Investigations of the Neogene floras in Poland*

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The paper presents an overview of the palaeobotanical and palynological investigations undertaken on the Neogene sedimentary sequences in Poland during the preceding 50 years. A general outline of the palaeogeographic development of the Polish Lowland and the northern part of the Central Paratethys basin in southern Poland is also presented. On the basis of more than 100 examined profiles containing floral remains the main stages of development of the Neogene vegetation are described.

Key-words – palaeobotany/palynology, vegetation, Neogene, Poland.

INTRODUCTION

THE first macroscopic plant remains from the Neogene of Poland were described before the onset of the second world war by Zabłocki in 1928 and shortly followed by a second article in 1930, and the first palynological paper was published by Kostyniuk in 1938. Since these pioneering works, numerous other studies have been undertaken on palaeobotanical and palynological composition of the Neogene in Poland during the last 50 years. There were three main centers of research in Poland. In Kraków (south Poland), investigations of Neogene floras were initiated by Professor Władysław Szafer (1946, 1947, 1954) who has published on the Pliocene flora of Krościenko, Czorsztyn and the Miocene flora from Stare Gliwice in Silesia (1961). These studies intended to increase understanding on plant evolution and history of vegetation during the younger Tertiary Period. Later, on the basis of long-term studies in the western Carpathians and southern Poland (Łańcukca-Środoniowa 1966, 1979; Zastawniak 1972, 1980; Oszat & Stuchlik 1977, Stuchlik 1979; Dyjor & Sadowska 1986; Sadowska 1989; Oszczypko, Wójcik & Stuchlik 1992 and others) the history of vegetation can be comprehensively summarized.

The second center of palaeobotanical and palynological investigations of Polish Neogene is in Warsaw. After the second world war a group of palaeobotanists from the Polish Geological Institute (Doktorowicz-Hrebnicka, Grabowska, Mamczar, Raniecka-Bobrowska, Zalewska and others) and from the Muzeum of the Earth Polish Academy of Sciences (Czeczott) began detailed investigations of Neogene floras. These were mainly based on studies from brown coal deposits in western Poland and also other sediments in Polish Lowland. These investigations are now continued by a group of palynologists (Grabowska, Kohlman-Adamska, Slodkowska, Ważyńska and Ziembińska-Tworzydło).

In the sixtees another center of palaeobotanical and palynological investigations has been established in Wroclaw (western Poland) by Stachurska and Sadowska. The main area of their studies was south-western Poland, mainly brown coal deposits.

Palaeogeogaphy of the Polish Neogene

The Polish Neogene is characterized by the appearance of two different sedimentary basins. In southern Poland the sedimentary basin is filled by marine, brackish and freshwater sediments and was connected with the northern part of the Central Paratethys. This basin was filled by upto 1000 m of thick siliclastic sediments with some intercalations of lignites and rare brown coal seams with rich micro- and macrofloras. The palaeogeography of this area is here presented after Ney *et al.* (1974). The other sedimentary basin of the Polish Lowland was related to the eastern part of the North Sea which occupied all of north-western Europe at that time. An outline of the palaeogeographical development of this area is presented after Piwocki (1998). Between these two sedi-

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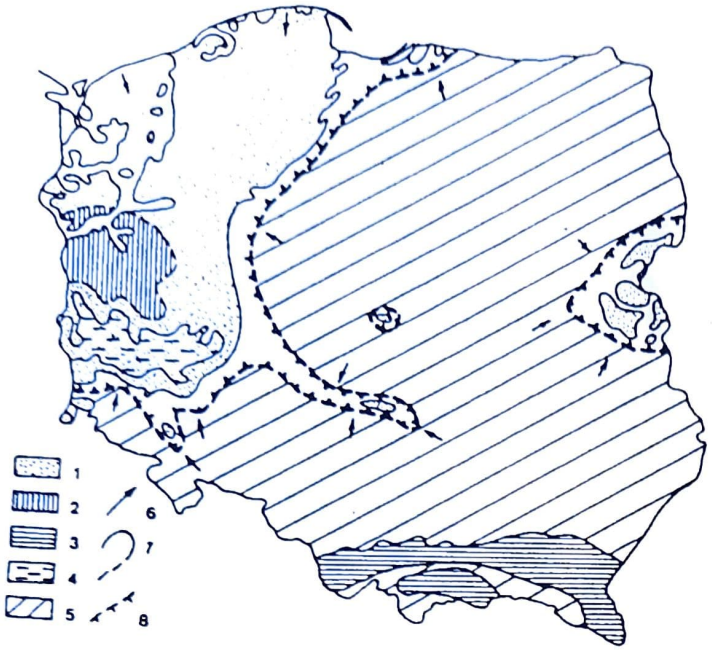


Fig.1. Palaeogeography of the lower part of the Lower Miocene in Poland (after Piwocki 1998). 1- continental sediments, 2- brackish sediments, 3- marine sediments, 4-occurrence of brown coal, 5- land areas (accumulation and erosion regions), 6- direction of the transport of clastic material, 7- present-day extent of the sediments (found and supposed), 8- presumable original extent of the sediments.

Fig. 2. Palaeogeography of the upper part of the Lower Miocene in Poland (after Piwocki 1998). Explanation see Fig. 1.

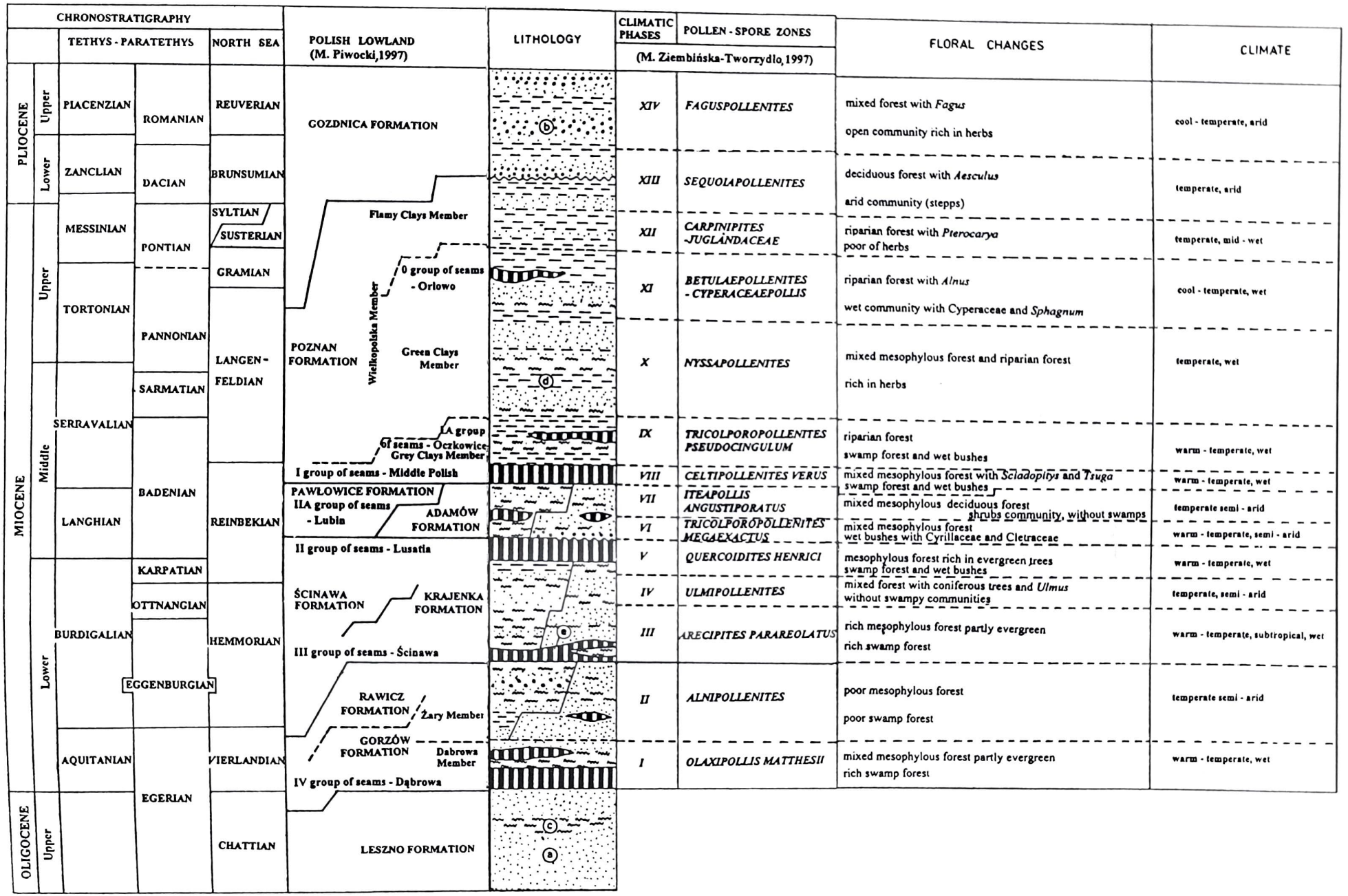
mentary basins a Meta-Carpathian Range existed, and this functioned as a montane watershed between North Sea and Paratethys Sea.

In southern Poland the first transgression of the Paratethys took place in Upper Oligocene (Egerian). Marine sediments were accumulated only in two areas: the southernmost area (Carpathians) and the Fore-Sudetic area. After uplifting of the Sudetes, fine-grained sands intercalated with sandy muds (the Leszno Formation) were deposited in a brackish environment in western and south-western Poland (Piwocki 1998). After regression of the sea in the Fore-Sudetic Monocline, lacustrine sediments (fine-grained sands, muds and clays with plant detritus) accumulated forming the Gorzów Formation. In marshy areas on wet plains after retreat of marine waters, brown coal seams were formed under humid and warm climate (the so called IV-Dąbrowa seam group-See Fig. 1 and Tab. 1). In the continental sediments small layers or lenses of brown coal alternated with coarse-grained sands and sandy kaolinite clays forming the Rawicz Formation (Żary Member).

The next transgression of Paratethys Sea occurred in Eggenburgian and Ottnangian but the sea occupied only the south-eastern parts of the Carpathians with some narrow lagoons extending between the two basins (Nowy Sącz and Nowy Targ). At that time the Paratethys Sea also occupied a small patch in south-eastern Poland. The Meta-Carpathian Range still served as a watershed between the North Sea and Paratethys. The broad lowland depression of northern Germany and western Poland, where an intensive erosion process took place, enabled small scale marine incursions of the North Sea to reach the western part of the Polish Lowland. A series of alluvial sediments intercalated by marshy lacustrine and occasionally brackish sediments together with sands, clays with plant remains have formed the Krajanka and Scinawa Formations, and the latter includes a brown coal seam, No. III-Ścinawa group (see Fig. 2 and Tab.1)

Further development of the Carpathian Foredeep took place at the end of Lower Miocene (Karpatian). At that time the Paratethys Sea entered from the south-eastern part of Poland and extended upto the Nowy Targ Basin and then, reached the westernmost border of the Carpathians, met another arm of the Paratethys Sea extending from the south to the Moraia Gate, and crossed the Meta-Carpathian

Table 1. Chronostratigraphy, lithostratigraphic scheme, climatic phases and pollen-spore zones (after Piwocki & Ziembińska-Tworzydło 1997)



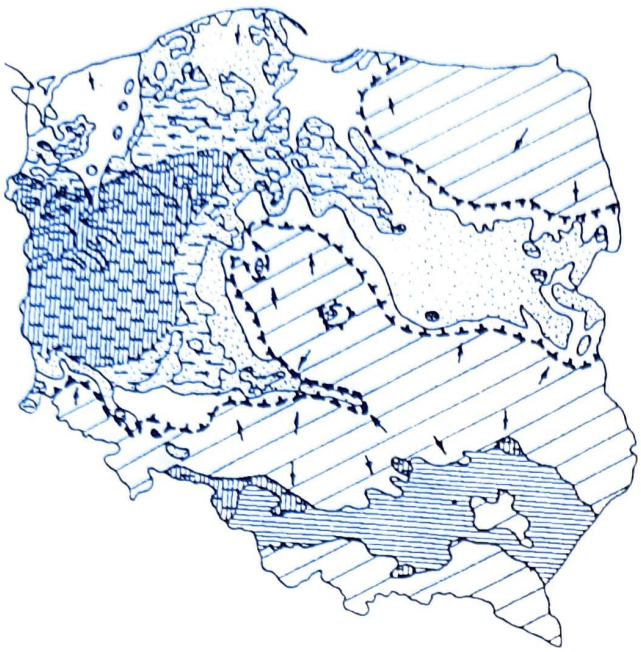


Fig. 3. Palaeogeography of the lower part of the Middle Miocene in Poland (after Piwocki 1998). Explanation see Fig. 1

Range forming the western part of the Carpathian Foredeep. The maximum extension of the Paratethys Sea to the north and north-west took place in the lower part of Middle Miocene (Badenian). Marine waters from the inner basin covered broad areas to the north of the Carpathian Foredeep forming its outer basin. At that time in Polish Lowland a large-scale subsidence took place, that caused a significant enlargement of the sedimentary basins. Intensive sedimentation of lacustrine, gyttja, alluvial sands, muds and clayey sediments, all with abundant plant remains, occurred. Humid and warm temperate to subtropical climate was favourable for development of peat-forming vegetation, producing thick brown coal seams-II-Lusatian seam group in western and northern Poland (see Fig. 3 and Tab. 1). Further subsidence of vast areas in Poland, except Carpathians, Sudetes and Meta-Carpathian Range with Holly Gross Mts. (Góry Świetokrzyskie) took place during the whole Middle Miocene. In the lower part of Middle Miocene accumulation of sands, muds and clays, with intercalations of brown coal lenses in alluvial and marshy-lacustrine environments formed the Adamów Formation, while locally in western Poland in brackish environments the Pawlowice Formation with the IIA Lubine seam group of brown coal was formed. Further developing on large area marshy and peat bog vegetation caused accumulation of many brown coal seams on large areas of Polish Lowland-I Middle Polish seam group-in the oldest part of the Poznan Formation (see Fig. 4 and Tab. 1). At that time in southwestern Poland on the Lower Silesia border a short connection of the Paratethys Sea with the inland basin in the Polish Lowland took place, and the Carpathian Foredeep has been divided into the eastern and western part.

Fig. 4. Palaeogeography of the upper part of the Middle Miocene in Poland (after Piwocki 1998). Explanation see Fig. 1.

The last transgression of the Paratethys Sea occurred during the younger part of Middle Miocene (Sarmatian) in south Poland. During the Late Sarmatian the sea definitively retreated the territorial expanse of Poland. Freshwater sediments were accumulated in distinct sedimentary basins (Nowy Targ, Orawa). In Polish Lowland in many shallow accumulation basins with freshwater sediments, mainly grey-greenish clays, clays and muds, sands with occasionally lenses of brown coal were deposited (Wielkopolska Member within the Poznań Series). This type of sedimentation was continued till the end of Miocene and developed in several sedimentary cycles, that gave a basis to distinguish lithostratigraphic units of lower rank with the O-Orlowo seam group (see Fig. 5).

Fig. 5. Palaeogeography of the Upper Miocene in Poland (after Piwocki 1998). Explanation see Fig. 1.

Fig. 6. Palaeogeography of the Pliocene in Poland (after Piwocki 1998). Explanation see Fig. 1.

At the turn of the Miocene, the Sudetes uplifted and the Marginal Fore-Sudetic Fault developed, forming a sediment complex with molassa features. Vast piedmont fans, overlapping one another, intercalated with alluvial sediments as gravels, with an admixture of cobbles, coarse-grained sands with gravels and kaolinite muds and clays formed the Gozdnica Series (see Fig. 6 and Tab. 1), the youngest Neogene series, which persisted from the uppermost Upper Miocene to the Upper Pliocene.

Main stages of development of the Neogene vegetation of Poland

Description of the main stages of development of the Neogene flora and vegetation of Polish Lowland is based on the palynological synthesis edited by Wazyńska (1998), some papers of Sadowska (1977, 1989, 1995); Dyjor *et al.* (1977); Dyjor & Sadowska (1986); Ziembińska-Tworzydło (1974, 1998); and others. For the Paratethys basin the following papers have been evaluated: Oszat & Stuchlik (1977), Łańcukca-Środoniowa & Zastawniak (1997), Stuchlik (1979), Oszczypko & Stuchlik (1972), Łańcukca-Środoniowa 1966, 1979), Oszast (1960, 1967, 1973); Zastawniak (1972, 1980); Szafer (1946, 1947; 1954). The stratigraphy and lithostratigraphic schemes are presented after Piwocki, and climatic phases with spore-pollen zones after Ziembińska-Tworzydło (Piwocki & Ziembińska-Tworzydło 1997) in Tab. 1.

Lower Miocene

According to Ziembińska-Tworzydło (Piwocki & Ziembińska-Tworzydło 1997) fourteen climatic phases have been distinguished :

Climatic phase I- Olaxipollis matthesii spore-pollen zone is characterized by abundant occurrence of elements of the palaeotropical group (*Alangiopollis, Cicatricosisporites chattensis, Cingulisporis marxheimensis, Cornaceaepollis satzveyensis, Fususpollenites fusus, Engelhardtioipollenites quietus, Sapotacaeoipollenites* and others). Two main types of vegetation have occupied the lowland territory of Poland. In humid and warm climatic conditions, river valleys and wide flood-land areas, swamp forests were developed. A considerable area was covered by Taxodiaceae-Cupressaceae swamp forests with admixture of *Glyptostrobus, Nyssa, Alnus* etc. On the peripheries of these forests a marshy shrub vegetation, with Cyrillaceae-Clethraceae, Betulaceae, Myricaceae and others, was developed. These peat-producing vegetation accumulated a considerably thick brown

coal seam, described by Piwocki and Ziembińska-Tworzydło (1997) as lithostratigraphic unit the IV-Dabrowa seam. Mixed mesophytic forests, mainly composed by *Quercus-Castanea* and Juglandaceae (*Engelhardtia* and *Platycarya*), Sapotaceae, *Platanus*, with considerably rich and abundant undergrowth (*Ilex, Myrica,* Leguminosae, and others) were developed on more dry habitats.

Climatic phase II- Alnipollenites spore-pollen zone in general was similar to the previous one. In the consequence of changing the climatic conditions, which became cooler and more arid, a general impoverishment of forest can be observed. The area of swamp forests became smaller and *Alnus* as a dominant component, partially replaced the Taxodiaceae-Cupressaceae group. The undergrowth of these forests was more abundant and the main role was played by ferns. Mixed mesophytic forests were impoverished too, mainly in their palaeotropical elements. The climate of this phase was not suitable for brown coal formation. Only a few brown coal intercalations are observed in the upper part of the Rawicz Formation (Piwocki 1998).

Climatic phase III- Arecipites parareolatus spore-pollen zone is characterized by return of better climatic conditions for the vegetation development. The climate was warm-temperate to subtropical, the warmest one observed during the Miocene (Ziembińska-Tworzydło 1998). Most of the palaeotropical elements, which were present in the Climatic phase I returned and the mixed mesophytic forests became much richer. Palms (*Arecipites parareolatus*), probably as an important component of the marshy shrub vegetation, are known from many sites in the western part of the Polish Lowland. The warm-temperate climatic conditions were suitable also for development of the Taxodiaceae-Cupressaceae swamp forests, which accumulated as several large lenses of brown coal seams, determined by Piwocki (Piwocki & Ziembińska-Tworzydło 1997) as the III-Ścinawa seam group (Fig.2).

Climatic phase IV - Ulmipollenites spore-pollen zone is characterized by general cooling and aridity of the climatic conditions. The area of swamp forests significantly decreased and in general the palaeotropical group of elements decreased too. The mixed mesophytic forests became poorer also in warm-temperate elements of the arctotertiary group of elements. Along the rivers riparian forests dominated by *Ulmus* and other arctotertiary elements expanded.

In the Carpathian Foredeep there are no palaeobotanical evidence from the Lower Miocene (Egerian, Eggenburgian and Ottnangian).

Middle Miocene

Climatic phase V- Quercoidites henrici spore-pollen zone is the beginning of a period of great floral and vegetational differentiation. The uppermost part of the Lower Miocene (Karpatian) is the first stage, where we have palynological evidence in the Paratethys basin (Carpathian Foredeep and Sudetic Foreland). Palynoflora from the Nowy Sacz profile (Oszczypko & Stuchlik 1972) and Twardawa (Raniecka-Bobrowska 1973) has still a Lower Miocene character with some old Tertiary elements as Sapotaceae, Symplocaceae and others. On the transition to lower Badenian the biodiversity of these floras are greater.

In a humid and warm climatic conditions on large territory of Polish Lowland, as well as in the Paratethys basin, abundant development of marshy plant communities both, swamp forests (Taxodiaceae-Cupressaceae, *Nyssa* and *Alnus*), and shrub and brushwood peat-bogs vegetation (Clethraceae, Cyrillaceae, Myricaceae, Betulaceae) prevailed. Due to development of these communities and favourable palaeotectonic conditions, on large territory of Polish Lowland thick brown coals seams-II Lusatian seam group-have been formed (Fig. 3). On more arid areas rich mesophytic forests with a number of evergreen elements were developed. Palaeotropical (mostly subtropical) oaks (*Quercoidites henrici, Qu. microhenrici*), palms (*Arecipites parareolatus, A. convexus*), Juglandaceae (*Engelhardtia, Playtcarya*), Myricaceae, Spotaceae, Symplocaceae, and many evergreen shrubs (Leguminosae, *Ilex* and others) played a considerable role in the vegetation composition. Also from the arctotertiary geoflora the group of more warm temperate elements were com-

mon and abundant (*Carya, Pterocarya, Eucommia, Sequoia, Zelkova* and others).

Climatic phase VI - Tricolporopollenites megaexactus spore-pollen zone is very similar to the previous one, but in the marshy vegetation greater role was played by peat-bog forming shrub and brushwood vegetation (Cyrillaceae-Clethraceae, Myricaceae). In a little more arid climate conditions that were in general similar to the previous climatic phase, brown coal seams have been accumulated in many parts of the Polish Lowland-IIA group of seams-Lubin in the lower part of Adamów or Pawlowice Formation (Piwocki & Ziembińska-Tworzydło 1997). Palaeotropical elements are still common in the mixed mesophytic forests (*Magnolia, Podocarpus, Olaxipollis metthesii* etc.).

In the Carpathian Foredeep (northern part of the Paratethys basin) the Lower Badenian vegetation is represented by floras from salt mine Wieliczka, Swoszowice and some localities in Gdów Bay (Łańcucka-Środoniowa 1966, Łańcucka-Środoniowa & Zastawinak 1997). Swamp forests were developed only on small areas. The main vegetation cover was formed by mixed mesophytic forests with many thermophilous elements (*Cinnamomum, Laurus, Eurya, Mastixia*) representing the last phase of so called mastixioidean flora (Łańcucka-Środoniowa 1966). The flora is characterized by a considerable participation of thermophylous elements and a predominance of angiosperms over gymnosperms, while in the Late Badenian flora of the Nowy Targ-Orawa basin a remarkable change in the vegetation is expressed by predominance of conifers over angiosperms (Oszast & Stuchlik 1977).

Climatic phase VII- Iteapollis angustiporatus spore-pollen zone is the beginning of the impoverishment of the Miocene flora. The climatic conditions were cooler and more arid. Many thermophilous plants from the palaeotropical group disappeared, some subtropical elements (Araliaceae, *Ilex, Itea, Myrica,* Symplocaceae) were regularly present but in small amounts. The temperate group of taxa (*Acer, Alnus, Carpinus, Fagus, Ulmus* and from conifers *Pinus, Sciadopitys* and *Tsuga*) became more frequent than in the previous phases.

Middle and Upper Miocene

Climatic phase VIII - Celtipollenites verus spore-pollen zone was somewhat similar to the previous one but poorer in palaeotropical elements. The warm and humid climatic conditions favoured widespread development of swamp forests (mainly *Alnus* and Taxodiaceae-Cupressaceae-*Nyssa*), peat-producing brushwoods (*Salix,* Myricaceae, *Ilex*) and herbaceous bushes (Cyperaceae, Sparganiaceae, Typhaceae, Osmundaceae and others) on marshy habitats. At that time on vast areas a uniform seam of brown coal -I Middle Polish group of seam (Fig. 4) was accumulated. On more arid habitats mixed mesophytic forests with prevalence of warm-temperate elements (*Carya, Eucommia, Fagus, Tilia, Pterocarya* and others) and increasing more cool-temperate elements (*Betula, Carpinus, Corylus, Quercus* and others) were developed.

Climatic phase IX - Tricolporopollenites cingulum spore-pollen zone was the time of extinction of the majority of palaeotropical elements-only *Magnolipollis neogenicus* Krutzsch and *Tricolporopollenites marcodurensis* Pf. & Thoms. were still present. A number of subtropical elements also disappeared, and in the pollen spectra warm-temperate elements prevailed both quantitatively and also with great taxonomic diversity. The climatic conditions were still warm-temperate and humid, promoting development of marshy vegetation and riparian forests with some evergreen elements in the brushwood. At that time, some coal lenses in the upper part of the I group Middle Polish Seam were accumulated-The IA group of seams-Oczkowice.

In southern Poland the Late Badenian vegetation was differentiated in the Carpathian basins (Nowy Targ-Orawa basin) and on the northern margin of the Paratethys (Tarnobrzeg). The Late Badenian flora in the Carpathians is characterized by predominance of conifers over angiosperms and successive decline of thermophilous elements. Remarkable is the high amount of *Alnus kefferstein*i type in the pollen spectra (Oszast & Stuchlik 1977). Somewhat different is the Late

Badenian flora from the vicinity of Tarnobrzeg that is characterized by predominance of angiosperms over gymnosperms and with high proportions of shrubs in the vegetation cover (Oszast 1967).

Climatic phase X- Nyssapollenites spore-pollen zone is represented only in few localities in Polish Lowland. The name of the zone attributed to high amount of *Nyssapollenites* pollen in the profile of Gozdnica (Stachurska *et al.* 1971, Sadowska 1992). This was a period of temperate and humid climate, in which great accumulation of sandy and greenish clay and silt of the Poznan Formation took place. The main role in the vegetation was played by riparian forests composed mostly of temperate and warm-temperate elements, while palaeotropical group of elements appeared only sporadically.

In southern Poland the vegetation cover was differentiated. In the Carpathian Mts. the formation of altitudinal belts including the montane coniferous belt (*Abies, Picea, Tsuga*) in higher elevation and mixed deciduous forest belt (*Carpinus, Quercus, Tilia, Acer, Betula, Ulmus*) in lower altitude began. In river valleys and on marshy habitats riparian and swamp forests were developed (*Glyptostrobus, Alnus, Fraxinus, Populus* and others). On the northern peripheries of Central Paratethys, in the Chmielnik region (Zastawniak 1980) the vegetation cover was similar to the previous phase. A considerable high role was played by shrubs (mainly Leguminosae) and deciduous trees (*Acer, Castanea, Pterocarya, Ulmus* and others).

Climatic phase XI - Betulaepollenites-Cyperaceaepollis spore-pollen zone was characterized by successive worsening of the climatic conditions. The climate was temperate but humid, promoting development of swamp forests with *Nyssa, Alnus,* and admixture of Taxodiacae, as well as peat-producing brushwoods with Salicaceae, Betulaceae, Myricaceae, also being rich in herbaceous rush communities (Cyperaceae, Sparganiaceae, Typhaceae, *Butomus*). These were suitable conditions for brown coal accumulation, recognized by Piwocki (Piwocki & Ziembińska-Tworzydło 1977) as the 0-Orlowo Seam Group (Fig. 5). River valleys formed suitable conditions for development of riparian forests composed mainly by deciduous temperate elements (*Betula, Quercus, Acer, Carya, Pterocarya* and others.)

The evolution of vegetation in Pannonian reflects changes connected with the palaeogeography and sedimentary basin configuration. In southern Poland Pannonian fossil floras have been found in the Nowy Targ-Orawa basin in two profiles : Czarny Dunajec and Koniowka (Oszast & Stuchlik 1977). In the vegetation cover the most important role was played by mixed deciduous forests composed mainly of temperate elements such as *Acer, Betula, Carpinus, Quercus, Tilia* and *Ulmus*. More warm-temperate elements such as *Aralia,* Cyrillaceae, *Engelhardtia,* Sterculiaceae, *Symplocos* disappeared from the flora. The role of coniferous forests considerably increased. Spruce (*Picea*) forests have formed a montane zone on higher altitudes in the Carpathian Mts. The role of herbaceous plants became greater and open herbaceous communities spread widely. The area was occupied by swampy forests decrease but the main role still belonged to Taxodiaceae and *Alnus*.

Upper Miocene - Pliocene

Climatic phase XII - Carpinites-Juglandaceae spore-pollen zone was a period of the beginning of general aridness of the climate. Most of the palaeotropical elements disappeared. Temperate and relatively high humidity of the climatic conditions favoured development of rich riparian forests with *Alnus, Pterocarya* and *Ulmus*. On more dry habitats deciduous forests with Juglandaceae (*Carya* and *Juglans*), *Carpinus, Betula, Quercus*, and some admixture of conifers (*Pinus, Tsuga, Abies* and *Picea*) were developed. Only a few profiles, with the classical one at Sośnica in south-western Polish Lowland (Stachurska *et al.* 1971), are palynolgically documented. This profile occurs in sediments with the Flame Clay Member (Piwocki & Ziembińska-Tworzydło 1997) at the top of the Poznan Formation (Fig. 5).

In southern Poland the Pontian flora (Szafer 1946, 1947, 1954: Oszast & Stuchlik 1977) was characterized by further decrease of swamp forests and development of mixed deciduous forests, riparian forests and herbaceous plant communities. Swamp for-

ests, from which considerably decreased the Taxodiaceae-Cupressaceae group, and alder (mainly *Alnus glutinosa*) became the dominant tree, developed only in local areas. *Alnus* was also an important tree in riparian forest together with *Salix, Fraxinus* and *Pterocarya*. Coniferous forests (*Picea, Abies, Pinus, Tsuga*) occupied vast territories of the Carpathian Mts. On lower slopes and in more dry valleys deciduous forests (*Acer, Betula, Carpinus, Corylus, Quercus, Tilia* and others) were abundantly developed.

Climatic phase XIII - Sequoiapollenites spore-pollen zone was the last climatic phase in the Neogene in which *Sequoiapollenites* appeared in the Polish Lowland (Ziembińska-Tworzydło 1998). Continuation of the arid climate favoured development of deciduous forests and herbaceous plant communities characteristic for steppe and forest-steppe vegetation. The most important trees in the forest were *Betula, Carpinus, Corylus, Quercus*, and *Ulmus*. As relics still in the vegetation were present some warm-temperate elements (*Magnolia, Castanesea, Ilex, Myrica, Aesculus, Carya, Celtis*). Sediments with this assemblage described here are known from the locality Ruszów (Stachurska *et al.* 1967) in the lower part of the Gozdnica Formation.

In Polish western Carpathians the Dacian flora from Domański Wierch (Zastawniak 1972, Oszast 1973) and Krościenko and Mizerna areas (Szafer 1946, 1947, 1954) is characterized by the domination of *Picea* forests with admixture of *Pinus* and some Tertiary relics (*Sciadopitys* and *Tsuga*). Coniferous forests dominated all montane zones. The area of mixed deciduous forest (*Acer, Alnus, Betula, Carpinus, Corylus, Quercus, Tilia*) considerably decreased, and the herbaceous plant communities became more frequent and differentiated in species composition.

Climatic phase XIV - Faguspollenites spore-pollen zone is characterized by increase of aridity and cooling of the climate. In the youngest part of the Gozdnica Formation (Sadowska 1992), in the profile from Rózce (Stuchlik 1994) and in the Bełchatów region (Krzyszkowski & Szucznik 1995) the assemblage of abundant beech pollen *Faguspollenites* is present. In the mixed deciduous forest temperate elements are dominating (*Fagus, Carpinus, Corylus, Betula*) with some more warm-temperate relics (*Ilex, Myrica*). Herbaceous plants became more and more numerous and diversified, forming open landscape grassland and steppe-like vegetation cover. The present-day extent of the Pliocene sediments in the Polish Lowland is shown in Fig. 6.

In the Carpathians, Reuverian was the last stage before the Pleistocene cooling of climate occurred. It is represented by the flora from the Mizerna locality (Szafer 1954). Conifer forests predominated the mountainous regions, while in lower altitudes mixed deciduous forests, with considerably high proportions of shrubs in the undergrowth, were developed. Some warm-temperate elements (*Magnolia, Liriodendron, Styrax*) returned to the forests in lower altitudes.

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