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MIDDLE AND LATE MIOCENE FLORISTIC CHANGES IN THE NORTHERN AND SOUTHERN PARTS OF THE CENTRAL PARATETHYS

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ABSTRACT: As a result of micro- and macropalaeobotanical studies on Miocene sediments from southern Poland and northern Bulgaria (the Northern and Southern parts of the Central Paratethys) the main trends in floristic and coenotic evolution have been established. The fossil floras of both regions are briefly described and compared. The changes in the development of the fossil flora and vegetation have been clarified with regard to palaeoclimatic and palaeogeographic conditions.

KEY WORDS: Central Paratethys, Southern Poland, Northern Bulgaria, Palaeobotany

INTRODUCTION

Over the last 20 years or so an informal collaboration has existed between the Institute of Botany, Polish Academy of Sciences and the Institute of Botany, Bulgarian Academy of Sciences. This collaboration has been developed in the last few years in the form of an official research agreement between the Polish and Bulgarian Academies of Sciences. This report presents the preliminary results of our joint investigations.

SHORT GEOLOGICAL DESCRIPTION

SOUTHERN POLAND

In Southern Poland the first Neogene marine transgression took place during the Egerian (Ney *et al.* 1974), when the sea covered a small area in the Sudetan plain. The Eggenburgian and Ottnangian transgressions were not large and the sea occupied only the south-eastern part of Polish territory. The sea, in the form of a narrow strait, stretched from the east through the Nowy Sącz Basin up to the Nowy Targ Basin.

Modifications of the basins and the development of the Carpathian depression started in the Karpatian period. From the east the marine gulf of the Forecarpathian Basin reached up the Jasło–Krosno and Nowy Sącz depressions as far as the margins of Nowy Targ–Orawa Basin. At the same time the Carpathian depression was divided by the “Cracow belt” into two parts.

The last marine transgression occurred in the Badenian and Sarmatian. At the beginning of the Sarmatian there still existed a connection between the eastern and western basins of the Carpathian depression (Fig. 1). As a result of a gradual regression from west to east during the late Sarmatian, the sea finally retreated from southern Poland and the late Miocene is represented by a sequence of freshwater and continental sediments.

NORTHERN BULGARIA

During the Miocene north-western Bulgaria was a part of the Central Paratethys area. The sedimentation there began in the middle Miocene (Badenian). The middle and upper Miocene are represented by a series of marine-brackish sediments rich in plant remains. These deposits are of great interest, not only from a palaeobotanical point of view, but because they contain many other fossils – molluscs, foraminifers and ostracods. The correlation of the biostratigraphic units based on these fossil groups has been presented by Kojumdgieva *et al.* (1989). The foraminiferal zones form the basis for the separation of the substages in the marine Badenian. The separation of substages and minor subdivisions in semimarine and brackish-water sediments is based principally on molluscs, but the foraminifers and ostracods have additional stratigraphic importance. From the lithological point of view, the Neogene sediments are grouped into 11 lithostratigraphic units (Formations) introduced by Kojumdgieva & Popov (1988).

The palaeogeography and evolution of the basin were discussed by Kojumdgieva & Popov (1989). In the middle Miocene a longitudinal Miocene depression was

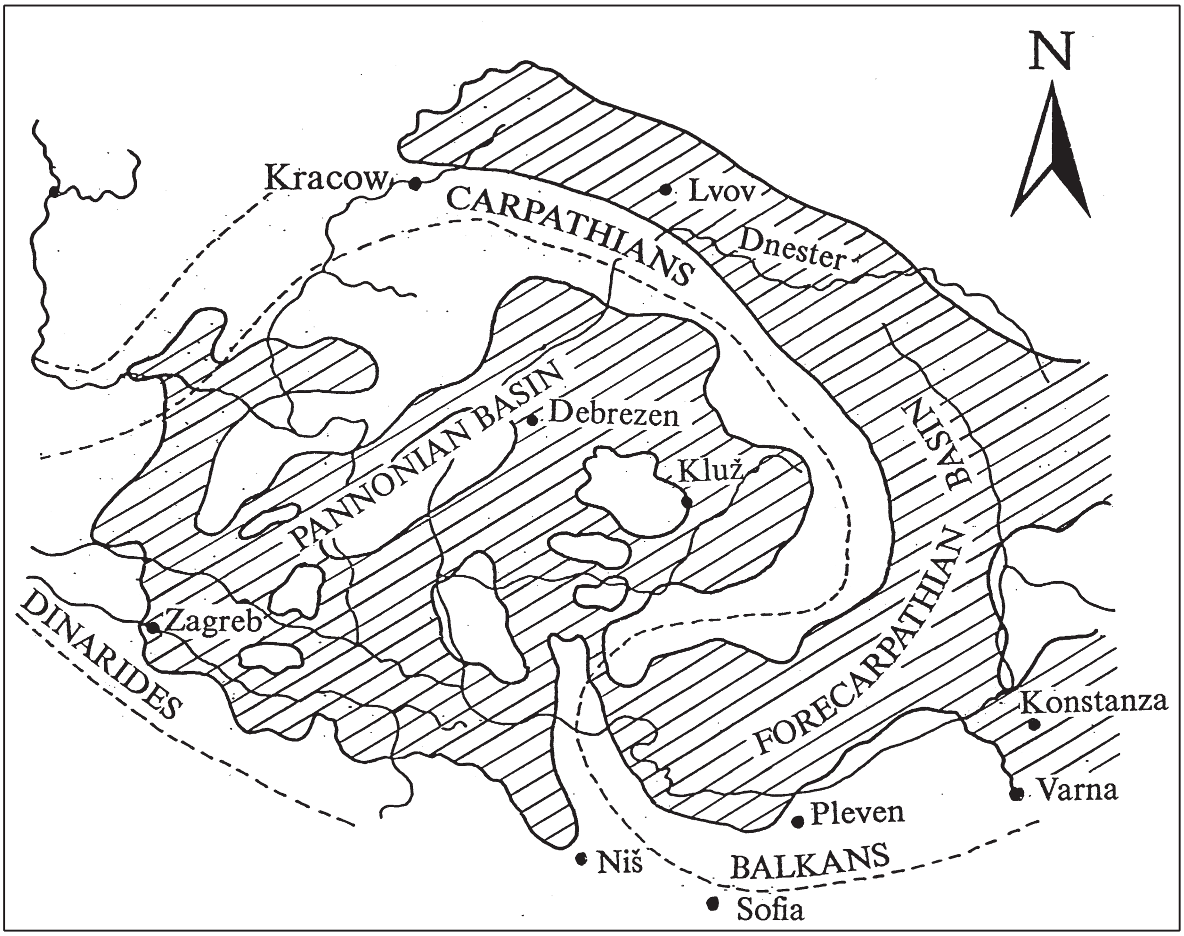

Fig. 1. Palaeogeographic scheme of the Central Paratethys area

formed in north-western Bulgaria, probably as a result of the compression of blocks behind the Carpatho-Balkan arc and its movement to the north-east. The Forecarpathian Basin occupied the depression and its borders. This Badenian – early Sarmatian depression was filled up with sediments during the middle-late Sarmatian and disappeared, but a new one (Lom depression) was formed, probably by concentric extension derived from the active pressure of the Southern Carpathians. This depression also existed in the Meotian-Pliocene interval, gradually beeing filled with sediments. The Meotian – middle Pontian Basin covered this depression and its borders.

The fossil macroflora (leaf imprints) in north-western Bulgaria has been studied from 32 localities of Volhynian and Bessarabian age, as well as seeds, fruits and cuticles which had been obtained from many outcrops and borehole specimens (Petkova 1977, Palamarev & Petkova 1987, Palamarev 1991, Palamarev & Uzunova 1992, Uzunova 1995, 1996 and others). The middle and late Miocene pollen assemblages have been studied from four boreholes and some outcrops (Ivanov 1995, 1997). All these data are used in the present report for comparison with the palaeoflora from southern Poland.

DEVELOPMENT OF THE FOSSIL FLORAS

BADENIAN

The Badenian was a period of expanding transgression of the Paratethys and as a result the sea covered northern Bułgaria and large areas in the south of Poland – Krosno–Jasło, the Nowy Sącz and Nowy Targ–Orawa Basins.

There are many localities with macro- and microfloras in southern Poland which have been studied by many authors (Zabłocki 1928, 1930, Iljinskaya 1962, 1964, Łańcucka-Środoniowa 1966, 1984, Łańcucka-Środoniowa & Zastawniak 1997, Oszast & Stuchlik 1977, Stuchlik 1992). The early Badenian flora is characterized by an abundance of warm-temperate elements like Mastixioideae, Lauraceae, *Castanea*-*Castanopsis*, *Eurya* etc. The palaeofloristic data indicate that more favourable climatic conditions persisted in the lowlands outside the area of the Carpathian mountains. The character of the flora in the lowlands is more subtropical and warm-temperate and rather uniform (Oszast 1967, Dyjor & Sadowska 1984). In the areas of Swoszowice, Wieliczka and Gdów Bay the palaeoflora represents the last phase of the so-called mastixioidean flora (Syabryay & Stuchlik 1994). At the same time the differentiation of the flora into 2 or 3 altitudinal vegetation belts could be recognized in the mountain region (Oszast & Stuchlik 1977): swamp forest in the valleys of the Carpathian rivers; a lower montane zone of warm- temperate mixed forest, and an upper montane zone of coniferous forest dominated by *Picea*, *Abies* and *Tsuga*.

The late Badenian flora indicates a trend towards a gradual fall in the temperature and a decrease in the humidity. It is characterized by the predominance of gymnosperms over angiosperms and a successive decline of the more thermophilous elements (Oszast & Stuchlik 1977). In the upper Badenian sediments, macroscopic plant remains occur that indicate the Mediterranean character of the climate (*Pinus halepensis, Tetraclinis articulata, Juniperus oxycedrus, Chamaerops humilis*) (Szafer 1961). Such sclerophyllous elements do not appear in the southern part of the basin, probably due to the absence of the uppermost Badenian sediments.

In the southern part of the Central Paratethys the fossil flora is characterized by a higher incidence of thermophilous and palaeotropical plants. Polydominant hygromesophilous forest principally composed of Lauraceae, Magnoliaceae, Juglandaceae, Theaceae, Sapotaceae and Symplocaceae existed during the early and middle Badenian (Palamarev 1971, 1991, Ivanov 1995). The role of arctotertiary elements in the composition of these palaeocommunities was limited and many of them were represented only sporadically. The climate of that time was subtropical with a high humidity.

Along the seacost and river banks a swamp forest of Taxodiaceae, Cyrillaceae, Myricaceae, *Byttneriophyllum* and *Bumelia* developed. It reached its maximum distribution at the beginning of the late Badenian, coincident with palaeogeographic changes and the so-called lagoon period in the development of the southern part of the Central Paratethys (Trashliev 1984).

As a whole, the vegetation of the Badenian in the southern part of the Paratethys is characterized by a predominance of subtropical and warm-temperate floral elements. During the late Badenian hygromesophytic forest maintained its character, but a tendency towards a decrease in the role of thermophilous elements can be observed. At the same time the number and quantity of arctotertiary elements increased, just as it did in the northern part of the basin.

At the end of the Badenian the sea retreated from Bulgaria until the early Sarmatian transgression and the uppermost Badenian sediments are not represented.

SARMATIAN

The early Sarmatian floras and vegetation in both southern Poland and northern Bulgaria retain the main features of the late Badenian floras (Oszast & Stuchlik 1977, Oszast 1973, Syabryay & Stuchlik 1994, Ivanov 1995).

The main characteristic feature of the flora from the northern part of the Central Paratethys is the abundance of small-leaved elements (Fabaceae) as well as *Acer, Alnus, Betula, Carya, Castanea, Fagus, Ulmus* and *Zelkova* (Stuchlik 1992). More warm-temperate elements like *Laurophyllum* and the Symplocaceae are found sporadically. As was pointed out by Szafer (1961) the climate of that period was somewhat cooler, but humid in comparison with the end of the Badenian. During the second half of the Sarmatian (s. str.) the sea retreated from southern Poland and freshwater sedimentation took place. The development of the flora was similar to that of the early Sarmatian. The plant associations contained warm-temperate species, but some sclerophyllous forms (*Rhamnus* cf. *alaternus, Pyracantha, Punica, Rhus, Celtis, Pistacia, Myrtus, Olea* and *Jasminum*) and Mediterranean evergreen oaks (Zastawniak 1980).

In the southern part of the Central Paratethys the Sarmatian sediments can be divided into three substages: the Volhynian, Bessarabian and Chersonian (Rögl & Steininger 1983, Popov 1992). The Volhynian and the lower part of the Bessarabian correspond to the Sarmatian s. str.

The sedimentation in the Bulgarian part of the basin began in the early Volhynian as a result of the transgression of the Forecarpathian Basin in a south-westerly direction. The sediments of this age are very rich in micro- and macro-plant remains (Petkova 1977, Palamarev & Petkova 1987, Palamarev 1991, Palamarev & Uzunova 1992, Ivanov 1995). On the basis of palaeoecological analysis (Palamarev 1991, Ivanov 1995) the following main palaeocommunities have been distinguished: **A)** aquatic plants (*Ruppia, Najas, Eulimnocarpus, Nuphar, Nelumbo, Ceratophyllum, Potamogeton*); **B)** hygrophytic (swamp) forest (*Glyptostrobus*, Taxodiaceae, *Myrica, Bytneriophyllum, Cyrilla, Nyssa, Bumelia*); **C)** riparian forest (*Platanus, Alnus, Ostrya, Ulmus, Pterocarya, Salix, Populus, Staphylea, Fraxinus, Periploca, Vitis, Smilax*); **D)** hemixerophytic shrubs and trees (*Arbutus, Berberis, Anagyris, Nerium, Paliurus, Celastrus*); **E)** hygromesophytic to mesophytic forest. To complete their classification they recognized those palaeocommunities which developed on areas of varied relief. In different biotopes grew laurophyllous forest (*Persea, Ocotea, Litsea, Eurya, Cedrela* and *Schefflera*) and oak-magnolia mesophytic forest (*Magnolia, Quercus, Liriodendron, Castanea, Symplocos, Corylopsis* and *Eucommia*) with the characteristic presence of *Taiwania* and *Cunninghamia* in them. In comparison with the Badenian palaeocommunities the Sarmatian ones are characterized by a greater proportion of arctotertiary elements. A tendency towards an increase in the role of floristic elements associated with warm-temperate and temperate climates (*Be-*

tula, Alnus, Carpinus, Corylus, Ostrya, Fagus, Eucommia, Tilia, Staphylea and *Cornus*) can be observed. The most favourable climatic conditions for the development of a fossil flora, in comparison with to the rest of Sarmatian (s. l.), existed during the Volhynian time. This was a period of great diversity and species rich communities. At that time *Engelhardia*, *Castanopssi* and representatives of Lauraceae, Theaceae, Sapotaceae and others dominated the composition of mixed mesophytic and hygromesophytic forest.

PANNONIAN

The evolution of vegetation during the Pannonian period reflects changes in the palaeogeography and basin configuration. A large regression in the diversity of vegetation took place in the first half of the Pannonian.

In the northern part of the basin the area occupied by swamp forest decreased (Oszast & Stuchlik 1977). Due to the cooling of the climate, thermophilous taxa disappeared, namely *Engelhardia, Nyssa,* the Cyrillaceae, *Aralia, Decodon* and *Symplocos*. Broad-leaved forest was wide spread, but with a prevalence of temperate deciduous elements. The palaeoflora was characterized by an increase in the more temperate genera such as *Alnus, Betula, Carpinus* and *Ulmus*. Herbaceous plants played a greater role and open herbaceous communities spread widely. The climate was temperate and relatively dry.

In the southern part of the basin the Pannonian period coincided with the end of the Bessarabian, Chersonian and Meotian (Fig. 2). During the late Bessarabian and Chersonian the vegetation changes were related to the aridity and cooling in the climate after the retreat of the warm Miocene sea and a transformation of the floras from subtropical to warm-temperate and temperate is observed. The role of dominants in the mixed mesophytic forest was played by species of *Quercus, Castanea, Ulmus, Carya* etc. Some subtropical floristic elements are sporadically represented in the composition of the palaeofloras (e. g. *Engelhardia*, *Reevesia*, *Itea*, *Symplocos*, Sapotaceae, Theaceae etc.)

Starting in the Bessarabian and persisting until the middle Meotian, a xerophytic herbaceous community of the type Chenopodiaceae-*Artemisia*-Caryophyllaceae spread widely, while subxerophytic forest and shrub communities played a greater role. The latter were composed of species of *Celtis, Anagyris, Caesalpinites, Robinia, Sophora, Celastrus, Paliurus* etc. Generally in the Bessarabian palaeoflora an increase in Mediterranean elements can be observed. This period may be described as a semi-arid phase (Palamarev & Ivanov 1998), which also became established in other Balkan lands (Pantič & Mihailovič 1980) as is confirmed by sedimentological data (Koleva-Rekalova 1996). The climate of this period can be described as warm, with long dry periods and minimal rainfall. This phase coincides with the maximum distribution of open herbaceous communities in the northern part of the Central Paratethys area, but the climate in that area was cooler and less dry.

PONTIAN

The late Pannonian (=late Meotian) and Pontian floras were affected by the transgression of the Paratethys sea both to the south and the north. In southern Poland the Pontian flora (Szafer 1946, 1947, 1954, Oszast & Stuchlik 1977) was characterized by a slight decrease in the area of *Picea* forest which had been formed in the late Pannonian. At the same time the mixed deciduous forest with *Fagus, Quercus*, and *Carya* remained unchanged, but subtropical species disappeared altogether. The remains of marshy vegetation still survived and the main components were Taxodiaceae and *Alnus*, the latter becoming the dominant tree.

In the southern part of the Paratethian area mixed mesophytic forest prevailed with a dominant role not only for warm-temperate and temperate species such as *Quercus, Carya, Castanea* and *Ulmus,* but also for *Magnolia, Castanopsis, Zelkova, Eurya, Ilex* and *Aralia*. Some subtropical elements still existed, probably as relicts. In the late Meotian and early Pontian a slight increase in the role of swamp and riparian forest was observed. Just as in the northern areas there was a characteristically higher incidence of *Alnus* in them. At the same time a decrease in the distribution of xerophytic herbaceous communities is evidence of moister climatic conditions. The climate of that period can be described as warm-temperate or temperate, but with a somewhat lower air temperature and higher humidity than the early Meotian.

CONCLUSIONS

Comparisons of the palaeofloristic data from the northern and southern parts of the Central Paratethys area show similarities in the evolutionary trends of the vegetation (Fig. 2). At the same time, there are many differences which were due to the different geographical locations of the studied palaeofloras. For example, the quantity of thermophilous elements in floristic complexes of the same age is greater in the southern part of the basin. The majority of these elements like *Lygodium*, Gleicheniaceae, *Corylopsis, Itea, Reevesia*, Araliaceae, Arecaceae etc. disappeared earlier from the northern floras than from the southern ones. At the same time arctotertiary species belonging to the genera *Picea, Tsuga, Abies, Fagus* and *Betula* appeared or became dominants in the communities earlier in the northern part than in the southern. The two regions belong to different floristic

STAGE	SUBSTAGES			SOUTH POLAND	NORTHWEST BULGARIA
MIOCENE UPPER	PONTIAN			Mixed deciduous forests with dominance of the species of *Fagus, Quercus, Carya*. The subtropical species disappeared altogether. The remains of marshy vegetation still survived and the *Alnus* became dominant tree in them. The forests of *Picea* existed in the mountain areas and *Abies* and *Tsuga* became more diverse in them.	Mixed mesophytic forests with dominance of warm-temperate and temperate species of *Quercus, Castanea, Ulmus* and *Carya* and the presence of *Magnolia, Castanopsis, Eurya, Ilex, Aralia*. Increasing in the role of the arctotertiary species. Changes in the taxonomic composition of swamp forests. Decreasing in the distribution of herbaceous xerophytic paleocommunities.
MIOCENE UPPER	PANNONIAN	MAEOTIAN		Disappearance of thermophyllous elements like *Engelhardia*, *Nyssa,* Cyrillaceae, *Aralia, Decodon, Symplocos.* Wide spreading of broad-leaved forests with prevalence in them of the elements of temperate deciduous flora. A greater role of herbaceous plants and distribution of open herbaceous communities. Forming of *Picea* forests in the mountains.	Appearance and maximum in the development of herbaceous xerophytic paleocommunities: Chenopodiaceae-*Artemisia*-Caryophyllaceae. Subxerophytic shrub coenosis of *Celtis, Anagyris, Caesalpinites, Robinia, Sophora, Paliurus* etc. Restricted distribution of thermophyllous elements in the composition of mixed mesophytic forests. Limited role of riparian and swamp forests.
		CHERSONIAN	SARMATIAN S. L.		
MIOCENE MIDDLE	SARMATIAN S. STR.	BESSARABIAN	SARMATIAN S. L.	Prevalence of mesophytic multispecies deciduous forests. The proprtion of arctotertiary species increased. Thermophyllous elements like *Laurophyllum*, Symplocaceae were sporadicaly presented. Tendency toward cooling of the climate.	Wide distribution of laurophyllous forests and oak-magnolia mesophytic forests. Significant increasing in the participation of arctotertiary elements in the composition of the flora. Restriction in the distribution of the swamp forests. Tendency toward cooling of the climate.
		VOLHYNIAN	SARMATIAN S. L.		
MIOCENE MIDDLE	BADENIAN			The thermophilous elements like Mastixioideae, Lauraceae *Castanea-Castanopsis, Eurya, Cyrilla, Platycarya* disapeared slowly. *Engelhardia* still played an important role. The significance of the arctotertiary group of species clearly increased in the flora.	Mixed mesophytic and hygromesophytic forest communities with dominance in it of the species of Lauraceae, Magnoliaceae, Juglandaceae, Theaceae and Sapotaceae. Limited role of arctotertiary elements in the composition of the flora. Tendency toward decreasing in the role of thermophyllous elements. Wide distribution of swamp forests.

Fig. 2. Correlation of the palaeofloristic changes in the southern Poland and northern Bulgaria during the middle and late Miocene

provinces: the West European and East-European-Pontian. Moreover, on the basis of the presence of specific palaeocommunities and many endemic species (from the genera *Eostangeria, Matudaea, Broussonetia, Ocotea, Lithocarpus, Skimmia, Cercidiphyllum, Rubus, Prunus, Kadsura, Caesalpinites, Decodon* and *Schefflera*) a Miocene Central-Balkan subprovince was created in the Balkan Peninsula by Palamarev (1991).

Despite local floristic differences, we should conclude that the evolution of the vegetation in both regions reflects global climatic events and major palaeogeographic changes. The main trends in floristic evolution are a decrease in palaeotropical elements and an increase in arctotertiary ones. This was due to a gradual change in the climatic conditions during the studied period, leading to replacement of subtropical climate by a warm-temperate and later a temperate one. These climatic fluctuations are well reflected in the floristic complexes, with the main floristic and changes in vegetation associated with well-defined stratigraphic levels. The changes can be used to correlate the marine and continental sediments from the studied areas.

The main floristic changes are observable at the Badenian/Sarmatian boundary when an invasion of arctotertiary elements occurred, due to the cooling of the climate over large areas. The next great change occurred during the late Bessarabian – early Meotian (=early Pannonian) when in the south an increase in the abundance of xerophytic elements, and in the north a wider distribution of herbaceous palaeocommunities are observed. This change was induced, not so much by the cooling of the climate as its drying. After this period, during the late Meotian – Pontian, humid climatic conditions existed in the areas studied. Temperate elements prevailed in the palaeocommunities, but in the southern parts of the basin some subtropical elements still existed as relicts from the Badenian and Sarmatian periods.

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