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Palaeofloristic and palaeoclimatic reconstruction on the territories of Ukraine and Poland during the Badenian–Sarmatian*

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ABSTRACT. On the basis of palynostratigraphic studies of some Badenian and Sarmatian profiles climatic parameters for the Central and Eastern Paratethys region (southern Poland and western Ukraine) have been established and the ecological structure of the vegetation analyzed. Using Grichuk's method based on "climatic areals" for several profiles circograms and climatograms have been established and on its basis the evolution of the flora and vegetation presented. This study has permited the identification that the Late Badenian and Early Sarmatian floras of Central and Eastern Paratethys belong to one substage of the first evolution stage of the Miocene flora.

KEY WORDS: palaeoclimate, palaeovegetation, Paratethys, Badenian–Sarmatian

INTRODUCTION

Cenozoic floral and vegetational evolution is proceeded into a few stages from tropical-subtropical to temperate. The first Miocene stage is characterized by the maximum distribution of tropical-subtropical elements of the flora in the early part (Eggenburgian), and gradually becoming impoverished though the Late Badenian – Early Sarmatian time, for which the lowest distribution of macrothermic elements was typical. The Middle Sarmatian represents the beginning of the next stage of flora evolution.

The development of terrestrial palaeolandscapes depends highly on different geological events and changes to the environment. Landscape change depends on a balance between tectonic events, relief, climatic changes, hydrologic regime, soils, and plant cover. The change of one factor causes adequate disturbance of others, especially with regard to creating mechanisms for changing plant cover.

Palynological studies are very useful for describing the development and changes of plant cover and for assessing other factors of palaeogeographic reconstruction. On the basis of palynological research of various profiles the vegetation cover as well as features of the palaeolandscape can be reconstructed.

The main goal of this work was to study sequences of palynocomplexes and to analyse previously published data in order to consider palynological description of Badenian–Sarmatian sediments. This has allowed the reconstruction of the palaeolandscapes of this age, permitting the comparison of them to identify spatial and temporal changes. The study of stratigraphic sequence of spore and pollen assemblages from the Badenian–Sarmatian sediments and their palaeoecologic interpretation allows the evolutionary process of terrestrial vegetation to be reconstructed more exactly.

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MATERIAL AND METHODS

Palynological descriptions of sedimentary sequences from the following localities have been analyzed: Twardawa, Biała (Sadowska 1989), Stara Kuźnia (Dyjor & Sadowska 1984, Sadowska 1989), Stare Gliwice (Oszast 1960, Stuchlik 1974, Dyjor & Sadowska 1984), Koniówka, Czarny Dunajec (Oszast & Stuchlik 1977), Ukrainian Plain and Kerch peninsula (Shchekina 1979), and the Carpathian region (Syabryaj 1978). All of these localities are situated within the territory of Central and Eastern Paratethys (Fig. 1).

Fig. 1. Map of Poland and Ukraine (Part of Paratethys)

On the basis of sequential stratigraphic study of the Badenian–Sarmatian fossil plant remains (pollen and spores) the palaeovegetation has been reconstructed and studied to identify quantitative climatic parameters for the Central and Eastern Paratethys parts of Poland and Ukraine. In addition the ecological structure of the Badenian–Sarmatian plant cover has been analyzed.

For reconstruction of the quantitative climatic parameters, temperatures for the coldest and warmest months and average annual temperatures for every studied stage have been determined using the method of Grichuk and co-authors (Grichuk et al. 1987). This method is based on "climatic areals" of contemporary plants, and represents a "Nearest Living Relative" approach for palaeoclimatology. These "climatic areals" have been constructed from data from meteorological stations within the areals of distribution of contemporary genus analogues in the same coordinate system. In this system the ordinate axes for temperature of January and on the abscissa axes temperature of July were shown. One of the principles of this method is the superposition of "climatic areals" of taxa from each fossil flora complex. As a result of superposition of "climatic areals" in the same coordinate system we have climatograms with temperature area of coexisting plants, which could grow together within these temperature boundaries. The average annual temperature was calculated as an arithmetic mean of the coldest and warmest months. For quantitative palaeoclimatic description of the mountain region we focused on forest plants of the lower mountain zone, which reflected the latitude type of the vegetation.

For palaeoecological reconstruction the method of Golbert and co-authors (Golbert et al. 1977), actually for the European Neogene modernized by us, has been used. Our attention was focused on the common character of the ancient plant groups and palaeoecological peculiarities of ancient plant assemblages. These data have been graphically presented as circograms (Fig. 2). Every taxa complex was divided into three groups: hydro-mesophilous "A" (plants of humid and over humid environment), xerophilous "B" (plant of arid environment) and ecologically undefined "C" (plants of humid and arid environment without obvious belonging to one of them). Inside of every group taxa were divided by the degree of heat-tolerance (Fig. 2). Percentage content of every taxon has been recalculated in temperature degree and these data were used for construction of cartograms/climatograms.

In addition the coefficient of hygrophility (K_r) – as a relation of amount of hydrophytes to another member of pollen/spore complex and coefficient of thermophility (K_t) – as a relation of the amount of tropical-subtropical plants to another member have also been calculated. The main criterion used to infer changes in

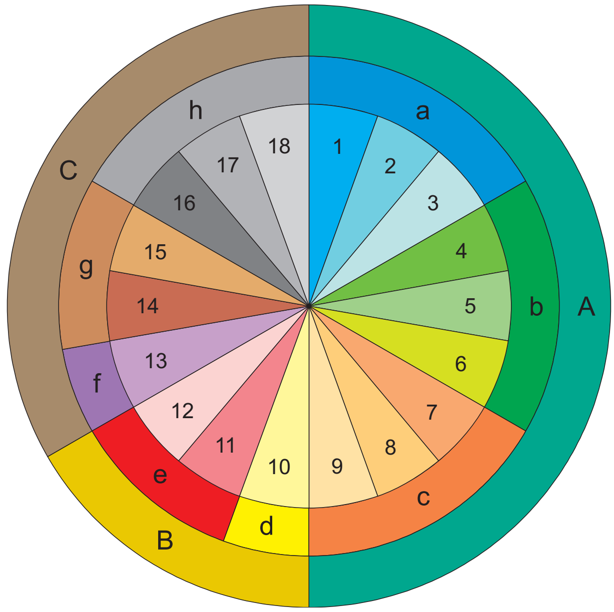

Fig. 2. Explanation to circograms; **A** – **hygromesophilous group: a** – tropical-subtropical subgroup: **1 –** Spores (*Asplenium*, *Cibotium*, Cyatheaceae, *Dicksonia*, *Dryopteris*, *Gleichenia*, *Lygodium*, *Polypodium*); **2** – Gymnospermae (*Keteleeria*, *Podocarpus*, *Taxodium*); **3** – Angiospermae (*Aralia*, *Cyrilla*, *Diospyros*, *Engelhardia*, *Loranthus*, *Parrotia*, *Reevesia*); **b** – subtropical-warm-temperate subgroup: **4** – Spores (*Botrychium*, *Equisetum*, *Osmunda*, *Polypodiaceae*, *Sphagnum*); **5** – Gymnospermae (*Abies*, *Ginkgo*, *Glyptostrobus*, *Sciadopitys*, Taxodiaceae (without *Taxodium*), *Taxus*, *Tsuga*); **6** – Angiospermae (*Carpinus*, *Carya*, *Castanea*, *Cyclocarya*, *Diervillea*, *Fothergilla*, *Hamamelis*, *Ilex*, *Juglans*, *Liquidambar*, *Lonicera*, *Nyssa*, *Parthenocissus*, *Platanus*, *Platycarya*, *Quercus*, *Staphylea*, *Tilia*, *Viburnum*, *Zelkova*;) **c** – warm-temperate-temperate subgroup: **7** – Coniferae (*Larix*, *Picea*); **8** – Angiospermae (*Betula*, *Cornus*, *Eucommia*, *Fagus*, *Potamogeton*, *Pterocarya*, *Sparganium*, *Typha*;) **9** – Algae, water ferns (*Azolla*, *Salvinia*); **B** – **xerophilous group: d** – tropical-subtropical subgroup: **10** – Angiospermae (*Eucalyptus*, *Morus*, *Myrtus*, Proteaceae; **e** – subtropical-warm-temperate soubgroup: **11** – Gymnospermae (Cupressaceae, *Ephedra*); **12** – Angiospermae (*Berberis*, *Castanopsis*, *Celtis*, *Comptonia*, *Olea*, *Pistacia*, *Rhus*); **C** – **ecologically undefined group: f** – tropical-subtropical subgroup: **13** – Angiospermae (*Buxus*, Euphorbiaceae, Sapotaceae); **g** – subtropical-warm-temperate subgroup: **14** – Coniferae (*Cedrus*, *Pinus sylvestris* type); **15** – Angiospermae (*Acer*, Elaeagnaceae, Ericaceae, *Euonymus*, Fabaceae, *Fraxinus*, Gentianaceae, *Myrica*, *Ostrya*, Rosaceae, Rubiaceae); **h** – warm-temperate-temperate subgroup: **16** – Coniferae (*Pinus haploxylon type*, *Pinus* sp.); **17** – Angiospermae (*Alnus*, *Corylus*, *Salix*, *Ulmus*); **18** – Herbs

the Neogene vegetation composition is quantitative assessment of groups with their ecological tolerance deduced from the ecology of their modern analogues.

RESULTS

SILESIAN AND WESTERN CARPATHIAN PART OF THE CENTRAL PARATETHYS BASIN

In the Late Badenian as an effect of tectonic movement in the Carpathian Foredeep the marine transgression occurred and marine beds were deposited on the territory of the Carpathian Foredeep, which was surrounded by elevated Western Beskid mountains to the south.

The Badenian sediments were studied palynologically from the Twardawa and Biała localities (Sadowska l989), Stara Kuźnia (Dyjor & Sadowska 1984), Stare Gliwice (Oszast 1960, Stuchlik 1974, Dyjor & Sadowska 1984), and Czarny Dunajec and Koniówka (Oszast & Stuchlik 1977).

According to Oszast and Stuchlik (1977), Sadowska (1989) and others, the sea shore and low-lying sites were covered by swamp forest and peat-bogs with taxodiaceaeous conifers, *Nyssa*, *Carya*, *Liquidambar*, *Pterocarya*, *Alnus*, *Myrica*, *Salix* and others. These communities were not so broadly distributed in the Carpathian Foredeep as in the Polish Lowland.

Mixed forests with *Pinus*, *Abies*, *Tsuga*, *Picea*, *Cedrus*, *Sciadopitys*, *Fagus*, *Quercus*, *Engelhardia*, *Castanea*, *Juglans*, *Tilia*, and *Ulmus* were spread on elevated areas in the mountain foreland and the mountains. Some thermophilous elements Araliaceae, *Platycarya* and Cyatheaceae were present in plant communities near the Paratethys sea shore, but the role of more thermophilous plants (*Parrotia*, Palmae, *Reevesia*, *Symplocos* and others), especially Mediterranean elements

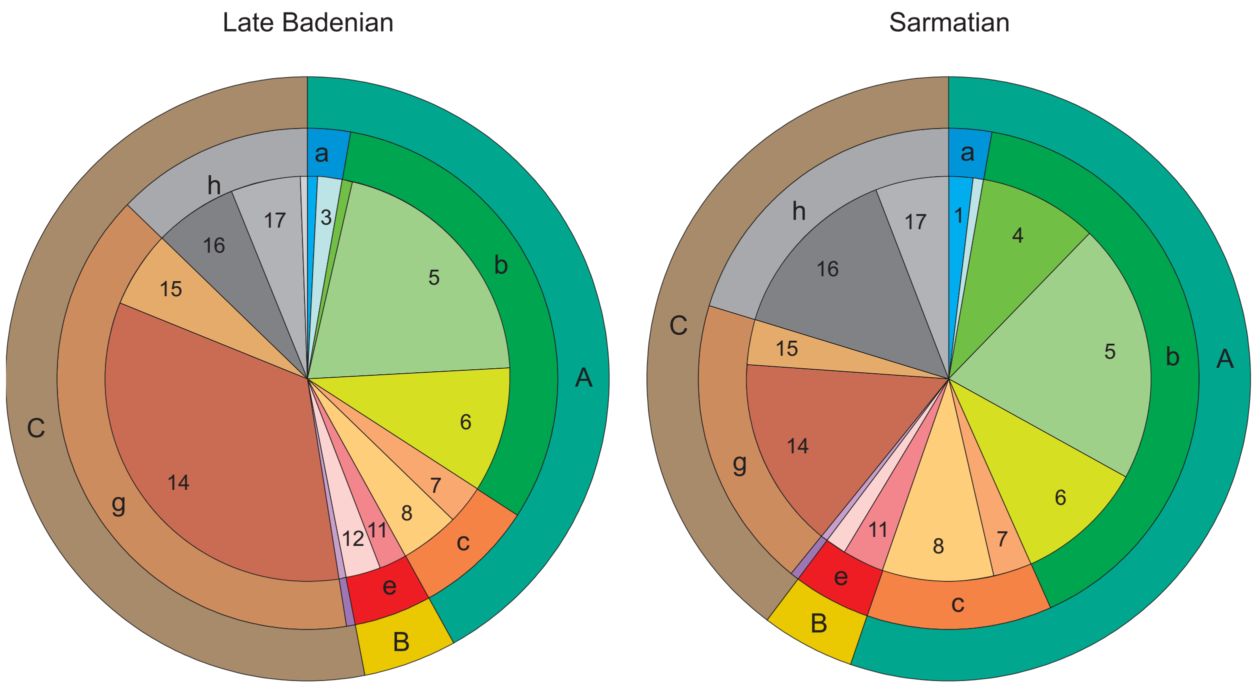

Fig. 3. Circograms for Twardawa (Late Badenian and Sarmatian); explanations see Fig. 2

(*Buxus*, *Olea*, and *Morus*), was very small (Fig. 3).

Comparing the circograms of the Polish localities we can see that the circograms from Biała (Fig. 4) and Stara Kuźnia (Fig. 5) are in contrast to the other ones, and show that the role of the ecologically undefined group "C" is larger than that of hydrophilous plants. This is in part due to the great amount of *Pinus sylvestris* pollen in the first one, and a great

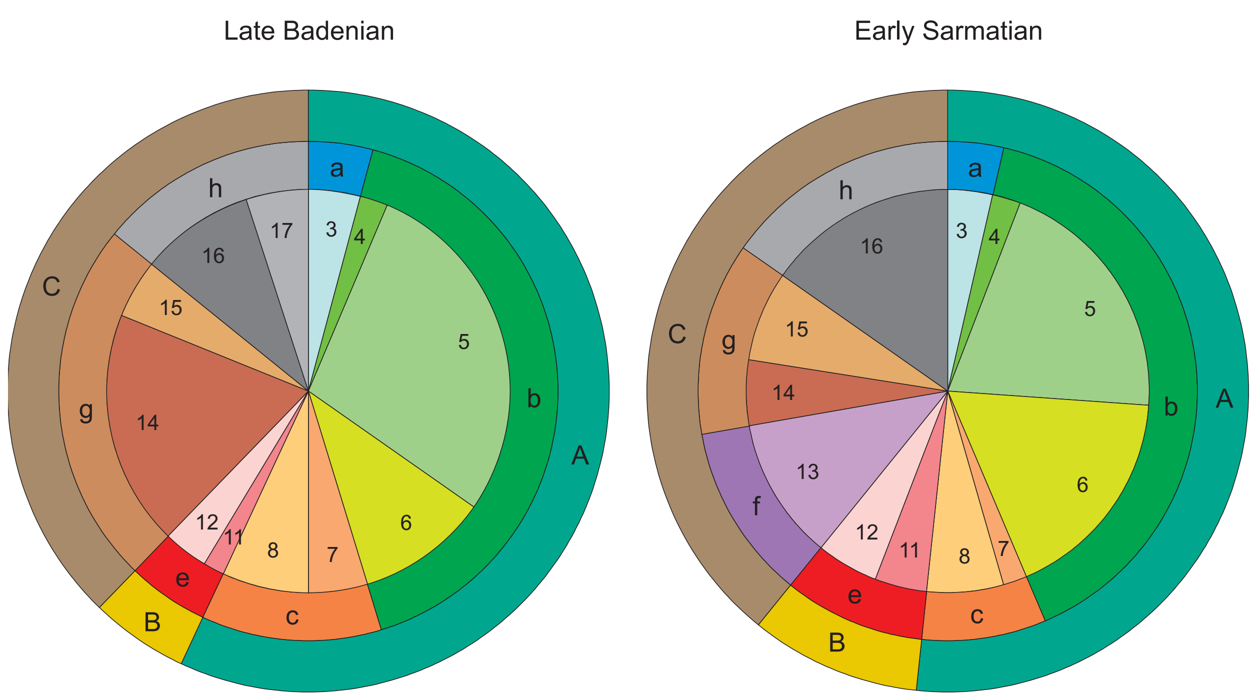

Fig. 4. Circograms for Biała (Late Badenian and Early Sarmatian); explanations see Fig. 2

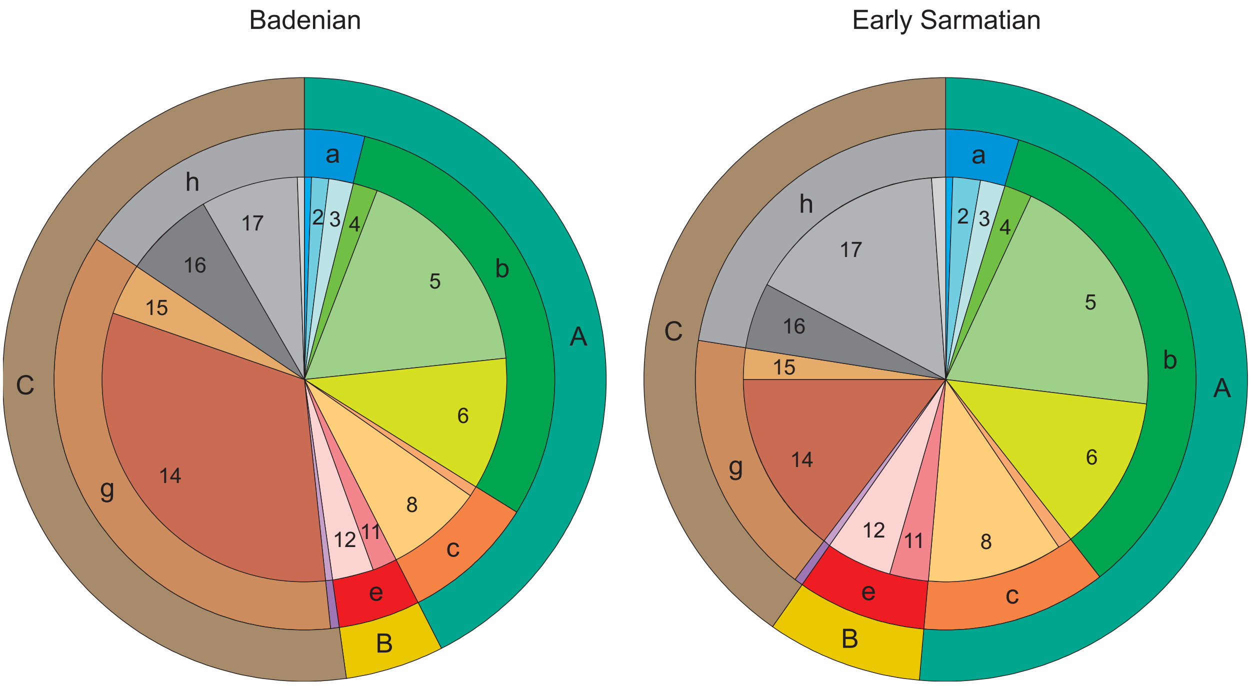

Fig. 5. Circograms for Stara Kuźnia (Badenian and Early Sarmatian); explanations see Fig. 2

amount of herbs reported in the second locality.

Sadowska (1989) considered that the role of conifer pollen in marine deposits in this region is much higher than the role of coniferous trees in contemporaneous plant communities.

This phenomenon in Koniówka (Fig. 6), situated in the mountainous part of the Carpathian Foredeep, may be explained, that de-

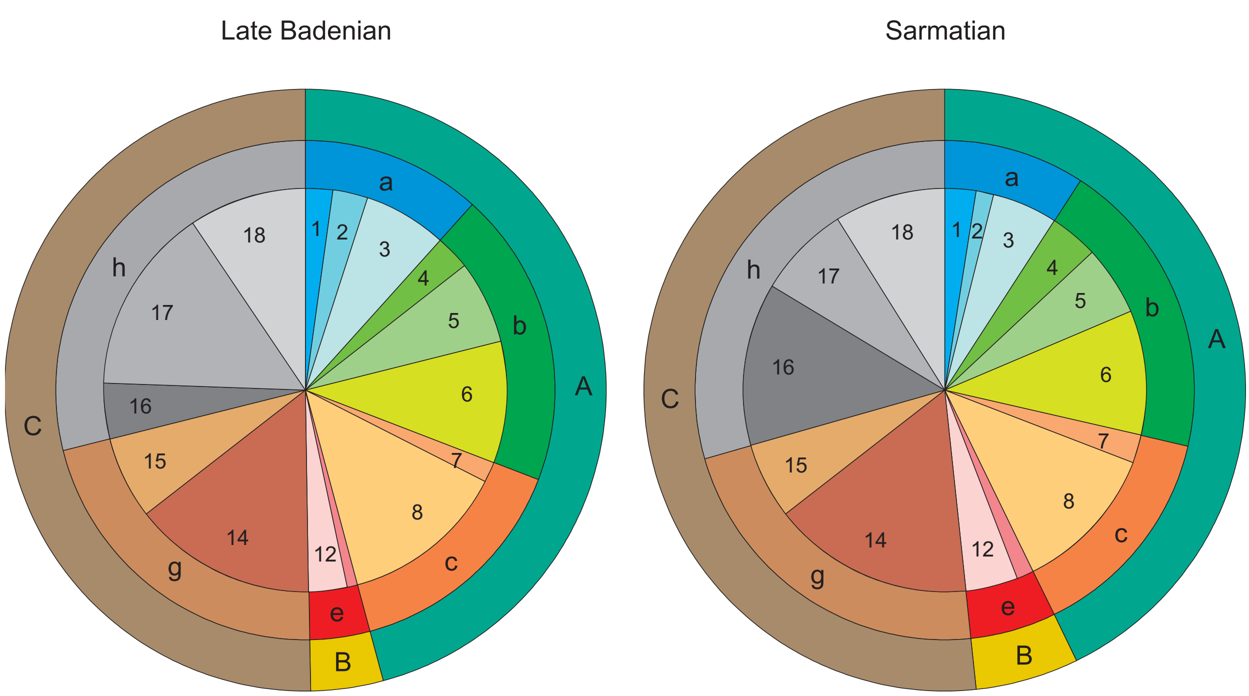

Fig. 6. Circograms for Koniówka (Late Badenian and Sarmatian); explanations see Fig. 2

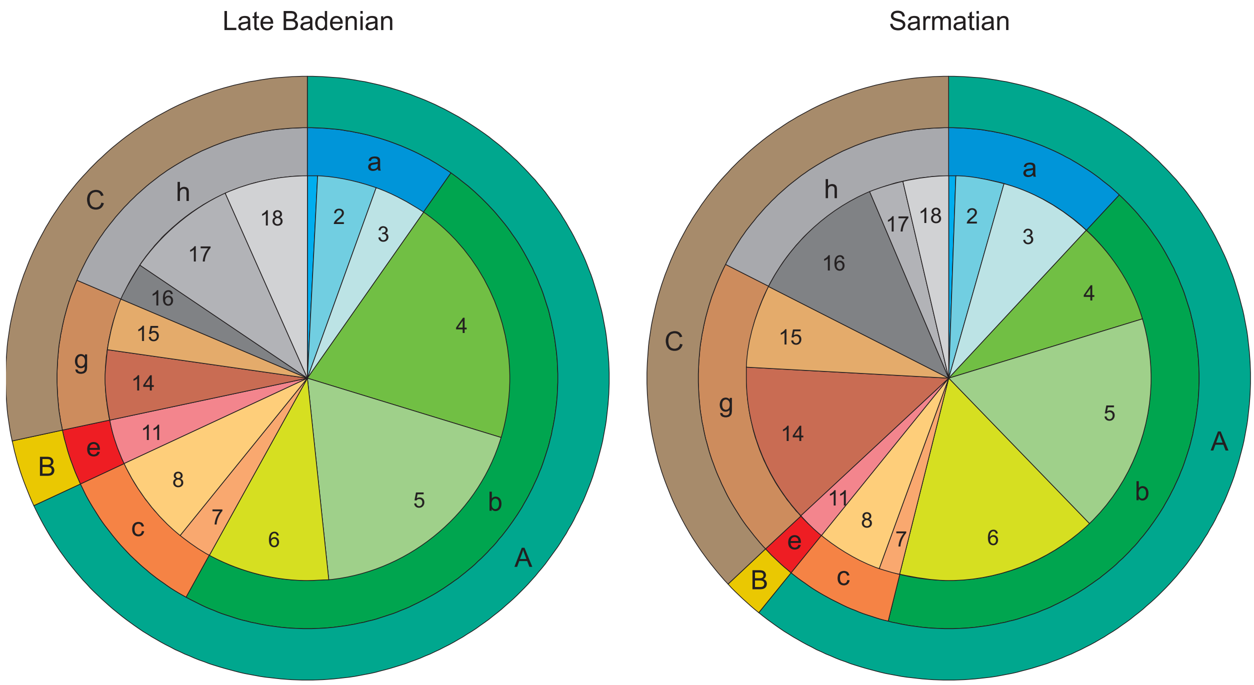

Fig. 7. Circograms for Czarny Dunajec (Late Badenian and Sarmatian); explanations see Fig. 2

pending from the elevation of mountains the alpine vegetation zone has been formed, and pollen of herbs communities enriched the ecologically undefined group of plants. The Badenian circogram of Czarny Dunajec (Fig. 7) and Stare Gliwice (Fig. 8) demonstrate greater thermophility of plant assemblage around this locality.

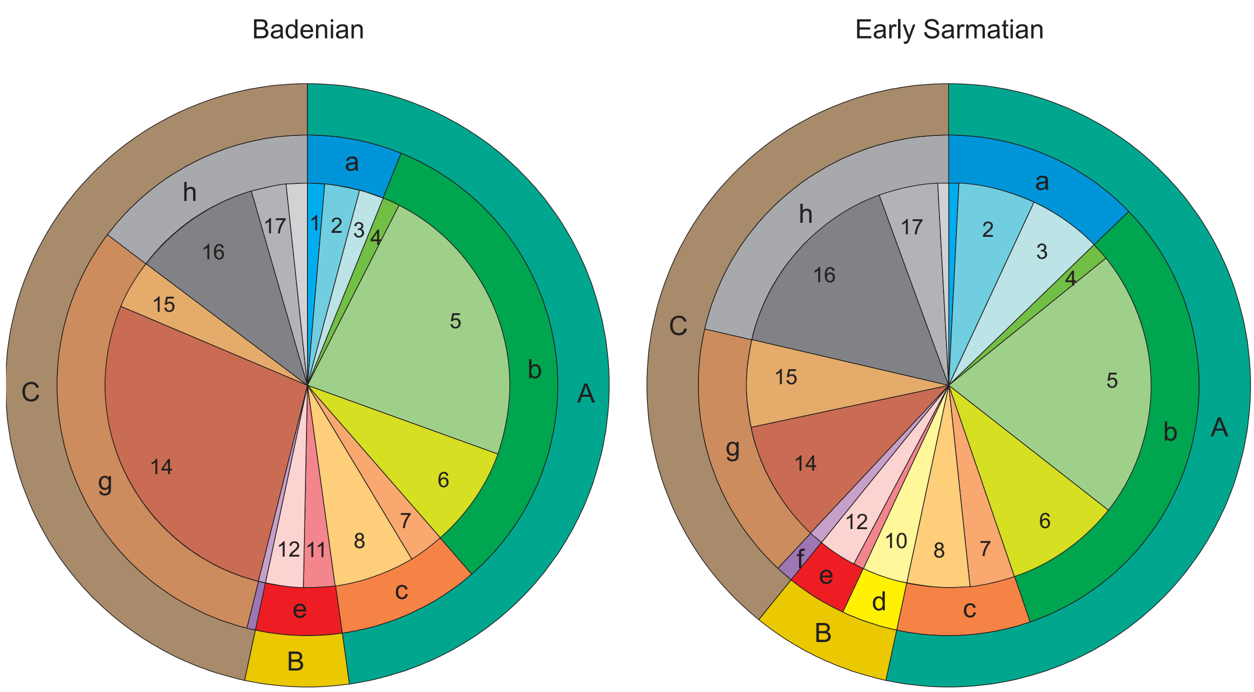

Fig. 8. Circograms for Stare Gliwice (Badenian and Early Sarmatian); explanations see Fig. 2

Climatic parameters for the Late Badenian (Figs 9–14) and Early Sarmatian (Figs 15–20) of Central Paratethys (Poland)

The retreat of the Paratethys sea from the Carpathian Foredeep took place in the Early Sarmatian (Dyjor & Sadowska 1984). The Early Sarmatian vegetation cover was formed by rich forest assemblages, including assemblages of marshy and wet habitats on the areas newly exposed after the marine regression and in river valley swamp forests (*Taxodium*, *Alnus*, *Liquidambar*, *Nyssa*, *Salix* and others). The role of taxodiaceous conifers became more considerable. Mesophytic polydominant forests in which broad-leaf deciduous trees (*Fagus*, *Quercus*, *Pterocarya*, *Carya*, *Acer*, *Carpinus*, *Engelhardia*, *Celtis* and others) dominated, were widely distributed. They occupied more elevated zones. The increase in the amount of *Celtis* was typical for these assemblages of all localities. In higher mountain zones dark co-

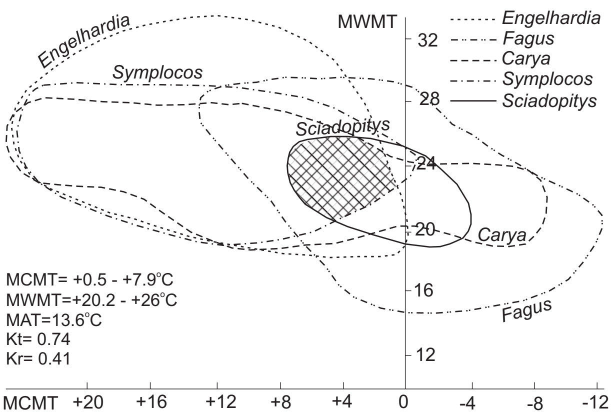

Fig. 9. Cartogram/climatogram for Twardawa (Late Badenian); abbreviations: **MCMT** – middle cold month temperature, **MWMT** – middle warm month temperature, **MAT** – average annual temperature, **Kr** – coefficient of hygrophility, **Kt** – coefficient of thermophility

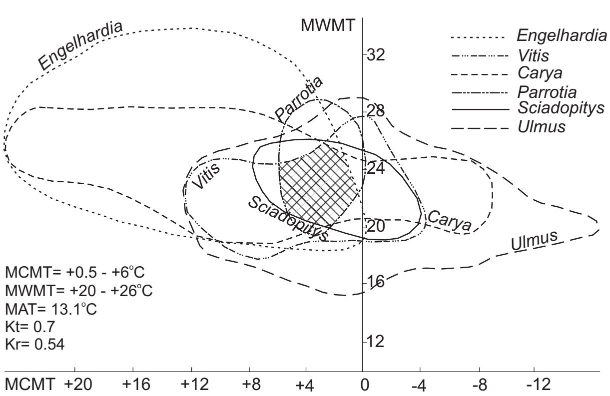

Fig. 10. Cartogram/climatogram for Biała (Late Badenian); abbreviations see Fig. 9

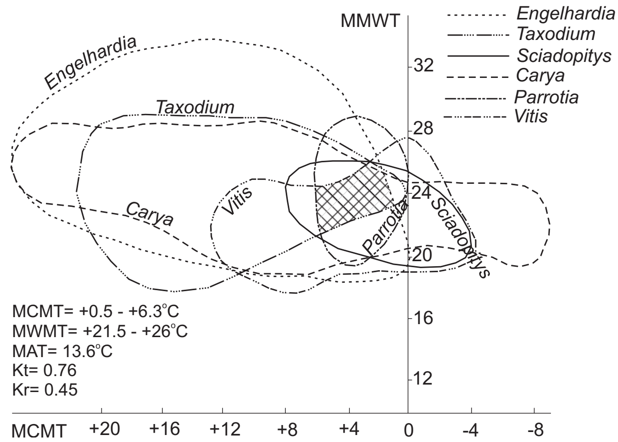

Fig. 11. Cartogram/climatogram for Stara Kuźnia (Badenian); abbreviations see Fig. 9

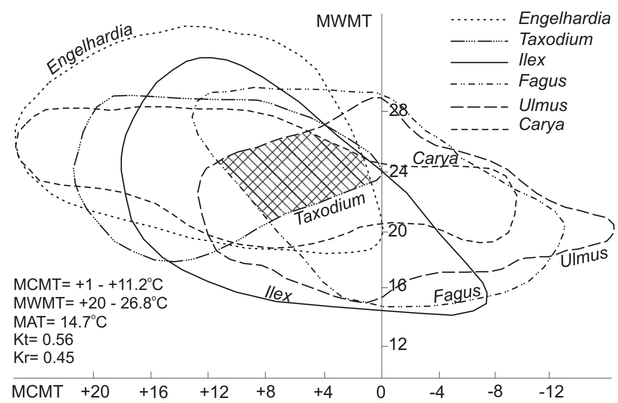

Fig. 12. Cartogram/climatogram for Koniówka (Late Badenian); abbreviations see Fig. 9

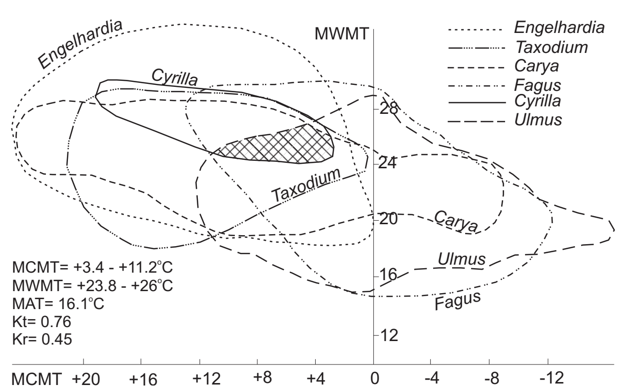

Fig. 13. Cartogram/climatogram for Czarny Dunajec (Late Badenian); abbreviations see Fig. 9

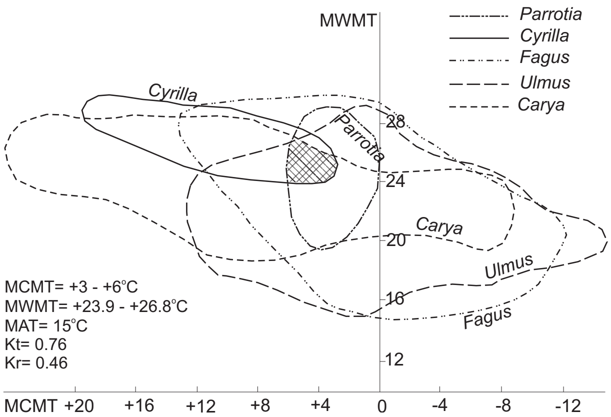

Fig. 14. Cartogram/climatogram for Stare Gliwice (Badenian); abbreviations see Fig. 9

niferous plants communities (*Abies*, *Tsuga*, and *Picea*) were widespread. The group of taxa that demanded warm conditions did not decrease considerably, as is indicated by the somewhat smaller coefficient of thermophility (0.55–0.64). These taxa (*Cyrilla*, *Platycarya*, and Sapotaceae) did not live long. The amount of xerophilous plants increased and the coefficient of hydrophility lowered (0.42–0.54). It is possible that a negligible level of aridization of the climate took place during this time (Figs 3–7).

In general the similarity of the Badenian and Sarmatian floristic descriptions was significant for most of the localities, with the excep-

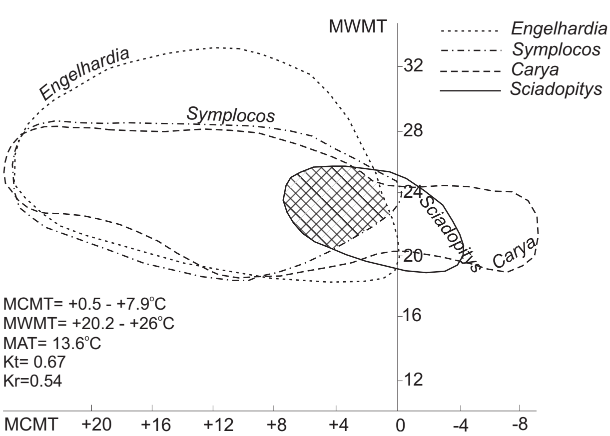

Fig. 15. Cartogram/climatogram for Twardawa (Sarmatian); abbreviations see Fig. 9

tion of the locality Stare Gliwice (Fig. 8) which has a very interesting Sarmatian flora. The spore and pollen assemblages from sediments overlying the marine deposits, including the layer with *Syndesmia*, is not comparable with the Sarmatian spore and pollen assemblages obtained from the profiles at Biała, Twardawa, Stara Kuźnia and others. This assemblage is not uniform. According to Oszast (1960) the Stare Gliwice profile is divided into three parts: bottom, middle and top. Each part has a different description of spore and pollen assemblages. The summary curves, e.g. corresponding to the Taxodiaeae-Cupressaceae group, which include the hydrophilous and xerophilous plants, and curves of several species of one genus (*Pinus*) or various genera

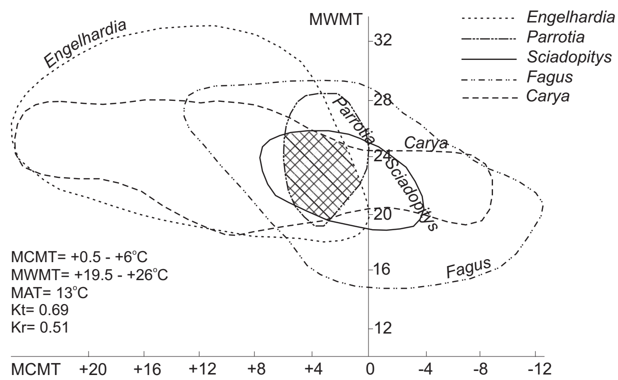

Fig. 16. Cartogram/climatogram for Biała (Early Sarmatian); abbreviations see Fig. 9

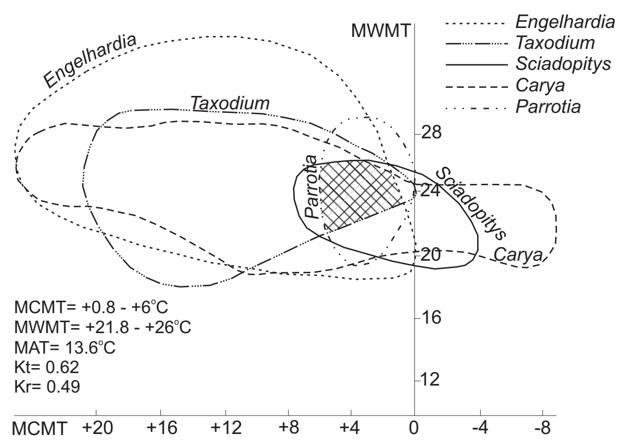

Fig. 17. Cartogram/climatogram for Stara Kuźnia (Early Sarmatian); abbreviations see Fig. 9

from one family (*Carya*, *Pterocarya*), make the interpretation of this palynocomplex difficult. We constructed for the lower most part of this section a circogram, which reflects the consid-

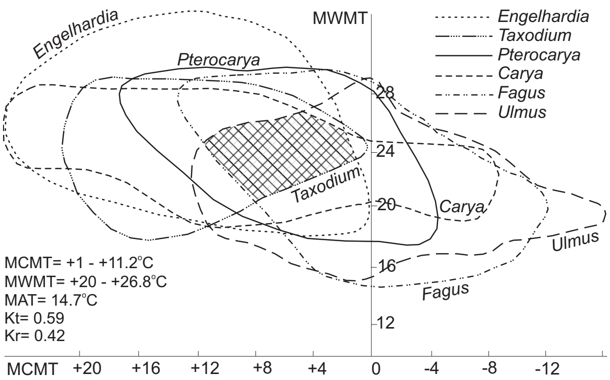

Fig. 18. Cartogram/climatogram for Koniówka (Sarmatian); abbreviations see Fig. 9

erable amount of tropical and subtropical plants, including members of hygrophilous and xerophilous groups. The presence of *Ephedra* and *Pistacia*, the frequent *Abies* and *Podocarpus*, and other features, make this complex more comparable with the Badenian from the Ukrainian Transcarpathians. These localities are close geographically: Stare Gliwice at the latitude 50°20′ and the Transcarpathian some more to the south, latitude 48°40′. However, the presence of ecologically undefined genera such as *Myrica*, Oleaceae, *Ostrya*, *Euonymus*, *Ulmus* and others, did not allow the lower complex from Gliwice section to be identified

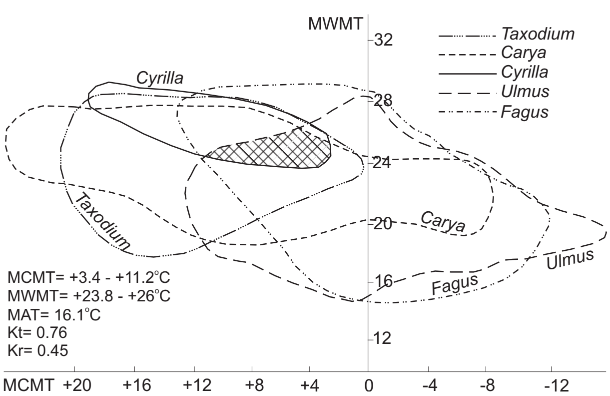

Fig. 19. Cartogram/climatogram for Czarny Dunajec (Sarmatian); abbreviations see Fig. 9

with other Badenian flora complexes from the Carpathian Foredeep or the Badenian complex from Ukrainian Carpathians. Maybe environmental features of the Stare Gliwice locality is the cause of such an exclusive complex. In addition the temperature parameters in the Stare Gliwice region are considerably higher: for Badenian MCMT = +3 – +6°, MWMT = 23.9–26.8°, MAT= +15°, (Fig. 14), Kr = 0.46, Kt = 0.75; for Sarmatian MCMT = +3.4 – +12.4°, MWMT = +23.8 – +26°, MAT = 16.8°, (Fig. 20); Kr = 0.6, Kt = 0.76

According to Szafer (1961) the deposits with rich macroflora from the lower most part occurring in gray clays belongs to the Upper Tortonian (Badenian). The spore and pollen complex from the middle part of this section is very close to that from the Lukov suite (the upper part of Lower Sarmatian) in the Transcarpathian (Molchanoff 2000).

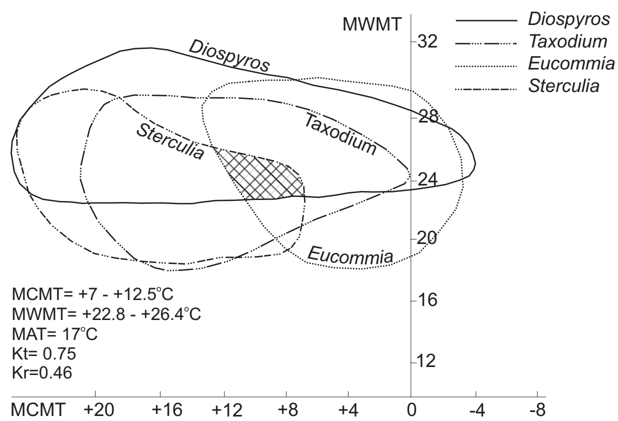

Fig. 20. Cartogram/climatogram for Stare Gliwice (Early Sarmatian); abbreviations see Fig. 9

The resemblance of the Stare Gliwice lower palynocomplex to Badenian, and its position under the deposits correlated with the upper late Early Sarmatian permits the suggestion that this complex belongs to the early Early Sarmatian and it is otherwise very similar to the Late Badenian. That is the evidence of the succession of the Sarmatian flora from the Badenian. Nevertheless we think that without new palynological investigations of the most interesting profile of Stare Gliwice, its upper part including layer with *Syndesmia* in particular, the exact age indication of these deposits is impossible to determine at present.

In all profiles in the Polish part of Central Paratethys the succession of Early Sarmatian flora from the Badenian in the very similar conditions was apparent. According to Stuchlik (1980) and Dyjor and Sadowska (1984) the Late Badenian flora is closer to the Early Sarmatian than to the Middle Badenian.

UKRAINIAN PART OF CENTRAL AND EASTERN PARATETHYS BASIN

Palynological data from the following regions has been analyzed: Carpathians (Syabryaj 1978, Syabryaj & Shchekina 1983) in the Central Paratethys, and the South of Ukraine Plain and Crimea (Shchekina 1979, Syabryaj & Shchekina 1983) in Eastern Paratethys.

In the Eastern Carpathians transgression and periodical volcanic activity took place during the Late Badenian. In the mountain regions the following amplitudinal vegetation zones have been reconstructed: in the foothill area, marginal assemblages of moisture-loving plants as thermophilous ferns and marshes, including swamp forests with *Taxodium*, *Osmunda*, *Myrica* and marshy shrub vegetation in the marginal part of the swamps; in the lower mountain zone warm-temperate deciduous forests (*Juglans*, *Liquidambar*, *Engelhardia*, *Castanea*, *Platycarya* and others) with considerable amount of subtropical elements, including hard-leaf shrubs as *Cinnamomum* and Myrtaceae; in the upper mountain zone warm-temperate deciduous and deciduous-coniferous forests, coniferous forests including the dark-coniferous taiga communities (*Abies*, *Picea*, *Tsuga*, *Cedrus*); and above the timberline alpine meadows.

To the end of the Badenian subtropical assemblages and communities with thermophilous ferns slightly diminished. The increasing amount of herbaceous pollen, chiefly of plants from the mountain meadow communities, indicated the appearance of open areas on high altitude of the rising mountains.

According to Shvareva (1983) micro- and macroremains show that similar subtropical communities were present on south-western macro slope and formed a large part of forest composition on the north-eastern macro slopes (Precarpathian Foredeep). In valleys riparian forests with abundance of *Alnus* were characteristic for this region. Components of deciduous forests have smaller leaves than in the Transcarpathian forests. This indicates some water deficit during the growing season.

Owing to the next Badenian regression and rising of mountain the common sea basin of Parathetys surrounding the Carpathians was broken. The Transcarpathian and the Precarpathian parts began to existed as isolated basins. However, succession of the Early Sarmatian flora from the Late Badenian one is observed in the Transcarpathian region and in the Precarpathians also (Fig. 21).

In the South part of the Ukraine Plain which belongs to Eastern Paratethys, materials for palynological investigations have been obtained from boreholes in the northern Pri-

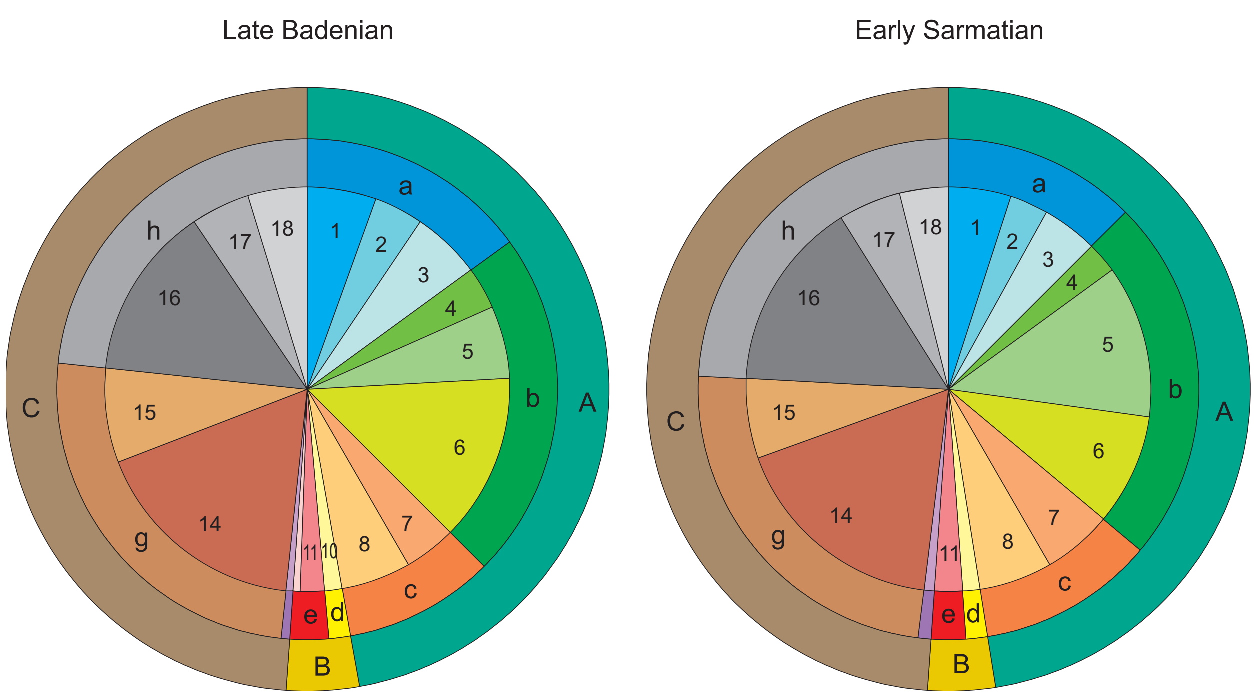

Fig. 21. Circograms for Carpathians (Late Badenian and Early Sarmatian) region; explanations see Fig. 2

chernomor'e and Kerch peninsula, from the Konkian (Upper Badenian) deposits with Late Badenian mollusks and the Lower Sarmatian deposits covering the Konkian sediments without hiatus. In Sarmatian rocks there is a rich marine mollusk fauna, and lower beds of the Lower Sarmatian contain rare coal intercalations. The Konkian marine basin occupied the southern part of Ukraine and its northern boundary was near a latitude of 48° and toward to west was moved southward from Zaporozh'e. In this part of Ukraine there was another type of landscape. The plain relief was inherent to the big territories of southern part of Ukraine.

The circograms (Fig. 22) demonstrated the equal content of hydrophilous and ecologically undefined plants, more amount of xerophilous one, including *Ephedra*, *Pistacia*, and *Comptonia*.

During the Late Badenian the territory of Eastern Paratethys, including Crimea, were occupied by mesophilous polydominant deciduous and deciduous-coniferous forests, in which the amount of conifers increased (mainly different species of *Pinus*, small frequency of *Abies*, *Tsuga*, and *Podocarpus*) over the previous Karaganian time. Deciduous components of forests were represented by *Quercus*, *Fagus*, *Carpinus*, *Ulmus*, *Zelkova*, *Carya*, *Juglans*, *Corylus*, *Fraxinus*, *Elaeagnus*, *Liquidambar*, *Pterocarya*, *Celtis*, *Ilex*, and members of the Moraceae. *Quercus*, *Alnus*, *Salix*, and *Myrica* were as dominants but their amount was smaller than in Karaganian plant cover. Single Magnoliaceae, *Parrotia*, very rare Myrtaceae, Sapotaceae, very great amount of Ericaceae were characteristic of the vegetation communities of the Prichernomor'e part of Ukraine, but in the Crimea peninsula the subtropical elements are more numerous, in particular *Taxodium* was very numerous. So the tropical-subtropical plants cover more considerable area on the circogram (Fig. 23). Not numerous ferns (mainly Polypodiaceae, single *Osmunda*) and increased amount of herbs (including Chenopodiaceae) was typical for eastern Prichernomor'e vegetation. In the Crimea herbs are only occasionally encountered.

In the Crimea plants belonging to the xerophilous group are not frequent and cover only 11° on the circogram (Fig. 23). The presence of *Ephedra* shows the presence of a dry summer that is in this region similar to that from Prichernomor'e.

The relief of the Donetsk basin and the Ukrainian shield was dissected topographically. Here there were a few types of plant assemblages that are connected with the different relief types. The mixed pine and deciduous forests occupied the water sheds and more elevated parts of this structures. Valley forests

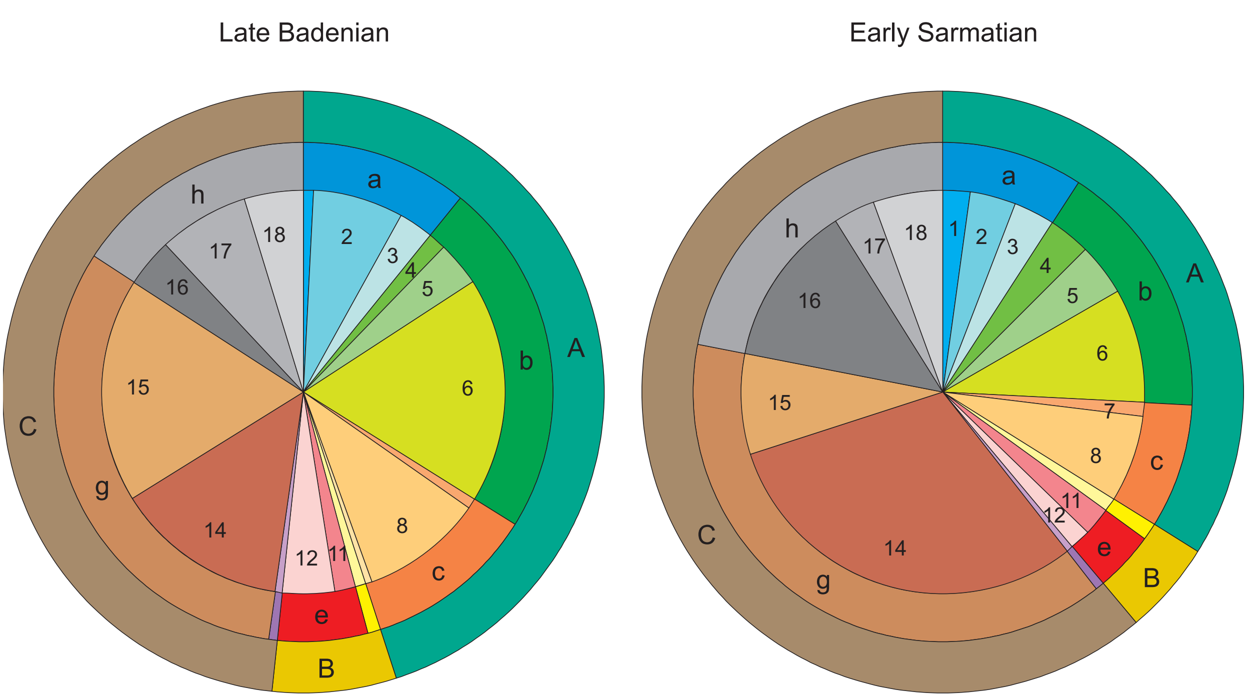

Fig. 22. Circograms for Plane Ukraine (Late Badenian and Early Sarmatian); explanations see Fig. 2

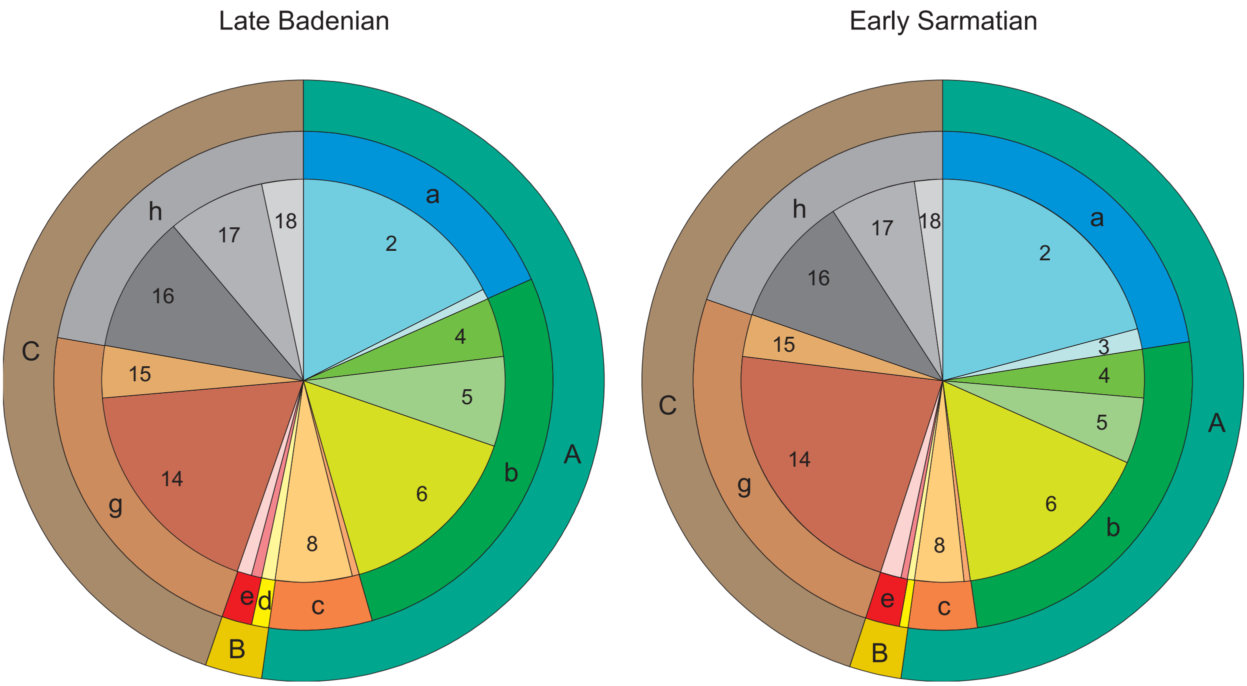

Fig. 23. Circograms for Crimea (Late Badenian and Early Sarmatian); explanations see Fig. 2

were spread along the river benches. In the Dnieper-Donets depression the rivers and lakes were abundant and swamp forests with *Taxodium*, *Nyssa*, *Glyptostrobus* and others were widespread.

Climatic parameters for the Late Badenian (Fig. 24–26) and Early Sarmatian (Fig. 27–29) of Central and Eastern Paratethys

The Early Sarmatian in the Eastern Carpathian region was characterized by an intensive regime of oscillatory movements, sea transgression to the southwestern part of Transcarpathians and a second phase of volcanism. The vegetation of this stage was characterized by the spread of coniferous forests with spruce and spruce-fir assemblages and various species of *Tsuga*. By the end of the Early Sarmatian the pine forests play the main role in the regional vegetation. The broad-leaved formation included beech forests in addition to oak-beech and some beech-chestnut assemblages. Deciduous forests were rich with underwood layer in which *Cinnamomum* existed yet. During the Early Sarmatian the temperature

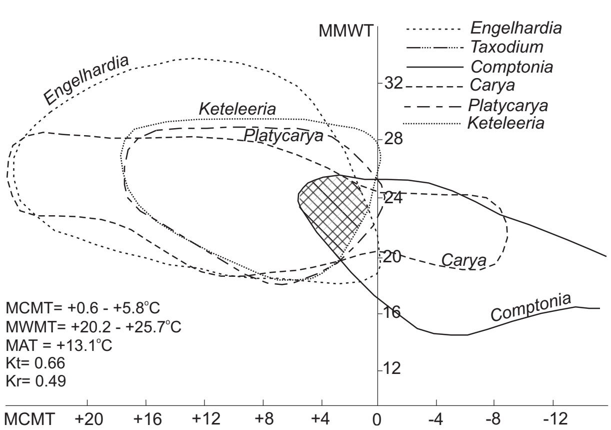

Fig. 24. Cartogram/climatogram for Carpathian region (L. Badenian); abbreviations see Fig. 9

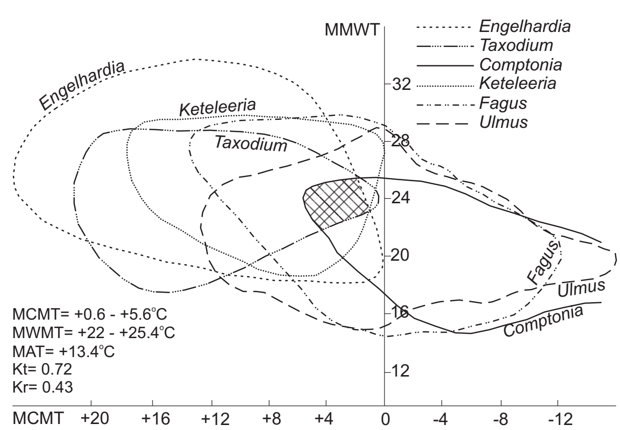

Fig. 25. Cartogram/climatogram for Plane Ukraine (Late Badenian); abbreviations see Fig. 9

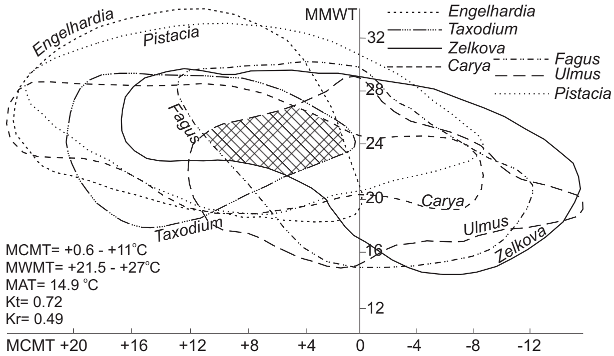

Fig. 26. Cartogram/climatogram for Crimea (Late Badenian); abbreviations see Fig. 9

was falling slightly down and some deficit of air moisture took place (Fig. 21).

In the part of the Eastern Paratethys vegetation cover changed owing to some expansion of the marine basin in the beginning of the Early Sarmatian. Probably the groundwater

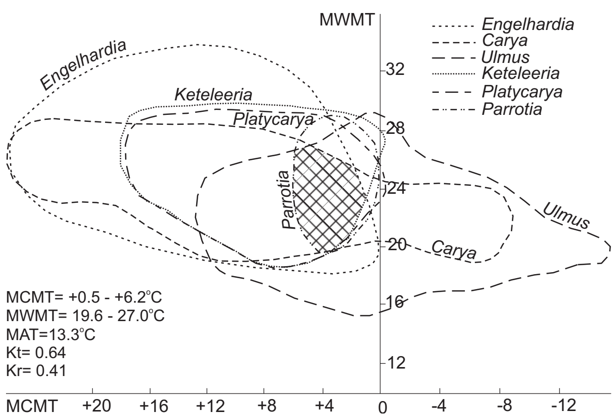

Fig. 27. Cartogram/climatogram for Carpathian region (E. Sarmatian); abbreviations see Fig. 9

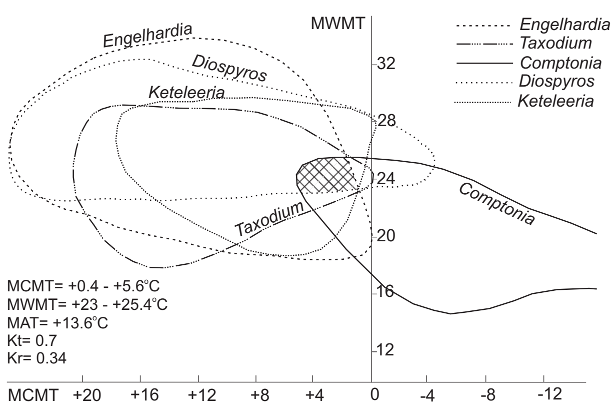

Fig. 28. Cartogram/climatogram for Plane Ukraine (Sarmatian); abbreviations see Fig. 9

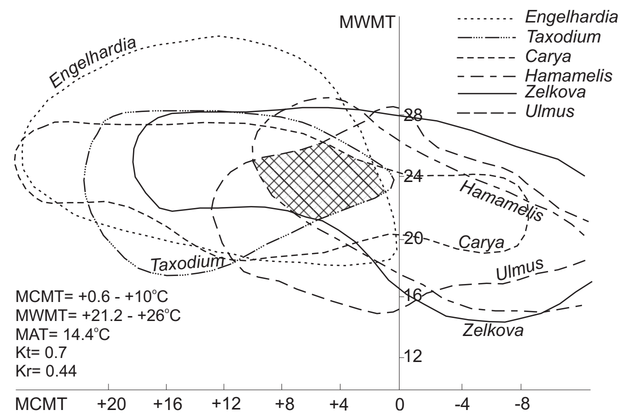

Fig. 29. Cartogram/climatogram for Crimea (Early Sarmatian); abbreviations see Fig. 9

level became higher. The Crimea peninsula changed into an island. Coniferous forests occupied great territory of the continent. At the same time mesophilous forests with numerous members of Fagaceae, Juglandaceae, Betulaceae, Aceraceae, subtropical relicts as *Cinnamomum*, and lianas *Alangium*, were characteristic (Fig. 22). More to the East herbaceous communities, as dry meadows occupied dry soils, replacing the coniferous and mixed forests. Open landscapes became significant element in the northern Priazov'e. (Fig. 30).

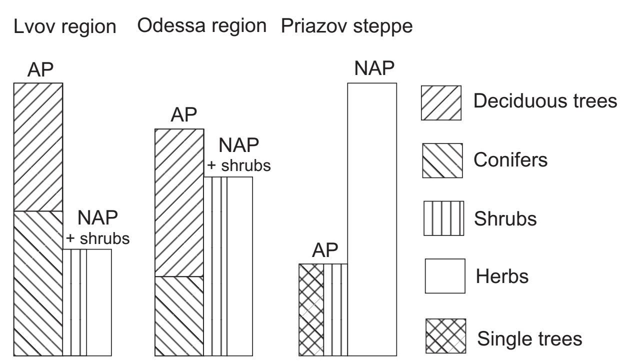

Fig. 30. Changes of plant cover composition from the to the West to the East (Early Sarmatian)

The common picture of vegetation on the Crimea island underwent remarkably little change though this time (Fig. 23). Predominating were warm temperate forests with more subtropical shrubs, coniferous forests and very poor herbaceous component. According to Syabryaj and Shchekina (1983) the Late Badenian and Early Sarmatian floras were only two parts of one stage of floral evolution.

CONCLUSION

The Badenian–Sarmatian stage of geological time was an essential period for floral and vegetational evolution. It is known as a stage when different kinds of useful minerals in particular fuel minerals (brown coals) were deposited, so the more complete palaeoenviromental description of this time will be useful.

The evolutionary process during Late Badenian – Early Sarmatian continued the main trends of forest floral and vegetational evolution, stimulated by a gradual cooling of climate. At this time the replacement of subtropical forest communities by warm temperate and temperate ones is observed in Central Paratethys, and in the south-eastern part of Ukraine (Eastern Paratethys) the replacement of temperate forests by herb communities took place. This process was observed in all of the studied sections despite spatial differences.

The palaeofloristic and palaeoclimatic reconstruction showed that the Late Badenian and Early Sarmatian floras were closer to each other than to the flora of the previous and following stages. This confirms Iljinskaya's (1960) opinion based on mega-floristic studies of the Transcarpathian flora, showing that the Late Badenian flora is closer to the Early Sarmatian flora than it is to the Middle Badenian flora.

This palaeofloristic and palaeoclimatic reconstruction has permitted the consideration that the Late Badenian and Early Sarmatian floras of Central and Eastern Paratethys belong to one sub-stage of the first evolution stage of the Miocene flora.

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