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STRATIGRAPHICAL CRITERIA IN THE PALYNOLOGY OF THE NEOGENE

Stratygraficzne kryteria w palinologii Neogenu

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ABSTRACT. A review of difficulties in the stratigraphical interpretation of the Neogene pollen flora is presented. The factors influencing the picture of pollen diagrams are shown. On the basis of the palynological investigations of the Neogene sediments from Poland the most significant criteria to estimate the age of pollen floras of the Miocene and Pliocene are defined.

KEY WORDS: Flora, Neogene, palynostratigraphy

INTRODUCTION

Specialists studying the Tertiary plant macrofossils often point to difficulties in their stratigraphical interpretation resulting from both – the preservation and varied living conditions of the Tertiary plant communities. In palynological studies the problem is not often mentioned.

In the Neogene – as we know – only some sporomorphs are limited to one or two stages only and they are important from the stratigraphical point of view. As most often they are very rare taxa – their absence cannot indicate the age of sediments. All the other taxa appear from the Oligocene to Pliocene. Therefore, stratigraphy of the Neogene is based on the quantitative proportion of the pollen taxa and, at the same time, on the general picture of vegetation. However, this picture may differ significantly, depending on various factors which influenced the composition of the plant communities in the Miocene and Pliocene period, and also pollen grains precipitation and preservation in the sediments.

The mentioned dependances are generally known but often are not taken into account, while comparing pollen diagrams and their stratigraphical interpretation. It results in incorrect estimation of the age of the sediments.

DIFFICULTIES IN STRATIGRAPHICAL ESTIMATION OF THE POLLEN FLORA

One of the most important factors which can differentiate pollen diagrams of the same age is geographical localization of the investigated sediments in Europe. The vegetation of Europe varied in different regions of the continent in respect of palaeotropical and arctotertiary element participations (Mai 1981, 1989). These differences haven't been so far precisely defined. It seems that the pollen floras of the Oligocene and Early Miocene are more similar in all Europe – they have the same, subtropical character. However, between the spectra of the Middle Miocene, Late Miocene and the Pliocene these differences become even more visible. Whereas the pollen floras of the Middle Europe of that time are warm – temperate in character, pollen diagrams from southern and western Europe still contain significant amount of subtropical taxa.

Palaeogeography and topography of the plant habitats is the next important factor which can differentiate the pollen diagrams of the same age. It is very difficult to compare the Miocene pollen diagrams from the Polish Lowland localities to these, from the coasts of the Paratethys sea, in the Carpathian Foredeep. The former contain mainly taxa of swamp-forest and shrub-bogs like *Taxodium, Nyssa, Alnus, Liquidambar, Myrica, Rhus, Ilex, Cyrillaceae, Ericaceae, Quercoidites henrici*, while the latter reflect the mesophilous forest abundant in the Mediterranean climatic genera, with predominanting of *Pinus, Engelhardtia, Quercus, Fagus, Ulmus, Tilia, Carya, Castanea*. It is probably connected with the smaller extent of swampy communities in the areas of Carpathian Foredeep as compared to Polish Lowland. At the coasts of the Paratethys sea and on the neighbouring uplands deciduous and mixed forests were predominant. But, such communities also differed unquestionably from those, growing on the drier habitats on the Polish Lowland in the same time, where such plants like *Pinus, Sequoia, Betula, Quercus, Symplocos, Araliaceae, Cornaceae* dominated. Oak was probably represented by the different species on the two areas – *Quercoidites henrici* in pollen spectra from the Lowland is common, whereas in the spectra from the Silesian part of Carpathian Foredeep, *Quercus* type prevails and *Quercoidites henrici* is scarce. Such differences may be due not only to the various habitats but they were also connected with climatic differences between the nearby areas. Mediterranean climate was probably dominating in the Miocene in the south of Poland. Therefore the mentioned separateness of the *Quercus* pollen type is connected with that climate.

In this region the evergreen oak species were supposingly the most numerous. Domination of various forms of *Quercus* pollen in the same period on the nearby areas has a considerable meaning, because – as we know – *Quercoidites henrici* type is commonly regarded as stratigraphically older.

However, when at the beginning of the Sarmatian the regression from the the western part of the Carpathian Foredeep took place, plant communities of the area bacame analogous to those from the Lowland.

Even greater difficulties are encountered while comparing the spectra of continental and marine sediments. For instance, pollen diagrams from the Paratethys marine sediments of the Badenian age are characterized by a high amount of *Coniferae* saccatae pollen grains. Among the deciduous trees *Quercus, Ulmus, Castanea, Fagus* and *Juglandaceae* are prevalent, while the profiles of the continental sediments on the Polish Lowland area are mostly characterized by the high values of swampy bogs and forests plants – (Dyjor & Sadowska 1986, Sadowska 1977, 1989). The high participation of *Coniferae* saccatae pollen may be connected with easiness of their transport and precipitation over the open sea. But not always do conifers prevail in the marine sediments (Kvavadze & Stuchlik 1990). Therefore the coniferous trees (excluding *Taxodiaceae-Cupressaceae*) must have constituted a remarcable admixture in the forests on the Paratethys shores in comparison to the extensive Lowland areas, where in the Badenian, *Taxodiaceae-Cupressaceae* dominated.

The changeable composition of pollen spectra not always reflects climatic changes. It has been caused very often by the changes of edaphic factors – drying or dampening of the soil. So, the picture of flora points to the different habitats, facies and different types of the Miocene bogs caused by the different phases of the plant succession. Such phases were not identical in all parts of Europe, between the separate coal basins significant differences are visible. These changes in pollen diagrams are usually easily noticeable in lithological profiles – the clays contain more swampy plants pollen (mainly *Taxodium, Nyssa, Alnus, Liquidambar*), whereas brown-coal deposits – more shrub-bogs element (*Ilex, Rhus, Myrica, Mastixiaceae, Cyrillaceae*). Hence, spectra of the latter seem to be "older" than the spectra of the same age from the clay sediments.

On the other hand, the spectra of deposits of the same type and of the similar age (e.g. from brown-coals) can vary, depending on the type of plant association they originated from. The petrological investigations of the Miocene brown-coals from Polish deposits showing the big variety of coal lithotypes prove the big diversity of plant communities and fast changes of their succesional phases (Szwed-Lorenz 1991). And so, habitats and phases of the Miocene swamps and bogs which we observe in pollen diagrams, can strongly diversify the spectra of the same age, or, on the contrary, can make the pollen floras of the different age similar.

CRITERIA OF THE STRATIGRAPHICAL IMPORTANCE

If we compare the Neogene pollen diagrams from the different parts of Central Europe, we can notice stratigraphical criteria which allow us, despite the palaeogeographical and edaphical differences, to estimate the age of the sediments. Of course, for stratigraphical approach, the changes of microflora caused by the climatic changes are the most important.

One of the mentioned is the domination of some taxa or a group of taxa in each stage of the Miocene and Pliocene. Although they are common in several stages during a long time of the Neogene, their maxima are usually limited to one stage. E.g. for Ottnangian – *Engelhardtia, Myrica* and *Tricolpopollenites liblarensis* maxima are typical, the Carpatian is characterized by more abundand *Quercoidites henrici, Rhus and Myrica*, the Badenian – by high values of *Nyssa, Quercus, Sequoia* and for Sarmatian – *Alnus* and *Celtis* maxima are typical (Sadowska 1977, 1990).

Pollen taxa of a limited range are also very important for stratigraphy. These, mainly tropical-subtropical plants, like *Platycarya, Myrtaceae, Olacaceae, Palmae, Sapotaceae, Tricolporopollenites fusus* and some ferns are common in the Paleogene and pass to the Early Miocene, being absent or sometimes only sporadic in Late Miocene or Pliocene. On the other hand, some of such genera like *Aesculus, Acer, Theligonum* and many of herbaceous pollen taxa are characteristic for the Pliocene but very rare or absent in the Miocene. However, we must remember that there existed some differences between geographical provinces of Europe in the Neogene and significance of the mentioned plants is not the same everywhere.

In the time of the Miocene the amount of all thermophilous taxa decreases. Although some authors consider it to be a continuous process, the others assume its cyclic character under the influence of a repeatedly changing climate, they are all unanimous, that the percentage of these taxa is much lower in the Late Miocene than in the Lower and Middle Miocene. In the Pliocene the decrease of this group is very clear and – as mentioned above – distinctly thermophilous, subtropical taxa do not appear in this stage at all. Instead of this, pollen grains of the other group – of the moderate climate plants – become prevailing.

My investigations show that the ratio of the two groups is more or less the same – about 15% in the Karpatian, in the Badenian thermophilous plants reach about 6% of all the flora, decreasing to 2.5% in Sarmatian and they are sporadically recorded from the Pliocene (Dyjor & Sadowska 1977, Sadowska 1990).

Among the trees of moderate climate zones, the role of such conifers like *Picea, Abies, Tsuga* and *Sciadopitys* strongly increases in Pliocene. The average participation of these trees in the Late Miocene reaches 45% (Oszast 1973, Jahn et al. 1984) while in microfloras of the Miocene age they reach from few percent in the Karpatian to over ten in the Sarmatian. In the Pliocene the role of *Picea* strongly increases. Whereas in the Miocene this genus does not exceed 5%, in the Pliocene it reaches from 25% to 50% (Oszast l.c., Jahn et al. l.c.). Nevertheless it is necessary to notice, that the localities of the Pliocene age in Poland are mostly situated in the mountains, which could be one of the reasons for such high amount of *Picea*.

It is also very interesting, that while in the Early Miocene pollen grains of *Pinus sylvestris* type prevails, from the Middle Miocene to the Early Pliocene the percentage of *Pinus haploxylon* type increases and next, in the Late Pliocene, *Pinus sylvestris* type is predominant again. Undoubtedly, it is connected mainly with the various species of *Pinus* growing on various habitats in different stages of the Polish Neogene and it is also important from the stratigraphical point of view.

The proper criterion for distinguishing the Miocene and Pliocene pollen floras is the proportion of the "Tertiary" and "Quaternary" taxa (Oszast 1973, Zagwijn 1986). The Miocene is characterized by a distinct predominance of the "Tertiary" genera, on the Miocene/Pliocene border the proportion of these groups oscillates about 50%, and, in the Pliocene, the "Quaternary" genera become prevailing (Oszast l.c.). Also, the number of the "Tertiary" genera and forms of pollen grains is clearly lower in the Pliocene which shows that vegetation of this period was not as rich as in the Miocene.

A very important feature for the Miocene/Pliocene boundary dating is a rapid decrease of *Taxodiaceae-Cupressaceae* values. In our localities this group reaches the highest percentages (sometimes more than 60%) in almost all of the spectra from the Late Oligocene to the Late Miocene, whereas in the Lower Pliocene it is usually below 10%, only sometimes reaches 20%, and in the Late Pliocene it does not exceed 5% (Stachurska et al. 1967, 1971, 1973, Oszast 1973, Ziembińska-Tworzydło 1974, Sadowska 1977, 1990, Stuchlik 1980, Dyjor & Sadowska 1984, Jahnet al. 1984 and others).

Also a considerable and rapid increase of the herbaceous plants in the Pliocene is visible in all pollen diagrams from the Polish localities. They comprise from 5–20% in the Early Pliocene to 30–40% in the Late Pliocene (Stachurska et al. 1967, 1973, Stuchlik 1980, Jahn et al. 1984). In all the Miocene profiles the amount of these plants is not higher than 1%. Only *Filicinae* spores in some of the Miocene profiles are more abundant.

CONCLUSIONS

In stratigraphical considerations we usually compare the respective taxa – their amounts, ranges, proportion of different groups participations and their interrelations. But when we observe the microflora of all the Neogene though we can also notice how the picture of all plant communities changes in each stage of this period.

Swamp forests and bogs dominating during the Early and Middle Miocene on the vast area of Poland and Central Europe, retreated in the Sarmatian and in the Late Miocene mesophilous forests became dominant. The forests of the Late Miocene still contained the admixture of thermophilous elements, pointing to warm-temperate climate. The palynological investigations of the Miocene sediments from western Poland do not indicate strong aridization of climate in the Lower Sarmatian. It accords with Gregor (1990). However, the regression of the Paratethys sea from the western part of the Carpathian Foredeep and drying of the big lake of Poznań Basin at the end of the Miocene and in the Early Pliocene caused climatic continentalization. It was due to the climatic and palaeogeographic changes which took place in the whole Europe (Mai 1989). In the Pliocene swamps and bogs dissapeared, replaced by deciduous and mixed forests containing numerous shrubs and herbs. The cooling of the climate during the Pliocene results in domination of the temperate climate forests at the end of this stage.

Such changes of the Neogene forests are recorded by most of the researchers of fossil floras of this period. For proper estimation of the sediments age it is absolutely necessary to take into consideration the whole of pollen flora picture, and all the factors influencing its differentiation.

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STRESZCZENIE

Stratygrafia neogenu opiera się jak wiadomo głównie na ilościowym udziale poszczególnych taksonów w różnych piętrach, a tym samym na zmieniającym się obrazie roślinności. W badaniach palinostratygraficznych muszą być brane pod uwagę następujące czynniki, które mają wpływ na ten obraz:

– paleogeografia badanego stanowiska,

– środowisko, w którym tworzyły się analizowane osady (kontynentalne, brakiczne, morskie),

– rodzaj osadu (węgiel brunatny, ił, mułek piaszczysty itp),

– typ zbiorowiska roślinnego które dominuje w diagramie pyłkowym (las bagienny, torfowisko, las mezofilny). Wymienione czynniki mogą znacznie różnicować diagramy palinologiczne tego samego wieku lub sprawiać, że diagramy z różnych pięter neogenu są do siebie podobne. Zależności te są na ogół znane palinologom, często jednak pomijane w stratygraficznej interpretacji profilów. Jako przykład można podać znaczne różnice jakie występują między diagramami pyłkowymi osadów Karpatianu i Badenianu z obszaru Niżu Polskiego, z wysokim udziałem pyłku zbiorowisk bagienno-torfowiskowych, a diagramami z brzegów Paratetydy na obszarze zapadliska przedkarpackiego, w których dominuje pyłek lasów mieszanych. Lasy tego ostatniego typu porastały również suchsze stanowiska na Niżu ale ich skład był odmienny. Stały się one analogiczne dopiero w Sarmatianie, po regresji morza Paratetydy z zachodniej części zapadliska przedkarpackiego (Sadowska 1977, 1990, Dyjor & Sadowska 1986). W diagramach pyłkowych widoczne są z reguły różnice między odcinkami odpowiadającymi w profilu litologicznym węglom brunatnym i osadom ilastym, odzwierciedlające różne stadia sukcesji roślinnej. Spektra z pokładów węgla wydają się zwykle "starsze" od spektrów osadów ilastych. Tę wielką różnorodność i zmienność węglotwórczych zbiorowisk roślinnych potwierdzają badania petrograficzne polskich węgli brunatnych (Szwed-Lorenz 1991).

Porównanie licznych flor pyłkowych miocenu i pliocenu z obszaru Polski i środkowej Europy dowodzi jednak, że istnieją kryteria wspólne dla wielu z tych flor, które pozwalają określić ich wiek, pomimo różnic regionalnych i facjalnych. Opierają się one na zmianach flory wywołanych głównie czynnikami klimatycznymi. Są to następujące kryteria: – wyraźna dominacja niektórych taksonów lub grup taksonów w poszczególnych piętrach miocenu i pliocenu, np. rodzajów *Engelhardtia*, *Myricą* i *Tricolpopollenites liblarensis* w Ottnangianie, *Quercoidites henrici*, *Rhus* i *Myrica* w Karpatianie czy *Celtis* w Sarmatianie (Sadowska 1977, 1990),

– obecność taksonów o ograniczonym zasięgu, stratygraficznie ważnych dla danego piętra, np. *Palmae* w dolnym miocenie, *Aesculus* w górnym pliocenie (Ziembińska-Tworzydło 1974, Jahn et al. 1984),

– spadek udziału procentowego taksonów "trzeciorzędowych", a zwłaszcza rodzajów ciepłolubnych w ciągu miocenu na korzyść "czwartorzędowych' roślin klimatu umiarkowanego i dominacja tych ostatnich w pliocenie oraz brak roślin subtropikalnych w pliocenie (Oszast 1973, Stuchlik 1980, 1987, Zagwijn 1980, Sadowska 1987),

– wyraźne zmniejszanie się liczby taksonów egzotycznych, trzeciorzędowych w pliocenie (Oszast l.c., Jahn et al. l.c.),

– silny spadek udziału grupy *Taxodiaceae-Cupressaceae* na granicy miocenu i pliocenu (Oszast 1973, Sadowska 1977, 1990, Stuchlik 1980),

– zmienny stosunek udziału *Pinus sylvestris* i *Pinus haploxylon* w ciągu neogenu (Sadowska 1977).

– wzrost roli drzew szpilkowych "czwartorzędowych", a zwłaszcza *Picea*, w pliocenie (Oszast 1973, Stuchlik 1980, 1987, Jahn et al. 1984, Sadowska 1987),

– silny wzrost roli roślin zielnych w pliocenie w porównaniu z miocenem Oszast l.c., Stuchlik l.c., Jahn et al. l.c.),

– zmiana typu zbiorowisk leśnych z bagienno-torfowiskowych we wczesnym i w środkowym miocenie na mezofilne w późnym miocenie i pliocenie (Stuchlik 1980, Sadowska 1987, 1990).

Zmiany jakie zachodziły w zbiorowiskach roślinnych neogenu na obszarze Polski powodowane były czynnikami geologicznymi i paleogeograficznymi, takimi jak ruchy górotwórcze, transgresje i regresje mórz, a zwłaszcza regresja ciepłego morza Paratetydy z zachodniej części zapadliska przedkarpackiego na początku Sarmatianu oraz wysychanie rozległego zbiornika serii poznańskiej we wczesnym pliocenie. Zjawiska te były przyczyną regionalnych zmian klimatu, które towarzyszyły generalnym zmianom klimatycznym i paleogeograficznym jakie miały miejsce w całej Europie (Mai 1989). W ich wyniku zwarte bagienne lasy cypryśnikowe i krzewiaste torfowiska jakie panowały w Polsce we wczesnym i środkowym miocenie, ustąpiły w późnym miocenie na rzecz liściastych i mieszanych lasów. Lasy te stały się zbiorowiskami panującymi w pliocenie, wzbogacając się o bogate podszycie krzewów i roślin zielnych.