PANNONIAN VEGETATION FROM THE NORTHERN PART OF VIENNA BASIN

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Abstract. The studied pollen assemblages come from the Pannonian (Tortonian and Early Messinian) sediments in the Moravian and Slovak part of the Vienna Basin. Vienna Basin represents a pull-apart basin situated between the Eastern Alps and Western Carpathian mountain ranges. Due to the paleogeographic changes and climatic oscillations during the Late Miocene, the number of thermophilous taxa decreased, and some of them disappeared completely. The variable heights and forms of the uplifted mountain chains created ideal conditions for mixed mesophytic forests and extrazonal vegetation (*Cedrus, Tsuga, Picea*). The swamp, riparian, often hydrophilous (*Azolla*, *Nymphaea*, *Potamogeton*) and halophyte (Chenopodiaceae) plants represent coastal swamps, local lagoons, and marshlands. Occasional occurrences of dinoflagellates indicate slightly higher salinities, whereas green algae of the genus *Pediastrum* represent freshwater environments. The amount of herbaceous plants (*Artemisia*, Asteraceae, Lamiaceae, *Polygonum*, Daucaceae, Caryophyllaceae, *Plantago)* increased.

■ Late Miocene, Palynology, Vienna Basin, Paleoclimate.

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Geology

Important changes in the paleogeography of the Western Carpathians can be documented during the Late Miocene. The basins represent grabens or half grabens; partly “pull apart“ basins along strike slipe zones, but mostly flexural type basins without apparent brittle tectonics, except for normal faults at the basins´ margins (Kováč 2000).

The Vienna Basin is situated within the Alpine-Carpathian mountain chain, between the Eastern Alps and the Western Carpathians. It represents a polyhistoric basin with Neogene to Quaternary sedimentary fill, deposited in various types of basins in relation to the paleotectonic development of the orogen. During the Late Miocene, due to paleogeographic changes, the connection with the Pannonian basin became gradually closed. Lake Pannon retreated southwards, and the northern coast of the back-arc basin was slightly elevated due to progradation of deltaic and alluvial facies, especially in the lowlands. Lake Pannon was continuously filled by sediments transported by rivers from uplifting mountain chains. The sedimentary environments changed from deep to shallow lake and deltaic environment, followed by development of alluvial plains. Due to Paratethys isolation, the salinity decrease led to the development of a totally fresh-water environment by the end of this period. (Kováč et al. 1998).

Material and methods

All the studied samples were pelitic, partly calcareous sediments. The lignite layers have not been used in these studies.

The pollen data come from the well-preserved and well-determined plant macrofossil samples of the E. Knobloch collection deposited in the Moravian Museum Brno, (Poštorná, Dubňany, Moravská Nová Ves surface localities – 13 samples), claypit Gbely, deep boreholes (Suchohrad 32, Suchohrad 38, Jakubov 54 – 30 samples), and six shallow boreholes (28 samples) made by the interdisciplinary research programme (archeology, natural environment) of the Masaryk University Brno at the Slavic (Great Moravian) settlement Pohansko near Břeclav.

For maceration of the samples, HCl, HF and heavy liquid $ZnCl_2$ were used. Pure glycerine or glycerine gels were used mostly as the observation media.

The coexistence approach is an efficient and reliable method for quantitative terrestrial palaeoclimate reconstructions in the Tertiary. It is based on the assumption that Tertiary plant taxa have similar climatic requirements to their nearest living relatives. The aim of the coexistence approach is to find for a given fossil flora, the climatic interval in which all the nearest living relatives of the fossil flora can coexist (Mosbrugger and Utescher 1997).

Vegetation and climate

Detailed palaeontological study of the Late Miocene sediments of the Vienna Basin were realized by Bůžek (1962) at the locality of Poštorná. At different localities, systematic macrofloristic studies were carried out by Knobloch (1962, 1963, 1968, 1969, 1972, 1981, 1985). In these studies Knobloch categorised the Pannonian and Pontian vegetation of this area into the four different mutually associated floristic biotopes – 1.vegetation of the open water level (*Azolla*, *Nymphaea*, *Trapa*, *Potamogeton, Ceratophyllum*) 2. coastal and coastal rim plants (*Carex*, *Scirpus*, *Phragmites*, *Sparganium*) 3. plants associated with brown coal swamp forest (*Glyptostrobus*, *Nyssa*, *Alnus*, *Byttneriophyllum*, *Myrica*, *Acer*), and 4. vegetation growing on the moist inner land stands (*Carpinus*, *Betula*, *Fagus, Liquidambar*, *Ulmus*, *Platanus*)

At the Poštorná locality, Gabrielová (1966) interpreted a marshy environment during the Pannonian based on the pollen data from the coal seam. Kalvoda (1979), Lázničková (2006) and Doláková et al. (2006) identified many herbaceous taxa. Konzalová (2005) carried out a detailed palynological study of the Pannonian palynospectra. She documented an aquatic environment with a mix of freshwater and brackish plankton, coastal herbaceous plants, swamp and riparian forest, mixed mesophytic forest, and extrazonal vegetation. In the studied samples she found an absence of *Myrica* compensated for by water plants frequently showing higher inundation.

Based on the previously published research and our new pollen data, it was possible to characterize vegetation assemblages and climate during the Pannonian.

Due to paleogeographical changes and climatic oscillations, the number of thermophilous taxa decreased during this time span, and some of them disappeared completely from this area (e. g. Sapotaceae, Palmae). Mostly broad-leaved deciduous elements of warm – temperate mixed mesophytic forests such as *Quercus*, *Celtis*, *Carya*, *Tilia*, *Zelkova*, *Ostrya*, *Liquidambar*, *Carpinus, Betula, Juglans* dominate generally (Pl.1, figs 2, 10-14). Thermophilous elements and mixtures of *Engelhardia*, evergreen Fagaceae morphospecies *Quercoidites microhenrici,* and less frequently *Quercoidites henrici*, *Trigonobalanopsis*, *Symplocos, Cornaceaepollis satzveyensis*, T*ricolpopollenites liblarensis* up to a maximum of 25 % were present (Pl I., figs 5-9).

The various heights and forms of the uplifted mountain chains created ideal conditions for a higher presence of extrazonal vegetation (*Cedrus, Tsuga, Picea, Cathaya*) (Pl.1, figs 15,16) in the investigated area. Nevertheless, according to Ferguson et al. (1998) *Cathaya* which grows nowadays at high altitudes, was adapted in the Miocene to the lower ground conditions with enough air humidity. The sharply demarcated facies changing both in time and space in their individual pollen spectra were created by intrazonal types of vegetation or by high amounts of herbaceous plants. They included marshes and coastal swamps with Taxodiaceae, *Nyssa,* and bush woods with *Myrica. Ilex* and *Sciadopitys* replenished the plant spectra in the floodplain lowlands. The prevailing vegetation types were often riparian forests with *Alnus* (up to 20%, often 4-porate pollen grains), *Salix*, *Pterocarya*, *Liquidambar*, *Betula* (up to 14%), *Fraxinus, Platanus* (Pl.1, figs 1-3). Polypodiaceae, *Osmunda,* and some thermophile ferns (Lygodiaceae) occured in the moist and shady places. Shrubs and lianas such as *Buxus*, *Ephedra*, Ericaceae, Vitaceae, *Lonicera*, Rosaceae type *Rubus* (Pl. 3, figs 15,16) occurred on drier substrates in the associated riparian forests. Accumulations of Chenopodiaceae in the interfluvial areas probably indicate local saline swampy environments during falls in sea level. The increased amounts of herbs (up to 30% in pollen spectra) indicate the existence of local open places such as wet meadows (*Thalictrum*, *Rumex*, *Valeriana*, Dipsacaceae, Lamiaceae, *Galium*) or areas which were never inundated (*Artemisia* – up to 17%, Asteraceae, *Campanula*, Fabaceae, Daucaceae, Caryophyllaceae, *Plantago* – Pl. 3). Poaceae could even have been components of the associations forming the undergrowth of the forest margin.

Aquatic plants created belts in shallow waters (*Nelumbo*, *Nymphaea*, *Myriophyllum*, *Sparganium*, *Potamogeton* – Pl. 2.), and along the water/land boundaries (*Decodon*, *Polygonum persicaria*, *Caltha*, *Valeriana* – Pl. 3). Very interesting findings are represented by microsporangia – massulae (within small circled microspores) with very characteristic glochidia of the freshwater fern *Azolla bohemica* (Pl. 2) described by Pacltová (1958). Isolated glochidia, found separately, were also frequent. According to Knobloch (1981) this genus occurs in eutrophic waters today. Due to the absence of glochidia, part of microsporangia is indistinguishable from the genus *Salvinia.* Similar results were published by Konzalová (2005) from the locality of Poštorná near Pohansko. Knobloch (1981) identified seeds and fruits of both mentioned taxa at Pannonian – Pontian localities within this area (*Azolla* – Dubňany, Čáry, and *Salvinia* – Ořechov-Mistřín).

Occasional occurences of dinoflagellates and green algae Tasmanaceae indicate a slightly higher salinity, *Botryococcus* can thrive in both brackish or freshwater environments, whereas green algae *Pediastrum*, *Mougeotia,* aquatic ferns *Azolla,* and aquatic and coastal plants (*Nelumbo*, *Nymphaea*, *Myriophyllum*, *Sparganium*, *Potamogeton* etc.) represent freshwater environments.

The noticeable *Pediastrum* cenobia belong predominantly to the species *P. simplex* and *P. boryanum* which are typical for open waters of eu- to mesotrophic conditions (Komárek and Jankovská 2001, Miola et al. 2006, Zetter 1987). The non-pollen palynomorph *Sigmopollis* occurred commonly. This morphotype is very similar to the Quaternary type 128 after Van Geel et al. (1983). In our samples it was often accompanied by type 74 as referred to by the same authors. Both these types possibly pertain to algal palynomorphs according to Van Geel et al. (1983), and Miola et al. (2006), indicating open water environments in eu-/mesotrophic conditions. Observations under the fluorescent microscope also support their determination as algal spores. Due to the chemical differences in sporopollenin of lower and higher plants, and also to different rates of corrosion, the algal bodies show very high fluorescence intensities, whereas other palynomorphs show much lower, and fungal remains are completely invisible (Van Gijzel 1971, Yeloff and Hunt 2005, Doláková and Burešová 2007).

The fact that the sea level fell at the beginning of the Late Miocene and led to large-scale erosion of older sediments in the area of the back-arc basin system is documented in the Early Pannonian pollen spectra, where a lot of redeposited sporomorphs of subtropical and tropical ferns appeared (Slamková 2004). A higher percentage of nonarboreal pollen (10-14%) indicates local marshes and partly open woodland vegetation. The increase in halophyte taxa documents the presence of coastal swamps, local lagoons and marshlands during the lowstand of the brackish sea (Kvaček et al. 2006).

During the Late Pannonian, the Western Carpathian paleogeography started to change. Lake Pannon retreated southwards and the northern coast of the back-arc basin was slightly elevated due to progradation of deltaic and alluvial facies, especially in the lowlands.

Swamp vegetation with straight growth in the swamp substratum is mainly characterized by Taxodiaceae trees. They are often present in association with Myricaceae, less often with Nyssaceae. The riparian forest elements subdominantly occurred with *Alnus* and *Ulmus,* mixed mesophytic forests with *Carya, Quercus, Craigia, Carpinus, Fagus* and herbs were represented by Chenopodiaceae, Asteraceae, Ericaceae, Poaceae and *Artemisia.* Extrazonal vegetation of the mountain areas with *Picea, Tsuga, Abies, Cedrus* is common in the pollen spectra.

Paleoclimatic data quantified by the Coexistence approach method (Mosbrugger and Utescher 1997) characterized a climate in several categories. Using primary pollen data from the Pannonian sediments of the Slovak part of the Vienna Basin, the mean annual temperature (MAT) was between 15.6–21.7°C, the coldest month temperature (CMT) between 5.0 13.6°C, the warmest month temperature (WMT) between 13.8–27.9 °C, mean annual precipitation (MAP) between 373.0– 520.0 mm, the wettest month precipitation (WtMP) between 73.0– 45.0 mm, the driest month precipitation (DMP) between 5.0– 9.0 mm, and the warmest month precipitation (WMP) between 27.0–227.0 mm (Kováč et al. 2006).

Discussion

A temperate climate with broad-leaved deciduous and warm – temperate mixed mesophytic forests, was interpreted for all the areas adjacent to the Vienna Basin. Increasing amounts of herbaceous plant pollen were also observed. It was presumed by Utescher et al. (2000), that the gradual cooling started from the 14 Ma untill the Late Pliocene and seasonality increased from the beginning of the Late Miocene Planderová et al. (1993a,b) noticed a clear floristic differentiation in representation of paleotropical and arctotertiary elements between the southern and northern part of Central and Eastern Europe during the Pannonian.

The Danube Basin situated at the Alpine-Carpathian-Pannonian junction represents a region of the Central Paratethys, strongly influenced by the orogen building processes and climatic changes (Kováč 2000). In the reference section of the Tajná 1 borehole, in the Lower Pannonian sequence, dominant vegetation was formed by the swamp representatives Taxodiaceae – Myricaceae with subdominant presence of *Nyssa, Alnus, Carya, Quercus* deciduous, *Engelhardia*, Chenopodiaceae and Poaceae. In the Middle Pannonian sequence, changes in proportion of the dominant elements are apparently related to the mild cooling of climate and beech has been partly supplanted by fir and deciduous oak. Taxa ratio in the predominant association changed. The proportion of beech in *Abies-Quercus* (deciduous) – *Fagus* association decreased. Oleaceae, *Myrica, Carya, Pterocarya, Alnus, Nyssa, Picea, Tsuga* and *Cedrus* occurred subdominantly (Kováč et al. 2006). Presence of an increasing number of coniferous taxa *Picea, Tsuga* and *Abies* also observed in earlier studies of the Pannonian sequences (Nagy and Planderová 1985), can be interpreted as a consequence of two factors: higher relief in the hinterland of the basin or transition to seasonality. From the Danube Basin, Planderová (1972, 1984, 1990) described reduced marshes, isolated lakes with floras surrounded by steppe meadows with scarce woody plants. In comparison with Hungary, the climate was cooler and drier with a dominance of *Artemisia* over other herbaceous pollen (Nagy 1985, Nagy and Planderová 1985, Planderová 1990) during the Late Miocene.

Erdei et al. (2007) confirmed the significant role of paleogeography – subsidence of the Pannonian basin – in the appearance of Pannonian floras and vegetation types with extremely low diversities. The authors characterised most of the Pannonian localities by monotonous azonal swamp associations with *Byttneriophyllum* predominating which indicates warmer climatic conditions.

In Poland, Wazynska (1998), Sadowska et al. (1993) and others presumed a temperate and relatively arid climate, thus not stimulating the development of swamp forest with *Nyssa* and *Taxodium*. They were replaced by moist riparian forests with *Alnus*, *Celtis* and *Pterocarya*. More arid terrains were occupied by mixed forests with large amounts of conifers, especially pines, and with only scarce paleotropical relics. The amount of herbaceous plant pollen increased during this time span (Poaceae, *Artemisia*, the family Asteraceae, Daucaceae etc.).

Pannonian (Meotian) pollen data from the Ukraine indicate the development of steppe or forest-steppe areas with Poaceae and *Artemisia* (Syabraj 2000, Syabraj et al. 2007).

Kovar-Eder (1987) analyzed Pannonian vegetation and climate in the Central Paratethys region. She has established that the percentage of evergreen species increased towards the southeastern part of the investigated area, and arguments for either xeromorphic mediterranean-like vegetation or for steppe-like conditions are invalid.

Very rich pollen assemblages were determined from the Late Pannonian sediments of the Styrian Basin (Hofmann and Zetter 2005). Six associated paleo-plant habitats were distinguished by the authors in the ancient wetland system, namely, belts of aquatic plants, freshwater marsh habitat, clastic swamp habitat, natural levee or crevasse-splay habitat, organic swamp and wet-prairie habitat. They identified 40 herbaceous taxa, which documented not only closed forest, but also the herbaceous vegetation of more xeric layers.

Conclusion

Due to paleogeographical changes and climatic oscillations, thermophilous taxa numbers decreased during the studied time span, and some of them disappeared completely from the northern part of the Vienna Basin. Based on the macropalaeobotanical and pollen data, a temperate climate with broad-leaved deciduous and warm-temperate mixed mesophytic forests was interpreted. The marked facies mutually changing in time and space in their individual pollen spectra were created by intrazonal types of vegetation (marshes, riparian, coastal and aquatic) or by high amounts of herbaceous plants (existence of local open places such as drier substrata in the associated riparian forests, and wet meadows). Variable height and form of the uplifted mountain chains created ideal conditions for a higher presence of extrazonal vegetation.

Based on pollen data from the Pannonian sediments of the Slovak part of the Vienna Basin quantified climatic data (mean annual temperature, mean annual precipitation...) were calculated.

Comparison with the adjacent areas confirms the existence of a climatically dependent gradient between the southern and northern part of Central and Eastern Europe during the Pannonian as documented by floristic differentiation in representation of paleotropical and arctotertiary elements. Increasing amounts of the herbaceous plants pollen were also observed.

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References

Bůžek, Č. (1962): Contribution to knowledge of Pannonian Flora in Poštorná u Břeclavi. – Čas. mineral. geol., 7 (3): 257-259. (in Czech, German summary)

Doláková, N., Burešová, A. (2007): Use of fluorescent microscopy in the study of redeposited palynomorphs in the cave and marine sediments of Moravia (Czech Republic). – Acta Palaeobotanica, 47 (1): 275-279.

Doláková, N., Kováčová, M., Beláčková, K., Lázničková, J. (2006): Development of the open land areas during the Miocene in the Czech and Slovak parts of the Central Paratethys. Scripta Fac. Sci. Nat. Univ. Masaryk. Brun., Geology, 33-34 (2003-2004): 24-25.

Erdei, B., Hably, L., Kázmér, M., Utescher, T., Bruch, A. (2007): Neogene flora and vegetation development of the Pannonian domain in relation to paleoclimate and paleogeography. – Palaeogeogr., Palaeoclimatol., Palaeoecol., 253: 115-140.

Ferguson, D.K., Pingen, M., Zetter, R., Hofmann, Ch. Ch. (1998): Advances in our knowledge of the Miocene palnt assemblage from Kreuzau, Germany. – Rev. Paleobot. Palynol., 101: 147-177.

Gabrielová, N. (1966): Preliminary report about palynological research at the locality Poštorná. – Zpr. geol. výzk. 1966, pp.285-286. (in Czech)

Hofmann, Ch.Ch., Zetter R. (2005): Reconstruction of Different Wetland plant Habitats of the Pannonian Basin Systém (Neogene, Eastern Austria). – Palaios, 20: 266-279.

Kalvoda, J. (1979): Microflora of the Upper Miocene at the locality Poštorná. – MS, Rigorous thesis, PřF MU, 100 pp., Brno. (in Czech).

Knobloch, E. (1962): Preliminary report about paleobotanical researches in Moravian Tertiary. – Zpr. geol. výzk. 1961, pp. 215-217. (in Czech).

Knobloch, E. (1963): Die Floren des südmährischen Neogens. – N. Jb. Geol. Paläont. Mh., 1: 1-11.

Knobloch, E. (1968): The plant association in Czechoslovakian Tertiary. – Čas. mineral. geol., 13 (1): 109-118 (in Czech, German summary)

Knobloch, E. (1969): Tertiäre Floren von Mähren. – Moravské muzeum a Muz. spol. Brno., pp. 1-201, Brno.

Knobloch, E. (1972): Die gegenseitigen Beziehungen der tschechoslowakischen und ungarischen Teritiärfloren. – Földt. Közlöny, Bull. Hung. Geol. soc., 102: 246-259.

Knobloch, E. (1981): Micropaleobotanical research of Pannonian and Pontian in Moravia and Slovakia. – Zem. Plyn Nafta, 26 (4): 741-757 (in Czech, German summary).

Knobloch, E. (1985): Die Floren des Pannonien im Wiener Becken und in der Donauebene. – In: Papp et al. (eds): Chronostratigraphie und Neostratotypen. Miocaen M6 Pannonien. – Jugosl. Serb. Akad. Wiss. Künste, Zagreb/Beograd. pp. 616-631.

Komárek, J., Jankovská, V. (2001): Review of the Green Algal Genus Pediastrum; Implication for Pollenanalytical Research. – Gebrüder Borntraeger, Berlin, 127 pp.

Konzalová, M. (2005): Upper Miocene (Pannonian, Pontian) palynomorphs from the south Moravian extension of the Vienna Basin (Czech Republic). – Documenta Naturae, 155 (5): 1-51. München.

Kováč, M. (2000): Geodynamický, paleogeografický a štruktúrny vývoj karpatsko-panónskeho regiónu v miocéne: nový pohlad na neogénne panvy Slovenska. Veda, Bratislava, pp. 5-203 (in Slovak).

Kováč, M., Baráth, I., Fordinál, K., Grigorovich, A.S., Halásová, E., Hudáčková, N., Joniak, P., Sabol, M., Slamková, M., Sliva, Ľ., Töröková, I., Vojtko, R. (2006): Late Miocene to Early Pliocene sedimentary environments and climatic changes in the Alpine-Carpathian-Pannonian junction area: a case study from the Danube Basin northern margin (Slovakia). – Palaeogeogr., Palaeoclimatol., Palaeoecol., 238 (1-4): 32-52.

Kováč, M., Baráth, I., Kováčová-Slamková, M., Pipík, R., Hlavatý, I., Hudáčková, N. (1998): Late Miocene paleoenvironments and sequence stratigraphy: Northern Vienna Basin. – Geol. Carpath., 49 (6): 445-458.

Kovar-Eder, J. (1987): Pannonian (Upper Miocene) Vegetational Character and Climatic Inferences in the Central Paratethys Area. – Ann. Naturhist. Mus., 88, A, Wien: 1987, 117-129.

Lázničková, J. (2006): Palynological study of selected localities in Upper Miocene of the Moravian part of the Vienna Basin. – MS, diploma thesis, MU Brno: 77 pp. (in Czech, with English summary).

Kvaček, Z., Kováč, M.,. Kovar-Eder, J., Doláková, N., Jechorek H., Parashiv, V., Kováčová, M., Sliva, Ľ. (2006): Miocene evolution of landscape and vegetation in the Central Paratethys. – Geologica Carpathica., 57 (4): 295-310.

Miolla, A., Bondesan, A., Corain, L., Favaretto, S., Mozzi, P., Piovan, S., Sostizzo, I. (2006): Wetkabds in the Venetian Po Plain (northeastern Italy) during the Last Glacial Maximum: Interplay between vegetation, hydrology and sedimentary invironment. – Rev. Paleobot. Palynol., 141 (1-2): 53-81.

Mosbrugger, V., Utescher, T. (1997): The coexistence approach – a method for quantitative reconstructions of Tertiary terrestrial palaeoclimate data using plant fossils. – Palaeogeogr., Palaeoclimatol., Palaeoecol., 134: 61-86.

Nagy, E. (1985): Sporomorphs of the Neogene in Hungary. – Geologica Hungarica, ser. Palaeont., 47: 1-470.

Nagy, E., Planderová, E. (1985): Palynologische Auswertung der Floren des Pannonien. – In: Papp et al. (eds): Chronostratigraphie und Neostratotypen. Miocaen M6 Pannonien. – Jugosl. Serb. Akad. Wiss. Künste, Zagreb/ /Beograd., pp. 586-615.

Pacltová, B. (1958): The plant microfossils (mainly sporomorphae) of the lignite deposits near Mydlovary in the České Budějovice basin. – Sbor. Ústř. Úst. geol. Paleont., 25: 109-176 (in Czech, English summary).

Planderová, E. (1984): Palynological evolution of Pannonian sediments from the West Carpathians. – Záp. Karpaty, sér. Paleont., 9: 131-134.

Planderová, E. (1972): Pliocene Sporomorphs from the West Carpathians Mountains and their Stratigraphisc interpretation. – Geol. Práce. Zprávy, 59: 209-284.

Planderová, E. (1990): Miocene Microflora of Slovak Central Paratethys and its Biostratigraphical Significance, Geol. Inst. D. Štúra, Bratislava, 144 pp.

Planderová, E., Ziembińska-Tworzydło, M., Grabowska, I., Kohlman-Adamska, A., Konzalová, M., Nagy, E., Pantić, N., Ryłova, T., Sadowska, A., Słodkowska, B., Stuchlik, L., Syabraj, S., Zdražílková, N., (1993a): On paleofloristic and paleoclimatic changes during the Neogene of Eastern and Central Europe on the basis of palynological research. – Proceedings of the International Symposium: Paleofloristic and paleoclimatic changes during Cretaceus and Tertiary, Dionýz Štúr Institute of Geology in Bratislava, pp. 119-129.

Planderová, E., Ziembińska-Tworzydło, M., Grabowska, I., Kohlman-Adamska, A., Sadowska, A., Słodkowska, B., Stuchlik, L., Ważyńska H. (1993b): Wahania klimatyczne w Neogenie Europy Środkowej na podstawie zmiennego udziału w palinoflorze składników paleotropikalnych i arktycznotreciorzędowych. – Przeglad Geologićny.Państw. Inst. Geol., 41(12): 829-834.

Slamková, M. (2004): Paleovegetácia a klimatické trendy počas stredného a vrchného miocénu vo Viedenskej panve; Dizertačná práca. – MS, Archív Katedry geológie a paleontológie, 87 pp. (in Slovak, English summary).

Syabraj, S. (2000): Tertiary Flora, Vegetation and Climate of Ukraine. – Chin. Bull. Bot., 17: 95-101.

Syabraj, S., Utescher, T., Molchanoff, S., Bruch, A. A. (2007): Vegetation and paleoclimate in the miocene of Ukraine. – Palaeogeogr., Palaeoclimatol., Palaeoecol. 253 (1-2): 169-184.

Stuchlik, L., ed. (1994). Neogene Pollen Flora of Central Europe. Part 1. – Acta Palaeobotanica, Suppl. 1: 1-56.

Utescher, T., Mosbrugger, V., Ashraf, A. R. (2000): Terrestrial Climate Evolution in Northwest Germany Over the last 25 Million Years. – Palaios, 15 (5): 430-449.

Van Geel, B., Hallewas, D.P., Pals, J.P. (1983): A Late Holocene deposit under Wetfiese Zeedijk near Enkhuizen (prov. of N-Holland, The netherlands): paleoecological and archaeological aspects. – Rev. Paleobot. Palynol., 38: 269-335.

Van Gijzel, P. (1971): Review of the UV-fluorescence microphotometry of fresh and fossil exines and exosporia. – In Brooks, J., Grant, P. R., Muir, M., Van Gijzel, P., Shaw, G. (eds).: Sporopollenin: Academic Press, London–New York, pp. 659-685.

Ważyńska, H. ed. (1998): Palynology and Paleogeography of the Neogene in the Polish Lowlands. – Prace Panstw. Inst. Geol., 160: 1-45.

Yeloff, D. E., Hunt, C. O. (2005): Fluorescence microscopy of pollen and spores: a tool for investigating environmental change. – Rev. Paleobot. Palynol., 133: 203-219.

Zetter, R. (1987): Untersuchungen and Pediastrum – Arten aus dem Ober Miocän des Burgenlandes (Österreich). – Beiträge zur Paläontologie von Österreich., 13: 69-87.

Explanation to the plates

PLATE 1

1. four-porate *Alnus – Alnipollenites verus* Potonié; Poštorná 3.
2. *Betulaepollenites betuloides* (Pflug) Nagy; Pohansko V9, 6 m.
3. *Salixipollenites* sp. + *Alnipollenites* sp.; Pohansko V9, 6 m.
4. *Nyssapollenites rodderensis* (Thiergart) Kedves; Pohansko V9, 4.2 m.
5. *Engelhardia* sp. – *Engelhardtioidites quietus* (Potonié) Potonié; Pohansko V9, 3 m.
6. *Tricolporopollenites liblarensis* (Thomson) Grabowska; Pohansko V7, 4.2 m.
7. *Reevesiapollis triangulus* (Mamczar) Krutzsch; Moravská Nová Ves 7.
8. *Quercoidites henrici* (Potonié) Potonié,Thomson etThiergart; Pohansko V9, 3 m.
9. *Platanus* sp. – *Platanipollis ipelensis* (Pacltová) Grabowska; Pohansko V9, 3 m.
10. *Sciadopitys* sp. – *Sciadopityspollenites serratus* (Potonié et Venitz) Raatz; Pohansko V9, 6 m.
11. *Zelkova* sp. – *Zelkovaepollenites potoniei* Nagy; Pohansko V9, 6 m.
12. *Quercus* sp. *Quercoidites* sp.; Pohansko V9, 6 m.
13. *Quercus robur* type; Pohansko V9, 3 m.
14. Juglans sp. *Juglanspollenites verus* Raatz; Pohansko V9, 3 m.
15. Picea sp – *Piceapollis* sp; Poštorná 3
16. *Tsuga* sp. – *Zonalapollenites maximus* (Raatz) Krutzsch; Pohansko V9, 6 m.

PLATE 2

1. Microsporangium *Azolla bohemica* PACLTOVÁ; Pohansko V9, 6 m.
2. Isolated glochidia of *Azolla bohemica* PACLTOVÁ; Pohansko V9, 6 m.
3. Micosporangium cf. *Salvinia* × cf. *Azolla*; Pohansko V9, 6 m.
4. *Pediastrum boryanum* (TURP) MENEGH; Pohansko V9, 4.2 m
5. *Pediastrum simplex* MEYEN; Pohansko V3, 8 m.
6. *Pediastrum boryanum* (TURP) MENEGH var. boryanum; Pohansko V3, 8 m.
7. *Nelumbo* sp. – *Nelumbopollenites europaeus* (TARASEWICH) SKAWIŃSKA; Pohansko V9, 4.2 m.

PLATE 3

1–5. *Artemisia* sp. several types cf. *Artemisiapollenites sellularis* NAGY; Pohansko V9, 3 m.

6. *Plantago* sp. – *Plantaginacearumpollenites miocaenicus* NAGY; Pohansko V9, 3 m.
7. *Centaurea jacea* type – Pohansko V9, 3 m.

8.,9. Daucaceae gen. indet. several types; Pohansko V9, 3 m.

10. Caryophyllaceae gen. indet.; Pohansko V9, 3 m.
11. Asteroideae – *Senecio* type.; Pohansko V9, 3 m.
12. Asteroideae – *Cichoreacidites gracilis* NAGY; Pohansko V9, 3 m.
13. Asteroideae – *Tubulifloridites macroechinatus* (TREVISAN) NAGY; Pohansko V9, 4.2 m.
14. cf. *Echinops* type; Pohansko V9, 3 m.
15. Fabaceae gen. Indet; Pohansko V9, 3 m.
16. Rosaceae gen. indet.; Pohansko V9, 3 m.
17. Rosaceae – *Prunus* type; Pohansko V9, 3 m.
18. *Thalictrum* sp.; Pohansko V9, 3 m.
19. *Humulus/Cannabis* type; Moravská Nová Ves
20. *Ranunculus* type; Pohansko V9, 6 m.
21. *Polygonum persicaria* – *Persicarioipollis persicarioidites* KRUTZSCH; Pohansko V9, 6 m.

PLATE 1

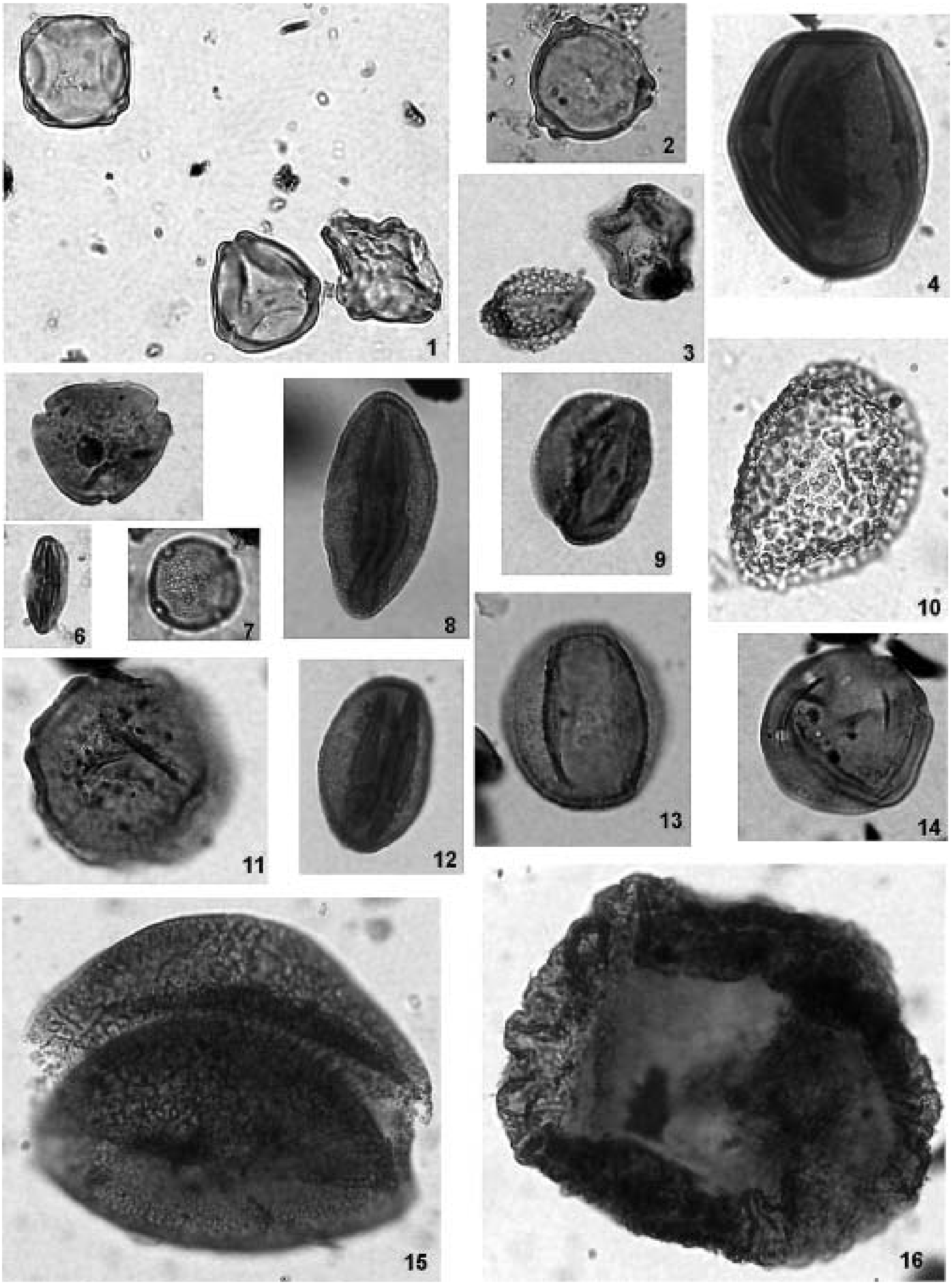

PLATE 2

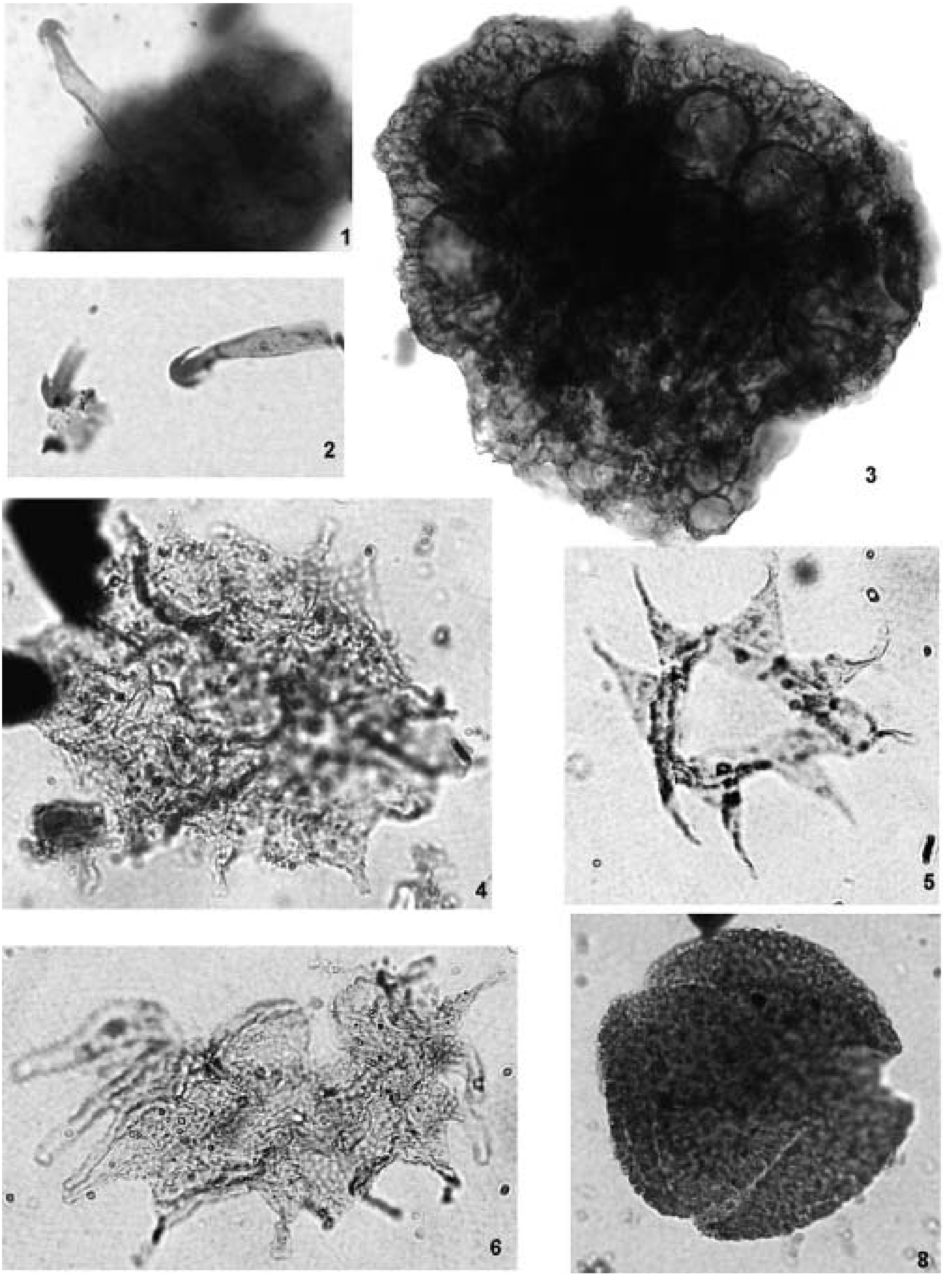

PLATE 3