Studia bot. hung. 35, pp. 5–23, 2004

A CLIMATE ANALYSIS OF LATE OLIGOCENE (EGERIAN) MACROFLORAS FROM HUNGARY

B. ERDEI[1] and A. A. BRUCH[2]

[1]*Department of Botany, Hungarian Natural History Museum*
H-1476 Budapest, Pf. 222, Hungary; E-mail: erdei@bot.nhmus.hu
[2]*Institute of Geosciences, Eberhards-Karl University, Tübingen*
D-72076 Tübingen, Sigwartstrasse 10, Germany; E-mail: angela.bruch@uni-tuebingen.de

Five Late Oligocene fossil plant assemblages from Hungary were subjected to a climate analysis adopting the Coexistence Approach. Four climate variables (mean annual temperature, temperature of the coldest and warmest month, mean annual precipitation) were estimated quantitatively. Resultant limits of values for the variables indicate a warm temperate (Cfa-type) climate, which conforms to the results of earlier qualitative palaeoclimate reconstructions. As compared to climate estimates of coeval floras from the Eastern Alps distinct values of temperature variables were displayed by Como (Italy) and Govce (Slovenia) which may be attributable either to palaeogeographical or methodological reasons.

Key words: climate analysis, Coexistence Approach, fossil plant assemblage, Late Oligocene

INTRODUCTION

Deposits of the Hungarian Palaeogene Basin comprise numerous well-dated fossil plant localities most of which have been subjected to taxonomic studies and have been published. We focus on Late Oligocene fossil leaf assemblages (Fig. 1) coming from North Hungary, *i.e.* from the Bükk Mountains (*e.g.* Eger-Wind, Andornaktálya) and from the Transdanubian Range (*e.g.* Pomáz, Vértesszőlős, Kesztölc, Verőcemaros).

Five of the Late Oligocene sites (Andornaktálya, Eger-Wind, Kesztölc, Pomáz, Vértesszőlős) were chosen for a climate reconstruction adopting the systematics based "Coexistence Approach" (CA) established by MOSBRUGGER and UTESCHER (1997). Earlier interpretations of climate in the Oligocene of Hungary were confined to the qualitative characterisation of climate trends, thus this is the first quantitative approach estimating temperature and rainfall variables for the Hungarian Oligocene.

GEOLOGICAL SETTINGS AND STRATIGRAPHY

All localities included in the present paper comprise fossil plant assemblages that were excavated from Egerian deposits of the Hungarian Palaeogene Basin.

There are numerous works treating the stratigraphy and tectonic evolution of the Palaeogene Basin (BÁLDI 1965, 1973, 1983, 1998, BÁLDI and SENEŠ 1975, BÁLDI *et al.* 1999, CSONTOS *et al.* 1992, KÁZMÉR and KOVÁCS 1985, NAGYMAROSY 1990). Probably the drift of the Pelso unit in SW–NE direction along the Balaton and Mid-Hungarian lines (fault system) accounts for the recent distribution of the Intra-Carpathian Palaeogene sedimentary basins which extends from Slovenia through Hungary to Slovakia (NAGYMAROSY 1990). Stratigraphy of the Hungarian Oligocene is showed by Figure 2.

Localities in the Bükk Mountains (NE Hungary)

The most abundant Late Oligocene (Egerian) fossil plant assemblage was recorded from the clay-pit of the Eger-Wind brickyard, the well-known classic macrofaunal (molluscs, corals, sharks) and large foraminiferal locality where the Egerian stratotype section (Paratethys regional stratigraphy) was designated. Besides, in the close vicinity of the locality at another surface section (near Novaj-Nyárjas) an additional "facio-stratotype" was indicated (BÁLDI and SENEŠ 1975, BÁLDI *et al.* 1999). In this way an even greater importance is attached to the fossil assemblage. Leaf remains of the Eger-Wind locality were exposed from marine,



Fig. 1. Late Oligocene fossil plant assemblages from Hungary.

brackish and limnic sediments of the Eger Formation overlying conformably the Kiscell Clay (Early Oligocene). According to NAGYMAROSY (pers. comm. in KVAČEK and HABLY 1991) in Eger-Wind the lower part of the Egerian is exposed and the sequence covers the upper part of the NP24 zone and the *Globorotalia opima opima* foraminifera zone to the lower part of the NP25 zone. However, BÁLDI *et al.* (1999) suppose that NP24 nannozone may correlate with the Upper Kiscellian only as well as they note that the separation of the NP24 and NP25

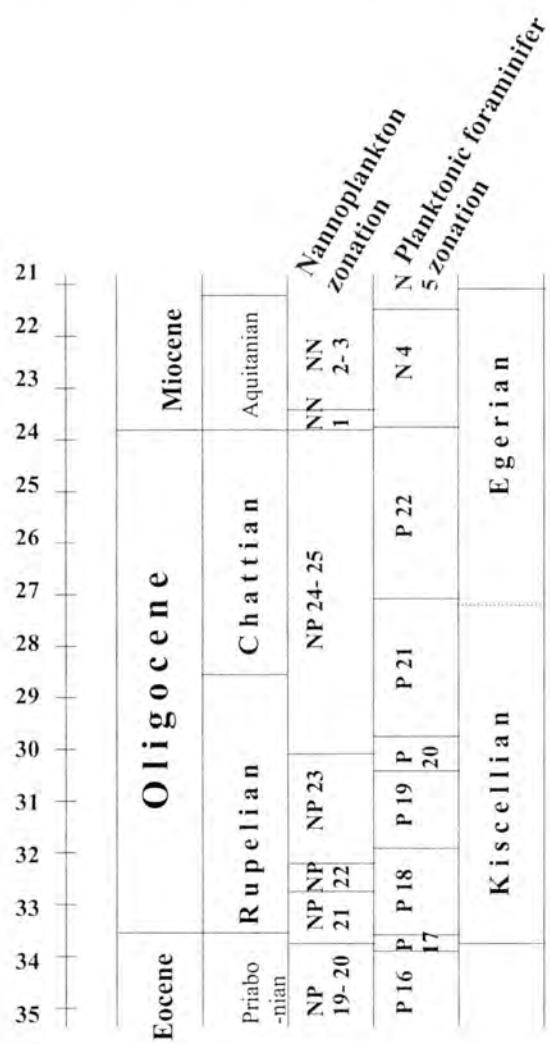


Fig. 2. Stratigraphy of the Hungarian Oligocene (after Báldi 1998).

nannozones in the Central Paratethys area is in most cases impossible. They also comment on the *G. opima opima* foraminifera zone, *i.e.* it is very probable that *Paragloborotalia opima s.l.* (*Globorotalia opima*) disappeared at the Kiscellian/ Egerian boundary. Therefore the original definition of the K/EB with the first appearance of *Pgr. opima s.l.* is erroneous (BÁLDI *et al.* 1999). Thus, considering the above we should not exclude that fossil plants of the Eger-Wind locality (the lower level, see later) may represent the upper part of the Kiscellian (Lower Chattian).

Four members of the Eger Formation are clearly recognisable in the Eger-Wind brickyard the lowermost member of which (marine glauconitic and tuffitic sandstones) provides no macroflora. In the subsequent layers three flora levels are recorded. The lower level flora is yielded by molluscan clay with deep littoral to bathyal fauna (mentioned above as a possible Late Kiscellian flora), the middle level flora by the alternating clays and sandstone comprising a shallow marine fauna and finally the upper level flora (younger Egerian, but still the upper part of Oligocene) by coarse sand and intercalating clays (brackish and limnic), respectively (KVAČEK and HABLY 1991). The stratigraphical position of the lower and middle members are dated by nannoplankton as mentioned above.

An additional fossil assemblage in Andornaktálya, in the close vicinity of Eger, is preserved in pelitic deposits of the Eger Formation. Lithologically the sequence is quite similar to the upper part of the Eger-Wind brickyard. The extremely poor nannoflora indicates an age not younger than Late Oligocene (NAGYMAROSY in VARGA *et al.* 1989).

Localities in the Transdanubian Range (N Hungary)

The Pomáz locality became known primarily for its mollusc fauna which promoted the stratigraphical revision of the fossiliferous strata (BÁLDI 1973). Plant remains are fossilised in fine grained clay (clayey coarse silt) indicating a low-energy sedimentary environment (SZAKMÁNY in HABLY 1994). Fossiliferous layers belonging to the Mány Sand Formation are dated by molluscs as Egerian (BÁLDI 1973) and according to its nannoflora (co-occurrence of *Helicopontosphaera recta* and *Triquetrorhabdulus carinatus*) placed to the NP25 zone (NAGYMAROSY pers. comm. in HABLY 1994).

The Vértesszőlős locality was exposed in the course of a road construction. Fossiliferous layers comprising fossil plant remains, a nannoflora of low diversity and molluscs are sandstones with intercalating clay lenses (Mány Sand Formation). Based on both the mollusc fauna (BÁLDI 1976) and its nannoflora (NAGYMAROSY pers. comm. in HABLY 1990) layers are attributed to the Egerian, to the

NP24–25 zones. Mollusc fauna as well as the lithology of fossiliferous layers indicate changing salinity and a near-shore or lagoonal facies.

The Kesztölc locality similarly to the Pomáz became known for its mollusc fauna (SCHRÉTER 1953). The geology of the outcrop as well as its Egerian fauna were treated by BÁLDI (1973) and LEÉL-ŐSSY (1984). Plant fossils are preserved in shaly clay with a thick coarse sand intercalation comprising a mollusc fauna (Mány Sand Formation).

MATERIAL

Those assemblages were chosen first of all that met the minimum requirements of climate reconstruction (Fig. 1), *i.e.* provided enough (at least 12) taxa for calculations, such as Eger-Wind, Pomáz, Vértesszőlős and Kesztölc. In addition, the Eger 1, 2 and Andornaktálya assemblages were also included in order to get results of higher resolution. All localities include macromorphologically preserved macro-/megafossils of leaves and fruits, all preserved without cuticles. Among the Egerian fossil floras that of Eger-Wind (Eger-Wind brickyard) is the most abundant and the most thoroughly investigated. The three flora levels were evaluated separately and climate was calculated for each assemblage. With regard to the most significant works treating the Eger-Wind flora both the taxonomic survey of ANDREÁNSZKY (1966) and its critical revision given by KVAČEK and HABLY (1991) are noteworthy. Palynological data were published by PLANDEROVA *et al.* (1975) and NAGY (1979). Floralist published by PLANDEROVA *et al.* (1975) was estimated by BRUCH (1998) using the Coexistence Approach. Results of the palyno-flora-based climate analysis are going to be compared with resultant climate variables of this study.

The first note on fossil plant remains of the Pomáz locality (Kartalja area) was given by BÁLDI (1973) and later a detailed survey of the flora was published by HABLY (1994). Plant fossils of Kesztölc were studied first by PÁLFALVY (1967), however he published merely a floralist without any descriptions or illustrations and later HABLY (1988) gave a detailed analysis of the flora. Floralists of both Vértesszőlős and Andornaktálya were published by HABLY (1990, 1993).

FLORA AND VEGETATION OF THE SITES AND CLIMATIC INTERPRETATIONS

All fossil assemblages involved in the analysis represent various combinations of mesophilous (zonal vegetation), riparian as well as swamp (intrazonal vegetation) vegetation types. Floralists of the localities and their nearest living relatives (NLRs) used in the analysis are indicated on Tables 1 and 2.

The generated floralists of the particular localities used in the analysis are similar in broad outlines, with both deciduous and evergreen plants, such as members of primarily Lauraceae, *Engelhardia*, *Platanus neptuni*, *Ulmus* comprised by all localities. Palm fossils were yielded by Vértesszőlős and Eger-Wind (upper level flora), Zingiberaceae by Eger-Wind (upper level flora) and Andornaktálya,

Table 1. Fossil taxa of the Eger-Wind flora and their "nearest living relatives" (= NLR).

Fossil taxa	NLR	Fossil taxa	NLR
Eger/lower level flora		Eger/upper level flora	
?Cephalotaxaceae		*Acer tricuspidatum*	*Acer* sp.
Daphnogene cinnamomifolia	Lauraceae	*Alnus oligocaenica*	*Alnus* sp.
Dryophyllum callicomifolium	Fagaceae	*Blechnum dentatum*	
"Elaeocarpus" europaeus		*Calamus noszkyi*	*Calamus* sp.
Juglandaceae	Juglandaceae	*Juglans acuminata*	
Laurophyllum sp.	Lauraceae	*Daphnogene cinnamomifolia*	Lauraceae
Myrica cf. *integerrima*	*Myrica* sp.	*Engelhardia orsbergensis*	*Engelhardia* sp.
Pinus sp.		*Engelhardia macroptera*	*Engelhardia* sp.
Platanus neptuni	*Platanus* sp.	*Ilex ?andreánszkyi*	*Ilex* sp.
"Quercus" cruciata	*Quercus* sp.	Laurophyllum sp.	Lauraceae
Salix vel *Populus*		Leguminosae	
Sassafras lobatum	*Sassafras* sp.	*Myrica* cf. *integerrima*	*Myrica* sp.
Zizyphus cf. *zizyphoides*		*Myrica longifolia*	*Myrica* sp.
Eger/middle level flora		*Osmunda lignitum*	*Plenasium* sp.
Daphnogene cinnamomifolia	Lauraceae	Pinus sp.	
Dryophyllum callicomifolium	Fagaceae	*Pronephrium stiriacum*	
Engelhardia orsbergensis	*Engelhardia* sp.	*Quercus rhenana*	*Quercus* sp.
Juglandaceae	Juglandaceae	*Rosa lignitum*	
Laurophyllum sp.	Lauraceae	*Sabal major*	Palmae
cf. *Lithocarpus saxonicus*	Fagaceae	*Sassafras lobatum*	*Sassafras* sp.
Myrica cf. *integerrima*	*Myrica* sp.	*Sequoia* sp.	Taxodiaceae
Myrica longifolia	*Myrica* sp.	*Smilax weberi*	*Smilax hispida, S. bona-nox*
Pinus sp.		*Spirematospermum wetzleri*	Zingiberaceae
Platanus neptuni	*Platanus* sp.	*Tetracentron agriense*	
Salix vel *Populus*		*Tetraclinis* sp.	

Table 1 (continued)

Fossil taxa	NLR	Fossil taxa	NLR
Eger/middle level flora		Eger/upper level flora	
?Trigonobalanopsis rhamnoides	Fagaceae	*?Trigonobalanopsis rhamnoides*	Fagaceae
Ulmus pyramidalis	*Ulmus carpinifolia*	*Tuzsonia hungarica*	
Ulmus sp.	*Ulmus* sp.	*Ulmus fischeri*	*Ulmus parvifolia*
?Zelkova zelkovifolia	*Zelkova* sp.	*Ulmus pseudopyramidalis*	*Ulmus* sp.
		Ulmus pyramidalis	*Ulmus carpinifolia*
		Ulmus sp.	*Ulmus* sp.

respectively. Fagaceae appeared in all localities except for Andornaktálya and Kesztölc, whereas remains of Taxodiaceae were missing only from Andornaktálya.

As the best extant parallel to the Eger-Wind lower level flora KVAČEK and HABLY (1991) designated the warm temperate to subtropical mixed mesophilous forests of Eastern Asia. In accordance with ANDREÁNSZKY's opinion (1966) they ranged its vegetation with the mesophilous forest type and presumed a total annual precipitation above 1,000 mm. The Eger-Wind middle level assemblage dominated by pine remains and Lauraceae is comparable with warm temperate subtropical seashore vegetation, whereas *Ulmus* and *Daphnogene* refer to a riparian forest. The Eger-Wind upper level assemblage is dominated by swamp and riparian plants, *i.e. Alnus*, *Acer tricuspidatum*, *"Rhamnus" warthae*. Thermophilous elements such as *Daphnogene*, *Engelhardia*, palms, Leguminosae, etc. refer to equable frostless climate (KVAČEK and HABLY 1991). The authors emphasised that riparian forests in warmer climatic zones are today often dominated by deciduous elements (Himalayas, SE China) and they play a subordinate role in climate estimates. They did not expect a pronounced change of climate from the lower to the upper level floras. ANDREÁNSZKY (1966) presumed warming trends to the same interval, whereas PLANDEROVA *et al.* (1975) suggested cooling trends to the upper level. Finally, KVAČEK and HABLY (1991) compared the climate of Eger-Wind with that confined today to Central and Eastern China. They presumed a climate without longer frost periods and characterised it with a MAT (mean annual temperature) of about 15 °C and a MART (mean annual range of temperature) of 20–25 °C. Considering leaf size and species composition HABLY (1988, 1990,

Table 2. Fossil taxa of the Pomáz, Kesztölc, Andornaktálya and Vértesszőlős floras and their "nearest living relatives" (= NLR).

Fossil taxa	NLR	Fossil taxa	NLR
Pomáz		Andornaktálya	
Daphnogene sp.	Lauraceae	*Carpinus* sp.	*Carpinus* sp.
Daphnogene cf. *bilinica*	Lauraceae	*Daphnogene bilinica*	Lauraceae
Daphnogene polymorpha	Lauraceae	*Daphnogene cinnamomifolia*	Lauraceae
Engelhardia macroptera	*Engelhardia* sp.	*Engelhardia orsbergensis*	*Engelhardia* sp.
Engelhardia orsbergensis	*Engelhardia* sp.	*Laurophyllum* sp.	Lauraceae
Laurophyllum sp.	Lauraceae	*Laurus* sp.	*Laurus* sp.
Leguminosae		Leguminosae	
Magnolia cf. *mirabilis*	*Magnolia* sp.	*Magnolia* cf. *dianae*	*Magnolia* sp.
Myrica hakeaefolia	*Myrica* sp.	*Myrica*	*Myrica* sp.
Platanus fraxinifolia	*Platanus* sp.	*Platanus neptuni*	*Platanus* sp.
Platanus neptuni	*Platanus* sp.	*Spirematospermum wetzleri*	Zingiberaceae
Quercus apocynophyllum	*Quercus* sp.	*Ulmus pyramidalis*	*Ulmus carpinifolia*
Pronephrium stiriacum		Vértesszőlős	
Rosa lignitum		*Acer angustilobum*	*Acer* sp.
Sequoia abietina	Taxodiaceae	*Adiantum* sp.	
Taxodium dubium	*Taxodium distichum*	*Betula* sp.	*Betula* sp.
Theaceae	Theaceae	*Cephalotaxus harringtonia fossilis*	*Cephalotaxus* sp.
Ulmus cf. *minuta*	*Ulmus* sp.	*Cornus* sp.	*Cornus* sp.
Ulmus pyramidalis	*Ulmus carpinifolia*	*Daphnogene* sp.	Lauraceae
Kesztölc			
Daphnogene cf. *cinnamomifolia*	Lauraceae	*Debeya hungarica*	
cf. *Acer* sp.			
Alnus sp.	*Alnus* sp.	cf. *Juglans acuminata*	

Table 2 (continued)

Fossil taxa	NLR	Fossil taxa	NLR
Kesztölc		Vértesszőllős	
Daphnogene bilinica	Lauraceae	*Laurophyllum* sp.	Lauraceae
Daphnogene cinnamomifolia	Lauraceae	Leguminosae	
Engelhardia orsbergensis	*Engelhardia* sp.	Palmae	Palmae
Laurophyllum sp.	Lauraceae	*Pinus* sp.	
Leguminosae		*Platanus neptuni*	*Platanus* sp.
cf. Palmae		*Quercus* sp.	*Quercus* sp.
Pinus sp.		*Rosa lignitum*	
Platanus fraxinifolia	*Platanus* sp.	*Sequoia* cf. *abietina*	Taxodiaceae
Platanus neptuni	*Platanus* sp.	*Smilax weberi*	*Smilax hispida, S. bona-nox*
Smilax weberi	*Smilax hispida, S. bona-nox*	*Taxodium dubium*	*Taxodium distichum*
Taxodium dubium	*Taxodium distichum*	*Ulmus plurinervia*	*Ulmus parvifolia*
Ulmus sp.	*Ulmus* sp.	*Ulmus pyramidalis*	*Ulmus carpinifolia*
Ulmus pyramidalis	*Ulmus carpinifolia*	*Zelkova zelkovifolia*	*Zelkova* sp.
Zelkova zelkovifolia	*Zelkova* sp.		

1993, 1994) suggested humid subtropical climate for the Kesztölc, Vértesszőlős, Andornaktálya and Pomáz assemblages.

METHOD

In order to estimate quantitatively palaeoclimate variables the "Coexistence Approach" (CA) established by MOSBRUGGER and UTESCHER (1997) was adopted. The starting point of the method is the presumption that the climatic requirements of particular fossil taxa is the most comparable with that of its modern "nearest living relative" (NLR). The method aims to describe in terms of climate variables a coexistence interval in which the most NLRs are able to exist. This evaluation is supported by a database comprising the NLRs (and their climatic requirements) of more than 3,000 fossil taxa of the Tertiary. In this paper we estimated four climate variables, *i.e.* the mean annual temperature (MAT), mean temperature of the warmest (WMT) and coldest month (CMT), and mean annual precipitation (MAP).

Naturally, the more NLRs the analysis is based on the more reliable output is resulted. We determined a minimum number of taxa as 12 needed for a reliable climate estimate. In the Eger-Wind flora the three flora levels were calculated using three separate and one combined datasets, causing two data sets with lower number of NLR taxa (Eger 1–8, Eger 2–10 taxa). It must be noted, however, that in the case of older (Palaeogene) floras, the proper identification of taxa and their NLRs on the species or genus level is limited to a higher degree.

RESULTS AND DISCUSSION

The climate variables for the three flora levels of the Eger-Wind assemblage were calculated using both separate and combined datasets (Table 3). Calculated coexistence intervals are showed by Figure 3. The lower, middle and upper levels

Table 3. Results of climate estimates indicating values of four climate variables for the Late Oligocene floras. CRL = No. of climatic relevant taxa.

Locality name	CRL	Mean annual temperature [°C]			
		min.	max.	min. border set by	max. border set by
Eger 1	8	9.3	21.3	*Sassafras*	*Sassafras*
Eger 2	10	15.6	20.5	*Engelhardia*	*Ulmus carpinifolia*
Eger 3	22	15.6	18.8	*Engelhardia*	*Smilax hispida, S. bona-nox*
Eger combined	28	15.6	18.8	*Engelhardia*	*Smilax hispida, S. bona-nox*
Andornaktálya	10	15.6	19.2	*Engelhardia*	*Laurus*
Kesztölc	12	15.6	18.8	*Engelhardia*	*Smilax hispida, S. bona-nox*
Pomáz	12	15.6	20.5	*Engelhardia*	*Ulmus carpinifolia*
Vértesszőlős	17	13.3	18.8	*Taxodium distichum*	*Smilax hispida, S. bona-nox*
Locality name	CRL	Temperature of the coldest month [°C]			
		min.	max.	min. border set by	max. border set by
Eger 1	8	–3.3	13.3	*Sassafras*	*Sassafras*
Eger 2	10	5	13.6	*Engelhardia*	*Ulmus carpinifolia*
Eger 3	22	5	10.2	*Engelhardia*	*Smilax hispida, S. bona-nox*
Eger combined	28	10	10.2	*Ziziphus*	*Smilax hispida, S. bona-nox*
Andornaktálya	10	5.6	11.7	*Laurus*	*Laurus*
Kesztölc	12	5	10.2	*Engelhardia*	*Smilax hispida, S. bona-nox*
Pomáz	12	5	13.6	*Engelhardia*	*Ulmus carpinifolia*
Vértesszőlős	17	–0.1	10.2	*Taxodium distichum*	*Smilax hispida, S. bona-nox*

Table 3 (continued)

Locality name	CRL	Temperature of the warmest month [°C]			
		min.	max.	min. border set by	max. border set by
Eger 1	8	21.6	28.1	*Sassafras*	Lauraceae
Eger 2	10	24.7	27.5	*Engelhardia*	*Ulmus carpinifolia*
Eger 3	22	24.7	27.5	*Engelhardia*	*Ulmus carpinifolia*
Eger combined	28	24.7	27.5	*Engelhardia*	*Ulmus carpinifolia*
Andornaktálya	10	24.7	27.5	*Engelhardia*	*Ulmus carpinifolia*
Kesztölc	12	25.6	27.5	*Taxodium distichum*	*Ulmus carpinifolia*
Pomáz	12	25.6	27.5	*Taxodium distichum*	*Ulmus carpinifolia*
Vértesszőlős	17	25.6	25.7	*Taxodium distichum*	*Ulmus carpinifolia*
Locality name	CRL	Mean annual precipitation [mm]			
		min.	max.	min. border set by	max. border set by
Eger 1	8	843	1613	*Sassafras*	*Sassafras*
Eger 2	10	823	1294	*Engelhardia*	*Ulmus carpinifolia*
Eger 3	22	1096	1250	*Calamus*	*Smilax hispida, S. bona-nox*
Eger combined	28	1096	1250	*Calamus*	*Smilax hispida, S. bona-nox*
Andornaktálya	10	823	1018	*Engelhardia*	*Laurus*
Kesztölc	12	897	1250	*Taxodium distichum*	*Smilax hispida, S. bona-nox*
Pomáz	12	897	1294	*Taxodium distichum*	*Ulmus carpinifolia*
Vértesszőlős	17	979	1250	*Ulmus parvifolia*	*Smilax hispida, S. bona-nox*

(Eger 1–2–3) comprised 8, 10 and 22 relevant taxa for climate estimates. The widest range of MAT, CMT, WMT and MAP was resulted by the calculation of the Eger 1 dataset, which is attributable presumably to the low number of taxa appropriate for the analysis. The range of coexistence intervals is more restricted with higher number of climatic relevant taxa. The combined (28 taxa) and the Eger 3 (22 taxa) datasets gave consistent results, for MAT, WMT and MAP. Minimum values of CMT were higher for the combined dataset than for Eger 3 (10.0–10.2 °C *versus* 5.0–10.2 °C). For the Eger 2 dataset maximum values for MAT and CMT (20.5 °C, set by *Ulmus carpinifolia*) are higher than for Eger 3 and the combined datasets. Since minimum values of MAT and CMT are consistent for Eger 2 and 3 and Eger 2 comprises relatively few taxa, it cannot be established definitely

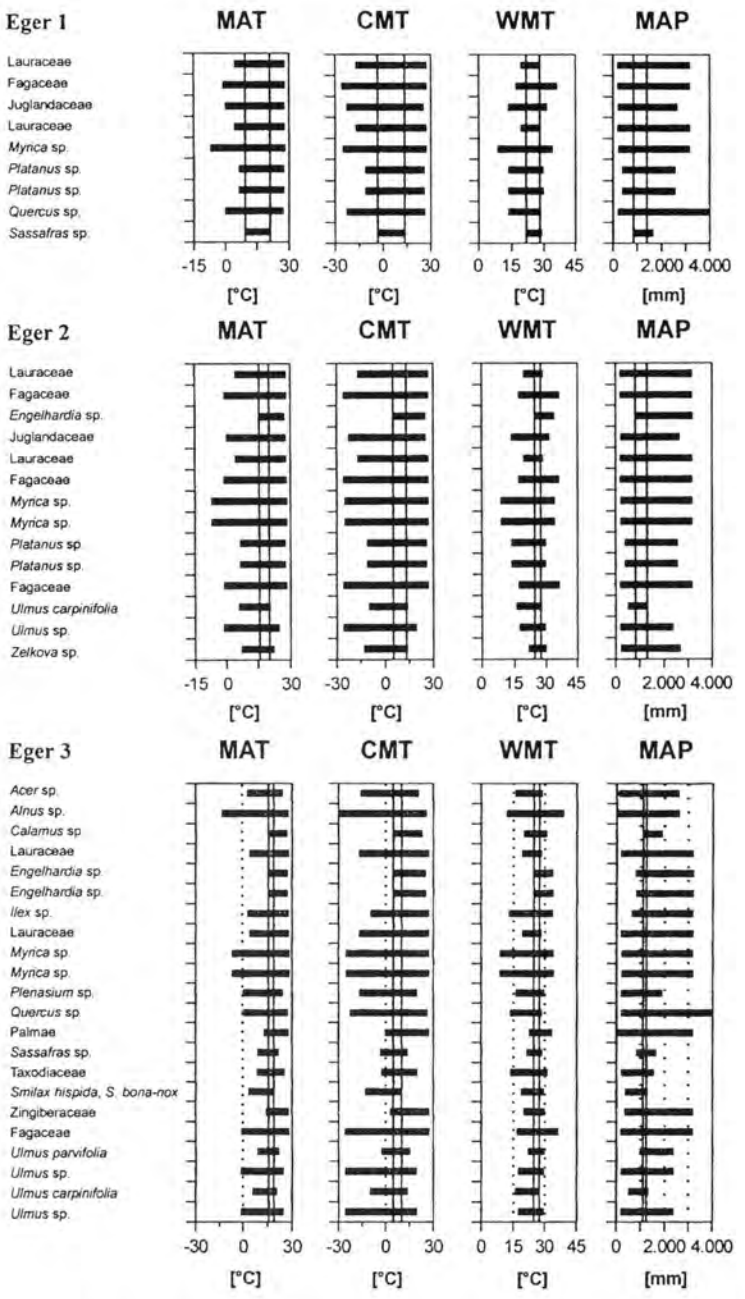


Fig. 3. Calculated coexistence intervals for the Eger-Wind dataset. (Eger 1 = lower level flora, Eger 2 = middle level flora, Eger 3 = upper level flora; MAT = mean annual temperature, CMT = temperature of the coldest month, WMT = temperature of the warmest month, MAP = mean annual precipitation).

whether real climatic distinction or purely methodological constraints account for the distinct values of temperature variables.

Results of the analysis of the Andornaktálya and Kesztölc datasets (Table 3, Figs 4, 5) correspond well to the estimates based on the Eger 3 and combined datasets, whereas those of the Pomáz dataset correspond to the results for Eger 2.

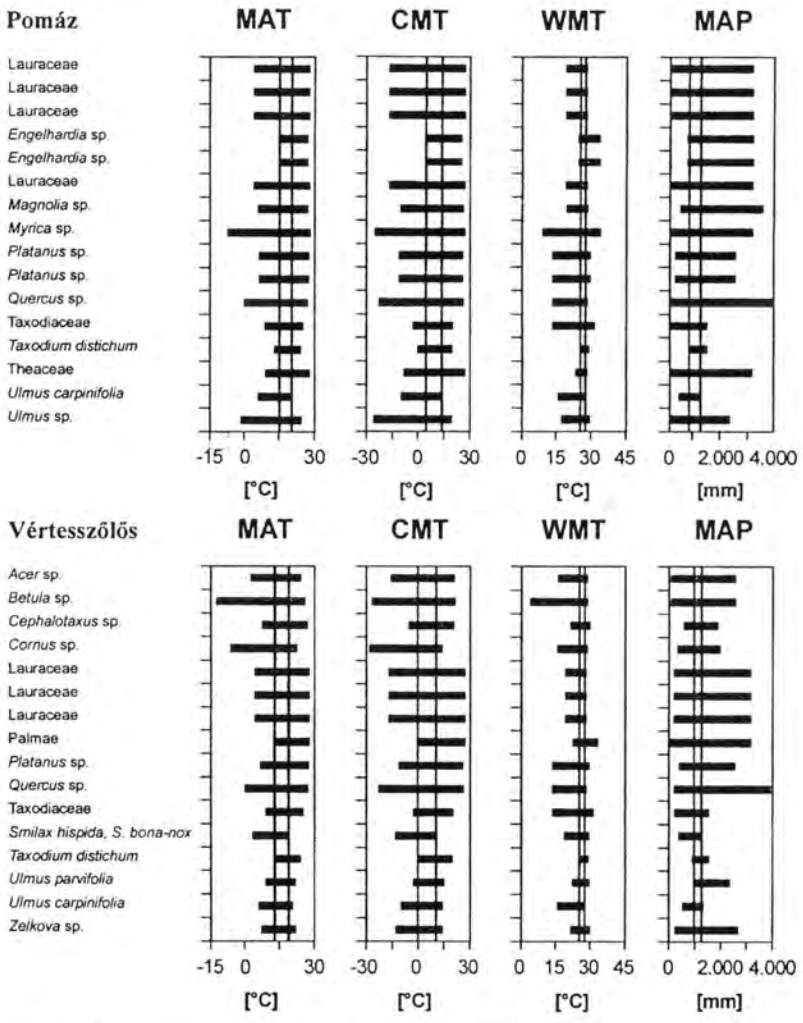


Fig. 4. Calculated coexistence intervals for the Pomáz and Vértesszőlős datasets. (MAT = mean annual temperature, CMT = temperature of the coldest month, WMT = temperature of the warmest month, MAP = mean annual precipitation).

In the case of Vértesszőlős the wide range of values for MAT and CMT raises difficulties in comparing the relevant variables, though a bit cooler climate would be indicated by the minimum values for both variables (MAT = 13.3 °C, even negative value for CMT = –0.1 °C). Values for both WMT and MAP are consistent for all localities.

The resultant climate variables correspond to a Cfa-climate *sensu* KÖPPEN (1931). MAT ranging between 15.6–18.8 °C in most cases (max. value 20.5 °C set by *Ulmus carpinifolia* in Eger 2 and Pomáz) conforms to that proposed by KVAČEK and HABLY (1991) for the Eger-Wind flora (~ 15 °C). In Vértesszőlős the minimum limit of value set by *Taxodium distichum* at 13.3 °C designates somewhat cooler climate, however, the maximum limit of value is similarly high as for

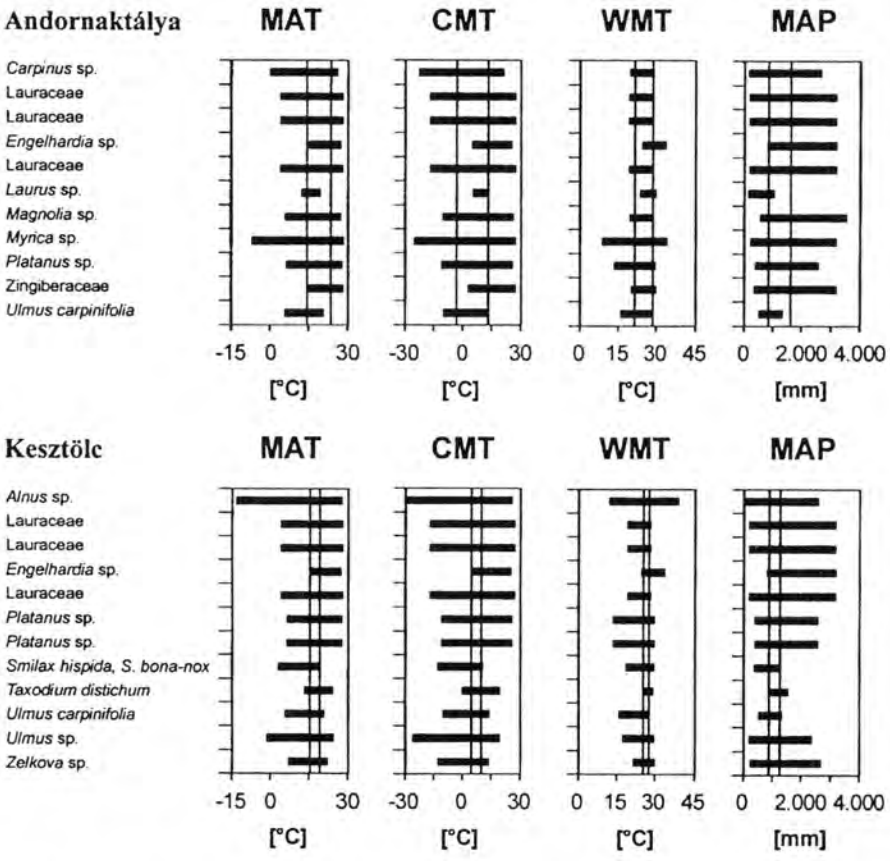


Fig. 5. Calculated coexistence intervals for the Andornaktálya and Kesztölc datasets. (MAT = mean annual temperature, CMT = temperature of the coldest month, WMT = temperature of the warmest month, MAP = mean annual precipitation).

the other datasets. Low minimum value of MAT is attributable to the absence of taxa such as *Engelhardia* or Zingiberaceae appearing at other localities (in most cases *Engelhardia* sets the lower limit of coexistence intervals for MAT). However, it should be taken into consideration that *Taxodium* appears also in intrazonal vegetation types, thus its distribution is influenced by the combination of the zonal climate and edaphic factors. Nevertheless, modern *Engelhardia* occupies a rather restricted area in Asia, thus it may indicate a more limited climatic spectrum than its fossil representatives required. MAP shows values between 823–1,294 mm (for Eger 1 max. value is 1,613 mm). The seasonal distribution of precipitation has not been predicted from the datasets in this study. HABLY (1988, 1990, 1993, 1994) suggested humid subtropical climate for the Kesztölc, Vértesszőlős, Andornaktálya and Pomáz assemblages based on leaf size spectra and species composition.

As it was expected the estimates of the particular climate variables are well in accordance for most datasets. This is attributable to the consistent floral composition of the localities. An exception is given by the Eger 1 dataset displaying broader limits of values for the particular climate variables. The most probable explanation to the divergent climate values is the low number of taxa relevant to the climate analysis, *i.e.* 8 taxa could be involved in the estimation. The wide coexistence intervals for MAT, CMT and WMT are also attributed to the high number of higher level taxa (*e.g.* Fagaceae) and *Sassafras* setting both the minimum and maximum values for all three variables. The application of a dataset without *Sassafras*, however, would result even wider limits of values. In this case the low number of appropriate taxa leads to even less informative estimates and may call in doubt the applicability of the CA to the Eger 1 dataset. This confirms the requirement of a minimum of generally 12 NLR taxa for the application of the CA.

Nevertheless, most localities are characterised by a relatively low number of (often higher level) taxa appropriate for climate analysis which may imply meth-

Table 4. Results of climate estimates based on coeval palyno-floras from the Eastern Alps (after Bruch 1998). (MAT = mean annual temperature, CMT = temperature of the coldest month, WMT = temperature of the warmest month, MAP = mean annual precipitation).

	Stratigraphy	Number of taxa	MAT (°C)	CMT (°C)	WMT (°C)	MAP (mm)
Eger-Wind/ pollen	Egerian	16	14.4–17.1	3.7–9.2	25.6–26.8	1,122–1,298
Treubach 1	Chattian	22	15.7–17.1	6.2–6.6	25.6–26.8	1,162–1,298
Como	NP 25	18	11.6–17.1	1.7–7.5	22.8–26.8	1,122–1,322
Govce	Egerian/Eggenburgian	12	12.5-17.1	–0.1–7.5	22.3–26.8	897–1,298

odological constraints, *i.e.* wide range of coexistence intervals for the climate variables. Due to the lithological character of the fossiliferous matrix (*e.g.* sandstone) preservation of fossils (macromorphologically preserved) did not allow a more accurate taxonomic identification which resulted in a high number of higher level taxa (*e.g.* family).

COMPARISON WITH CLIMATE ESTIMATES OF COEVAL PALYNO-FLORAS FROM THE EASTERN ALPS

A climate analysis adopting the Coexistence Approach to numerous Oligocene palyno-floras of the Eastern Alps/Central Paratethys has been so far applied by BRUCH (1998). Four of those more or less coeval sites were chosen for a comparison, *i.e.* Eger-Wind (pollen), Treubach (Treubach 1 in BRUCH 1998, Southern Germany), Como (Northern Italy) and Govce (Slovenia). Coexistence intervals of the four climate variables are showed by Table 4.

Values of MAT and WMT for the Eger-Wind/pollen and Treubach assemblages fit the best to those of the Egerian datasets. In the case of the Como and Govce palyno-floras resultant minimum values of MAT and WMT are lower than for the Egerian datasets. Coexistence intervals of CMT display lower limits of values in all palyno-floras than for the macroflora-based Egerian datasets.

The distinction between estimates of the temperature variables (CMT in all cases and slight difference in values of MAT) for the palyno-flora and macroflora-based datasets may be attributed to the distinctive depositional and taphonomical character of leaves and pollen, *i.e.* palyno-floras may comprise elements of the regional flora and vegetation in addition to the local plant cover represented mostly by leaf-floras.

Coexistence interval of MAP for the Govce flora is consistent with most Egerian datasets, whereas intervals for the other palyno-floras display narrower ranges of intervals with higher values similarly to the Eger 3 and Eger combined datasets.

To sum up, the Eger-Wind/pollen and Treubach assemblages display results well in accordance with results of the Hungarian Egerian floras, *i.e.* comparable climate is indicated by both. Intervals of MAT for the Govce and Como palyno-floras indicate, however, lower minimum values of MAT which may be attributable either to palaeogeography (tectonic development of the area) or to methodology, *i.e.* palyno-floras *versus* leaf-floras used for climate calculations, with a more regional climate signal given by pollen and a climate signal given by macroremains pointing to local microclimatic conditions.

There are numerous works treating the relative position, palaeogeography and development of the particular tectonic units of the area (BÁLDI 1983, CSONTOS *et al.* 1992, KÁZMÉR and KOVÁCS 1985, NAGYMAROSY 1990). The Late Eocene palinspastic reconstruction of the Outer Carpathian flysch nappes indicates that the entire Intra-Carpathian area must have been located several hundreds of kilometres to the south and west of its present position (OSZCZYPKO and SLACZKA 1985, CSONTOS *et al.* 1992). The more southerly latitudinal position of the Hungarian localities may account for the climatic distinction, *i.e.* higher values of MAT, between the Italian palyno- and the Hungarian macrofloras.

However, this question may be solved by comparing the data with others on a larger geographical scale, which may reflect palaeogeographical or latitudinal differentiations.

SUMMARY

The climate analysis of five Hungarian Late Oligocene fossil plant assemblages adopting the Coexistence Approach gave consistent results for most localities. A warm temperate climate corresponding to Cfa-type *sensu* KÖPPEN (1931) is resulted by the quantitative estimation of four climate variables (mean annual temperature – MAT, temperature of the coldest month – CMT, temperature of the warmest month – WMT and mean annual precipitation – MAP). Values of MAT conform to that suggested by KVAČEK and HABLY (1991) for the Eger-Wind assemblage. The seasonal variation in rainfall has not been predicted from the datasets in this study. Earlier systematics- and morphology-based, non-quantitative climate reconstructions (HABLY 1988, 1990, 1993, 1994) suggested humid subtropical climate for the Kesztölc, Vértesszőlős, Andornaktálya and Pomáz assemblages.

As compared to the palaeoclimate estimates of contemporaneous palyno-floras from the Eastern Alps completed by BRUCH (1998) the Eger-Wind/pollen and Treubach assemblages display well comparable climate with that of the Hungarian Egerian floras. Intervals of MAT for the Govce and Como palyno-floras indicate lower minimum values of MAT which may be resultant either from palaeogeography or from methodology, *i.e.* palyno-floras versus leaf-floras used for climate calculations – more regional *vs* local climate signal given by their floralists.

* * *

Acknowledgement – The study was supported by the Hungarian Scientific Research Fund (OTKA T037200) and it is a contribution to the program "*Neogene Climate Evolution in Eurasia* – NECLIME".

REFERENCES

ANDREÁNSZKY, G. (1966): The Upper Oligocene flora of Hungary. Analysis of the site at the Wind brickyard, Eger. – *Studia biol. hung.* **5**: 1–151.

BÁLDI, T. (1965): A felsőoligocén pektunkuluszos és cyrénás rétegek települési és ősföldrajzi viszonyai a Dunazug hegységben. (The stratigraphical and paleogeographical relations of the Upper Oligocene Pectunculus- and Cyrena-beds in Dunazug Mountains). – *Földt. Közl.* **95**: 423–436.

BÁLDI, T. (1973): *Mollusc fauna of the Hungarian Upper Oligocene (Egerian).* – Akadémiai Kiadó, Budapest, 551 pp.

BÁLDI, T. (1976): Correlation between the Transdanubian and N-Hungarian Oligocene. – *Földt. Közl.* **106**(4): 407–424.

BÁLDI, T. (1983): *Oligocene and Lower Miocene Formations of Hungary.* – Akadémiai Kiadó, Budapest, 293 pp.

BÁLDI, T. (1998): *Magyarország epikontinentális oligocén képződményeinek rétegtana.* (Stratigraphy of the epicontinental Oligocene formations of Hungary). – In: BÉRCZI, I. and JÁMBOR, Á. (eds): Magyarország geológiai képződményeinek rétegtana. (Stratigraphy of geological formations in Hungary). MOL Rt. and MÁFI, Budapest, pp. 419–435.

BÁLDI, T. and SENEŠ, J. (1975): Die Definition der Zeiteinheit OM. – *Chronostratigraphie und Neostratotypen* **5**: 41–42. Bratislava (VEDA).

BÁLDI, T., LESS, GY. and MANDIĆ, O. (1999): Some new aspects of the lower boundary of the Egerian stage (Oligocene, chronostratigraphic scale of the Paratethys area). – *Abhandlungen der Geologischen Bundesanstalt* **56**(2): 653–668.

BRUCH, A. A. (1998): Palynologische Untersuchungen im Oligozän Sloweniens – Paläo-Umwelt und Paläoklima im Ostalpenraum. – *Tübinger Mikropaläontologische Mitteilungen* **18**: 1–193.

CSONTOS, L., NAGYMAROSY, A., HORVÁTH, F. and KOVÁC, M.. (1992): Tertiary evolution of the Intra-Carpathian area: a model. – *Tectonophysics* **208**: 221–241.

HABLY, L. (1988): Egerian fossil flora from Kesztölc, NW Hungary. – *Studia bot. hung.* **20**: 33–61.

HABLY, L. (1990): Egerian plant fossils from Vértesszőlős, NW Hungary. – *Studia bot. hung.* **22**: 3–78.

HABLY, L. (1993): Egerian macroflora from the Andornaktálya sandpit (Hungary). – *Studia bot. hung.* **24**: 5–22.

HABLY, L. (1994): Egerian plant fossils from Pomáz, Hungary. – *Fragmenta Mineralogica et Palaeontologica* **17**: 5–70.

KÁZMÉR, M. and KOVÁCS, S. (1985): Permian-Paleogene Palaeogeography along the eastern part of the Insubric-Periadriatic lineament system: evidence for continental escape of the Bakony-Drauzug unit. – *Acta Geologica Hungarica* **28**(1–2): 71–84.

KÖPPEN, W. (1931): *Grundriss der Klimakunde.* – De Gruyter, Berlin, 388 pp.

KVAČEK, Z. and HABLY, L. (1991): Notes on the Egerian stratotype flora at Eger (Wind brickyard), Hungary, Upper Oligocene. – *Annls hist.-nat. Mus. natn. Hung.* **83**: 49–82.

LEÉL-ŐSSY, SZ. (1984): *Három Pilis-Visegrádi-hegységi felső-oligocén feltárás molluszka faunájának és kőzetanyagának vizsgálata.* (The study of the mollusc fauna and lithology of three Upper Oligocene outcrops from the Pilis-Visegrád Mountains). – Thesis, manuscript, ELTE, Budapest.

MOSBRUGGER, V. and UTESCHER, T. (1997): The coexistence approach – a method for quantitative reconstructions of Tertiary terrestrial palaeoclimate data using plant fossils. – *Palaeogeography, Palaeoclimatology, Palaeoecology* **134**: 61–86.

NAGY, E. (1979): Palynological evaluation of the holostratotype of the Egerian. – *Acta Biol. Szeged* **25**: 45–52.

NAGYMAROSY, A. (1990): Paleogeographical and Paleotectonical outlines of some Intracarpathian Paleogene Basins. – *Geologica Carpathica* **41**(3): 259–274.

OSZCZYPKO, N. and SLACZKA, A. (1985): An attempt to palinspastic reconstruction of Neogene basins in the Carpathian foredeep. – *Ann. Soc. Geol. Pol.* **55**(1/2): 5–75.

PÁLFALVY, I. (1967): Oligocén növénymaradványok Kesztölc környékéről. (Oligozäne Pflanzenreste aus der Umgebung von Kesztölc). – *Földt. Int. Évi Jel. 1965-ről* (Annual Report of the Geological Survey 1965), pp. 281–287.

PLANDEROVA, E., KLAUS, W. and NAGY, E. (1975): Palynologische Charakteristik des Egeriens und mikrofloristische Korrelation der Schichtengruppen in der Tschechoslowakei, Ungarn und Österreich. – *Chronostratigraphie und Neostratotypen.* **5**: 553–567.

SCHRÉTER, Z. (1953): A Kesztölc-Esztergom környéki harmadkori dombvidék. (The Tertiary hills of the Kesztölc-Esztergom region). – *Földt. Int. Évi Jel. 1951-ről* (Annual Report of the Geological Survey 1951), pp. 151–156.

VARGA, P., SZTANÓ, O., FODOR, L., HABLY, L., TARI, G., NAGYMAROSY, A., BÁLDI, T. and SZABÓ, S. (1989): Andornaktálya, felsőoligocén homokbánya. (Upper Egerian sand-pit of Andornaktálya). – *Report, Geological Department, ELTE, Budapest*, pp. 116–174.

(Received: 6 July, 2004)