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PALAEOCLIMATE RECONSTRUCTIONS FOR THE LATE MIOCENE IN SOUTHEAST BULGARIA USING POLLEN DATA FROM THE TUNDZHA BASIN

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Abstract: The results of palaeoclimate reconstructions of Neogene freshwater deposits of the Tundzha Basin (South Bulgaria, SE Europe) are presented. We analysed pollen and spores complexes with the aim of obtaining data about the climate conditions. The palynological analysis was performed on clayey sediments of the Elhovo Formation intercalated between coal layers from core C-432 situated in the central part of the Basin. The climate data reconstructed by the Coexistence Approach indicate a warm temperate climate with mean annual temperatures around 16 ºC and with mean temperature of at least 5 ºC during the coldest month. With annual precipitation rates commonly around 1000 mm climatic conditions were overall humid. Partly seasonally drier conditions suggested for the topmost part of Elhovo Formation by previous studies, were not evident from recent analyses. The Early Pontian climate was about 3-4°C warmer than today, with rainfalls at least 300 mm higher. These data coincide with the warming trend recognised in other regions in Bulgaria during the Early Pontian. Thus the data from current study contribute to the elucidation of the evolution of the local and regional Late Miocene climate patterns and contribute to the palaeoclimate model for the Balkan Peninsula.

Key words: Late Miocene, Bulgaria, Southeast Europe, palynology, climate, coexistence approach.

1. Introduction

Palaeoclimate reconstructions are essential for understanding the recent and future changes in the climate system under the pressure of internal and external forcing factors. In general the records of changing climate that are preserved in sedimentary archives provide data for describing the history of climate. In particular, the long and continuous sedimentary successions contain a unique record of climate changes. The fossil plant record helps to understand past climates, because of strong dependence flora and vegetation composition and structure on climatic conditions. In recent years, a different quantitative techniques have been developed, e.g. CLAMP (Wolfe, 1993); Coexistence Approach (Mosbrugger and Utescher, 1997); Climate Amplitude Method (Fauquette et al., 1998); ELPA (Traiser et al., 2005, 2007) and improved (e.g. Utescher et al., 2009b) making an effort to obtain more precise climate data from plant fossils. As a result a numerous climate reconstructions have been carried out for the Neogene period, aiming at the reconstruction of local and regional climatic patterns (Fauquette et al., 1999; Gebka et al., 1999; Utescher et al., 2000; Bruch and Gabrielyan, 2002; Ivanov et al., 2002; Bruch and Kovar-Eder, 2003; Fauquette and Bertini, 2003; Uhl et al., 2003; Bruch et al., 2004; Jiménez-Moreno et al., 2005; Bruch et al., 2006; Fauquette et al., 2006; Uhl et al., 2006; Akgun et al., 2007; Bruch et al., 2007; Fauquette et al., 2007; Ivanov et al., 2007a,b,c; Jiménez-Moreno et al., 2007a,b; Syabryaj et al., 2007; Uhl et al., 2007; Utescher et al., 2007; Akkiraz et al., 2008; Jiménez-Moreno et al., 2008,b; Kayseri and Akgun, 2008; Ivanov, 2009a; Utescher et al., 2009a).

Terrestrial climate records during the Miocene have been reconstructed recently from the microfloral record of Central and Eastern part of Balkan Peninsula. Quantitative climate data were calculated for Middle and Late Miocene palynological records from marine/brackish sediments of the Forecarpatian and Euxinian Basin (Ivanov et al., 2002, 2007c). The temperature records obtained reveal continental cooling from sub-tropical conditions in the Middle Miocene to warm temperate climate at the Miocene/Pliocene transition. Major global climatic events known from marine data archives (Zachos et al., 2001) such as the Mid-Miocene Climatic Optimum and Late Miocene Cooling trend are mirrored in the terrestrial curves. In general the temperature records coincide with overall climate trend for North Germany and Central Europe (Utescher et al., 2000; Mosbrugger et al., 2005). As regard the precipitation pattern, differences with Central European model were observed for the Late Miocene (Ivanov et al., 2007c; Ivanov, 2009a). In addition, fluctuations occur in all climate parameters and display cycles of humid/dryer and warmer/cooler conditions for the Late Miocene (Maeotian) in Bulgaria (Ivanov et al., 2002), which required more detailed studies of these events. Other recent studies on Late Miocene (Pontian) floras and vegetation revealed additional information for climate change (Ivanov et al., 2007a), incl. cyclic vegetation and climate pattern referred to orbital climate forcing (Utescher et al., 2009a).

The present study of the Upper Miocene sediments from the Tundzha Basin (Fig. 1) aims to elucidate the evolution and the variations of past climate, not sufficiently known in this area up to now.

2. Geological settings

The Tundzha Basin (also known as Elhovo or Elhovo-Yambol Basin) is situated in the South-eastern part of Bulgaria (Fig. 1). It provides important information on both dynamics of the system of fresh-water basins on Balkan Peninsula (Burchfiel et al., 2000; Nakov et al., 2001) and climate change and vegetation evolution in south-eastern part of Europe (Ivanov et al., 2007a). The basin is considered as a graben structure, which was formed as a result of movements in faults and extensions in the beginning of Late Miocene.

The Neogene sediments of the Tundzha Basin are assigned to the Elhovo Formation (Kojumdgieva et al., 1984) with two members (Fig. 1): Izgrev Member and Duganovo Member, and an undivided part. Angelova et al. (1991) have described the infiltration limestone sediments of the Duganovo Member as the Prustnik Limestone Formation, and dated it to the Pleistocene. The Elhovo Formation is unconformably overlain by a few meters of Pleistocene-Holocene sediments.

The sediments of Elhovo Formation are entirely of continental origin, were deposited in alluvial, fluvial and locally lacustrine-marshy environments (Nakov et al., 2001), and consist of an irregular alternation of claystone, sandstone and rare conglomerates. The thickness of the Formation is ca. 150 m to 200 m, but locally it reaches up to 300 m (Kojumdgieva et al., 1984). Within these deposits large lenses of gray and black clays, diatomite clays and lignite coal are grouped as Izgrev Member, which is locally present in the middle part of the basin (Fig. 1). The total thickness of the Izgrev Member reaches up to 40 m, with three main coal seams, each of them with a thickness varying from 3 m up to 8 m. Lignite was formed in an environment, characterized by low subsidence rate. Peat accumulation was terminated by a major flooding event resulting in a short-term establishment of a lake (Zdravkov et al., 2007).

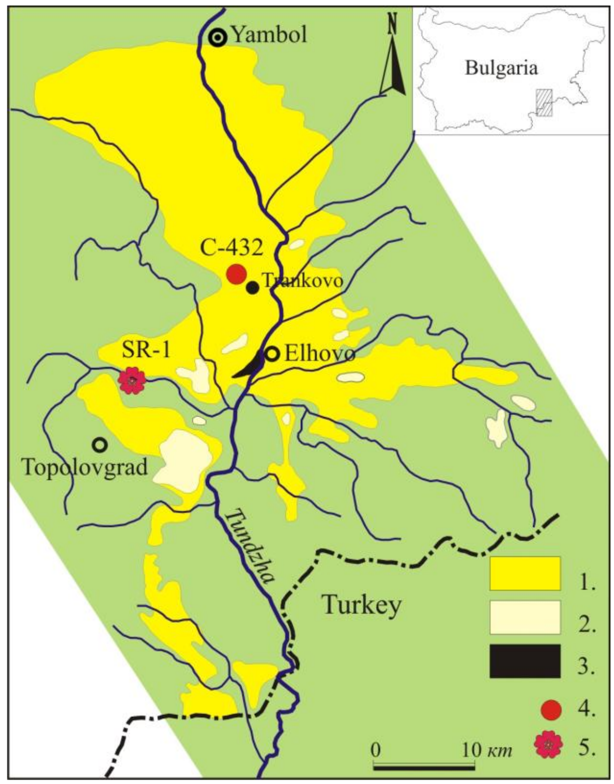

Fig. 1. Geological map of the Toundzha Basin, SE Bulgaria (redrawn from Kojumdgieva et al., 1984). Legend: 1. Elhovo Formation; 2. Douganovo Member of Elhovo Formation; 3. Izgrev Member of Elhovo Formation; 4. Position of core C-432, Trankovo; 5. Outcrop SR-1, Sinapovska River.

Diatom analysis of the clays from Izgrev Member has yielded a Pontian age for Elhovo Formation (Temniskova-Topalova et al., 1996; Temniskova-Topalova and Ognjanova-Rumenova, 1997). Among the vertebrate fauna discovered in the sediments from the upper part of the Elhovo Formation the following species were identified: *Deinotherium giganteum* Kaup, *Tetralophodon longi-*

rostris Kaup, *Anancus arvernensis* Croizet & Jobert, and *Zygolophodon borsoni* Hayes (Bakalov and Nikolov, 1962; Kojumdgieva et al., 1984; Nikolov, 1985). On the basis of these finds Kojumdgieva et al. (1984) assumed that the upper part of the Formation is Pontian-Pliocene, while the Elhovo Formation in was deposited in the Meotian-Early Pliocene time interval.

3. Materials and Methods

The sediments studied originate from core 432 (Fig. 1.) drilled near the village of Trankovo, Elhovo district. The profile comprises of browncoals, (diatomaceous) clays, and sandy clays (Fig. 2). The samples from the studied profile originates from the diatom clays and clays contacting to the lignite coals of the Izgrev Member. They were processed according to the standard technique for disintegrating Cenozoic sediments, which includes successive treatment by hydrochloric acid (HCl), fluoride acid (HF), potassium base (KOH), heavy liquid separation ($ZnCl_2$), and acetolysis.. The studied samples contain sufficient and well-preserved pollen grains, which enable us to apply quantitative techniques for climate reconstructions, and to analyse and interpret the results. On the basis of pollen/spore counts a percentage pollen diagram was plotted (Fig. 3.) showing the palynological record of the complete section. The percentage of each palynomorph taxon identified in the pollen spectra was calculated with respect to the total sum of arboreal (AP) and non-arboreal (NAP) pollen (AP+NAP=100 %). Local elements (L), such as spores, aquatic plants, were calculated on the basis of the sum AP+NAP+L=100 %. Total pollen sum for each sample is given in Append. 1, and graphically presented on the pollen diagram (Fig. 3).

To reconstruct palaeoclimate from the palynological record of theTundzha coal basin, the Coexistence Approach (CA) method was applied (Mosbrugger, 1995; Mosbrugger and Utescher, 1997). This method uses the climate tolerances of all Nearest Living Relatives (NLRs) known for a given fossil flora to determine a coexistence interval for each considered climate variable which allows the majority of NLRs of a fossil flora to coexist. The resulting intervals obtained for the different climate variables were then interpreted as the most probable ranges of palaeoclimate parameters for the fossil flora analysed. The Palaeoflora data base (Utescher and Mosbrugger, 1990-2007) was used for identifying the living relatives and their climatic requirements.

In the present study, four climatic parameters are considered and discussed below, namely:

- MAT: mean annual temperature (°C),
- CMT: mean temperature of the coldest month (°C),
- WMT: mean temperature of the warmest month (°C),
- MAP: mean annual precipitation (mm).

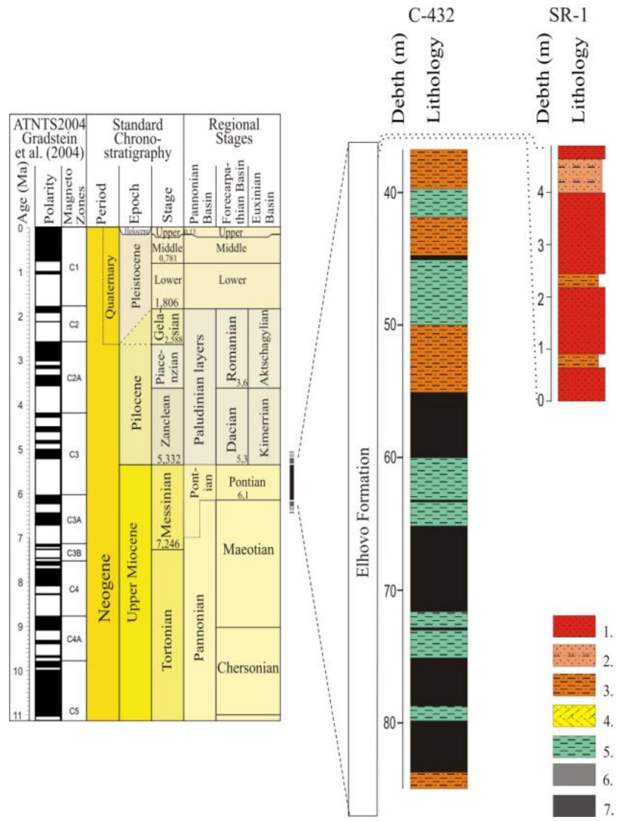

Fig. 2. Lithological column of the studied section C-432, Trankovo. For completeness the litological column of outcrop SR-1, Sinapovska River is given. Legend: 1. Sands and sandstones; 2. Sands with clayey interbedding; 3. Silty clays; 4. Yellow clays. 5. Diatomaceaous clays; 6. Clayey lignites; 7. Lignite coal.

These are the parameters which most reliably represent changes in palaeoclimatic conditions because their effect on plant distribution is most important. They are also best developed in terms of methodology (see (Ivanov et al., 2002; Mosbrugger and Utescher, 1997). As shown by previous palaeoclimate reconstructions for the Bulgarian Neogene, significant changes primarily involve mean annual temperature, temperature of the coldest month and mean annual precipitation, while temperatures of the warmest month are more constant and show smaller fluctuations (Ivanov et al., 2002).

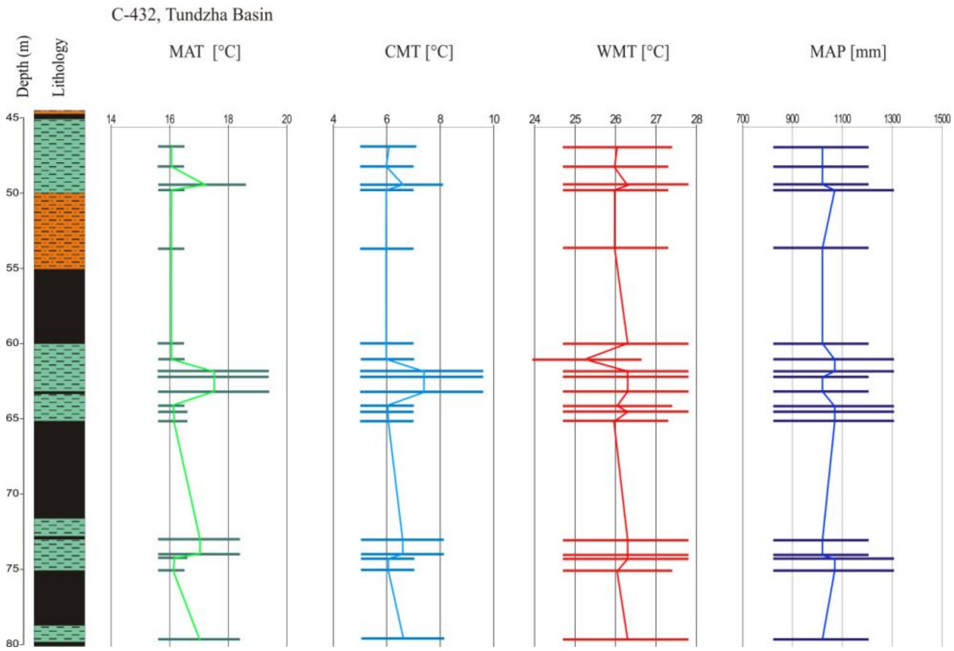

Fig. 3. Simplified percentage pollen diagram of core C-432, Trankovo, Tundzha Basin.

For the analysis, 19 microfloras from core 432 were selected providing required plant diversity for climate analysis. One sample (the top of section) was excluded because its diversity was below the limit of the method to produce reliable results (Mosbrugger and Utescher, 1997). Climate data calculated for the single microfloras, number of taxa contributing climate data, lower and upper limit of climate range obtained for the different variables are presented in Table 1, and illustrated on Fig. 4. In addition, the climate data from outcrop Sinapovska River (Ivanov et al., 2007b) are also used in terms to compare climate data and draw conclusions about climate dynamics.

4. Results and discussion

The fossil flora from Tundzha Basin is not sufficiently studied up to now. Recently studies on fossil macro- and microflora from upper part of Elhovo Formation (Ivanov et al., 2007b; Palamarev and Bozukov, 2004) have been undertaken, including also palaeoclimate interpretations (Ivanov et al., 2007b). Pollen analysis was applied on clayey sediments of Izgrev Member (Elhovo Formation)

Table 1. Climate data calculated for the single microfloras of core C-432. No taxa – number of taxa contributing climate data; min/max – lower/upper limit of climate range.

Depth (m)	No taxa	MAT min	MAT max	TCM min	TCM max	TWM min	TWM max	MAP min	MAP max
46	32	15,6	16,5	5	7,1	24,7	27,4	823	1206
47	34	15,6	16,5	5	7	24,7	27,3	823	1206
48	21	15,6	18,6	5	8,1	24,7	27,8	823	1206
49,0	32	15,6	16,5	5	7	24,7	27,3	823	1308
49,5	37	15,6	16,5	5	7	24,7	27,3	823	1206
54	19	15,6	16,5	5	7	24,7	27,8	823	1206
60	24	15,6	16,5	5	7	24,7	27,4	823	1308
61	23	15,6	19,4	5	9,6	24,7	27,8	823	1308
62	30	15,6	19,4	5	9,6	24,7	27,8	823	1206
62,5	23	15,6	19,4	5	9,6	24,7	27,8	823	1206
63,5	28	15,6	16,5	5	7	24,7	27,4	823	1308
64	28	15,6	16,6	5	7	24,7	27,8	823	1308
64,5	33	15,6	16,6	5	7	24,7	27,3	823	1308
65	23	15,6	18,4	5	8,1	24,7	27,8	823	1206
73	32	15,6	18,4	5	8,1	24,7	27,8	823	1206
74	27	15,6	16,6	5	7	24,7	27,8	823	1308
74,1	28	15,6	18,6	5	8,1	24,7	27,8	823	1206
75	28	15,6	16,5	5	7	24,7	27,4	823	1308
79	33	15,6	18,4	5	8,1	24,7	27,8	823	1206

for biostratigraphic purposes (Kojumdjieva et al. 1984), but the results were not published. Later the same materials were reanalyzed by (Ivanov and Lazarova, 2005) aiming to obtain information about fossil flora and vegetation structure. Scarce information about carpoflora from Elhovo Formation (incl. Izgrev Member) was reported in the overview of some Miocene floras by (Mai and Palamarev, 1997; Palamarev, 1990) and (Palamarev et al., 1999). Detailed pollen analyses has been recently performed by (Ivanov, 2009b) and is used for current reconstructions (Fig. 3).

The fossil flora identified during the micropalaeobotanic studies generally comprised representatives of 115 pollen taxa (Appendix 1.): 87 angiosperm pollen types from 50 families; 16 gymnosperm pollen types and 12 spore types (Ivanov, 2009b). Fossil flora is characterised by strong dominance of trees and shrubs, which is in contrast to the pollen flora from the outcrop Sinapovska River (SR-1). The last section showed a considerable pollen participation of herbaceous species and absence of representatives of spore plants. The herbaceous plants not only showed a high percentage participation (45.8 %), but considerable taxonomic diversity too (Ivanov et al., 2007b).

Analysis of the palynological data provided information on the probable climatic conditions during the sedimentation process. The palaeocli-mate reconstructions resulting from the application of the coexistence approach to the 19 palynofloras of core C-432 are shown in Fig. 3. The data from climate reconstruction for upper part of Elhovo Formation after (Ivanov et al., 2007b) – outcrop SR-1 (Sinapovska River) are used to correlate with recent data.

The present-day climate of Tundzha valley, Southeast Bulgaria is characterised by mean annual temperature (MAT) 12.2 °C, mean temperature of the coldest month (CMT) 0.9 °C, mean temperature of the warmest month (WMT) 22.7 °C, and mean annual precipitation (MAP) 541 mm (according to the Yambol Climatic Station, 143 m a.s.l.). The data for Elhovo Climatic Station, 130 m a.s.l. are as follow: MAT 12.3 ºC, TCM 1.1 ºC, WMT 22.9 ºC and MAP 545 mm (Stringmeteo, 2006-2009a; Stringmeteo, 2006-2009b; Velev, 1997).

Climate reconstructions based on palynological data from Izgrev Member of Elhovo Formation (the data obtained from core Trankovo C-432: Fig. 4; Table 1) display relatively stable climatic conditions for the entire time interval. The lower boundary of MAT coexistence intervals in all analysed pollen floras lies at 15.6°C. The upper boundary lies usually at 16.5°C, but higher values are also obtained (e.g. 18.4°C and 19.4°C) thus resulting in wider coexistence intervals. The middle values for the MAT are around 16°C except for some pollen floras from the bottom and middle part of the profile, which provide values ca. 17°C. Thus obtained

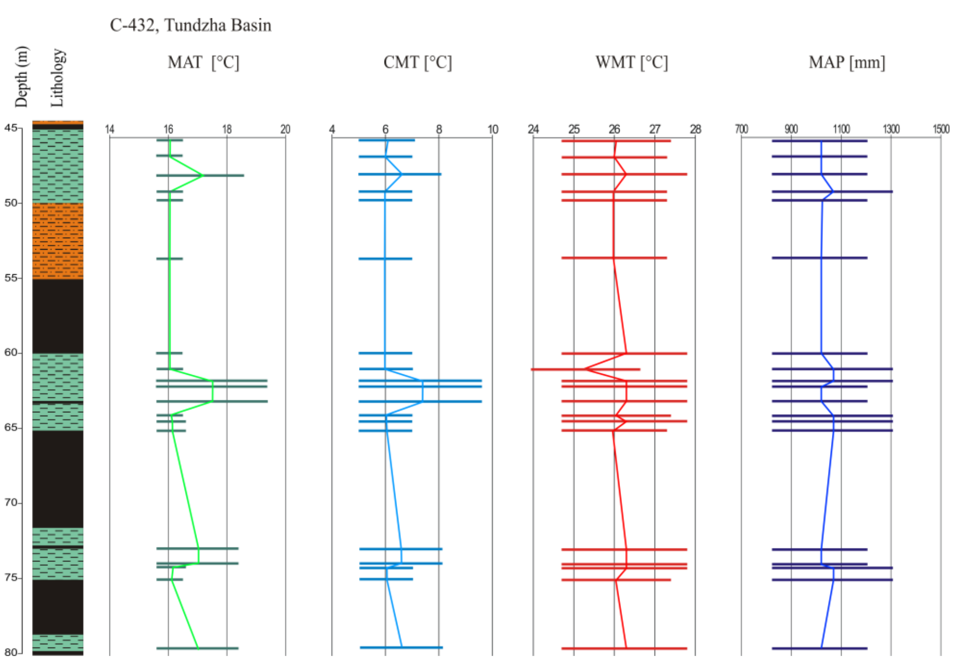

Fig. 4. Lithological section (cf. Fig. 2), coexistence intervals (bars) for mean annual temperature (MAT), and temperature of the coldest (CMT) and warmest month (WMT), and mean annual precipitation (MAT).

data for the annual tempera-tures shows relatively constant annual temperature during the sedimentation (Fig. 4). The invariability of this climate parameter and the lack of significant deviations testify to the absence of strong climate change.

The same is true for the winter temperatures. Coexistance intervals for CMT range mainly between 5.0°C and 9.0°C for most of the analysed microfloras (Fig. 4.). The most common middle values are 6.0°C. Only in sporadic cases higher values are obtained for the upper boundary, resulting in wider CA-intervals – 5.0-8.1°C and 5.0-9.6°C. In the upper part of the section, the upper CMT limit may decline to 7°C (at 15 m and 23 m in the profile). The lack of extreme winter temperatures was extremely important for the survival of palaeotropical plants, which required mild frost free winters.

Summer temperatures are in accordance with above mentioned results. The obtained data shows CA-intervals of 24.7-27.8°C and 24.7-27.3°C (Fig. 4.), while the middle values lies between 26.0-26.3°C. TWM show small oscillations of the upper limit of the intervals, which could not be interpret as significant climate change. Moreover, the results for annual and winter temperatures don't indicate increased seasonality and higher difference between winter and summer temperatures is not observed. Annual precipitation totals (middle values) are well above 1000 mm in the whole profile. The lower boundary of the coexistence intervals for MAP is at 823 mm and the upper is between 1206 and 1308 mm.

Summarizing the results obtained, it can be stated that a warm temperate climate persisted during the studied time period. Temperatures stayed at about the same level without significant fluctuations. Comparing to present climatic conditions it could state that temperatures were ca. 3-4°C higher than recent ones. The calculated MAP totals point to a permanently humid climate, with middle values above 1000 mm. Thus annual rainfalls during the studied time period were about twice higher as compare to recent levels of precipitation in the area of Tundzha Basin. The data obtained don't indicate any seasonally drier conditions.

The palaeoclimate data reconstructed using the NLR technique are over all supported by the broader vegetation data (Ivanov and Lazarova, 2005). For instance in most cases warm temperate and permanently humid conditions coincide with the presence of forest cover (mixed mesophytic forest with warmth-loving evegreens in the undergrowth). The calculated mean MAP total, commonly above 1000 mm, explains the rareness of xerophytic elements in the pollen spectra (Ivanov and Lazarova, 2005). Thus, all data indicate a very warm and humid climate.

These data coincide with the early Pontian warming trend recognised in Norethwest Bulgaria (Ivanov et al., 2002). Ivanov et al. (2002) point that after the late Maeotian cooling, the early Pontian begins with a warming trend. MAT reaches values of 15.6-17.2 ^{o}C, TCM lies between 5-7 ^{o}C, while MAP increases up to 1187-1308 mm. This event corresponds with the data obtained in current study.

Uncertainties of stratigraphical dating of the studied section do not allow direct correlation with climate curves available for other continental parts of Europe or global records, but work is in progress. However, if an earliest Pontian age can be assumed for the section, the data can be discussed in a European context. When compiling palaeoclimate data for the latest Miocene from various sources for different parts of Europe it is clear that the Elhovo region was characterized by favourable climate conditions with comparatively high MAT and mild winter temperature. Comparing temperatures (MAT, CMT) calculated for the Pontian of other areas (Ivanov et al., 2007a), the values obtained for the Tundzha Basin tend to be higher by a few degrees. This can be explained by a more southerly latitudinal position and/or a favourable microclimate caused by a small-scale relief. In the study area, MAP was apparently high when compared to other European regions.

The calculated values on the basis of the fossil macroflora from outcrop Sinapovska river (Ivanov et al., 2007b) had shown the annual temperatures within the range 14.4–15.8 °C, winter temperatures 3.7–5.8 °C, summer temperatures 25.6–26.4 °C, and the annual rainfalls 961–1179 mm. The values calculated on the basis of palynological data had shown wider CA-intervals: MAT 13.6–18.4 °C, CMT 2.4–9.4 °C, WMT 22.8–26,1 °C, and MAP 740–1206 mm. The wider interval of annual precipitation (740–1206 mm) might reflect diversity of the climatic conditions on a larger territory, including drier habitats (Ivanov et al., 2007b). The temperature values are by several degrees (1-2 °C) lower than the temperature values obtained in current study. This could correspond to slight cooling trend at the Pontian/Pliocene transition. Some drying is also possible. The expansion of herbaceous vegetation in outcrop SR-1 can be correlated with other late Neogene records in Bulgaria and surrounding areas (e.g. the upper part of the Staniantsi section – Utescher et al. (2009a). The increasing abundance of herbs combined with a low quantity of arboreal taxa, points to an opening of habitats, and probably decrease in mean annual precipitation.

5. Conclusions

Summarizing the results obtained it can be stated that a warm temperature climate with high rainfall and mild winter temperatures persisted in the time period regarded. Temperatures stayed about at the same level throughout the period of sedimentation of Izgrev Member of Elhovo Formation. All data indicate a very warm and humid climate without seasonally drier conditions. The early Pontian climate was about 3-4°C warmer than today, with rainfalls at least 300 mm higher that today. In general, these data coincide with the warming trend recognised in other regions of Bulgaria during the early Pontian.

The calculated climate values for the upper part of the Elhovo Formation (Ivanov et al., 2007b) shows some decrease in the annual and winter temperatures. A decrease of lower boundary of precipitations is also recorded. That could be attributed to a slight cooling trend at the end of Pontian, and possibly some drying.

Palaeoclimatic results shows that the climate in the Tundzha Basin in the period of sediment accumulation in the Elhovo Formation was warm temperate and permanently humid. Nevertheless the correlation of climate trends observed at Tundzha Basin with climate data from other late Miocene sedimentary successions is still tentative because of stratigraphic resolution, while the climate changes observed fit overall with observations from other regions of the European late Miocene.

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Appendix 1. List of palynomorph found out in the sediments of the Elhovo Formation with percentage proportions and distribution of taxa (after Ivanov et al. 2007b and this study).

Pollen/Spore type	Core C-432, Trankovo, Tundzha Basin (depth in m)																				
	42,0	46,0	47,0	48,0	49,0	49,5	54,0	60,0	61,0	62,0	62,5	63,5	64,0	64,5	65,0	73,0	74,0	74,1	75,0	79,0	SR-1
Abies sp.	0	0,1	0	0	0	0,8	0	0	0	0	0	0,7	0,5	0,3	0	0,2	0,5	0,2	0,1	0,9	0
Acer sp.	0	0,5	0,8	0	0,7	1,1	1,7	1	1,4	1,3	0,8	0,7	1,2	0,3	0,8	0,5	0	0,7	0	1,1	0
Achillea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,7	1,3	0	0	0
Alisma sp.	2	0,1	0	0	0	0,3	0	0	0	0	0	0	0,2	0	0	0	0	0	0	0,1	0
Alnus sp.	0	0,5	0,4	9,6	0,5	0	1,3	1,6	1	1,1	0	1,1	1,7	1,7	1,2	0,9	1,9	2,4	1,4	1,5	6,3
Anacardiaceae	0	0,1	0,2	0,3	0,9	0,9	0	0,9	0,6	0,2	1,3	0,4	0,2	0,3	0	0,5	0,2	0,2	0	0,4	0
Apiaceae	0	0,2	0,9	0,3	0,2	0,5	0,2	0,1	0,6	0,9	0,3	0	1	0,7	0	0,5	0	0,9	0,1	0,3	1,8
Araliaceae & Hedera sp.	0	0,3	0,7	0	0	0,6	0,2	0,3	0	0,2	0	0	0	0,2	0,4	0	0	0	0	0,3	0
Artemisia sp.	0	0	0	0	0	0,3	0	0,6	0	0	0	0	0	0	0	0	0	0	0	0	2,7
Aster type	0	0	0	0	0	0	0	0	0	0	0,2	0	0	0	0	0	0	0	0	0	0,9
Asteraceae	0	0	0,2	0,3	0	0,2	0,4	0,6	0,2	0,4	6,3	0,7	0,7	1,7	0,4	1,1	3,1	0	0	0,1	0
Asteroideae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,5
Betula sp.	0	3	2,8	3,3	0,9	2,3	0	1,1	3	2,4	3,7	3	3,7	5,1	1,6	2,9	2,1	4,1	2,8	2,6	1,8
Brassicaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,4
Buxus sp.	0	0,7	3	0	2,4	2,6	0,6	0,1	0	0	0	0,7	0	0	0,4	0,7	0,7	0,4	0,2	0,7	0
Caprifoliaceae	0	0	0,2	0	0,6	0,5	0	0	0	0	0	0	0	0	0	0,2	0,2	0	0,1	0	0,4
Carpinus betulus type	0	0	0,1	0	0	0,7	0,4	1,3	0	1,1	0	1,1	1,2	1,4	0	0,7	1,4	1,5	1,2	4,9	2,2
Carpinus orientalis/Ostrya type	0	1,1	1,4	0,3	0,5	1,1	0	1,4	0,8	0,8	1	3,3	3,4	0,8	0,8	3,2	2,4	2,6	2	3,8	3,6
Carya sp. 1 & 2.	2	6,1	3,7	4,1	3,7	2,6	3,2	4,9	1	8,8	6,8	5,9	7,9	8,8	3,7	3,8	7,3	8,1	8,9	4,3	0
Caryophyllaceae	0	0,2	0,1	0,3	0,4	0,7	0	0	0,4	0,8	0	0,4	1,7	0,2	0,4	0,9	0,2	0	0,2	0,4	0,4
Castanea sp.	0	0,3	0,8	0,8	0	0,4	0	0	0,6	1,3	2,3	3,2	1,5	2,7	0,8	0,5	0,7	0,9	1,8	0,2	0,4
Castanopsis sp.	0	0	0	0	0	0	0	0	0	0	0	0,2	0	0	0	0	0	0	0	0	0
Cedrus sp.	0	0	0	0	0	0,4	0,6	0	0	0	0	0	0	0	2,9	0,5	0,7	0	0,2	0,2	0,4
Celtis sp.	0	0,3	0,7	0,3	0	0,1	0	0	0	0	0	1,1	0	0,2	0	0	0	0,4	0,1	0	0
Centaurea sp.	0	0	0	0	0	0	0	0	0,2	0,8	0	0	0	0	0	0	0	0	0	0,1	0,9
cf. Altingia sp.	0	0	0,2	0,3	0	0,6	0,4	0	0	0	0	0	0	0,5	0	0	0,2	0	0,2	0	0
cf. Euphorbia	0	0	0	0	0	0	0	0	0	0	0,1	0	0	0	0	0	0	0	0	0	0
cf. Glyptostrobus	32	0	0,4	1,4	1,5	0,7	1,1	1,3	1,2	1,5	1,3	1,9	2,5	3,2	6,1	3,2	1,7	0,4	2,1	0,9	0
cf. Keteeleria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,4
Chenopodiaceae	0	0,1	0,8	0	0,5	1,3	0	0	1,4	1,9	3,4	1,9	0,2	5,1	0,8	1,1	0,7	0,7	0,2	0,7	11,6
Cichorioideae	0	0	0,2	0,3	0	0,2	0,4	0,6	0,2	0,2	1,3	0,7	0,7	1,7	0,4	1,1	0,7	0	0	0,1	1,4
Cornus sp.	0	1,4	1,7	0	0,5	0,6	0,2	0	0,4	0,9	0,5	0	0	0	0,4	0,7	0,2	0,2	0	0,1	0
Corrugatosporites sp.	0	0	0,2	0	0	0	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corylopsis sp.	0	0,1	1,7	0,6	0,4	1,8	0,4	0	0	0	0	0	1	0,3	0,8	0,9	0	0,9	0,2	0,3	0
Corylus sp.	0	2,2	0,5	0,3	1,6	1,3	0	0,7	1,6	1,3	0	0,4	2,5	1,2	0	3,4	0,7	1,7	1,1	2,3	2,7
Cupressaceae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	4	0	1	0	0	0,7	0	0	0	0,4	0,5	0	0,2	0	0	0,4	0,6	0	0	0	0,4
Cyrillaceae/Clethraceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0,5	0	0,2	0	0	0	0	0
Dipsaceae	0	0	0	0	0	0,1	0	0	0	0	0,3	0	0	0	0	0,2	0	0	0	0	5,4
Echinatisporis	0	0	0	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0
Engelhardia sp.div.	0	5,9	7,8	11,8	9,1	5,4	9,4	10	3,6	5,6	5,2	1,9	2,9	4,6	5,7	1,1	2,4	10,1	2,5	3,1	0
Ephedra sp.	0	0,1	0	0	0,2	0	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum sp.	0	0	0	0	0	0	0	0	0	0	0,1	0	0	0	0	0	0	0	0	0	0
Ericaceae	0	0,2	0	0,8	0,6	1,1	0,2	0,6	0,6	0,4	1	0	1,2	0,2	2	2,7	0,7	2	3,2	4	0
Eucommia sp.	0	0,4	1,9	1,4	0,5	0,6	0	1,4	1,2	1,3	0,5	0,4	0,5	1	0	1,6	1,2	0,2	1,2	2,5	0
Fabaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,9
Fagus sp.	0	1,9	3	1,1	1	4,5	0,4	2,6	0,8	0,6	0	2,6	0,2	1	5,7	7,4	5,2	3,9	5	4,5	0,4
Fraxinus sp.	8	12	13,3	7,4	12,4	16,3	3	13,9	8,9	4,5	5,2	2,2	0,5	1,4	2,4	1,4	1,9	3,3	2,3	4,6	0
Humulus/Cannabis type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,4
Ilex sp.	0	0	0,7	0	0	0,3	0	0	0	0,9	0	0	0	0	0	0,2	0	0	0	0	0
Juglans sp. 1 & 2.	0	0	0,2	0	0,4	0,3	0	0	0	0	0	0	0,5	0,2	0	0,9	0	0	0	0	0
Laevigatosporites	0	0	0,1	0,5	0,8	0,4	0,2	0	0,2	0,9	1,3	0	0	0,4	0	0,2	0	0	0	0	0
Liliaceae	0	0	0	0	0	0,1	0,2	0	0	0	0,8	0	0	0,5	0	0	0	0	0	0,1	0
Liquidambar sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0,5	0	0,2	0	0	0	0	0
Lonicera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,4
Lycopodium sp.	0	0,2	0	0	0,4	0	0	0,3	0	0	0	0,7	0	0	0	0	0	0	0,2	0	0
Magnolia sp.	0	0	0	0	0	0	0	0	0	0,2	0	0	0	0,5	0	0	0	0	0	0,3	0
Mentha/Salvia	0	0	0	0,8	0	0,2	0	0	0	0	0	0,4	0	0,2	0	0	0	0	0	0	0
Myrica sp.	0	3,2	1	3,5	0,2	1,3	0,4	0,3	0	0,8	0	0	0,7	0,2	0	1,6	0	3,7	1,4	0,9	0,4
Nuphar sp.	0	0	0	0,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nymphaeaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,9
Nyssa sp.	0	0,2	0,9	0,3	0,4	0,6	0	0,6	2,4	0,9	1,6	2,2	2,5	2,5	1,2	3,8	3,1	1,3	1,4	2,6	0,4
Oleaceae	0	3,9	4,7	0	1,8	3,5	0	0	0,6	0	3,4	1,1	0	1	0	0	0	0,6	0,6	0,3	0,4
Osmunda sp.	0	0	0	0	0	0,2	0	0	0	1,1	0,5	0	0,2	0,3	0	0	0,4	0	0	0	0
Persicaria sp.	0	0	0	0	0	0	0	0	0	0	0,3	0,4	0,2	0	0	0	0	0	0	0	0
Picea sp.	0	0,4	0,3	0,6	1,2	1,1	3,6	1,6	3,8	1,7	1,6	4,4	2,5	2,5	1,6	1,4	0,9	0,6	0,6	3,8	0,4
Pinaceae ind.	2	0	0	0	0	0,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinus diploxylon type	14	15,2	1,8	5,5	20,8	15,5	45	13,2	20,3	20,7	21,7	18,5	12,5	11,7	14,3	11,3	26,1	17,3	19,7	17,2	13,5
P. haploxylon/Cathaya	0	3,6	0,3	0,6	0	0,8	0,4	0,6	0,2	0	0	0	1,5	0,3	0,4	0,7	0	0,7	0,6	0,2	0,4
Pistacia sp.	0	0	0,2	0	0,9	0,2	0	0	0	0	0	0	0	0,2	0	0	0	0	0	0	1,4
Plantaginaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,8
Platanus sp.	0	0,2	0,5	9,6	0	0,6	0,4	0	0	0,4	0,3	0	0	0	0,4	0,7	0	0,2	0	0,6	0,4
Platycarya sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	0	1,4	2,8	0,6	1,8	1,7	0	0,4	1,4	0,6	0,3	1,5	0	2,5	1,6	3,8	5,5	1,5	3	1,8	6,7
Poaceae - Bambusoideae	0	0	0,3	0	0	0	0	0	0	0	0	0	0	0,4	0	0	0	0	0	0	0,4
Polygonum sp.	0	0	0	0	0,4	0,4	0	0,7	0	0	0	0	0	0	0	0,2	0	0	0,1	0,1	0
Polypodiosporites	0	1	0	0,3	0	0,1	0	0	0	1,4	0	0	0,2	0,3	0	0	0	0	0	0	0
Potamogeton sp.	0	0	1,3	0	0,4	0,3	0,2	0,3	0,2	0	0	0	0,5	0	0,4	0,2	0	0,5	0	0,7	0
Pteridium sp. & Pteridophyta	0	0	0	0	0	0	0,4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterocarya sp.1 & 2.	2	0,7	0,3	1,7	0,1	0,1	0	0	2	1,5	0	1,5	0,2	0,8	1,6	0,5	0	0,6	0,6	1,7	0,9
Quercus sp. 1 & 2.	4	7,5	7,1	6,6	11,1	5,7	1,7	6	1,2	1,7	0,5	1,9	0,5	0,7	1,2	0,9	0,9	1,5	3,3	2,7	3,1
Rosaceae	0	0,1	0,2	0	0	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0,3	2,7
Rubiaceae	0	0	0	0	0	0,3	0	0	0	0	0	0	0,2	0	0	0	0	0	0	0	0,4
Salix sp.	0	3,6	6,3	1,1	0,9	0,5	0,2	0	7	0,9	0,5	0,4	0,2	0	0,4	0,2	0	0,6	0,7	0,4	0,9
Sapotaceae	0	0,5	0,2	0	0,6	0,3	0	0,3	1	0,4	0,3	0,4	0,7	0,3	0	0	0,5	0,2	0	0,1	0
Sciadopitys sp.	4	0	0,1	0	0,2	0,2	0,4	0,1	0	0	0	0,7	1,5	0,2	0	0	0,5	0	0,2	0	0
Selaginella sp.	0	0	0	0	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sequoia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3	0	1,6	0	0	0	0	0
Sparganium sp.	0	0,2	1,9	0	0,2	1,5	0	3,1	1,4	0,5	0,8	0,7	0,2	5,2	2	7,2	5	1,2	0,2	1,1	0,9
Symplocos sp.	0	0	0,4	0	0	0,1	0	0	0	0,4	0,5	0,4	0,5	0	0	0,7	0,2	0	0,2	0,1	0
Tamarix sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,4
Taxodiaceae	8	1,1	0,2	0	0,5	0,9	0	1,3	0,2	0,4	0,3	1,5	0,5	1,4	0,4	0	0,7	0,7	1,4	1,3	1,4
Thalictrum sp. & Ranunculaceae	0	0	0,1	0	0,2	0,4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tilia sp.	0	0	0	0,3	0	0	0	0	0	0,6	0,5	0,7	0,7	0,3	0	0,9	0,2	0	0	0,2	1,4
Tricolporopollenites sibiricum Lubomirova	0	0,2	1,4	1,4	0	0,6	1,5	0,3	0	2,8	2,1	0,7	2,7	0,8	0,4	1,8	1,7	1,5	1,5	0,5	0
Tsuga sp.div.	2	1	1	0	1,3	2,1	4,1	3,3	2,8	4,3	3,7	1,1	0,7	0,7	1,2	1,4	0,9	2	0,9	3,4	0,4
Typha sp. & Typha/Sparganium	0	0,2	1,9	0	0,2	2,2	0	3,1	1,4	0,5	0,8	0,7	0,2	5,2	2	7,2	5	1,2	0,2	1,1	0,9
Ulmus sp.	2	12,9	12	15,7	12,4	7,2	13,2	19,4	19,7	8,3	13,1	20	27,3	19,1	29,8	20,9	16,4	15,7	18,5	10,7	3,6
Undeterminate polen	12	0,5	2,6	6,3	2	2,4	1,7	2,6	5,2	4,5	4,2	3,3	2	2,4	4,1	1,8	2,6	2,4	2,8	1,5	0
Urtica sp.	0	0	0,6	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0	0	0,1	0,5	0
Verrucatosporites	0	0	0	0	0,1	0	0	0	0	0	0	0	0,5	0,4	0	0,4	0,4	0,5	0	0,1	0
Viburnum sp.	0	2,2	2,3	0	0,7	0,1	0	0,4	0	0,9	0	0	0	0	0	0	0	0,4	0	0,4	0
Vitaceae	0	0,5	0	0	0,2	0,1	0	0	0	0	0	0	0	0	0	0,5	0,5	0	0	0	0
Zelkova sp.	0	2,9	3,4	0,6	2,7	2,3	2,6	3,9	2,2	8,8	3,1	3,7	4,7	5,4	3,3	2,3	1,4	1,7	4,7	3,7	0
Botryococcus sp. (Algae)	0	0	0	0	0	0,2	0	0	0	0	0	0	0	0,5	0	0	0	0	0	0	0
AP	100	98	93,6	97,5	96,5	93,6	98,7	97	95,6	94,5	86,9	94,1	95,1	87,2	96,3	90,8	89,1	95,6	95,9	95,6	45,8
NAP	0	2	6,4	2,5	3,5	6,4	1,3	3	4,4	5,5	13,1	5,9	4,9	12,8	3,7	9,2	10,9	4,4	4,1	4,4	54,2
Loc. el.	7,4	1,8	6,3	1,1	2,4	5,7	1,1	6,7	3,1	4,8	3,8	2,2	2,4	11,9	4,3	15,6	11,5	3,6	0,7	3,3	2,3
AP+NAP	50	938	957	363	817	1082	469	697	497	532	383	270	407	592	245	444	422	542	813	1046	224