2008) acquired the following climatic parameters: MAT, 15.3–17.2°C and MAP, 1300–1520 mm/yr, while for the samples from the Baia borehole the data obtained were the following: MAT, 16.5–16.6°C and MAP 1300–1355 mm/yr. For the samples of Lower Sarmatian age collected from the RBN 4 borehole (Moldavian Platform), the same author, Chirilă (2010), acquired the following values: MAT 15.6–17.2°C, MAP 1300–1355 mm/yr; CMT 9.6–12.5°C; WMT 23.6–28.5°C.

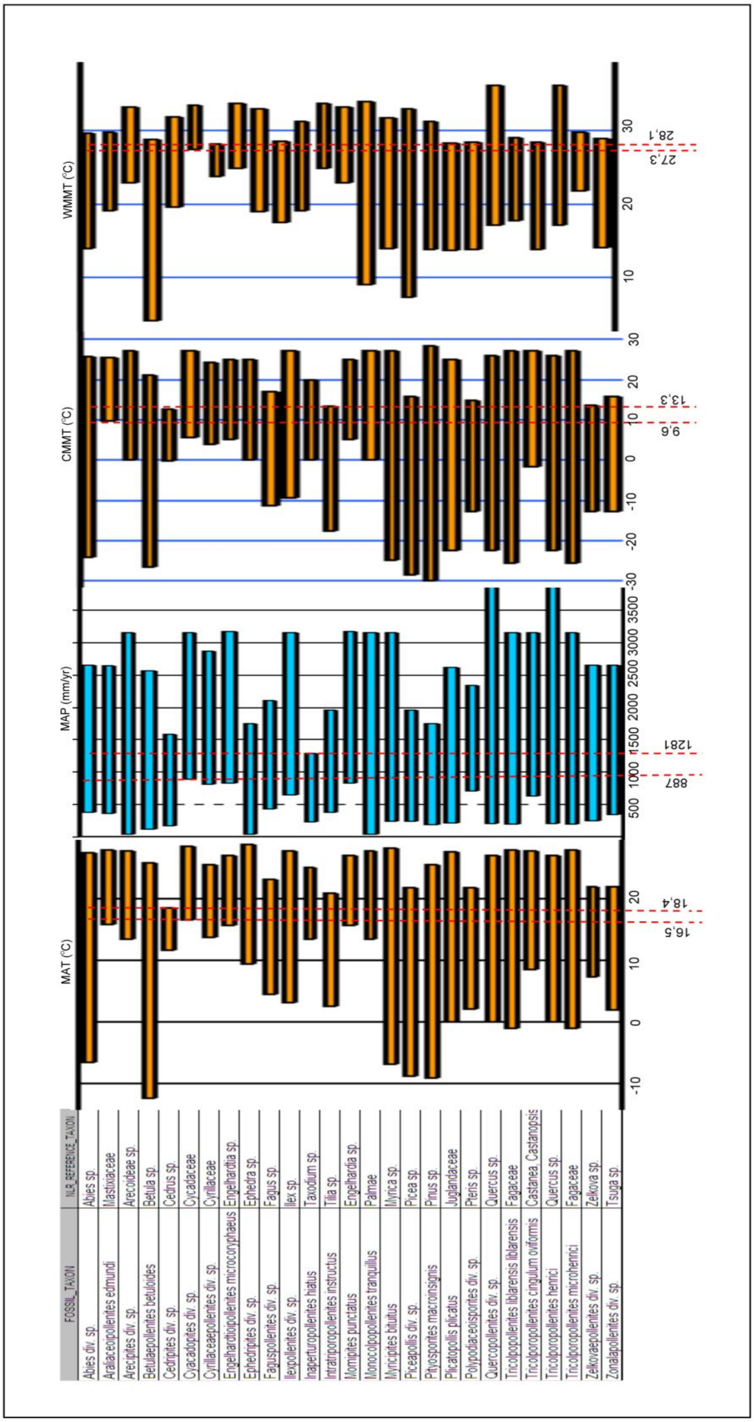

Fig. 2 Estimation of the MAT, MAP, CMT, and WMT values using the “Coexistence Approach” method.

Tab. 2 – Climatic parameters for the flora from the Bilca–Frătăuţii Noi borehole, derived from the microfloristic record. The taxa responsible for the minimum and maximum value are listed.

Climate parameter	Min-value	Taxa min-value	Max. value	Taxa max-value
TMA [°C]	16.5	Cycadaceae	18.4	*Cedripites*
PMA [mm/yr]	887	Cycadaceae	1281	*Inaperturopollenites hiatus*
CMT [°C]	9.6	*Araliaceoipollenite edmundi*	13.3	*Intratriporopo-llenites instructus*
WMT [°C]	27.3	Cycadaceae	28.1	*Cyrillaceaepollenites* div. sp.

For the Upper Badenian (Kossovian) – Lower Sarmatian from Mereşti–Harghita, Petrescu et al. (1988) reached the following values: MAT 14–15°C; MAP 800–1000 mm/yr).

Ştefârţă (1997) determined for the Volhynian age of the Republic of Moldova the following climatic values: MAT – 15°C, WMT – 25°C, CMT – 3–6°C, and MAP – 1000 mm/yr, while for the Bessarabian deposits the following climatic parameters were established: MAT 11°C, WMT 23°C, CMT 5–8°C, and MAP 700 mm/yr.

For the Bessarabian deposits from Stan's Hill–Bozieni, Ţabără et al. (2009) calculated a MAT of 15.3–16.6°C and a MAP between 1300 and 1520 mm/yr.

Following the TMA evolution in the Transylvanian Basin during the Badenian, Rusz (2010) established a value of 15.6–16.6°C. The author used the CA method for the Meresti palynological assemblage, Upper Badenian in age, established by Petrescu et al. (1988).

For the Upper Badenian from the Ukrainian Plain (Korobki region), Syabryaj et al. (2007) estimated a MAT of 15.6°C, a MAP between 1304 and 1356 mm/yr, a CMT between 6.6 and 7°C, and a WMT between 27.7 and 25.9°C.

For the Badenian from Ungaria (Nógrádszakál region), Erdei et al. (2007) calculated the following climatic parameters: MAT 14–16.5°C and MAP 846–1213 mm/yr.

In conclusion, the climatic parameters established using the CA method in the present study are similar to those reached by other researchers for different regions of the European Miocene.

The slight discrepancies regarding the MAT, MAP, CMT and WMT values are not as significant as to be noted. They are due to factors and conditions specific for each of the regions during the Sarmatian and the Badenian.

Conclusion

Based on the palynological contents identified for the Bilca–Fratautii Noi lithological column, the following vegetal systems can be distinguished:

- swamp vegetation such as *Salix*, *Nyssa*, *Cyrilla* etc.;
- a mixed mesophytic forest characterized by taxa of *Quercus*;
- a high-altitude area (mountainous) characterized by the representatives of the genus *Pinus*;
- a herbal zone with *Chenopodipollis* and *Ephedripites*;
- a fern zone composed of taxa belonging to *Laevigatosporites*, *Leiotriletes*, *Echinatisporis*, *Polypodiaceoisporites* etc.;
- Dinoflagelates represented mainly by the *Hystrichosphaera* genus.

Within the identified palynological assemblage, the values of the climatic parameters are the following: TMA 16.5–18.4°C, PMA 887–1281 mm/yr, CMT: 9.6–13.3°C, and WMT 27.3–28.1°C.

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CAPTION OF PLATES

Plate I

1. *Oligosphaeridium* sp.
2. *Hystrichosphaera* sp.
3, 4. *Operculodinium* sp.
5. *Echinatisporis* sp.
6. *Echinatisporis cycloides* KRUTZSCH 1963
7. *Araucariacites* sp.
8. *Abiespollenites absolutes* THIERGART 1937
9, 10, 13. *Pityosporites minutus* (ZAKLINSKAJA 1957) KRUTZSCH 1971
11. *Pityosporites* sp.
12. *Pinuspollenites miocaenicus* NAGY 1986
14. *Myricipites* sp.
15. *Engelhardtioidites* sp.
16. *Carpinuspollenites* sp.
17. *Engelhardtioidites microcoryphaeus* (POTONIÉ 1931) THOMSON et THIERGART ex POTONIÉ 1960
18. *Intratriporopollenites instructus* (POT. 1931) TH. et PF. 1953

Plate II

1. *Tricolporopollenites* sp.
2. *Polypodiceoisporites* sp.
3. *Pityosporites labdacus* (POTONIÉ 1931) THIERGART et PFLUG 1953
4. *Quercopollenites petrea* NAGY 1969
5. *Zonalapollenites verruspinus* KRUTZSCH 1971
6. *Ulmipollenites undolpsus* WOLFF 1934
7, 11. *Myricipites* sp.
8. *Stereisporites* sp.
9. *Artemisiaepollenites* sp.
10. *Artemisiaepollenites sellularis* NAGY 1969
12. *Intratriporopollenites instructus* (POTONIÉ 1931) THOMSON et PFLUG 1953
13, 15. *Myricipites* sp.
14. *Leiotriletes* sp.
15. *Salixpollenites* sp.
16. *Laevigatisporites haardti* (POTONIÉ et VENITZ 1934) THIERGART et PFLUG 1953
17. *Tricolporopollenites* sp.
18, 22. *Tricolporopollenites microhenrici* (POTONIÉ 1931) KRUTZSCH 1960
19. *Graminidites* sp.
21. *Tricolporopollenites* sp.
20. *Quercopollenites* sp.
23. *Neogenisporis neogenicus* KRUTZSCH 1962 (reworked)
24. *Abiespollenites* sp.
25. *Abiespollenites latisacatus* (TREVISAN 1967) KRUTZSCH 1971
26. *Piceapollis* cf. *neogenicus* NAGY 1969
27. *Tytthodiscus* sp.
28. *Pityosporites minutus* (ZAKLINSKAJA 1957) KRUTZSCH 1971

Plate I

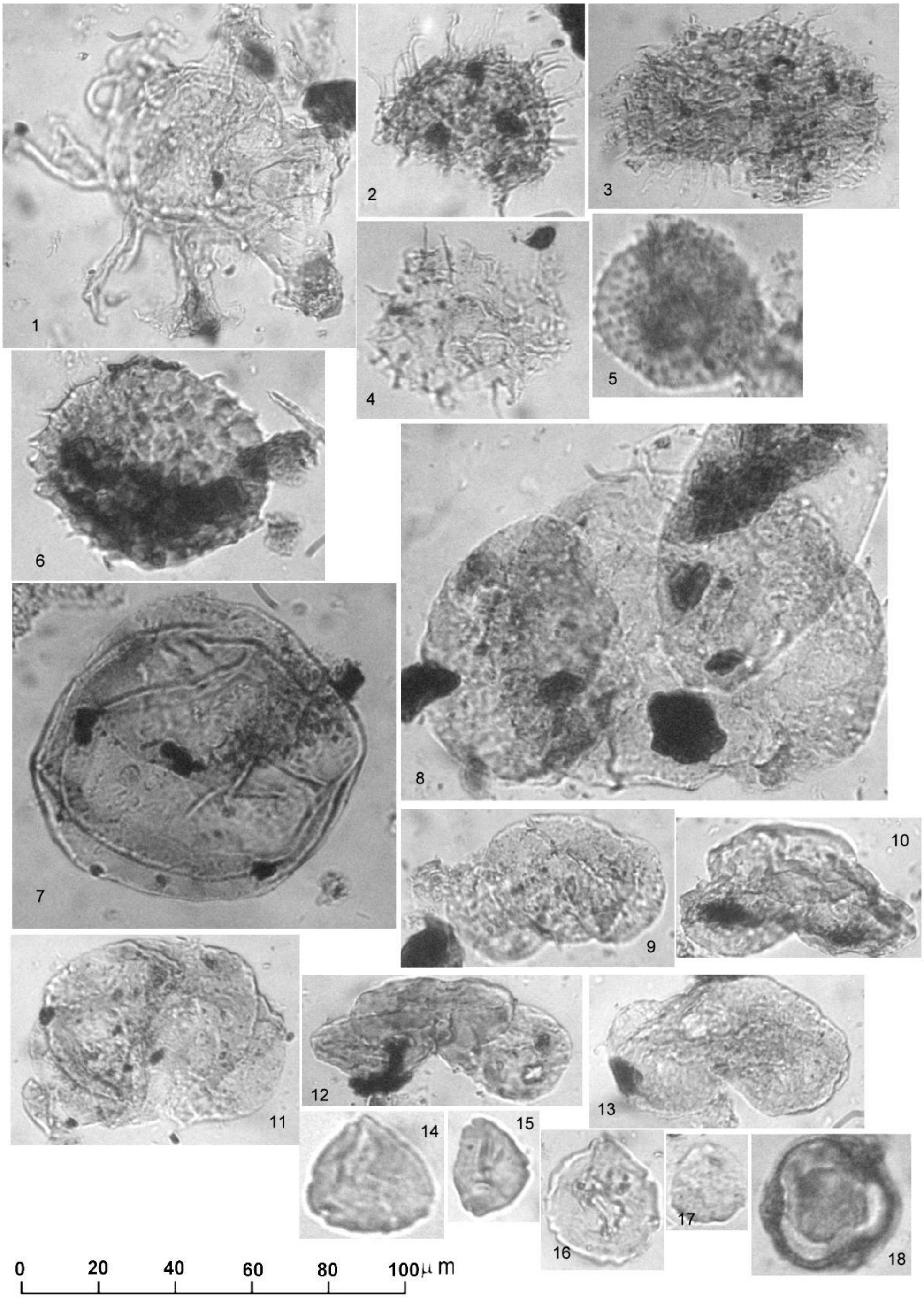
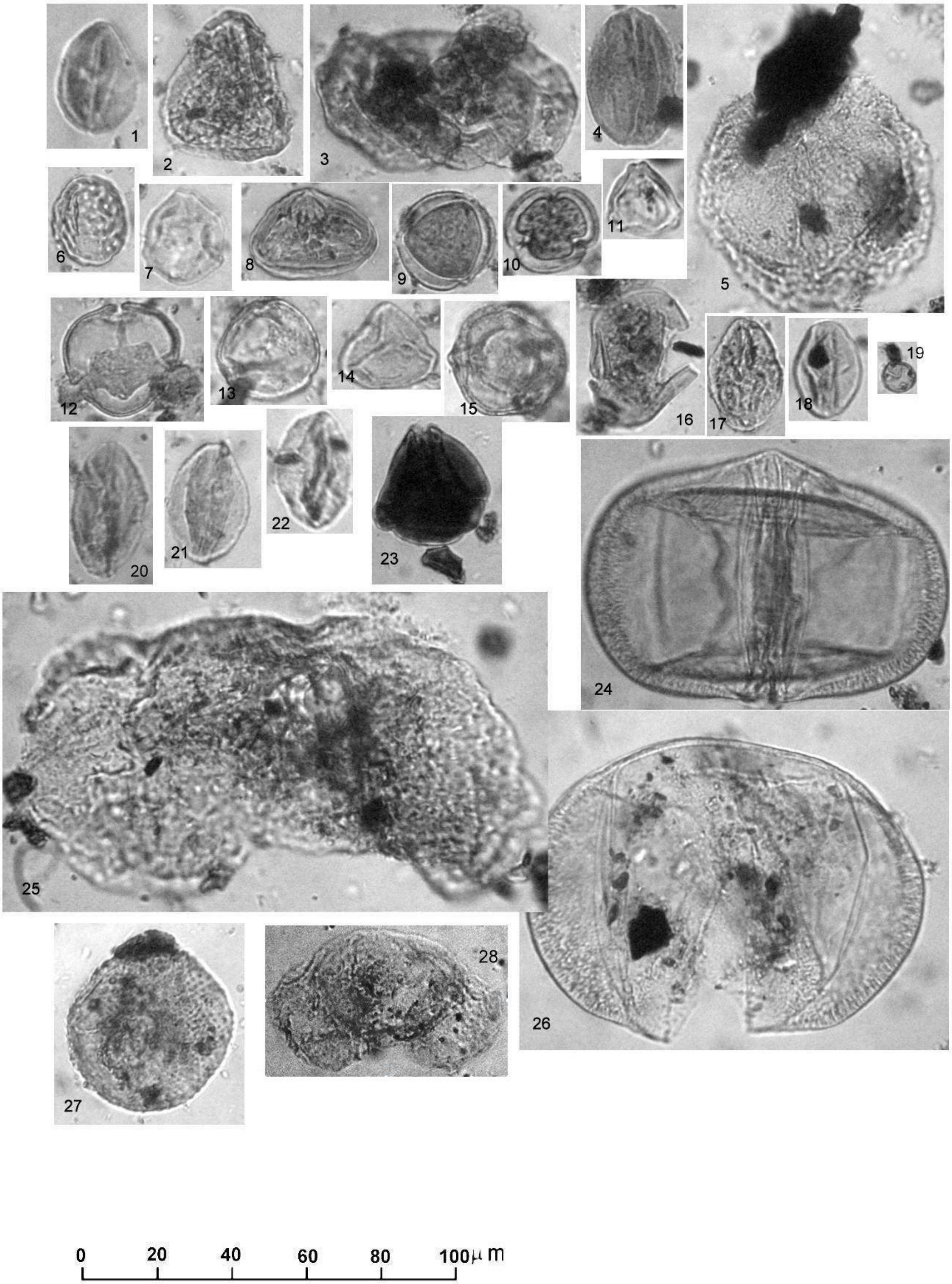


Plate II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