# New pollen data for subdivision of the Late Miocene sediments from Karlovo Basin, Central Bulgaria

**Viktoria Hristova & Dimiter Ivanov**

Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Acad. Georgi Bonchev St., bl. 23, 1113 Sofia, Bulgaria, e-mail: viktoria_anguelova@abv.bg (corresponding author)

Received: December 06, 2012 ▹ Accepted: January 18, 2013

**Abstract.** A new palynological study of the sediments from two borehole drillings in the east of the Karlovo Basin has been carried out. The investigated materials originate from grey-bluish and grey-greenish clays, as well as from diatomaceous clays above the main coal horizon. The pollen zones have been established on the basis of well-marked changes in the proportion of main components of the pollen spectra supported by cluster analysis. They correspond to the vegetation dynamics, changes in the hydrological regime of the water basin and local climatic conditions, and could be regarded as regional character zones for the Karlovo Late Miocene Basin (Central Bulgaria). Thus the main trends in vegetation dynamics for the period are outlined. The new data obtained on palaeovegetation and floristic changes are discussed and compared with the earlier palynological studies of the western part of the basin.

**Key words:** Karlovo Basin, Late Miocene, palynology, pollen zones

## Introduction

The Karlovo Basin occupies an important place in the system of lake-swampy sedimentary complexes in the Balkan Peninsula that had existed in Bulgaria during the Neogene. The Basin borders on the Balkan Range in the north, Mt Sredna Gora in the south and Mt Strazha in the east (Fig. 1). This specific location determines its unique character. The sediments contain a rich assemblage of pollen and spores and permit reconstruction of the local and regional floras composition and character. Irrespective of this, paleobotanical data about the Karlovo Basin are extremely rare, due to a lack of natural outcrops in that area. The fossil macroflora in the region is not studied. Sediments from the boreholes C-525, C-551, C-552 and C-567 situated in the western part of the Basin (Ivanov & Slavomirova 2004; Ivanov 2009; Ivanov & al. 2010) were objects to palynological study. Scanty paleovegetation data

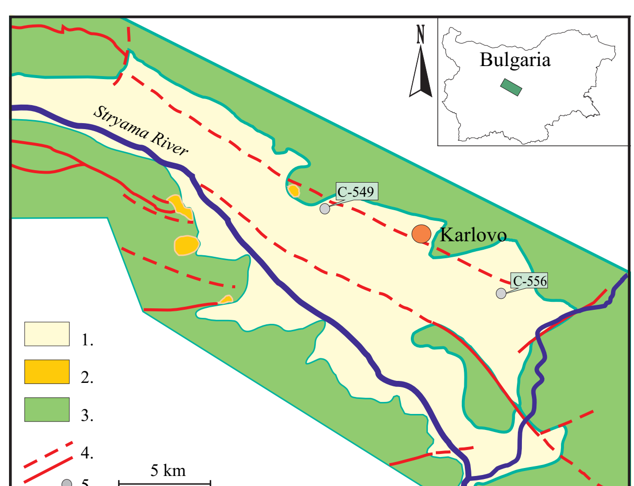


**Fig. 1.** Geological map of the Karlovo Basin (after Temniskova & Valeva 1996).
Legend: **1.** Pleistocene sediments cover; **2.** Karavelovo Formation; **3.** Pre-Neogene rocks; **4.** Faults; **5.** Investigated cores.

have been mentioned in some petrographic and geochemical studies of the lignite deposits in the area (Zdravkov & al. 2006; Stefanova & al. 2010). The objective of the present work is to use pollen data for reconstruction of the vegetation changes in the Karlovo Basin.

### Geology and paleogeography

Karlovo Basin is a graben structure of irregular triangular shape, 37 km long and 12–15 km wide (Fig. 1). It resulted from fault movements during the Late Miocene – Quaternary period. According to Angelova & al. (1991) and Ruseva & al. (1991), the Neogene sediments of the Karlovo Basin are divided into two formations and one member: Iganovo Formation with Moskovets Member and Karavelovo Formation (Fig. 1). On the basis of diatom analysis, Valeva & Temniskova-Topalova (1993) and Temniskova-Topalova & al. (1996) dated the Iganovo Formation and Moskovets Member back to the Late Miocene-Pliocene. Angelova & al. (1991) established an absolute age of 6.5 Ma for the base of Karlovo Graben, Late Pontian–Dacian for the Moskovets Member and Meotian-Pontian-Dacian age for the Iganovo Formation. The above-mentioned authors have dated the Karavelovo Formation to the Late Pliocene (Romanian) age on the basis of regional lithological correlations.

Angelova & al. (1991) regarded the formation of Karlovo Basin, probably at the end of the Meotian (6.5 Ma), as a result of rupturing processes and plate displacement. Temniskova-Topalova (1994) and Temniskova & al. (1996) described three trophic stages and outlined the periods of depth decrease of the Basin, accompanied by strong overgrowth and subsequent increase in water level. Sedimentation had begun with transition from the river delta to lake conditions and continued under lakes and lake-marsh conditions (Ivanov & al. 2010). The main lignite coal layer of the Moskovets Member was formed under the reotrophic conditions of a swamp basin (Zdravkov & al. 2006). During the peat accumulation process there was an open water area in the central part of the Basin, connected with the swamp. At the end of peat accumulation there was a period of drying up, followed by flooding of the marsh and sedimentation continued under the lake conditions (Zdravkov & al. 2006). The terrigenous sediments of Karavelovo Formation were deposited during the Pliocene (Angelova & al. 1991), probably in a drier climate. The modern morphological structure of the Karlovo Graben has shaped up approximately within the period 730 ka – 25 ka BP (Angelova & al. 1991).

## Material and methods

Our palynological study was based on a total of 59 samples coming from two cores, namely C-556 and C-549, located in the eastern part of the Karlovo Basin (Fig. 1). From C-556, 24 samples were processed within the range from 66.00 m to 70.50 m (at every 0.5 m). From C-549, 21 samples were processed within the range of 125.00–145.00 m (at every 1.00 m), of which seven samples (123.0, 124.0, 127.0, 135.0, 136.0, 137.0 and 141.0 m) were poor in fossil pollen and spores content.

The investigated materials were treated by standard methods for disintegration of the Neogene sediments, including with hydrochloric acid, hydrogen fluoride, potassium base and heavy liquid separation (Fægri & Iversen 1975).

Frequency of the fossil pollen and spores is presented as percentage of the pollen sum (ΣP), which includes the sum of tree and shrub taxa (AP) and of herbaceous taxa (NAP): $\Sigma P = AP + NAP = 100\,\%$. The percentage participation of local elements is calculated from the total pollen sum: $AP + NAP + L = 100\,\%$, where L includes plants, fern spores and pollen of aquatic vegetation. Participation rates of the algae (F) were calculated from the total pollen sum: $AP + NAP + L + F = 100\,\%$.

The results of pollen analysis are presented in the percentage pollen diagrams. Computer and statistical processing of data from the analysis and construction of diagrams employed TILIA 2.0.b.4 and TGView 2.0.2 software (Grimm 2004).

On the basis of the characteristic changes in percentage participation of the main pollen types in pollen spectra, local pollen zones (LPZ) have been separated for each section of the Basin with the help of cluster analysis. They are indexed in the pollen diagram alphanumerically (Figs 2, 3). Differentiation of pollen zones is based on sediments with specific fossil content (characteristic pollen complexes, type and frequency of palynomorphs) that distinguish them from their neighbours (Gordon & Birks 1972). The boundaries of the zones are defined by the characteristic changes in individual curves of the identified pollen types (Moore & al. 1991). Thus the differentiated biostratigraphic units represented assemblage zones (coenozones). A method of numerical zonation of pollen diagrams (Birks 1974; Birks & Birks 2006) was used to separate the zones. The obtained palynological data were grouped using cluster analysis. Cluster analysis was performed with the CONISS software (Grimm 1987). Square Root Transformation (Edwards and Cavalli-Sforza's chord distance) was applied to assess the degree of similarity between the compared pollen spectra, and the total quadratic deviation was used as distance measure. The result of cluster analysis is presented as a dendrogram and graphic depiction of the pollen diagram.

## Results

### Core C-556 (Fig. 2)

Local pollen zone KAR 556-1 (75.4–72.0 m)
*Alnus – Pinus – Taxodioideae*
Stratigraphic range: Late Miocene

This zone reflects the high participation of representatives of *Alnus* (up to 24.1%) and *Taxodioideae* (up to 12.0%). Other components of the hygrophytic palaeocenoses are represented by *Glyptostrobus* (0.2–3.0%), *Nyssa* (0.4–3.2%), *Myrica* (up to 1.9%), *Laevigatosporites* (up to 4.0%), and *Osmunda* (up to 2.0%). The pollen spectra from this zone registered the following participation: *Quercus* (3.5–13.6%), *Ulmus* (0.5–9.5%), *Carya* (1.6–7.6%), *Fagus* (3.3–7.4%), *Betula* (up to 2.5%), *Pterocarya* (up to 2.3%), *Juglans* (up to 1.5%), *Corylus* (up to 1.2%), and *Acer* (1.0%). Presence of warm temperate and thermophillous taxa of the genera *Eucommia* (up to 1.8%), *Engelhardia* (up to 0.5%), *Reevesia* (up to 0.5%), *Platycarya* (up to 0.2%), and *Ilex* (up to 0.2%) was registered in some pollen spectra. The highest values in this part of the profile belonged to *Cupressaceae* (up to 4.7%), *Tsuga heterophylla* type (up to 3.5%), *Ericaceae* (up to 1.8%), and *Sequoia* (up to 1.6%). The pollen of the *Pinus diploxylon* type was registered with values between 3.5% and 34%.

Herbaceous vegetation was represented by the species of *Poaceae* (up to 9.0%), *Chenopodiaceae* (up to 8.6%), *Artemisia* (up to 10.0%), *Apiaceae* (up to 1.3%), and *Asteroideae* (up to 0.9%).

Local pollen zone KAR 556-2 (71.9–66.0 m)
*Poaceae – Carya – Quercus*
Stratigraphic range: Late Miocene

This zone is characterized by widespread herbaceous vegetation (NAP up to 43.6%). *Poaceae* (2.8–25.1%) and *Chenopodiaceae* (0.4–10.7%) dominated the pollen spectra. *Artemisia* (up to 8.4%), *Asteroideae* (up to 2.0%), *Polygonum* (up to 1.2%), *Caryophyllaceae* (up to 0.9%), *Cichorioideae* (up to 0.7%), *Rosaceae* (up to 0.6%), and *Lamiaceae* (up to 0.2%) were also abundant. The percentage participation of *Alnus* was reduced and varied up to 35.6%, as well as that of Taxodioideae (2.5–9.6%), *Glyptostrobus* (up to 1.6%) and *Tsuga heterophylla* type (up to 1.1%).

The pollen curve of *Quercus* has shown values between 3.4–12.5%. The representatives of *Ulmus* (up to 15.1%) and *Carpinus orientalis/Ostrya* type (up to 11.5%) were registered with higher percentage. The pollen of *Carya* has reached the maximum of 16.3% (depth 67.5 m). The percentage of *Pterocarya* and *Juglans* increased up to 2.5%. The values of *Pinus diploxylon* type varied between 1.1–23.8%, with a peak of 51.7% (70.2 m). *Picea* (up to 1.3%), *Cedrus* (up to 0.9%), *Abies* (up to 0.7%), and *Podocarpus* (up to 0.4%) have been observed too. The xerophytic spieces of *Buxus* (up to 4.7%), *Oleaceae* (up to 3.6%), *Celtis* (up to 3.2%), and *Rhus* (up to 0.4%) have been found in this zone.

### Core C-549 (Fig. 3)

Local pollen subzone KAR 549-1A (145.0–137.5 m)
*Alnus – Taxodioideae – Quercus*
Stratigraphic range: Late Miocene

This subzone is characterized by high values of the representatives of *Taxodioideae* (up to 3%) and *Alnus* (0.3–12.5%). Significantly involved in the pollen spectra were the representatives of genus *Quercus* (2–4.9%). High pollen percentage was noted for the *P. diploxylon* type, between 1.3–32%. *Fagus* (0.4–4.4%), *Carya* (1.2–3.8%), *Nyssa* (up 2.1%), *Myrica* (up 1.8%), *C. orientalis/Ostrya* type (0.4–2.6%), and *Juglans* (0.1–1%) were also present. The herbaceous vegetation values varied between 2.8% and 12.3%. It was represented by the species of *Poaceae* (1.7–9.5%), *Chenopodiaceae* (0.5–2.6%), *Artemisia* (0.2–1.9%), *Apiaceae* (up to 1.4%), and *Thalictrum* (up to 0.4%), as well as by the spores of *Laevigatosporites* (up to 1.4%).

Local pollen subzone KAR 549-1B (137.0–125.0 м)
*Poaceae – Chenopodiaceae – Carya*
Stratigraphic range: Late Miocene

This subzone is characterized by a relatively higher proportion of NAP (up to 15.8%). Herbaceous vegetation was dominated by *Poaceae* (2.1–13.7%), *Chenopodiaceae* (0.1–2.4%) and *Artemisia* (up to 0.5%), as well as by *Apiaceae* (up to 1.1%), *Asteroideae* (up to 0.2%), *Thalictrum* (up to 0.3%), and *Caryophyllaceae* (up to 0.1%). In this zone, a reduced *Alnus* pollen proportion (up to 1.3%) and a slight increase of *Taxodioideae* (up to 5.4%) was observed, as compared


**Fig. 2.** Percentage spore-pollen diagram of the core C-556 (Karlovo Basin) with exaggerated factor 10.

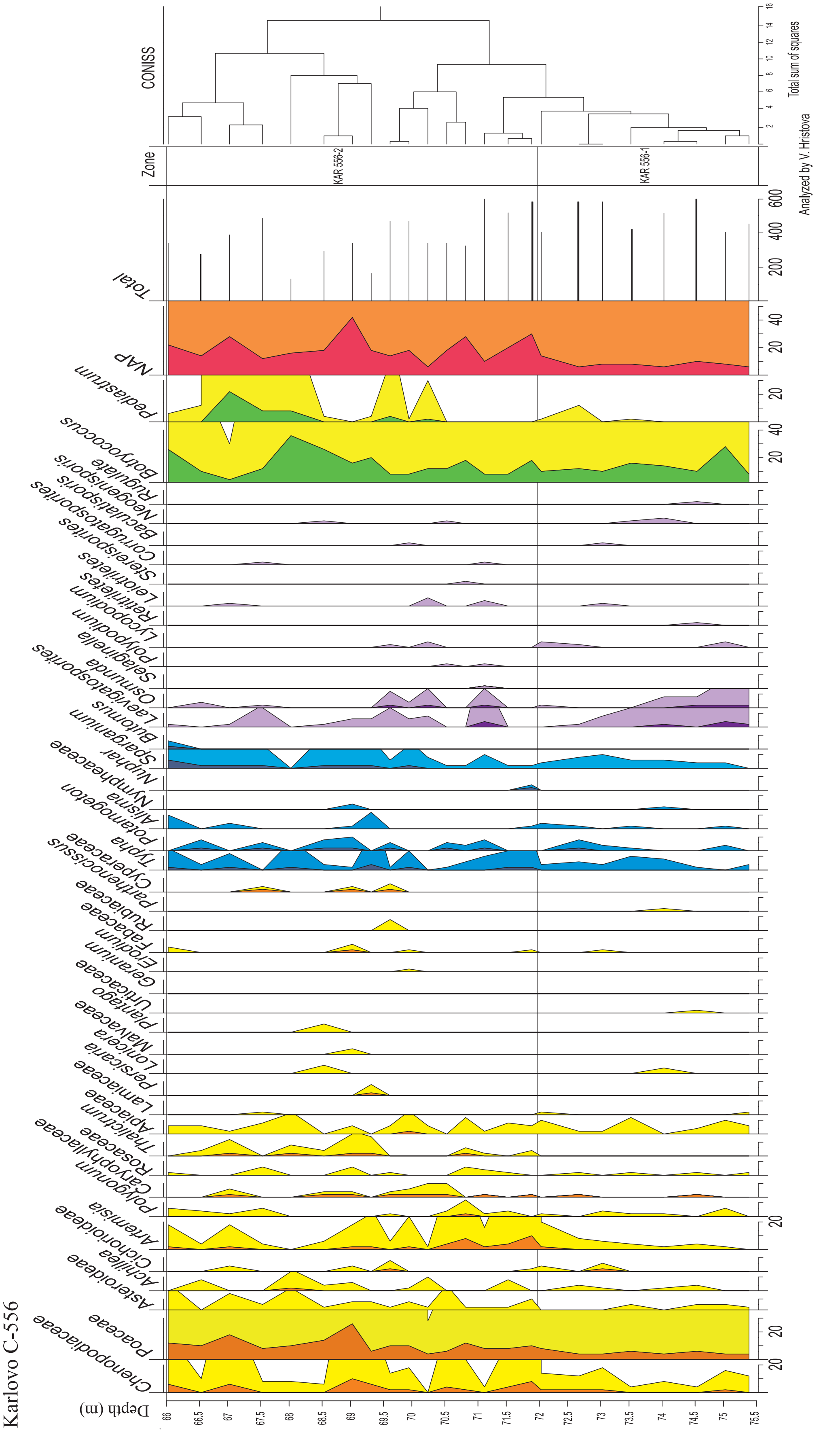


**Fig. 2a.** Percentage spore-pollen diagram of the core C-556 (Karlovo Basin) with exaggerated factor 10 (continuation).

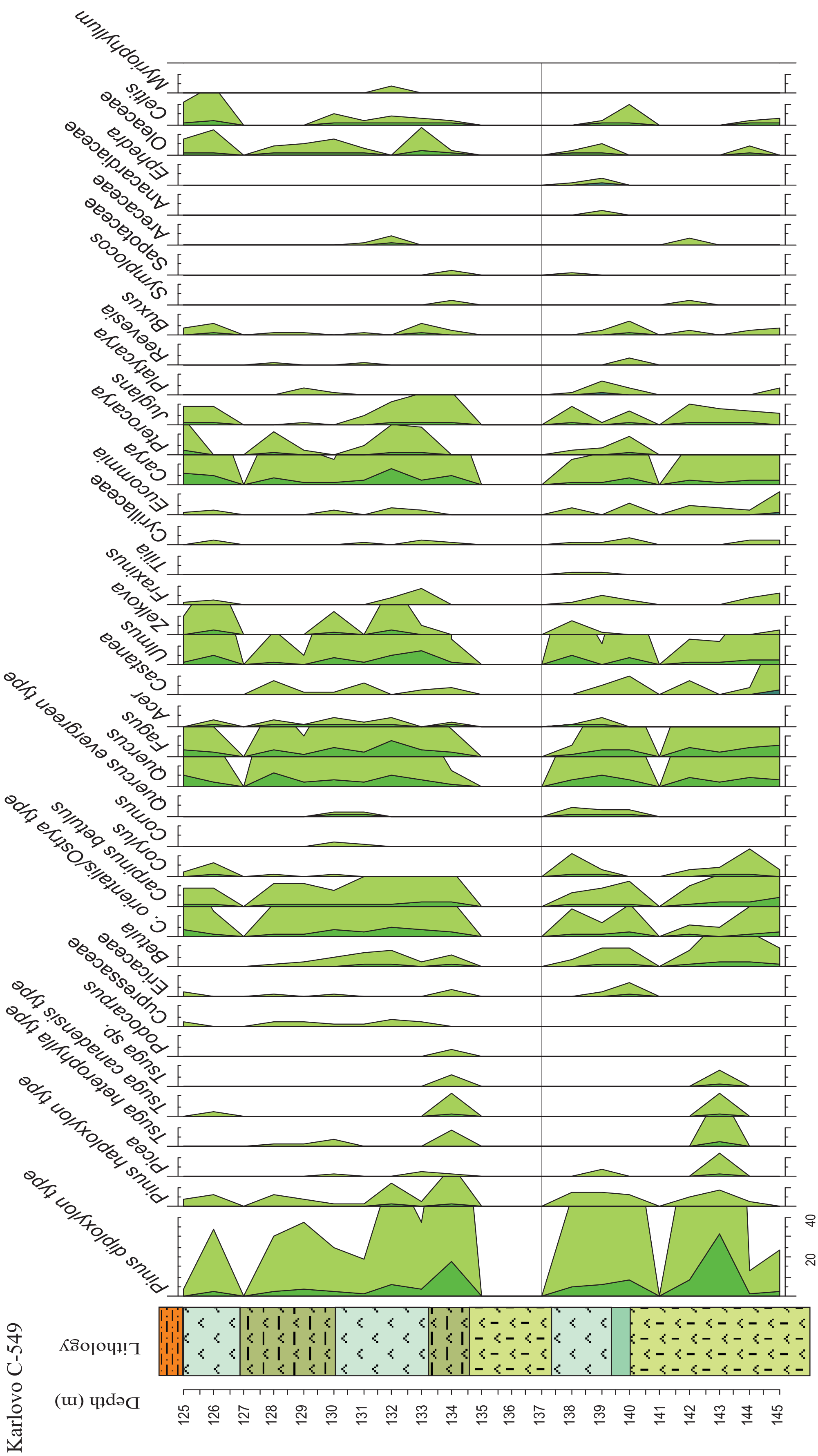


**Fig. 3.** Percentage spore-pollen diagram of the core C-549 (Karlovo Basin) with exaggerated factor 10.

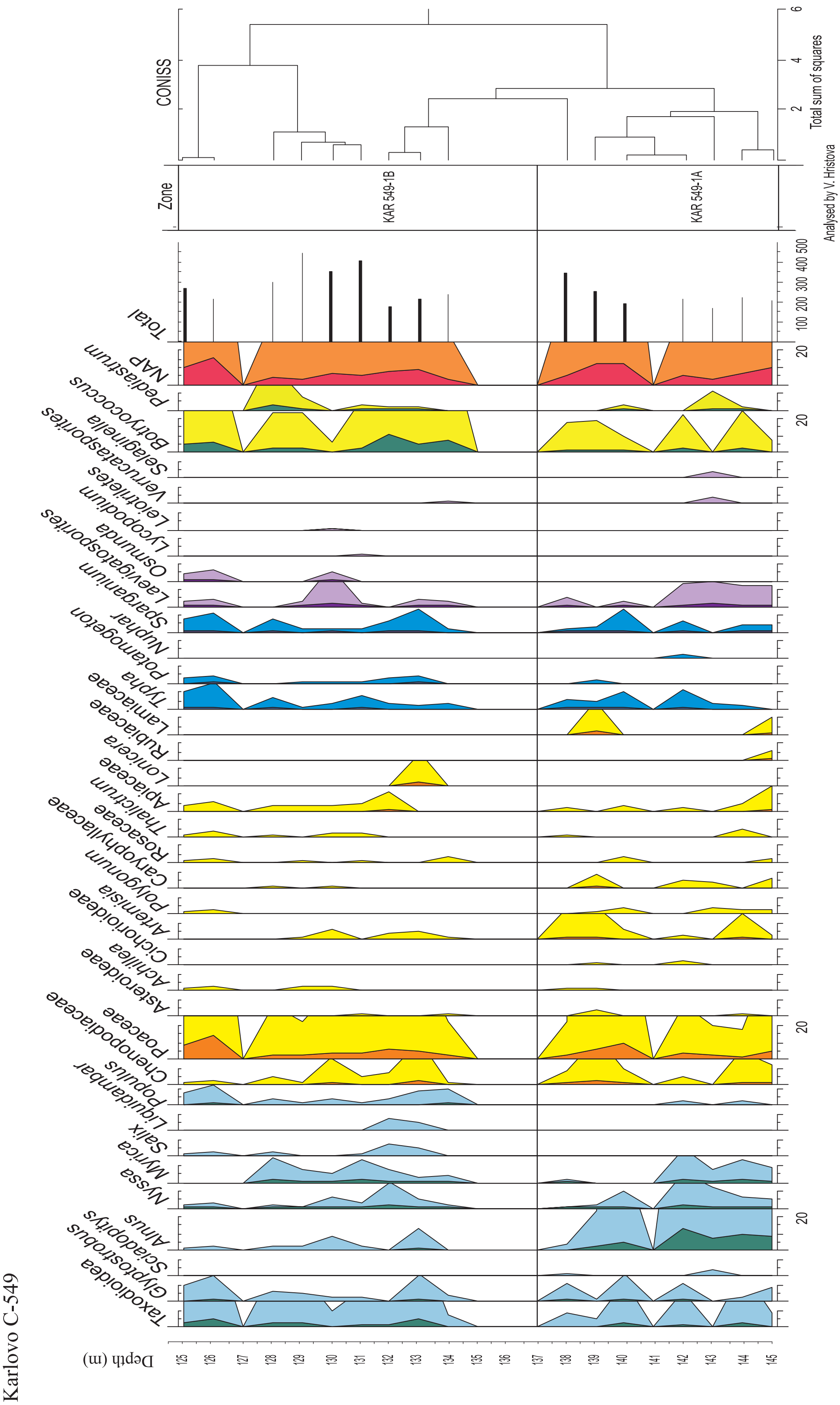


**Fig. 3a.** Percentage spore-pollen diagram of the core C-549 (Karlovo Basin) with exaggerated factor 10 (continuation).

to LPZ KAR 549–1. The quantitative contribution of *Quercus* was also lower and varied between 0.7–6.1 %. The *Pinus diploxylon* type (0.3–17.4 %) was registered in the lower part of the subzone. Higher values were indicated by the representatives of *Ulmus* (0.5–6.9 %), *Carya* (1.2–8 %), *Fagus* (1–7.2 %), *Carpinus orientalis/Ostrya* type (1.2–4.5 %), and *Carpinus betulus* (0.8–1.7 %). The pollen curves of *Nyssa* and *Glyptostrobus* reflected constant values. Thermophillous plants from the genera *Platycarya* (up to 0.2 %), *Reevesia* (up to 0.1 %) and *Engelhardia* (up to 0.1 %) participated in some pollen spectra from this part of the profile. Some xerophytic elements like *Celtis* (up to 1.8 %), *Oleaceae* (up to 1.3 %) and *Buxus* (up to 0.6 %) occurred too. The spores of *Laevigatosporites* (up to 2.3 %) registered higher values.

## Discussion

In the lower part of the boreholes reflected in **LPZ KAR 556-1, LPZ KAR 549-1A** and **LPZ KAR 549-1B** (Fig. 2, 3), the major role was assigned to representatives of the mixed mesophytic forest elements composed of *Quercus*, *Ulmus*, *Carya*, *Fagus*, *Betula*, *Pterocarya*, *Juglans*, *Corylus,* and *Acer*. They were widespread in the area of the Karlovo Basin, as evidenced by their high values in the pollen spectra. The species of *Pinus*, *Tsuga*, *Cupressaceae*, *Sequoia,* and *Picea* were subdominantly involved. *Cathaya* was present, whose modern living relative is common in the subtropical forests of South China (Jimenez-Moreno & al. 2005). The high levels of pollen of the *Pinus diploxylon* type in the pollen spectra are presumably due to the saccate pollen capacity for long-distance transport (Suc & Drivaliari 1991). A comparison with the established pollen complexes in the western part of the basin (Ivanov 2009; Ivanov & al. 2010) has shown that *Cunninghamia* and *Larix also* participated in these communities. *Alnus*, *Taxodioideae*, *Glyptostrobus*, *Nyssa,* and *Myrica*, were recorded with high levels in the pollen spectra, accompanied by *Laevigatosporites* and *Osmunda*. Of the forest species in the composition, *Alnus* dominated. The representatives of *Laevigatosporites* and *Osmunda* were a major component of the peat-forming vegetation. The presence of some thermophillous representatives of the genera *Eucommia*, *Engelhardia*, *Reevesia*, *Platycarya,* and *Ilex* give rise to assumptions that the climate at the beginning of the studied period was warm and with high air humidity.

The sediments of **LPZ KAR 556-2** (Fig. 2) have shown a decrease in the percentage contribution of pollen from tree and shrub species (AP to 56.4 %). Along with this, high values of the herbaceous vegetation were recorded. The NAP has reached 43.6 %, with *Poaceae*, *Chenopodiaceae*, *Artemisia*, *Asteroideae*, *Polygonum*, *Caryophyllaceae*, *Cichorioideae*, *Apiaceae*, *Rosaceae*, and *Lamiaceae*. The presence of *Chenopodiaceae* pollen in all samples from this zone (10.1 % at 69.0 m; 6.8 % at 67.0 m) indicates a phase with lower rainfalls and probably lower temperatures. An increase in the participation of xerophytic elements, such as *Celtis*, *Ephedra*, *Oleaceae*, *Rhus*, and *Quercus ilex* type in these sediments is associated also with lower rainfalls. The presence of *Ephedra* in LPZ KAR 556–2 is indicative of relatively dry weather conditions. Of the mesophytic forest communities, with constant values have remained the representatives of *Quercus* and *Castanea*. Along with this, the participation of *Fagus*, *Carya*, *Pterocarya,* and *Juglans* genera has increased.

Palynological data suggest a greater involvement of the fern vegetation of *Baculatisporites*, *Leiotriletes* and *Corrugatosporites* in the spectra at the bottom of the zone (at 70.5 m).

A comparison of the new palynological data from the western part of Karlovo Basin with pollen zonation made by Ivanov & al. (2010) (Fig. 4) has shown the following: pollen zones KAR 556-1, KAR 549-1A and KAR 549-1B correlate with the group of LPZ Kar 551-2, LPZ Kar 525-2, LPZ Kar 552-2, and LPZ Kar 567-2, with significant abundance of *P. diploxylon*, *Taxodioideae* and *Alnus*. They correspond to the period of development of vegetation after increase of the water level in the Basin and restoration of lake conditions. Pollen zone KAR 556-2 has many similarities with the group of LPZ Kar 551-3, LPZ Kar 552-3, and LPZ Kar 567-3. There was registered the same presence of *Quercus*, *Carya* and high values of NAP (Fig. 4). In KAR 556-2, the pollen spectra of herbs have been present up to 43.6 %. These data correspond to the high NAP values established in the west part of the Basin, where NAP reaches 48 % (Ivanov & Slavomirova 2004). An increase of herbaceous elements was noted in the Late Miocene sediments of the Stanyantsi and Tundzha Basins (Ivanov & al. 2007; Ivanov & al. 2008; Utescher & al. 2009). In the pollen spectra from the Sofia Basin (Late Miocene), herbaceous vegetation has reached 23.5 % (Hristova & Ivanov 2009 a, b).

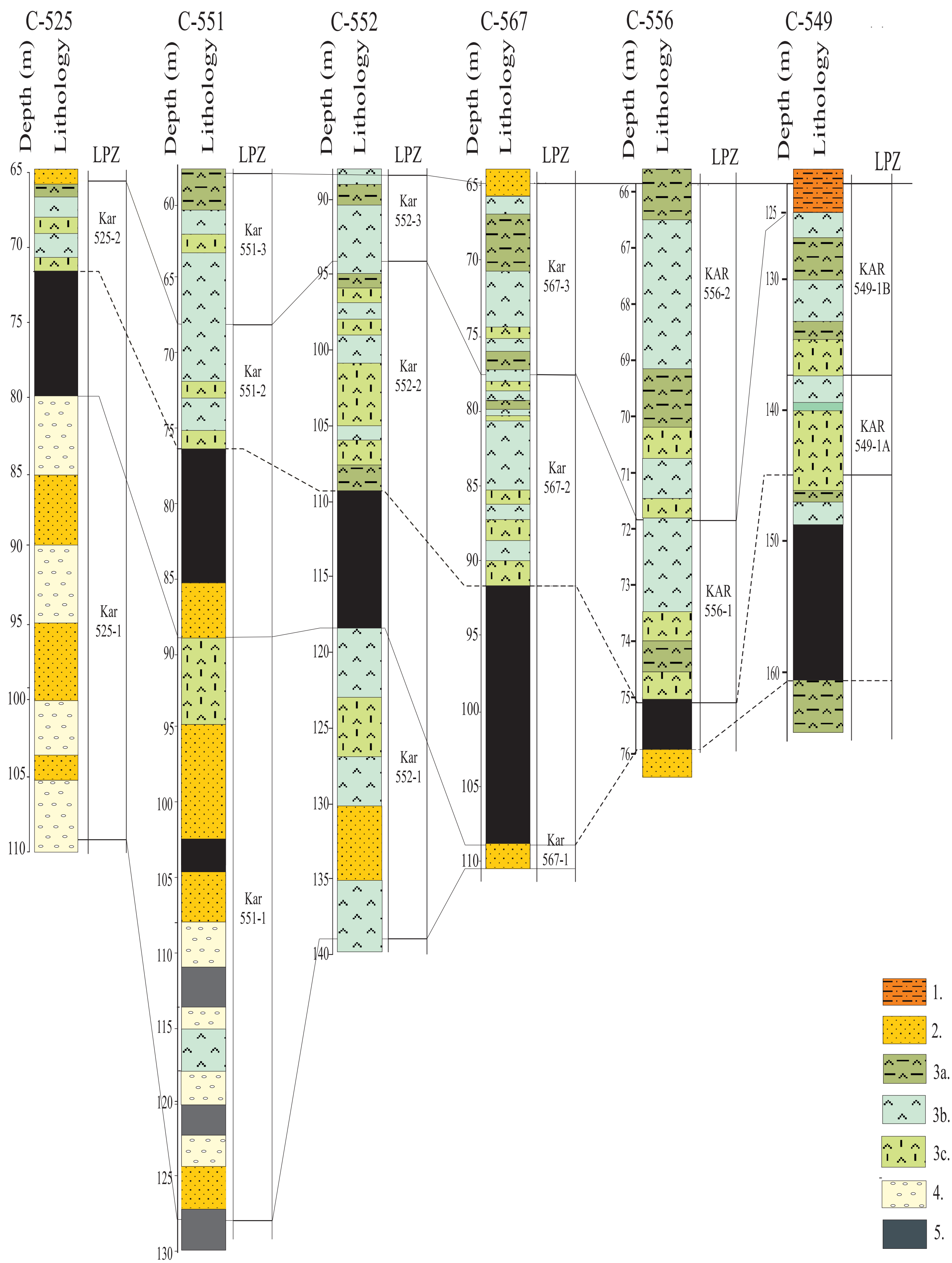


**Fig. 4.** Correlations between the Local Pollen Zones in the investigated cores from Karlovo Basin (after Ivanov & al. 2010). Legend: **1.** sandy clays; **2.** sands; **3.** diatomic layers with following genera: **3a** – *Fragilaria*; **3b** – *Aulacosira*; **3c** – *Actinocyclus*; **4.** – silts; **5.** – lignite coal.

## Conclusion

A new palynological study of sediments from two boreholes drilled in the eastern part of the Basin has been carried out. The main trends in vegetation dynamics in the Late Miocene time interval are outlined on the basis of pollen data. Two phases can be distinguished during sedimentation.

A wide distribution of mixed mesophytic forests composed of *Quercus*, *Ulmus*, *Carya*, *Fagus*, *Betula*, *Pterocarya*, *Juglans*, *Corylus*, and *Acer* species was registered at the beginning of the investigated period. Sediments of that time period reflected higher quantitative values of hygrophytic forest components: *Taxodioideae*, *Alnus*, *Glyptostrobus*, *Nyssa*, *Myrica*, *Salix*, *Liquidambar* and *Osmunda*. A decline in the percentage contribution of pollen from tree and shrub species was observed in the palaeoflora from the end of the period. Along with this, an increase of herbaceous elements was recorded (*Artemisia*, *Poaceae*, *Chenopodiaceae*, *Asteroideae*, *Polygonum*, *Caryophyllaceae*, *Cichorioideae*, *Apiaceae*, *Rosaceae* and *Lamiaceae*).

**Acknowledgements.** This work is a contribution to the project DNTS/Slovakia 01/7, NSF, Bulgaria/*SRDA SK-BG-0033-10,* Slovak Republic and to the international research program "*Neogene Climate Evolution in Eurasia* – NECLIME".

## References

**Angelova, D., Russeva, M. & Tzankov, T.** 1991. On the structure and evolution of Karlovo Graben. – Geotekton. Tektonofiz. Geodinam., **23**: 26-46 (in Bulgarian).

**Grimm, E.** 1987. CONISS: a Fortran 77 program for stratigraphically constrained cluster analyses by the method of incremental sum of squares. – Computers & Geosciences, **13**: 13-35.

**Grimm, E.** 2004. TG View 2.0.2 (software). Illinois State Museum, Springfield, Illinois, USA.

**Gordon, A. & Briks, H.J.B**. 1972. Numerical methods in Quaternary palaeoecology. I. Zonation of pollen diagrams. – New Phytol., **71**(5): 961-979.

**Hristova, V. & Ivanov, D.** 2009a. Palynological data of the fossil flora from Sofia Neogene Basin (Southwest Bulgaria). Preliminary results. – Dokl. Bulg. Akad. Nauk, **62**(3): 379-384.

**Hristova, V., Ivanov, D.** 2009b. Palynological analysis of the Late Miocene sediments from the Sofia Basin (SW Bulgaria). – Phytol. Balcan., **15**(3), 305-315.

**Ivanov, D.** 2009. Vegetation and climate dynamics in Bulgaria during the Middle and Late Miocene (based on palynological data). DSc Thesis, Inst. Botany, Bulg. Acad. Sci., Sofia (in Bulgarian).

**Ivanov, D. & Slavomirova, E.** 2004. Palynological data on the Late Neogene vegetation from Karlovo Basin (Bulgaria). First results. – Dokl. Bulg. Akad. Nauk, **57**(11): 65-70.

**Ivanov, D., Bozukov, V. & Koleva-Rekalova, E.** 2007. Late Miocene flora from SE Bulgaria: vegetation, landscape and climate reconstruction.– Phytol. Balcan., **13**: 281-292.

**Ivanov, D., Djorgova, N. & Slavomirova, E.** 2010. Palynological subdivision of Late Miocene sediments from Karlovo Basin (Central Bulgaria). – Phytol. Balcan., **16**(1): 23-42.

**Ivanov, D., Utescher, T., Ashraf, A., Mosbrugger, V., Slavomirova, E., Djorgova, N. & Bozukov, V.** 2008. Vegetation structure and dynamics in the Late Miocene of Staniantsi Basin (West Bulgaria). First results. – Dokl. Bulg. Akad. Nauk, **61**(2): 223-232.

**Fægri, K. & Iversen, J.,** 1975. Textbook of Pollen Analysis, 3rd ed. Munksgaard, Copenhagen.

**Russeva, M., Angelova, D. & Tsankov, Ts.** 1991. Geological Map of Bulgaria on Scale 1:100000. Karlovo Sheet. Komitet Geol. Miner. Resursi, Geol. Geophiz. AD, Sofia (in Bulgarian).

**Moore, P., Webb, J. & Collinson, M.** 1991. Pollen Analysis. 2nd ed. Blackwell Sci. Publ., London.

**Stefanova, M., Marinov, S., Zdravkov, A. & Kortenski, J.** 2010. Palaeoenvironmental reconstruction and climate change in Southeast Europe (Neogene Karlovo lignites, Central Bulgaria). – Geol. Balcan., **39**(1-2): 374.

**Suc, J.-P. & Drivaliari, A.** 1991. Transport of bisaccate coniferous fossil pollen grains to coastal sediments: an example from the earliest Pliocene Orb Ria (Languedoc, Southern France). – Rev. Palaeobot. Palynol., **70**(3): 247-253.

**Temniskova-Topalova, D.** 1994. Miocene diatomaceous floras in Bulgaria – composition, structure, evolution and biostratigraphy. – Autoref. DSc Thesis, Sofia Univ., 68 p.

**Temniskova, D., Ognjanova, N. & Popova, E.** 1996. Diatom analysis of the Neogene sediments from the Karlovo Coal Basin (South Bulgaria). II. Stratigraphy and palaeoecology based on siliceous microfossils. – Phytol. Balcan., **2**: 14-28.

**Valeva, M. & Temniskova-Topalova, D.** 1993. Diatom analysis of Neogene sediments from the Karlovo Coal Basin I. – Fitologiya, **46**: 67-84.

**Utescher, T., Ivanov, D., Harzhauser, M., Bozukov, V., Ashraf, A.R. & Mosbrugger, V.** 2009. Cyclic climate and vegetation change in the Late Miocene of West Bulgaria. – Palaeogeogr. Palaeoclimatol. Palaeoecol., **272**: 99-114.

**Zdravkov, A., Kostova, I., Sachsenhofer, R.F. & Kortenski, J.** 2006. Reconstruction of paleoenvironment during coal deposition in the Neogene Karlovo Graben, Bulgaria. – Int. J. Coal Geol., **67**: 79-94.